Digital Sprinters: The Road to Sustainability

Digital Technology as a Key Enabler for Climate Action in Emerging Markets

Deloitte.

Commissioned by Google

Google

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Executive summary

Introduction

More informed and purposeful development and deployment of digital technologies **can catalyze progress towards the 2050 net zero goals.**

Amid increasing climate change impacts, digital technology provides an opportunity for policymakers to reconfigure the relationship between growth, resource use, and consumption. A recent study from the World Economic Forum (WEF) indicates that effective use of digital solutions can potentially **reduce emissions by 20% by the year 2050,**[1] a significant contribution toward the reduction goals in that timeframe. This report sets out **to explore how digital technologies can be leveraged to meet the challenge of climate change, and what governments can do to facilitate the required innovation.**

Digital technology, driven by AI, IoT and cloud computing, collects, analyzes, and leverages data to reshape industries and improve decision-making, automation, and innovation, and is a critical component to help address climate change and reduce emissions. The "Impact Function" definition from Deloitte, comprising 4 elements, provides a structured approach to understanding the diverse tasks of modern digital tools.

Connect & Communicate

Connecting people to each other and to critical information

Monitor & Track

The real-time, extensive observation of the world and its natural and man-made systems

Analyse, Optimise & Predict

The development of insights from data, and the use of those insights to drive process efficiency and infer the future

Augment & Autonomate

Provision of an 'active bridge' between digital and physical, from simulation through augmentation to the creation of autonomous systems

The 2015 Paris Agreement triggered a global shift towards reducing greenhouse gases. The 2023 IPCC report called for immediate, aggressive, and universal action, presenting societal and economic opportunities. Increasing public awareness has also shaped political agendas, emphasizing sustainability, carbon reduction, and renewable energy. **Governments play a vital role in fully exploiting the potential of digital technology, not only by adopting digital tools themselves, but also by creating the necessary environment to accelerate this transition.**

This report, which focuses on emerging markets, proposes policies for leveraging digital technologies in the context of climate change with the goal of lowering, and even eliminating, emissions while also building resiliency to changes that cannot be prevented.

The report was drafted by **Deloitte** and commissioned by **Google.** It is based on the wealth of knowledge accumulated by Deloitte professionals globally in the fields of sustainability, technology, energy, and public policy. In composing the report, extensive research was conducted, and subject matter experts from academia, business, technology leadership, civil society, and local and international decision-makers were interviewed.

1. George, M., O'Regan, K. & Holst, A. (2022). Digital solutions can reduce global emissions by up to 20%. Here's how. World Economic Forum. Retrieved from

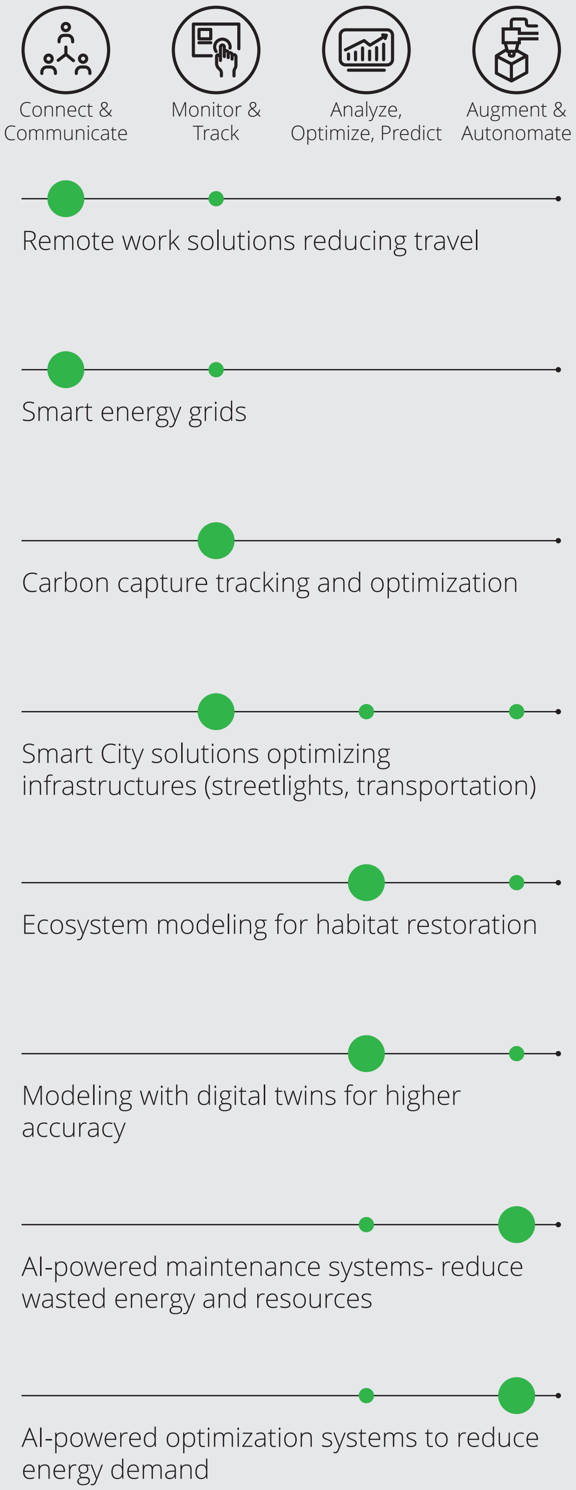
Climate Action: Three Pillars

There are many pathways for rising to the challenge of climate change, with necessary action mobilized in a myriad of ways. These can be described as centering around three pillars: **Mitigation, Adaptation and Resilience, and Foundation for Action**

Mitigation efforts refer to actions that pursue three distinct goals:

- **Reducing greenhouse gas emissions.** Digital technologies contribute to **energy efficiency** through AI-driven grid optimization and reduced consumption. They also aid in fuel consumption reduction by optimizing supply chains with AI-driven route planning and reducing emissions in road freight, shipping, and aviation. Resource efficiency and circular practices, including virtual meetings, also help lower emissions. The effective use of digital solutions has the potential to reduce emissions by 20%.[1]
- **Replacing traditional fuels with low-carbon alternatives,** such as solar and wind, presents challenges that digital technologies can address by predicting weather patterns that will help optimize the location of those structures.
- **Capturing & removing carbon.** Carbon capture and storage (CCS) technologies are still emerging, with digital technologies playing a role in their development and operation. Natural carbon removal processes can also be enhanced using digital tools like AI and drones to support reforestation and soil carbon sequestration initiatives.

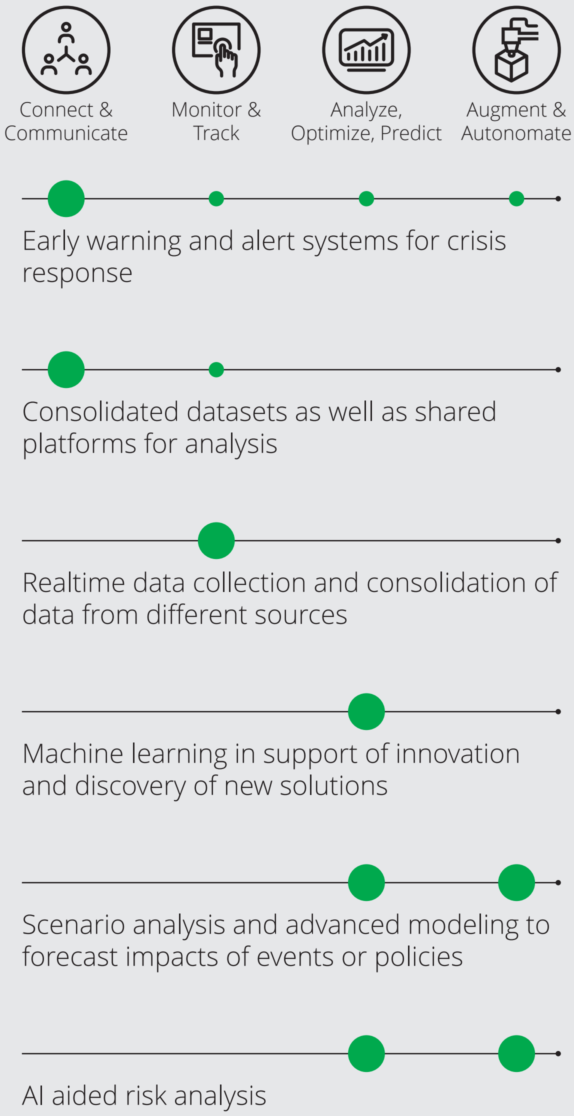
Mitigation Technologies and their associated Impact Functions



Adaptation and resilience efforts, which are intended to manage climate impacts and reduce vulnerability, focus on two major goals:

- **Securing and sustaining natural and human ecosystems.** Digital technologies play a crucial role in creating alert systems and robust infrastructure. With over 3.6 billion people living in areas highly susceptible to climate change impacts, the need for efficient crisis response and a resilient infrastructure such as smart healthcare is evident.
- **Sensing and forecasting for a faster and better response.** A critical aspect of this pillar involves gathering and analyzing data for precise forecasting, forming the basis for planning and response strategies. This rapid expansion of our knowledge base is made possible by advances in digital tools and AI.

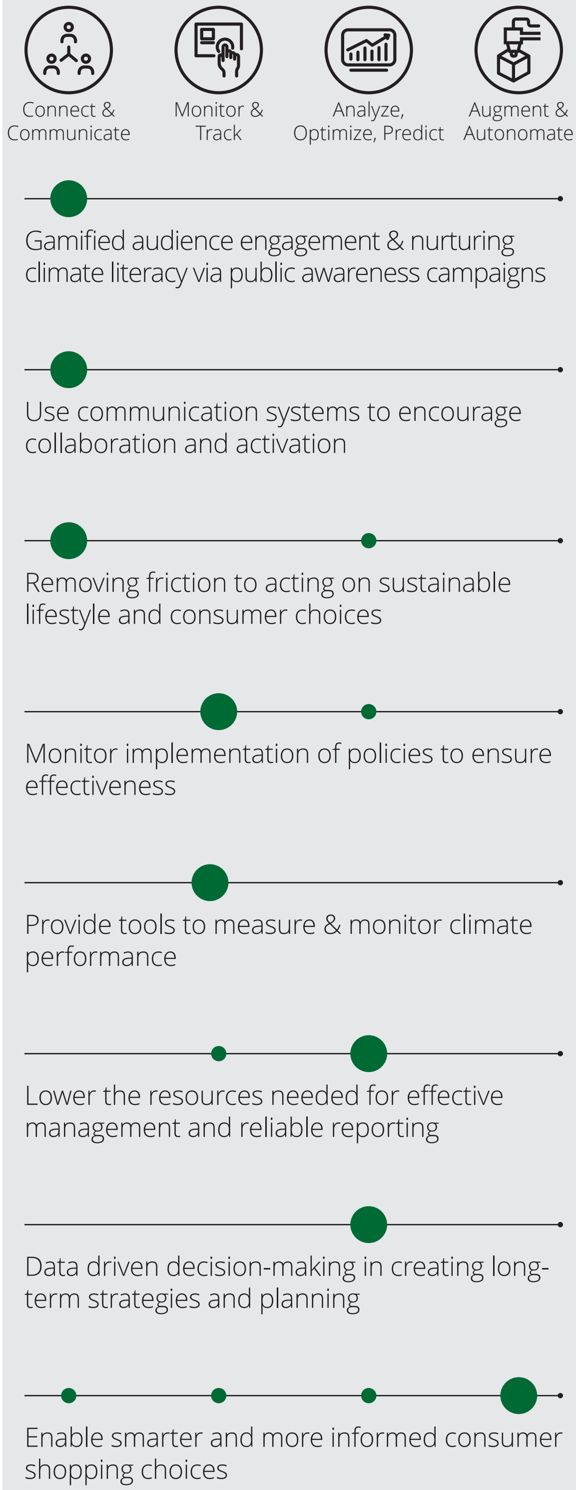
Adaptation Technologies and their associated Impact Functions



Finally, addressing climate change requires a collaborative, multi-level effort that involves governments, businesses, and individuals. For policymakers, this implies laying the right **foundations:**

- **Strategize and prioritize environmental actions** using digital tools to help set clear objectives and engage stakeholders.
- **Awareness** among the public as well as the business leaders and policymakers who must understand the complexities of climate systems and their impacts and who are sometimes unaware of the different solutions available.
- **Compliance and reporting:** business reporting for transparency and accountability is essential, with emerging regulations requiring large corporations to report carbon footprint metrics and forecasts of the future trajectory of said metrics over a given period of time. In this context, digital can precisely automate emissions monitoring and resource usage insights, facilitating compliance.

Foundations Technologies and their associated Impact Functions



Policy Recommendations for Deploying Digital Technologies for Climate Action

Governments can effectively **handle risks and challenges** around environmental action by **setting goals** and **creating a flexible framework** to achieve them

In presenting potential policy measures aimed at driving the adoption of digital tools to combat climate change, the Digital **Sprinters Framework proposed** by Google[2] offers a structured approach for the uptake of digital technologies. This framework defines four primary categories: Infrastructure, People, Market Environment, and Tech Innovation. Each category addresses specific policy aspects that can facilitate sustainable and inclusive economic growth while harnessing the power of digital transformation.

In terms of infrastructure, expanding global internet access and ensuring data availability are key prerequisites for deploying more sophisticated digital tools. As countries make progress in the fight against climate change, public leaders may consider investing in technologies like satellites and IoT to enhance data collection for climate solutions. In any case, prior to any major investments, governments should ensure their infrastructure projects are adaptive and align with climate and digital needs in the long run and for a more extreme world. In the people category, education and cross-collaboration between different sectors, coupled with empowering consumers, are key aspects. This report also underscores the role of public policy in establishing standards to encourage the adoption of digital solutions and in integrating digital technology into market functionality. Lastly, in the technology category, public leaders play a paramount role in encouraging digital innovation and assisting with the adoption of digital climate solutions.

2. The opportunity for "Digital Sprinters" (blog.google)

Google | Digital Sprinters Framework

Infrastructure

The physical **infrastructure** that enables digital solutions, such as increasing the amount of **available data,** and building systems that are **adaptive**

People

Engaging **people** in addressing global environmental issues requires a strong **academia** fueled by **interdisciplinary efforts,** as well as **public education** to empower the next generation

Market environment

Market environment aims to create a regulatory environment encouraging **integration of digital climate solutions into market functionality.** This **requires establishing standards to encourage** adoption

Technology

Technological innovation is crucial for achieving environmental goals, and it would be beneficial for governments to consider policies that **encourage digital innovation** and **assist with the adoption** of those digital tools

The following table summarizes the specific recommendations from each of the four categories:

Theme	Subtopic	Recommendations for governments
Infrastructure	Data availability	• Expand IoT into future grids, buildings, highways, and energy management • Enhance AI capabilities through real-time data integration and integrate AI solutions into new infrastructure projects • Establish a national climate and resilience center for standardized climate data • Facilitate data sharing through regulatory frameworks for data security and privacy
	Build adaptive infrastructure	• Evaluate new infrastructure investments under the lens of both climate change and digital technology by empowering relevant experts as part of the decision-making process • Explore partnerships between emerging countries and multilateral development banks (MDBs) and development finance institutions to equip new infrastructure projects with forward-looking technologies • Establish partnerships with online platforms to share critical information for early warning systems as climate becomes more and more extreme
People	Public education and academia	• Build digital engines and systems to educate young children and other stakeholders such as job seekers about climate change • Identify knowledge gaps related to climate and digital issues in academia and address them through international and regional collaboration and training programs • Guide policymakers to integrate climate courses into existing curricula to create a workforce well-versed in both climate science and digital technology
	Cross-collaboration	• Promote collaboration between researchers and industry innovators by facilitating platforms, initiatives, climate summits, and open-source digital technologies • Support public-private partnerships in the area of climate and digital in order to strengthen an innovative culture in public administration around climate change and maximize the impact and deployment of climate initiatives
Market environment	Establish standards to encourage adoption	• Establish protocols and frameworks for calculating and labeling the environmental footprint of products to allow for more informed decisions using digital tools • Leverage digital technology to facilitate the standardization and product labeling process in order to empower consumers to make sustainable decisions • Strike the right balance between privacy laws and the benefits of data-driven digital solutions for climate
	Integrate digital technology into market functionality	• Use digital tools to support enforcement of existing regulations that impose increased traceability requirements on businesses (EU Deforestation Regulation) • Employ digital tools to monitor real-time use and tailor prices, taxes, and subsidies to encourage climate-friendly policies
Tech Innovation	Encourage digital innovation	• Create innovation hubs and accelerators and host national and international challenge events to nurture new digital innovations for climate change • Encourage entrepreneurs to share IP rights to promote innovation and open data development • Support early stage businesses in the climate and tech field by reducing red tape, providing trade incentives, and facilitating global market access
	Assist with Adoption	• Encourage governments to employ AI solutions to identify critical areas of concern and then make informed decisions on how to counteract them • Encourage accountability by collecting and publishing data on the climate performance of state-owned and state-controlled companies and incorporate climate criteria into public tenders • Encourage municipalities and governments to adopt digital climate tech solutions, serving as pilot clients to demonstrate feasibility and improve government initiatives • Employ AI or digital twin solutions to identify critical areas of concern, or offer holistic perspectives on climate strategies (e.g. optimize public transportation stops)

Industry-specific Perspective

A useful way of focusing attention is by thinking along **industry lines,** strategically targeting **key areas** that have a significant impact on greenhouse gas emissions and environmental sustainability

Deloitte has identified four key industries - **Energy, Transportation, Industry,** and **Food** - as having a **significant impact on greenhouse gas emissions and environmental sustainability.** Within each sector, digital technology plays a crucial role in addressing climate change. In the energy sector, digital tech helps achieve carbon-free power, optimize grids, and support consumer efficiency. Transportation benefits from electrification, shared mobility, and fuel use reduction through optimization. Industry can leverage digital solutions for circularity, energy efficiency, and sustainable production. The agriculture industry can improve resource efficiency, reduce waste, and enhance resilience through precision agriculture and digital engagement with growers. Governments should consider focusing on regulating technology for cybersecurity and data sharing in energy, as well as support R&D in transportation, promote circular industrial zones, and develop digital skills in the food industry while encouraging smart urban agriculture and food redistribution.

Conclusion

Governments play a pivotal role in addressing climate change, calling for action in terms of **mitigation, adaptation & resilience, and setting foundations,** not to mention building awareness and supportive systems. Digital technologies can substantially contribute by facilitating **improved communication, monitoring and tracking,** software for **analysis and prediction, and augmentation and autonomation,** potentially **reducing up to 20% of necessary emissions by 2050.** Governments can unleash the full potential of digital technologies to combat climate change by creating a comprehensive policy approach in four core areas: **Infrastructure, People, Market Environment, and Technology Innovation.** Governments can use digital tech to build resilient infrastructures, enhance data analysis, and optimize resource consumption. Increases in available data also enable the internalization of environmental costs in prices, thus fostering environmentally friendly choices. Encouraging technological innovation, supporting capital funding, and adopting solutions internally all contribute to the climate action landscape. Leveraging technology for connection and communication helps educate citizens and promote environmentally friendly activities. Government investments in these areas, when interconnected, have the potential to drive innovation and solve climate challenges across domains.

By harnessing digital technology's power across these four domains, governments can **create a strong foundation to mitigate environmental damage and adapt to climate realities effectively.**

1. Introduction

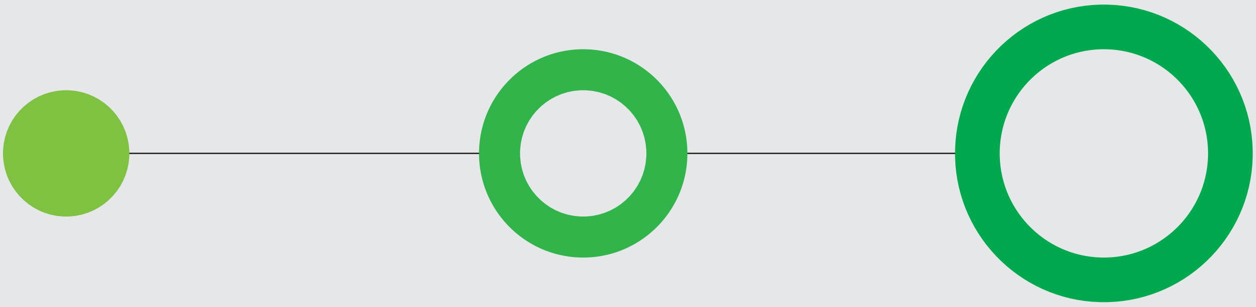
As the realities of climate change and its impacts become even more pronounced, substantial changes can be seen across almost all socio-economic systems. Digital technology offers a way for policymakers to address this, restructuring the balance between growth, resources, and their consumption. Furthermore, digital technology offers the potential to nurture a possible avenue for equitable and sustainable growth for all communities. This report **explores how digital technologies can be leveraged to meet the challenge of climate change, and what governments can do to facilitate the required innovation.**

In 2015, the Paris Agreement represented a shift in global efforts to combat climate change with a clear recognition of the global nature of the challenge, and the required response - lowering the amount of greenhouse gases (GHGs) in the atmosphere.

Impacts of climate change

Scientists have shown that greenhouse gases (GHGs) created by human activity contribute to global warming. Even the smallest increase in average temperatures can have a massive impact on the delicate and complex web of ecosystems all around us. From minor inconveniences to devastating and life-altering disasters, the changes in climate patterns can be felt all over the world, affecting people in every region and from every socioeconomic class. The impacts of global warming can be seen as interconnected dimensions: the immediate climatic changes, their physical impacts on natural systems and human infrastructure, and finally the social, economic, and political consequences.

Negative impacts of climate change



Climatic changes

- Higher surface and ocean temperatures
- More volatile/unpredictable weather
- Heat waves
- Droughts
- Higher rainfall, Rainstorms
- Sea level rise
- Changes in climate zones

Impacts on systems & infrastructure

- Fires
- Flooding
- Changing ocean habitats
- Coastal erosion
- Lower agricultural yields and viability
- Water contamination leading to Water scarcity
- Biodiversity loss
- Shipping interruptions
- Physical damage to infrastructure and transport systems

Social, economic, and political consequences

- Food insecurity
- Health risks and more incidences of disease
- Economic losses (industries, infrastructure, market characteristics)
- Climate migration
- Wars driven by resource scarcity, most likely water sources

Uneven and Unequal

Though a global phenomenon, climate change might not impact everyone equally. Those who historically contributed least to climate change tend to be the most vulnerable to its impacts and may be the worst-equipped for the transitions required for mitigation efforts. People in vulnerable areas may be up to 15 times more likely to die in extreme weather events than those in the most resilient areas,[1] and while agricultural losses account for approximately one quarter of climate event-related economic losses, this figure reaches 83% for developing regions susceptible to drought. With almost 9% of the global population going hungry, this is much more than an economic issue[2].

1. (IPCC, 2023)
2. (UN Finance Initiative, 2023)

In 2023 the Intergovernmental Panel on Climate Change (IPCC) stated unequivocally that at the current pace and scale, climate action is falling short on delivering the goals of the Paris Agreement and so called for immediate, aggressive, and universal action. From a **societal perspective,** this is an opportunity for governments to reflect on intended effects, implement equitable legislation, and find ways to improve everyone's lives. From an **economic perspective,** the rapid decarbonization needed could yield an economic dividend of US$43 trillion by 2070[3] or 60% more than the current US GDP.

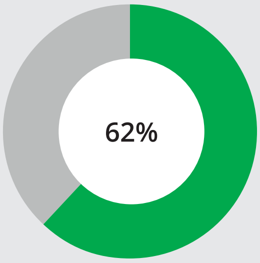
Governments are also pushed to take action due to **growing public awareness and demand.** In 2022, an AP-NORC poll found that approximately 62% of American adults thought the federal government was doing too little.[4] Similar recent surveys conducted by Deloitte, such as the "Millennial Survey," showed that about two thirds of Gen Z's are willing to pay a premium for more sustainable products and half of Gen Z and Millennials are even pressuring businesses to act on climate change.[5]

The political landscape is evolving, with an increased focus on sustainability, carbon reduction targets, and renewable energy initiatives. In the US, three pieces of legislation passed by the Biden administration look to dedicate more than US$500 billion over the next decade to transitioning to a low-carbon future. This represents a threefold increase in climate spending.[6] In Europe, the EU has pledged at least €1 trillion in sustainable investments as part of the European Green Deal and other funding. The EU has also adopted a transformative policy agenda seeking to change how the European economy operates by linking economic growth to climate neutrality targets. On a local level, Gartner estimates that by 2026 the top 50 cities will allocate almost an eighth of their budget to strategies responding to climate change.

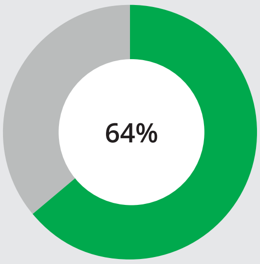
As climate change is not an acute event that can be contained through extreme temporary measures, it requires **major structural changes** in terms of policy, processes, market incentives and even infrastructure to assist with deep, long-lasting systemic behavioral changes. While the world has taken steps in that direction, it is necessary to pick up the pace, and the **way forward can be paved with digital technology.**

Digital technology, driven by AI, IoT and cloud computing, collects, analyzes, and leverages data to reshape industries and improve decision-making, automation, and innovation, and is a critical solution to help address climate change and reduce emissions. The "Impact Function" definition by Deloitte, comprising 4 elements, provides a structured approach to understanding the diverse tasks of digital technology.

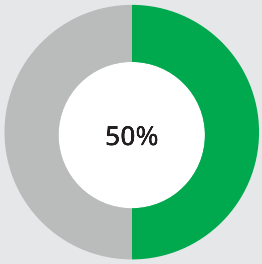
3. (Deloitte, RMI, 2023)
4. (AP-NORC Poll, 2022)
5. (Deloitte, 2019, 2022, 2023)
6. (Masterson, 2022)



People that think government is **doing too little**



Gen Z's willing to pay a **premium for sustainability**



Gen Z and Millennials actively **pressuring businesses to act**

Connect & Communicate
Connecting people to each other and to critical information

Monitor & Track
The real-time, extensive observation of the world and its natural and man-made systems

Analyse, Optimise & Predict
The development of insights from data, and the use of those insights to drive process efficiency and infer the future

Augment & Autonomate
Provision of an 'active bridge' between digital and physical, from simulation through augmentation to the creation of autonomous systems

Generative AI

Generative AI tools such as Gemini with its capacity to create and synthesize content, are increasingly being scrutinized for their environmental footprint even as they stand poised as a transformative force in enhancing data-driven decision-making. By leveraging advanced algorithms and learning patterns from vast datasets, generative AI systems can analyze information comprehensively, revealing nuanced insights and patterns that may elude traditional analytics. However, the rapid expansion of AI has led to a significant surge in the demand for cloud-computing resources, exemplified by hyperscalers extensive data center operations in desert areas like Arizona for example.

As an enabler of the future, generative AI intends to streamline decision-making processes by providing real-time, context-aware recommendations, ultimately empowering organizations to make more informed and efficient choices based on the wealth of data at their disposal. Yet, this advancement comes at a cost. The substantial energy consumption and water energy usage of data centers, essential for powering AI systems, are emerging as critical concerns, particularly in water-stressed regions like Arizona. For example, the data centers of one GAFAM company, integral to AI operations, are projected to use over 50 million gallons of water annually, a stark figure in light of the worsening drought conditions and extreme temperatures in the region.[8]

In the context of climate change, it becomes essential to balance the innovative potential of generative AI with its environmental implications. While these AI technologies offer significant benefits for sustainability efforts, such as optimizing resource use and enhancing efficiency, their own resource-intensive nature poses a challenge. It is vital to develop strategies to mitigate the environmental impact of AI, including advancing renewable energy use in data centers and improving their overall efficiency.

8. (Hao, 2024)

All four impact functions are critical for success, but the most relevant impacts are specifically concentrated around monitoring and tracking the state of the natural world and analyzing and optimizing systems to reduce climate change. The future holds increasing opportunities for emissions savings within the "Augment & Autonomate" aspect as automation processes across agriculture, industry, and manufacturing become increasingly sophisticated and automated, aiding in the fight against climate change.

> "Only digital technologies move at the speed and scale necessary to achieve the kind of dramatic reduction in emissions that we need to see in the next 10 years."

Inger Andersen, UNEP Executive Director

To make this future a reality, the world needs governments to lead the way in two areas. First, it is important for governments to advance policy measures that **foster an enabling environment** for digital technologies to accelerate action on climate mitigation and adaptation through systemic change. Second, governments may recognize the pivotal role they play as **key consumers of these digital technologies** for climate and become first adopters.

To approach this daunting task, this report **suggests ways for governments to set policies aimed at leveraging digital technologies in the context of climate change** with the goal of lowering, and even eliminating, emissions while also building resilience to changes we cannot prevent. To do this it starts by laying a foundation of common terminology and understanding around digital technology and climate change. Digital technologies are reviewed through Deloitte's "Four Impact Functions" framework, which addresses the most important functions of technology in the short-to-midterm. Climate change is addressed through the three core pillars of climate action: Mitigation, Adaptation & Resilience, and Foundational Capabilities. Lastly, after laying this groundwork, the report discusses how governments could approach climate change-related policy using Google's Digital Sprinters framework which divides government actions into four primary focuses: Infrastructure, People, Market environment, and Technological innovation.

Technology

The 4 Impact Functions

Connect & Communicate

Monitor & Track

Analyse, Optimise & Predict

Augment & Autonomate

Climate Change

Climate Pillars

Mitigation: Decarbonation through process transformation

Adaptation & Resilience: Managing the impact and adjusting to the new realities

Foundations: Establishing the structure to drive effective action

Policy

Digital Sprinters

Infrastructure

People

Market environment

Technology

This report, which focuses on emerging markets, was drafted by Deloitte and commissioned by Google. It is based on the wealth of knowledge accumulated by Deloitte professionals globally in the fields of sustainability, technology, energy, and public policy. In composing the report, extensive research was conducted, and subject matter experts from academia, business, technology leadership, civil society, and local and international decision-makers were interviewed. The report also includes numerous case studies, selected for their relevance to the corresponding section and with a focus, as much as possible, on applications in emerging markets.

Nonetheless, this document is not intended as an exhaustive description of the many actions being taken around the world by diverse actors of all sizes from all sectors. Rather, the report attempts to define what needs to be done and how, using industry segmentation to determine where it would be most effective to deploy these solutions.

2. Climate Action: Three Pillars

There are many pathways to rise to the challenges of climate change, with necessary action mobilized in a myriad of ways. These can be described as centering around three pillars and can be broadly classified as follows:

- **Mitigation:** Decreasing the severity of climate change by lowering the amount of GHG emissions in the atmosphere
- **Adaptation and Resilience:** Dealing with the impacts of climate change that will occur or that are already occurring in many cases
- **Foundation:** Creating social, economic, and policy conditions to address climate change through education and awareness, reporting and compliance measures, accelerated research, and better strategic decision-making

Climate Catalyst Blueprint: Decoding the pillars for climate impact

Mitigation efforts
reduce the causes of climate change

- **Reduce**
  reduce absolute emissions from human activity
- **Replace**
  low-carbon substitutes and alternatives
- **Restore**
  remove GHG emissions from atmosphere and restore ecosystems

Adaptation efforts
building resilience to impacts

- **Secure and Sustain**
  create resilient human infrastructures, and protect biodiversity and natural ecosystems
- **Sense and Forecast**
  Gather and analyze data for precise forecasting, forming the basis for planning and response strategies

Foundation Setting

Strategizing & Prioritizing	Awareness	Compliance & Reporting

2.1 Mitigation

Digital Technology for Mitigation

- Implementing smart grids to optimize and monitor energy distribution, enhancing efficiency and reliability in electricity supply
- Utilizing AI systems to analyze, predict and minimize energy consumption, achieving optimal energy usage.
- Automating maintenance with AI to minimize energy and resource wastage, ensuring efficientoperation
- Optimizing Smart City infrastructure such as streetlights and transport systems
- Expanding connectivity in regions with poor internet access in order to facilitate remote work and cut down on energy usage and emissions
- Monitoring environmental changes and illegal activities to protect ecosystems, supporting law enforcement efforts
- Utilizing digital modeling to plan and predict outcomes in habitat restoration projects
- Modeling with digital twins for cost-efficient predictions through reduced need for physical models
- Implementing systems to monitor and ultimately optimize carbon capture processes

Mitigation largely refers to activities designed to lower the absolute amount of GHG emissions in the atmosphere. French President Emmanuel Macron expressed the fear that *"by not mitigating* CO_2 *and destroying our biodiversity, we are killing our planet."* **The aim of mitigation is to reach net zero GHG emissions,** meaning that the absolute amount of emissions being added to the atmosphere from human activity is zero by lowering all possible emissions and permanently capturing or reabsorbing the rest. According to the IPCC, to achieve the 1.5 °C target, emissions need to decline by 43% by 2030 and reach net zero by 2050.[9]

Broadly, mitigation activities focus on **reducing** GHG emissions in existing processes, **replacing** existing processes, models, and resources with carbon-free and lower-carbon alternatives, and **restoring** atmospheric GHG levels with carbon capture and removal methods. The longer it takes to decarbonize existing processes, the more future investments will be needed for alternative solutions such as carbon capture and direct removal.

9. (IPCC, 2023)

2.1.1 Reduce Emissions by Optimization

Main Actions

- Optimization of the electricity grid
- Reducing energy demand through efficiency and optimization, green building practices, or behavior change
- Optimization of distribution/supply lines, logistics, and cargo management
- Real-time monitoring systems to track waste generation and treatment processes in order to reduce emissions and over-production
- Implementing circular economy principles in industrial processes through data analytics thereby optimizing resources

Reduction efforts aim to cut carbon emissions by optimizing processes on a large scale, driven by advancements in digital technology like AI. A major focus is **energy efficiency**, especially in electricity production and consumption. This involves actions across the **entire energy chain,** from grid optimization to reducing consumption by end users, with monitoring and tracking sensors and AI playing vital roles. In Sub-Saharan Africa, where many regions don't yet have access to sufficient energy supply, digital technologies such as smart grids can help solve the lack of energy infrastructure challenge by offering solutions to cut energy grid losses. Augmentation and autonomation also help lower electricity use, as exemplified by smart street lights in Germany that respond to environmental conditions, reducing maintenance, CO_2 emissions, and electricity costs by up to 70%.[10]

Reducing **fuel consumption** is another priority. Optimization of global supply chains through AI-powered smart route planning and cargo management can significantly lower emissions, especially for road freight, shipping, and aviation. This is a significant component considering that road freight and shipping account for 40% of all CO_2 emissions from transport as well as approximately 20% of aviation emissions.[11]

Resource efficiency also plays a role in reducing emissions by streamlining production, transport, and waste treatment processes. Circular industrial practices further contribute by minimizing resource use and waste. Virtual meetings and other Connect & Communicate solutions, like Zoom, have gained popularity, enabling people to work from home and reduce the carbon footprint of in-person meetings. Similarly, studies conducted on the topic suggest that transitioning from in-person to virtual conferences can cut carbon emissions by 94%.[12]

A report from the World Economic Forum (WEF) indicates that effective use of digital solutions[13] can potentially **reduce emissions by 20%,**[14] a significant contribution to the 2050 reduction goals. In the energy sector, for instance, GHG reductions can be achieved by enhancing carbon-intensive electricity generation processes and enhancing energy efficiency in buildings as well as deploying and managing renewable energy using artificial intelligence powered by cloud computing and highly networked facilities with 5G. In terms of materials, emissions can be reduced by improving mining production and supply chain processes powered by foundational technology such as big data analytics and cloud computing.

10. (Beaton, 2018)
11. (Our World in Data, 1990-2019)
12. (Tao, Steckel, Jaromir Klemes & You, 2021)
13. Digital solutions include: IoT, Drones & Imaging, Automation & Robotics, Augmented/Virtual Reality, Blockchain, 5G, Cloud, Big Data Analytics, Measurement & Reporting, Digital Twins, and AI/Machine Learning
14. (George, 2022)

Finally, regarding mobility, environmental footprints can be reduced by leveraging sensing technologies like IoT, imaging, and geo-location to gather and analyze real-time data to improve route optimization. Building on the estimated 7.5% reduction that is achievable based solely on current commitments, the 20% emissions reduction estimate is a major step towards the 45% reduction needed by 2030 to meet the Paris Agreement targets.[15]

15. (Masterson, 2022)

Case Study 1: Schneider Electric

In its commitment to combat climate change, Schneider Electric, a French provider of digital energy and automation solutions, embarked on a project to construct the IntenCity office building in Grenoble, France. The goal was to create an ultra-efficient structure that achieved zero carbon emissions while complying with the stringent French Environmental Regulation RE2020. Leveraging the power of digital technology, Schneider Electric employed innovative solutions to make IntenCity a beacon of sustainability and energy efficiency.

IntenCity's achievements in energy efficiency are truly remarkable. It boasts energy usage per square meter at only approximately 11% of the European average, with precise control, real-time monitoring, and continuous improvement monitored by its Building Information Modeling (BIM) System.

At the heart lies Schneider Electric's Ecostruxure Building Operation (EBO) software, a system that provides comprehensive operational control over all the energy systems within the building. It enables minute-by-minute monitoring and control of each system's performance, ensuring optimal efficiency and resource use, and includes its Ecostruxure Power Monitoring Expert (PME) tool, which aggregates and analyzes data from various sensors and meters, identifying patterns and opportunities for optimization.

IntenCity also made extensive use of clean energy sources. The building features an impressive 4,000 square meters of solar panels and two vertical wind turbines, generating a significant amount of electricity locally and offsetting a substantial portion of the building's energy consumption. This commitment to solar power aligns with Schneider Electric's dedication to sustainable energy solutions.

2.1.2 Replace with Low-Carbon Alternatives Optimization

Main Actions

- Analyzing and predicting energy supply and demand to optimize the transition to renewable sources like solar, wind, and hydropower.
- Enhancing the efficiency of biofuels and hydrogen through data-driven analysis and optimization processes.
- Tracking and monitoring usage patterns of electric vehicles and infrastructure in order to optimize charging strategies
- Optimizing bus stops and routes to make public transportation more attractive
- Communicating low-carbon lifestyle choices such as consuming less meat or selecting locally produced and low-carbon products
- Monitoring and optimizing the use of sustainable materials in the construction and manufacturing sectors for environmental sustainability.
- Utilizing real-time monitoring to optimize resource use in agriculture and predict crop yields more effectively.

The mission to reduce carbon emissions also **involves replacing traditional fuels with carbon-free or low-carbon alternatives,** especially in the transportation sector. This transition relies on sources like solar, wind, and hydropower, as well as alternative fuels such as **biofuels** and **hydrogen**. However, integrating these alternatives into the energy grid at scale presents challenges, necessitating storage and grid management solutions. Digital technologies play a key role in addressing these challenges and offer significant business opportunities.

Additionally, **substitution** plays a crucial role in **reducing emissions.** This involves replacing materials, chemicals, and practices with more sustainable alternatives. Advances in artificial intelligence and changes in industrial and regenerative agricultural practices, such as adopting circular economy principles, are driven by digital technologies. For instance, Amsterdam's "Haut" skyscraper significantly reduces its carbon footprint with the help of digital tools like 3D modeling and sensor-controlled temperature installations. The broader trend of shifting to electricity-based energy sources also falls under this category.

Case Study #2: Government initiative to equip apartments with sensors

Government initiatives for the adoption of smart meters can have a significant impact for consumers, the economy, and the environment. A government initiative in Israel to ensure every apartment building has meters that monitor electricity highlights the multidimensional impact such initiatives can have. Historically, electric companies would send individuals out to read meters – with the relevant cost to the electric companies (and consumers); not to mention, this constant driving around caused a steady stream of pollution via petrol consumption. By adopting smart sensors, companies can eliminate these unnecessary emissions while additionally saving money on gasoline and employees' time.

For instance, an energy supplier in the UK has implemented smart meters to help their customers reduce energy consumption. These smart meters provide detailed insights into energy usage, which are split into 30-minute periods and are accessible via an online dashboard. This level of detail allows customers to monitor their energy use more closely, identifying patterns, spikes, and anomalies in consumption. These smart sensors may also open up the free market in the future and encourage people not to use electricity during certain peak hours, in order to balance the grid as well as use cleaner (and cheaper) energy – or adopt clean energy as a competitive advantage.

2.1.3 Restore Carbon Levels

Main Actions

- Utilizing tracking technology to monitor the progress of ecosystem restoration and reforestation, ensuring these natural habitats effectively sequester carbon.
- Applying analytical tools to optimize the CCS/CCUS process, enhancing its efficiency in capturing and storing carbon emissions
- Enhancing direct air capture techniques by integrating predictive modeling, allowing for adaptive responses to atmospheric CO_2 variations and optimizing the capture process
- Analyzing agricultural practices and soil health data to predict and enhance the carbon sequestration potential of farmlands
- Monitoring biomass growth and CO_2 capture rates to optimize the production of bioenergy, ensuring effective carbon capture and storage.

In addition to reducing emissions and replacing traditional fuels with low-carbon alternatives, addressing climate change also requires strategies to **capture and remove carbon** from the atmosphere. This is crucial to managing carbon levels and achieving the Paris Agreement goals. Current assessments suggest that historical CO_2 emissions have nearly exhausted the carbon budget to limit global warming to 1.5°C. Carbon dioxide removal (CDR) is recognized as a necessary component of the global mitigation strategy to combat climate change. However, existing CDR solutions are in their **early stages,** with uncertain effectiveness, potential impacts, risks, and benefits, particularly at a large scale. These solutions encompass **carbon capture and storage (CCS) technologies** that capture CO_2 emissions before release and store them. While **not purely** digital solutions, they **rely on** various digital technologies for development and operation. Currently, most captured CO_2 is injected underground, although there are emerging opportunities for use (CCUS). These solutions are not yet economically viable at scale, but advancements, including those driven by AI, hold promise for the future.

Furthermore, digital technologies can **enhance natural carbon removal processes** driven by ecosystems. Oceans, soil, and plants naturally absorb and transform CO_2. Ecological carbon removal methods involve conserving and restoring natural carbon sinks like forests and peatlands, as well as soil carbon sequestration. **Digital tools like Google Earth support the analysis of vast farmland data,** enabling insights into forest fires, insects, and forest management. AI and drones assist in reforestation by collecting and analyzing terrain data and dispersing seeds. For instance, the Australian startup AirSeed, in collaboration with WWF, employs "octocopters" to sow seeds efficiently. However, tree planting must be carefully managed to avoid unintended consequences, such as water scarcity or reduced carbon sequestration. To address this, AI and digital solutions help determine the right tree species and locations for reforestation. The Alliance of Bioversity International and the International Center for Tropical Agriculture (CIAT) have developed the free online tool "Diversity for Restoration," which models habitat sustainability for reforestation projects and recommends suitable species for planting.

Climate Cost of Digital Technologies

Large-scale application of digital technologies to climate efforts will only reach their full potential if they are balanced with the **potential negative impacts** incurred by their widespread and intense use. To achieve this, a concerted effort is needed to ensure that as digital technology use grows, **sustainability of the digital solutions and the industry itself also increases.** This involves embracing renewable and clean energy sources on one the front and extending hardware equipment lifecycles through better design and support coupled with improved recycling practices on the other.

The tech sector accounts for 2-3% of greenhouse gas emissions.[16] Similarly, in 2022, the electricity usage of global data centers represented 1.0% to 1.3% of the world's total electricity demand.[17] A study published in Nature Climate Change in 2022 indicated that cloud and hyperscale data centers contribute 0.1% to 0.2% of worldwide GHG emissions.[18] The study also found that approximately one quarter of these data centers' processing tasks are dedicated to machine learning applications. Nevertheless, tech players enjoy the benefits of scale at their facilities and can implement significant emissions reduction solutions such as operating on carbon-free energy. In fact, major cloud providers, including Google, have committed to net-zero goals and are actively transitioning their data centers to clean energy.

16. (UNEP, 2021)
17. (IEA, 2023)
18. (Kaack, L.H. et al., 2022)

2.2 Adaptation & Resilience

Digital Technology for Adaptation & Resilience

- Monitor & Track real-time air pollution, fire, floods and other weather hazards from various sources and consolidate these data for a comprehensive overview
- Improving communication of consolidated datasets in the field of environmental researchthrough shared platform for analysis
- Applying advanced optimization and prediction models in urban planning to forecast the impact of events or policies on city carbon footprints
- Enhancing risk assessment in agricultural sustainability with "Analyze, Optimize & Predict" capabilities using AI-aided analysis
- Improving analysis and prediction of extreme weather events for early warning systems and alerts to facilitate crisis response
- Investing in machine learning to augment and automate existing climate digital solutions and develop new ones
- Expanding telemedicine and smart healthcare through remote digital platforms

The IPCC defines adaptation & resilience as **"the actions taken to manage impacts of climate change by reducing vulnerability and exposure to its harmful effects and exploiting any potential benefits."**[19] Given the historical and current emissions levels as well as near-term trajectories, the impacts of climate change are unavoidable and already being felt around the world. At its core, adaptation & resilience looks to reduce the vulnerability to climate change risks. This necessitates the adaptation of all systems – natural and human.

Adaptation & resilience efforts largely aim to **secure and sustain** natural ecosystems and human infrastructure and wellbeing. The basis for this is **sensing**, or data collection and analysis to establish the knowledge base required for understanding our reality, anticipating the future, and informing timely action.

Adaptation Technologies and their associated Impact Functions

	Connect & Communicate	Monitor & Track	Analyze, Optimize, Predict	Augment & Autonomate
Early warning and alert systems for crisis response	●	•	•	•
Consolidated datasets as well as shared platforms for analysis	●	•		
Realtime data collection and consolidation of data from different sources		●		
Machine learning in support of innovation and discovery of new solutions			●	
Scenario analysis and advanced modeling to forecast impacts of events or policies			●	●
AI aided risk analysis			●	●

19. (IPCC, 2018)

2.2.1 Secure and Sustain Natural and Human Systems

Main Actions

- Strengthening infrastructure to monitor and adapt to extreme weather, ensuring robustness against climate stresses
- Utilizing digital tools to predict, plan, and maintain business operations during climate challenges
- Implementing systems to monitor and predict climate events, optimizing aid deployment and recovery processes
- Employing technology to monitor and support conservation, protection, and restoration of ecosystems
- Utilizing digital tools to analyze, optimize, and guide the just transition towards a low-carbon economy
- Applying predictive analytics to adapt agricultural practices and crop selection, ensuring stable food production
- Using digital platforms to provide training and alternative employment opportunities for those impacted by climate change
- Developing humane and effective strategies to assist climate migrants, leveraging data to plan and communicate aid

In today's world, over 3.6 billion people are living in areas highly susceptible to the physical impacts of climate change, which include extreme weather, rising sea levels, and wildfires.[20] Climate change has far-reaching social and economic consequences. In fact, over the past decade, the direct cost of climate-related disasters has been estimated at $1.3 trillion.[21] To address these challenges, we need resilient infrastructure and efficient crisis response systems. Digital climate solutions are key in this, not only for human-centric systems but also for protecting natural ecosystems. Natural ecosystems possess some adaptability, but there are limits to their resilience, underscoring our responsibility to safeguard these ecosystems from irreversible damage and biodiversity loss.

Ensuring food security, health, and livelihoods is vital in achieving a just transition. Digital solutions, like smart healthcare systems and sustainable supply chains, can bolster these goals. This is particularly true for coastal or indigenous groups, who face disproportionate impacts and risk losing their ways of life. OKO, a Nairobi-based Insurtech startup, focuses on providing innovative and accessible crop insurance solutions to smallholder farmers in Kenya. Utilizing advanced technology like satellite imagery and mobile platforms, OKO designs personalized insurance products aimed at protecting farmers from the financial risks associated with adverse weather conditions and crop failures. This approach addresses a crucial need in the agricultural sectors of developing countries, where climate-related risks can severely impact livelihood. OKO's model represents a significant step towards enhancing the resilience of small-scale agriculture against the backdrop of climate change, ensuring that farmers have a safety net to rely on in times of uncertainty.

20. (Conservation, 2022)
21. (International Monetary Fund)

Case Study #3: Hawaii

In a world of rapidly changing climate patterns and growing environmental concerns, governments around the globe are seeking solutions to promote sustainability. One example of using digital solutions to combat these changes can be found in Hawaii's Department of Transportation's (HDOT) use of Google Cloud Climate insights.

While the state of Hawaii is renowned for its breathtaking landscapes, the archipelago's unique geography makes it especially vulnerable to the adverse effects of climate change – specifically erosion and rising sea levels. The HDOT recognizes the urgency of safeguarding the 2,500 miles of highways for which it is responsible, 20% of which are at risk. By partnering with Google Cloud, it was able to proactively assess risks and analyze various climate factors and understand both asset conditions and potential community impact. This allowed the HDOT to make informed decisions and prioritize investment and maintenance decisions while incorporating the human element.

Case Study #4: WWF

Over the past few decades Indonesia has witnessed the alarming loss of more than half of its tropical rainforests – a trend that impacts both its inhabitants, comprising hundreds of indigenous peoples, and over 3,000 animal species. Every year more than one million hectares are cleared and lost. Determined to stop this, Deloitte joined forces with the World Wild Fund for Nature (WWF-NL) and a large number of public and private entities. Together, they were able to build a scalable AI system that uses satellite imagery and geospatial data to model out and predict future changes much quicker than before, thus answering questions around how deforestation may occur and what impact it may have. This data was then visualized in a web-based tool given to local governments and then validated when predictions became true. By using this data, governments can now create and execute targeted preventative measures to protect forests and create long-term sustainable intervention systems. In addition to the real impact this will have on Indonesian biodiversity, this could also have a material impact on the livelihood of its residents, as an estimated 99 million Indonesians, over 35% of the country's population, are dependent on the rainforest and its extended ecosystem services for their livelihood. This action may also have a significant impact on emissions. Currently, 85% of Indonesian emissions come from this rainforest and peatland loss, which contributes to the 5% of the global greenhouse gas emissions (GHG) for which Indonesia is responsible.

2.2.2 Sense and Forecast for a faster and better response

Main Actions

- Utilizing digital systems to collect, organize, and analyze data for informed climate action
- Employing predictive tools to forecast climate trends, optimizing both immediate and long-term responses
- Implementing digital alarm systems that predict extreme weather events to communicate early warnings to vulnerable communities
- Charting digital pathways to outline and optimize climate action strategies
- Analyzing the impact of policies and technologies through climate digital solutions to measure their effectiveness in climate mitigation and adaptation

Case Study #5: Making Mining More Sustainable

Enhancing energy efficiency stands out as a crucial avenue for diminishing the carbon footprint of mining operations. Technological and process-oriented strategies encompass advancements in energy monitoring and management, the implementation of in-pit crushing and conveying, and the optimization of haul truck payload. Additionally, the integration of autonomous technologies in loading, hauling, crushing, and drilling holds promise for reducing fuel consumption while simultaneously enhancing safety and productivity. For example, it is estimated that the adoption of driverless technology in the mining process could result in a notable 10–15% reduction in fuel usage and an 8% decrease in maintenance costs.[24] The Syama gold mine in Mali, primarily owned by the Australian-based Resolute Mining, is poised to become the first fully automated mine in the world. This entails the utilization of automated machinery for tasks such as clearing the drill point, extracting ore, and loading ore onto haul trucks. Machines that previously operated for 15-16 hours can now run for 22 hours a day. This efficiency gain not only lowers operational costs but can also reduce the environmental footprint by optimizing resource use and reducing waste. [25]

Addressing climate change, often deemed a "slow-moving crisis," requires rapid growth and expansion of our **knowledge base.** This challenge involves both **long-term planning** and **quick responses** to immediate threats. Climate change presents a paradox – it is an immensely complex system with intertwined factors that breed uncertainty regarding changing weather patterns and mitigation effects. However, years of research and data collection, coupled with technological advancements and the advent of Artificial Intelligence, have **greatly enriched our understanding and response capabilities.**

Digital technologies have already made a significant impact, but their potential remains vast. Sensing, a critical aspect of this pillar, involves gathering and **analyzing data for precise forecasting, forming the basis for planning and response strategies.** In this context, digital climate solutions such as weather models, early warning systems, and climate data platforms offer valuable insights into climate patterns. For instance, Google's collaboration with the Indian Central Water Commission and Bangladesh's Water Development Board has already made it possible to send over 40 million notifications to people in flood-affected areas. Similarly, partnerships with emergency management offices in California and Colorado have been instrumental in identifying and enabling SOS alerts during fires.

Tools like the World Food Programme's Vulnerability Analysis Mapping system, which employs satellite data, swiftly identify food shortages. Google Research has also developed Google Flood Hub, a tool involving AI models that process diverse publicly available data sources to forecast floods and alert affected populations up to 7 days before disaster strikes.[22] Similarly, systems like Kuzi (by Selina Wamucii) detect early signs of pest infestation to protect crop yields across Africa. For tourism-dependent regions with shrinking peak seasons, such as the coastal areas in the EU (within 50 km from the sea) that generate approximately 30% of the block's GDP and house around a third of its population, digital technologies with early warning systems are essential.[23]

Beyond crisis management, these advanced systems contribute to establishing globally consistent, locally relevant datasets, enhancing our understanding of climate realities for more accurate projections and decisions. Sensing can also encompass innovative data use, as seen in research that employed X (formerly Twitter) and Google Trends data to monitor COVID-19 cases in Canada. Such methods have the potential to predict disease outbreaks, with AI's large-scale data analysis capacity improving accuracy and paving the way for future systems.

22. See https://sites.research.google/floods/l/0/0/3
23. (European Commission)
24. (Mining Technology, 2018)
25. (Mining Technology, 2018bis)

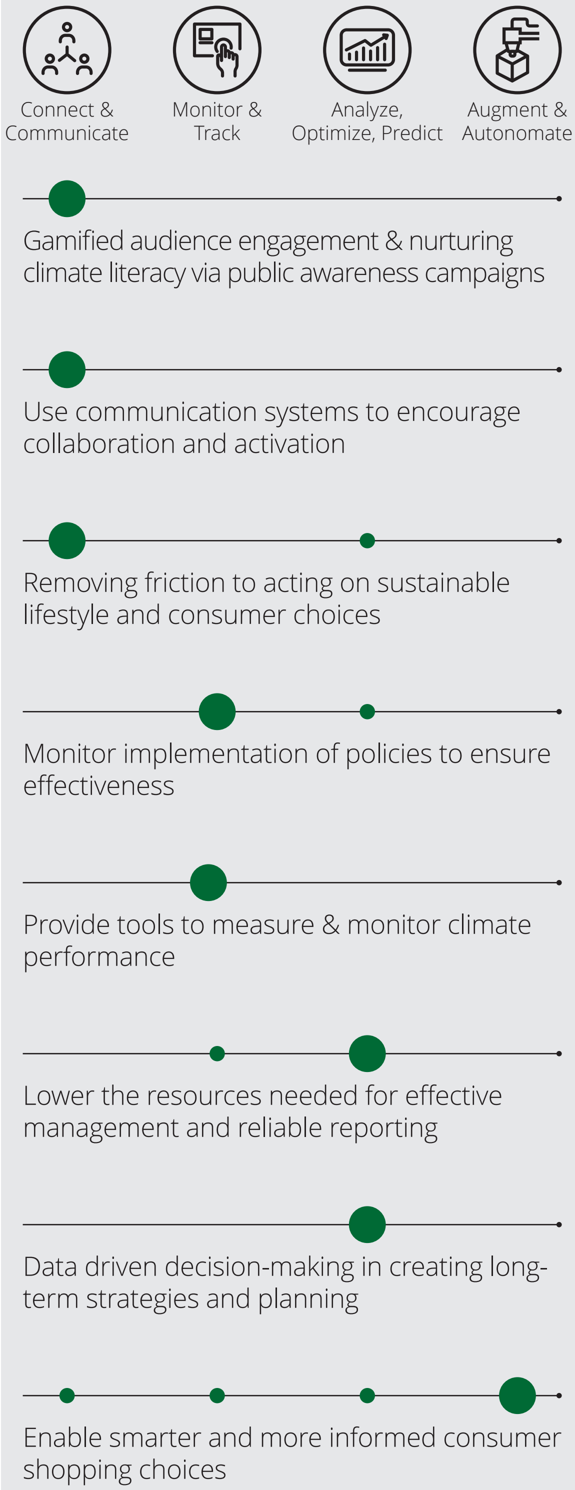
2.3 Setting Foundations

Utilizing Digital Technology for Setting Foundations

- Enabling smarter and more informed consumer choices
- Providing the tools to measure and monitor climate performance and lower the resources neededfor effective management and reliable reporting
- Monitoring implementation of policies to ensure effectiveness
- Data driven decision-making in creating long-term strategies and planning

The response to climate change requires mobilization on an unprecedented scale. No government can single-handedly achieve what is required, and climate action must be a cross-border, cross-industry, multi-level effort. Mobilizing all these different actors requires a robust foundational system to motivate action and focus attention by **strategizing and prioritizing digital** public efforts. Furthermore, action can also be a personal choice informed by education and awareness, or incentivized through regulation and expectations of **compliance and reporting.**

Foundations Technologies and their associated Impact Functions



2.3.1 Strategizing and Prioritizing

Main Actions

- Using advanced predictive models to define clear objectives and set ambitious targets, underpinning strategic climate action plans
- Using Big Data Analytics to identify the most suitable mitigation and adaptation measures
- Using digital tools to communicate scientific evidence and socio-economic factors whenengaging with stakeholders
- Continuously monitoring and analyzing the outcome of environmental initiatives in order toprioritize resources and ensure they are allocated to the most impactful and cost-effective projects
- Utilizing Monitor & Track technologies that provide new insights to drive informed decisions, allowing for real-time adjustments and responsive measures to climate change

Digital tools can help governments, businesses, and NGOs effectively **strategize and prioritize** their approaches to climate action. Digital climate solutions can enable data-driven decision-making and enhance stakeholder engagement

For example, **transforming scaled digital information into actionable insights** can help organizations understand which solutions to tackle. Examples include Google's Environmental Insights Explorer, which helps governments understand, strategize, and prioritize urban climate action, Google's Data Commons, which standardizes a wide variety of data sets, Google's Global Forest Watch, which helps prevent deforestation, and Google Earth Engine, which powers marine conservation (Global Fishing Watch and Global Surface Water Explorer).

Electrified Fleet Solution

Canadian freight and logistics firm Purolator committed last year to reduce emissions by 42% by 2030 and reach net-zero by 2050. Working with Deloitte, they developed a strategic roadmap that included analyzing usage patterns, picking the best vehicle types, and making key energy and infrastructure decisions. In doing so, they are on track to reach their goals and electrify a majority (60%) of their last mile deliveries by 2030. This was made possible thanks to Deloitte's 'Electrified Fleet Solution,' a Google Cloud offering that assists companies all along the way from integrating data through to monitoring impact using an interactive dashboard.

2.3.2 Awareness

Main Actions

- Supporting climate digital tools that analyze and optimize the environmental footprint of consumer choice and guide their decision making
- Using digital technology to widely communicate environmental certification or qualifications to the public in order to validate and inform on climate impact of products

Online shopping habits and platforms create the opportunity to utilize digital tools such as search and tagging to educate about sustainable alternatives and their advantages and make them more accessible, removing some of the friction and hassle of making the sustainable choice. Beyond **Google Flights'** feature of providing information on carbon emissions for flights, a broader initiative is the Travel Impact Model (TIM). TIM is a sophisticated, publicly accessible model developed by Google for predicting per-passenger CO_2 emissions from flights. This model powers emissions data on various platforms, including major travel sites like Booking.com, Expedia, and Skyscanner through the Travalyst coalition, enhancing the scope of informed sustainable travel choices. Digital tools can also be used to incentivize sustainable choices, making them more discoverable and accessible to both individuals and enterprises. These tools are not just for raising awareness; they also enhance efficiency and effectiveness in running and monitoring sustainability programs.

2.3.3 Compliance and Reporting

Main Actions

- Supporting enhanced corporate climate-related disclosures and reporting, including greenhouse gas footprint and climate-related risks
- Encouraging standardization of metrics and sustainability indicators across disclosure frameworks to allow for comparability and decision usefulness
- Encouraging digitalization of greenhouse gas emissions footprint accounting systems that can underpin a robust reporting climate-related reporting ecosystem
- Encouraging utilization of digital tools in assessing climate-related risks

Using Google Data to Meet Reporting Obligations

UK Bank NatWest teamed up with Google Cloud, Deloitte, and Climate Engine to use Google Earth to capture climate-related data points in its commercial banking portfolio. Launched with its agricultural customers, this information will allow farmers to build a comprehensive picture of the challenges they face as well as assist in fulfilling reporting obligations imposed by the EU Taxonomy and Taskforce on Nature-related Financial Disclosures (TNFD). This information will also allow farmers to build a tailored picture of the challenges facing them, such as flood, drought, fire and biodiversity risks, all at a field-specific level.

Regular corporate reporting on climate-related issues and indicators fosters knowledge exchange, best practice sharing, and **accountability, further propelling progress toward climate goals**. Recently, a global trend toward **standardization** and unified climate and sustainability reporting has emerged, marking a shift from a mostly voluntary practice. Regulations such as ISSB standards in various jurisdictions, the SEC rule requiring registrants to provide climate-related disclosures in their annual reports, and EU requirements like the Sustainable Finance Disclosure Regulation (SFDR) and the Corporate Sustainability Reporting Directive (CSRD), already in effect or imminent within two years, mandate corporations to measure, monitor, and report their climate-related activities.

Digital technology makes many of these requirements feasible, with existing solutions that automate emissions tracking and provide insights into resource usage, waste generation, and emissions. Other platforms, like WasteBits, facilitate compliance in the waste management sector. The Climate TRACE coalition leverages over 300 satellites, 11,000 sensors, and AI algorithms for emissions monitoring. These innovations enable corporations to meet reporting requirements and prioritize climate management while fostering continuous improvement.

Climate change is a pressing crisis composed of many disparate, complex factors. To provide effective mitigative, adaptive and foundational measures to combat it, **society can benefit from digital technologies** that offer the opportunity to both minimize emissions as well as progress society to a more **equitable and sustainable future.** This is especially true for emerging markets coping with a unique set of challenges. Due to the global nature of this crisis and the need for government involvement, policymakers have a distinctive role to play, a role they can fulfill, among others, by **considering and promoting the right digital technologies to combat climate change**. The next chapter will further discuss this role of government and explore the means through which it can drive society into the future.

3. Government: Approaching Climate Action

Governments play a key role in enabling and accelerating the digital transition needed to combat climate change. First and foremost, policy leaders may act to alleviate barriers that might stand in the way of digital development and define policy goals to achieve that transition. This chapter thoroughly examines the tools public leaders can use to unleash the full potential of this transformation using the Digital Sprinters Framework proposed by Google.

3.1 Barriers to Government Action

The journey toward widespread adoption and effective implementation of these technologies is not without hurdles. While digital climate solutions promise significant advancements, a set of barriers may hinder the full realization of their potential: governmental decentralization and bureaucratic delays present obstacles to effective climate action technologies, as they slow progress and create challenges in navigating complex regulatory systems. Resource constraints, such as insufficient public funds and a shortage of qualified personnel, especially in some emerging markets, hinder public leaders from pursuing climate-related initiatives, exacerbated by a massive funding gap estimated at $30-60 trillion.[26] The public-private divide further complicates matters, with communication issues, complex regulations, and the knowledge gap between policymakers and tech experts causing uncertainties in private markets. Finally, governments should consider addressing foundational challenges related to data quality, universal access to digital solutions, and bridging the awareness-action gap to promote climate-related actions.

Key Public Barriers

Government Decentralization	Resource, Restraints	Public-Private Divide	Foundational Access and Data
Decentralization of government work and siloed approach	Insufficient budgeting for climate infrastructure projects, lack of capital – for early stage and at scale up ("valley of death")	Miscommunication about the goals, actions and strategies needed to address climate change	Measuring climate impact & lack of usable reliable data
Conflicts between public considerations	Lack of dedicated manpower	Knowledge gap between policy makers and tech experts	Concerns about data privacy and government trust
Outdated, conflicting or frequently changing regulations	Lack of skilled labor	Market uncertainty – particularly on the demand side which complicates the identification of levers to focus on	Lack of awareness and "awareness/action" gap

26. (Deloitte Insights, 2021)

3.2 Setting Foundations

In order to advance digital-oriented climate policies, governments may act to alleviate as much as possible the aforementioned barriers. In most cases, this requires designing a comprehensive policy approach that cultivates a **dynamic economic environment** combined with a **tech-oriented mindset** that fosters the development and incorporation of digital tools as an integral part of government action on climate change. As Sam Ricketts, co-founder of Evergreen Action, observed: "we cannot tackle the 21st century imperatives of climate change with 20th century solutions."[27] The key goals and outcomes of incorporating digital technology to address climate change can be summarized as follows:

1. **Incorporate digital technologies as an integral part of governmental climate change efforts:** this includes utilizing digital solutions within public institutions focused on climate initiatives, increasing transparency, and avoiding siloed activity when considering climate actions through data integration and sharing platforms as well as digital collaboration tools.
2. **Create the foundations and environment required for developing and implementing digital solutions:** this implies not only facilitating the collection, verification, and use of data in developing climate solutions, but also work on standardizing and building a supporting regulatory environment.
3. **Encourage and facilitate digital innovation for climate action:** this includes working to increase capital flows through government investments as well as encouraging private financial markets to participate through incentivization.

3.3 Policy Recommendations

In presenting the potential policy measures for achieving these goals, the **Digital Sprinters Framework** proposed by Google offers a structured approach. This framework defines four primary categories: **Infrastructure, People, Competitiveness (Market environment), and Tech innovation.** Each category addresses specific aspects of policy that can facilitate sustainable and inclusive economic growth while harnessing the power of digital transformation.

27. (Volcovici, 2021)

Goal in a digital context

To ensure affordable access to the internet and digital infrastructure as a necessary foundation for using digital solutions

3.3.1 Infrastructure

The role of infrastructure investments in addressing climate change extends far beyond traditional notions of infrastructural development. While highways and buildings are of course important, in the modern world, **access to the internet is seen as a prerequisite and governments in the Global South play a key role in maximizing internet coverage, including remote and underdeveloped areas.**

1. Data Availability

Governments can increase the amount of data available through data capturing technologies. This includes **expanding IoT into future grids and commercial and residential buildings,** embedding sensors in highways to monitor congestion, implementing smart grids for efficient energy management, integrating IoT solutions to connect government structures to the digital realm, or even **investing in new data collection methods,** like drones and satellites. This lays the foundation needed for developing and implementing data-based climate tech solutions.

For example, the Indian government has been investing heavily into satellites through the ISRO, its national space program building observation and weather satellites, including a joint project with the US-based NASA called "NISAR" to monitor movement on Earth's land and ice surfaces in extreme detail.[28]

Governments can drive the enhancement of AI capabilities through projects that provide real-time data for optimization and informed decision-making. They can set an example by **integrating these solutions into new infrastructure projects,** enabling AI to predict and respond to disasters such as fires, floods, earthquakes, and tornadoes. This data can also support a **national climate and resilience center** for standardized climate data, and enable effective modeling, prediction, and resilience planning for extreme weather events. To complement these efforts, creating an environment or platforms for data sharing, including the necessary regulatory framework for data security and privacy, can further benefit researchers, entrepreneurs, and the public.

28. (NASA, 2023)

2. Build Out Adaptive Infrastructure

It is essential for governments to evaluate new infrastructure investments **through the lens of both climate change and digital technology.** Because decision makers do not always have the knowledge, they may call on climate change and tech savvy experts to assess the project and share their recommendations. In practice, these experts could either provide their recommendations as external consultants or, if the legal framework is adapted accordingly, even sit on committees that would confer them some decision-making power.

This approach can help governments **anticipate the future needs** required to fight climate change through digital tools.
For instance, in the context of developing countries where budget constraints necessitate maximizing cost-effectiveness, public leaders could explore partnerships with multilateral development banks (MDBs) and development finance institutions to equip new infrastructure projects with forward-looking technologies. Although such technologies, like EV charging stations in parking lots, might offer low immediate utility in regions with minimal EV presence, they could become critical over time. Financing partnerships can help justify higher initial investments, given the expected long-term climate benefits and eventual cost savings from avoiding retrofitting infrastructure at a later stage. Collaboration with concessionary finance partners who share a vision of sustainable development can enable these governments to implement such future-ready projects without compromising their immediate financial priorities.

Finally, it is important for governments to consider what new systems are or will be needed to adapt to a more extreme world. These systems are not constrained to physical infrastructure (such as dams or safer bridges) but may also include **partnerships with online platforms** to share evacuation warnings, or other critical information to enable early warning systems.

Fires, floods, and heat waves: oh my!

Governments around the world are using technology to save lives and implement adaptation and transition measures: India and Bangladesh's water companies rely on Google Research's Flood Forecasting whose algorithms predict, monitor, and visualize floods in addition to **sending life-saving alerts** to those affected.[29] California and Colorado fire departments used similar software to identify fires and send SOS alerts. Austin, Texas uses Google's free Tree Canopy tool to prioritize tree planting in vulnerable areas and determine the placement of bus shelters to increase shade,[30] while Portugal uses the same software to inform its policies and planning. Canada used data from Google Environmental Insights Explorer to realize that the majority of its pollution comes from transportation (allowing it to suggest alternatives), while Mexico helped benchmark air quality and solar potential.[31] Finally, Ireland and South Africa both analyzed usage, the former to improve cycling infrastructure and the latter to monitor reduction in fossil fuel-powered vehicles.

29. (Matias, 2020)
30. (Kempe, 2023)
31. (ICLEI, 2019)

Goal in a digital context

To train the talent needed and empower them to take action, incorporate digital tools and climate concerns into their professional and personal lives

3.3.2 People

1. Public education and academia

Governments can educate young children and other stakeholders to build a strong foundation and to **empower the next generation** to utilize digital tools to address climate change. This of course implies introducing basic climate change and technology classes in public schools and offering upskilling training courses to adult job seekers to facilitate their reintegration into the job market and gradually raise awareness among the workforce about climate change issues. At the compulsory education level, Guatemala has introduced environmental education laws since at least 2010[32] while the Italian education system requires at least 33 hours of climate change teaching per year for all grades.[33]

Beyond basic education, governments also play a crucial role in advancing academic research as a way to address climate change. They can start by **identifying gaps in academic knowledge** relevant to climate and digital issues and take measures to address these gaps through **international collaborations** and by supporting programs that train climate scientists on digital processes and digital researchers on climate.

Finally, governments have the opportunity to encourage academia to **incorporate climate courses into existing computer science and engineering departments.** This will result in a well-rounded educational experience, producing a workforce well-versed in climate science and digital technology, which is crucial given the interdisciplinary nature of climate change.

2. Cross-collaborations

Promoting collaboration among researchers and innovators is also key. Governments could encourage the creation of platforms and initiatives that facilitate cooperation, addressing common and cross-border digital climate challenges. By creating opportunities for international cooperation, such as climate summits and research consortiums, or by **supporting the development of open-source digital climate technologies,** governments can foster innovation and accelerate progress in the climate sphere.

Governments could also advance the fight against climate change by facilitating **public-private partnerships**. Connecting players from the private sector to players from the public sector can maximize the impact and deployment of climate initiatives and strengthen the culture of innovation within the public administration. For instance, Google has already partnered with governments and organizations around the world by combining its communication and AI-driven geo-spatial products to facilitate effective and timely crisis response. Similarly, the UNEP has partnered with Google in Thailand to create a new machine learning model that reveals a more detailed and accurate view of plastic pollution in the Mekong river.[34]

32. (Climate Laws, n.d.)
33. (UNESCO, 2020)
34. (UNEP, 2021)

3.3.3 Market Environment

Goal in a digital context

To create, update and utilize regulation and policy to take full advantage of digital solutions in combatting climate change

It is important for governments to establish a regulatory ecosystem that promotes sustainable, efficient, and competitive markets and supports the adoption of digital solutions. This encompasses policies that prioritize competitive markets over protecting specific players, tax regimes that adhere to international standards and predictability, as well as initiatives that **stimulate the development and expedite the integration of digital climate solutions.**

1. Establish standards to encourage adoption

Efficiency standards, certifications, and regulations can all incentivize businesses to embrace digital solutions, setting benchmarks for energy/resource efficiency, emissions reduction, and environmental mandates like zero-waste and water-saving policies. This levels the playing field, eliminates potential market advantage for high polluters, and encourages technological adoption. For example, London's "ultra-low" emissions zone leverages monitoring and tracking technologies to selectively charge heavily polluting vehicles entering the city.

Governments can promote climate actions through **standardization,** establishing protocols or frameworks for **calculating and labeling the environmental footprint of products.** Proceedings such as the Empowering Consumers in the Green Transition, the Green Claims Directive, and the European Green Digital Coalition not only **empower consumers to make informed choices** based on environmental impact and facilitate product comparisons, but also allow governments and businesses to validate new technological claims. For example, the International Organization for Standardization's Environmental Technology Verification (ETV) can help in this regard.[35] Consumers, with the ability to prioritize sustainability, create a market incentive for companies to adopt emission-reducing digital solutions. Additionally, these methodologies, which consider the entire product lifecycle and supply chain, encourage companies to think more holistically about their environmental impact. Governments can effectively utilize digital technology, such as sophisticated algorithms and cloud-based calculators, to aid in this process. These technologies enable the accurate calculation of a product's environmental footprint throughout its entire lifecycle and supply chain. By integrating these digital tools, governments can streamline the process of measuring and reporting environmental impacts, making it easier for businesses to comply with sustainability standards and for consumers to understand the true environmental cost of their purchases.

It is also important for governments to review policies that may hinder new digital climate solutions. For instance, privacy laws should **strike a balance between achieving intended goals and enabling the benefits of large-scale data and digital climate solutions.** Similarly, governments should consider how they handle Intellectual Property (IP) rights, as encouraging entrepreneurs to share their IP can build trust, spur innovation, and promote open-data and open-model development.

35. (ISO-14034, 2016)

2. Integrate digital technology into market functionality

Governments can also use digital tools to support existing regulations that impose increased traceability requirements on businesses. In Europe, for instance, pursuant to the new EU Deforestation Regulation, operators must record the geographical coordinates of the land where the commodities they place on the market were produced. This strict traceability is meant to ensure that only deforestation-free products enter the EU market. To ensure enforcement of this regulation, Member State authorities use a new digital system that centralizes relevant information about the commodities and products placed on the EU market such as geographical coordinates and country of production. When combined with remote monitoring via satellite images, policymakers are able to boost the effectiveness of this regulation.

Finally, governments can promote efficient markets and manage the implementation of climate and energy policy measures through **digital tools.** They can monitor specific actions in real time, tailor tax credits and rebates for climate-friendly practices and implement **'time of use pricing'** to encourage energy-efficient consumption patterns. Digital platforms can also support cap-and-trade systems, allowing the free market to trade emissions allowances. While carbon trading marketplaces are by no means a new concept, digital technology can help ensure transaction integrity, streamline processes, enhance transparency, and improve accountability.

Carbon Credits Complexity and Controversy

Carbon markets, though promising, encounter inherent challenges, which are evident in the two types of carbon markets that exist: the Voluntary and the Compliance markets, and the significant price gap between them.

Compliance markets entail regulations that compel companies to trade their carbon emissions, often overseen by a certifying body. However, they face three main issues. The first is "carbon leakage," where companies move projects to other regions to evade tariffs while still polluting. The second issue involves varying industry fines for non-compliance, which can sometimes make it economically attractive for specific companies or industries to pay fines instead of participating. Furthermore, compliance markets alone fall short of fulfilling the goals of the Paris Agreement, necessitating the presence of "voluntary markets." In these markets, companies voluntarily offset their emissions without regulatory mandates. However, voluntary markets have their issues, particularly regarding quality. They trade at a fraction of the price of compliance markets due to concerns about the integrity of offsets. Several factors contribute to this quality gap, primarily due to insufficient oversight and transparency. These include the potential for double spending, questionable project ratings with speculative methodologies, and a historical focus on emissions prevention rather than actual carbon removal.

In recent years, there has been a positive shift toward focusing on technologies and projects that remove carbon, providing hope for improving the quality and impact of these markets. Digital technology, including remote sensing, IoT, and data analytics, enhances the transparency and reliability of carbon credit systems. By providing real-time monitoring, technology addresses challenges related to verification, standardization, and efficient trading in carbon credit markets, ultimately fostering a more effective and trustworthy system for mitigating GHGs.

3.3.4 Technology Innovation

Without technological innovation, none of the solutions needed to achieve our goals would exist. It is therefore of particular value **for governments to consider what policies they can enact to encourage both new digital solutions to be created and existing solutions to be utilized, expanded, commercialized, or shared.**

Goal in a digital context

To promote digital innovation by creating an environment that supports and encourages it and then by adopting it internally

1. Encourage Digital Innovation

Governments can foster digital innovation in the field of climate science in several ways. Firstly, they can establish dedicated innovation hubs, accelerators, and centers to foster new ideas and solutions. Hosting national and international challenge events is another effective approach, as it engages the public in finding innovative digital solutions for pressing issues. This not only stimulates **collective responsibility but also mobilizes diverse talents toward common goals**. Hackathons and incubators are especially valuable for early-stage solutions, and training digital-focused entrepreneurs on effectively presenting their climate impact to potential investors can enhance their impact.

Governments may be able to significantly bolster the climate tech sector by streamlining regulations and supporting early-stage companies in navigating export and accreditation processes. For instance, implementing trade incentives and providing detailed market intelligence can be pivotal. Such policies not only enhance the credibility and visibility of climate tech exports but also ensure global access to essential climate solutions. For example, Denmark's state-backed export credit agency, EKF, has been instrumental in helping Danish wind energy companies expand globally. The impact of these initiatives is profound: they result in a larger market size for climate tech, validated credentials, and reduced entry barriers, thereby attracting both capital and entrepreneurial interest. This creates a positive feedback loop, as seen in the rapid growth of the solar energy sector, where governments policies have provided a conducive environment for innovation and expansion.

ClimaTech Run

Organized by Egypt's Ministry of International Cooperation, Ministry of Communications and Information Technology, and Ministry of Environment, the ClimaTech Run is a global multi-stage program for tech entrepreneurs and digital artists focused on sustainability and climate action. The program aims to connect science and creativity around technology to address climate challenges. It includes tracks for tech startups and digital artists, offering prizes and opportunities to be part of the ClimaTech Global Network Programme.

IP Protection

Governments dedicated to fostering innovation in the climate tech sector can play a pivotal role by ensuring robust intellectual property (IP) protection. By granting patents, trademarks, and copyrights, governments not only secure the intellectual efforts of inventors and entrepreneurs but also build an atmosphere of trust that attracts investment. This is crucial for the commercialization and scaling of new climate technologies. For example, Tesla's decision to open its electric vehicle patents in 2014 demonstrated a unique approach to IP that encouraged industry-wide innovation and progress in electric vehicle technology.[36]

In the face of the global challenge of climate change, the role of information sharing and democratized access to information becomes even more critical. Strong, fair, and balanced IP protection, tailored to encourage collective innovation and equity, is essential. The Climate Technology Centre and Network (CTCN), under the UNFCCC, exemplifies this approach by providing technical assistance and knowledge sharing to support countries in deploying climate technologies.

In summary, effective IP protection in the climate tech sector should aim to not only safeguard individual innovations but also to catalyze broader collaboration and collective problem-solving, essential for addressing the complex challenge that is climate change.

2. Assist with Adoption

Governments can **employ Artificial Intelligence solutions to identify critical areas of concern and then make informed decisions on how to counteract them.** For example, governments can use Google's Environmental Insights Explorer to understand where public transportation stops will be most effective at reducing air pollution by cutting down on traffic. Similarly, **digital twin solutions can potentially offer holistic perspectives on climate strategies and facilitate the effective planning** of these projects, as well as provide risk analysis and mitigation through simulations and scenarios before real world implementation.

Governments can also indirectly assist with adoption by holding leaders of public organizations accountable for their climate performance, by collecting and publishing data about state-owned company climate performance, or by **incorporating climate criteria into their tenders**. Globally, governments spend approximately US$13 trillion in public contracts every year, representing approximately 12% of GDP.[38] But even more importantly, governments can encourage municipalities to adopt digital climate tech solutions. As discussed previously, early-stage digital companies in the climate arena may suffer from few potential pilot clients. By adopting these technologies, governments not only help bring these solutions to life and **demonstrate feasibility,** but also improve the government's initiatives as well.

36. (Tesla, 2014)
37. (Port of Roterdam, 2022)
38. (World Bank, 2022)

Digital Twins

A "digital twin" is a virtual model designed to accurately reflect a physical object, process, or system. It is a digital replica of a living or non-living physical entity. By bridging the physical and the virtual world, data is transmitted seamlessly, allowing the virtual entity to exist simultaneously with the physical entity. Digital twins are used for various purposes including to analyze and simulate real world conditions for the physical counterpart, predict outcomes, and improve efficiency. They are widely used in multiple industries such as manufacturing, automotive, and healthcare to optimize the operation and maintenance of physical assets, systems, and manufacturing processes.

The example of the port of Rotterdam shows how digital technology can support emission reduction through a digital twin of the port. This digital image helps visualize ship movements, infrastructure, weather, geographic and water data to improve efficiency and overall operations. One of the goals is for ships to be able to enter and leave the port autonomously in 2030. The platform is designed to enhance the port's efficiency by minimizing wait times and optimizing the processes of docking, loading, and departure. It achieves this by leveraging real-time data on water levels, currents, and wind conditions to accurately forecast the most opportune moments for ships to dock and depart. While the environmental gains are still difficult to quantify, this approach will ensure that the port operates at its maximum capacity.[37]

Changing the Skies

Finding "optimal routes" is not restricted to avoiding traffic nor is it even restricted to land! Google has been working recently to cut down on 'contrails,' the white lines often seen behind airplanes on a clear day. These trails, formed of small ice crystals, can reflect back sun rays, causing the Earth to heat up a third of aviation's impact and half of the emissions caused by jet fuel. By using a combination of satellite data and AI, Google was able to design new flight patterns that minimize contrails and even monitor if the recommendations were implemented.

4. Industry-specific Perspective

Deloitte has identified four key industries that have a significant impact on greenhouse gas emissions and environmental sustainability: Energy, Transportation, Industry, and Food. This chapter explores the role of digital tools in combating climate change within each sector as well as how policy measures can promote digital innovation or foster the adoption of these solutions based on the four areas of Google's Digital Sprinters Framework.

4.1 Energy

Digital technology can play a substantial role in accelerating decarbonization of the energy sector, facilitating smart grid systems, and enabling consumer behavior. Digital sensors and technology allow for coordinated systems to optimize diversified grids by balancing production volatility of renewables and demand spikes (such as from EVs), enhancing storing solutions, and enabling two-way electricity flows. They also allow for asset planning according to actual demand and efficiency management, such as with predictive maintenance and optimizing transmission lines. Data-driven and collaborative decisions can also help with long-term energy system planning by anticipating future needs, thereby minimizing the social cost of poor policy choices.

Several companies are actively involved in leveraging digital technology to accelerate decarbonization of the energy sector and enhance smart grid systems. One such example is Intel, which is contributing significantly to smart grid modernization. Intel's focus is on providing a range of interoperable solutions designed to facilitate the connection, management, and security of various devices in a scalable manner. Their technologies aim to optimize the efficiency of electricity distribution, balance supply and demand, integrate renewable energy sources, and improve maintenance processes. Intel's efforts are particularly crucial to the transition from traditional to digitalized grid systems, providing essential support in the areas of security, communications, analytics, and manageability.

Digital technology can also help impact consumer behavior by **encouraging energy efficiency** through smartphone apps, web-based platforms, or integrated home systems that facilitate the deployment of new technologies such as **heat pumps** and **solar panels** and allow consumers to take a more proactive role in demand management. Alternatively, in regions with limited access to traditional banking services, digital technology allows customers to afford clear energy through flexible payment models and incremental payments over time.

Engie Energy Access

ENGIE Energy Access offers a range of solar home systems and mini-grid solutions throughout Africa, catering to both home and business needs. These solutions include basic lighting systems, advanced home systems with entertainment options, and robust setups for various business applications. ENGIE Energy Access utilizes pay-as-you-go (PAYG) software in its solar solutions. This software allows customers to make flexible payments for their solar home systems, making it more accessible for those who cannot afford the full cost upfront.

4.2 Industry

Efficiency in resource utilization and supply chain operations is crucial, as is the need to **reduce waste.** This underscores the significance of incorporating circular practices into industrial processes. Lastly, some foundational raw materials (such as steel or cement) require production processes that have significant climate impacts that should be addressed.

Digital solutions and data analytics can help support the circular economy. They can enhance recycling efforts, for instance, by improving sorting accuracy. Moreover, these technologies can facilitate reverse logistics, enabling the reuse and recycling of products, often by consolidating minimum quantities for recycling.

Digital technologies can also **enable more sustainable production in the first place.** Deploying "industry 4.0" technologies, IOT, smart factories, and digital twins can all increase efficiency in production processes and optimize energy usage. In addition, the **use of sensors for predictive and early maintenance can help lengthen machines' lifetimes and optimize their functionality.** Digital technologies can also utilize modeling and simulations as well as additive manufacturing to reduce waste. A prominent example of industry 4.0 is the joint venture between Porsche and the Schuler company in the automotive industry. The plant located in Halle an der Saale in Germany operates a fully digital and automated press shop and manufactures car hoods, doors, tailgates and car roofs. By using a fully vertically- and horizontally-integrated IT infrastructure, which connects all the machines and systems via Programmable Logic Controllers (PLCs) and closed circuits, the production team was able to set up the press line at least 50-70% faster and thus minimize CO_2 emissions.[39]

The crucial role of digital technology in the realm of carbon capture, utilization, and storage (CCUS) lies predominantly in the remote measurement and monitoring of carbon storage sinks. This includes ensuring the integrity of these storage sites and preventing potential leaks, which are key concerns in effective CCUS system management. The integration of digital solutions into Measurement and Verification (M&V) frameworks is essential for accurate, real-time monitoring and verification of carbon storage. This not only bolsters the reliability of CCUS projects but also fosters trust and transparency, which are vital to their acceptance and expansion.

4.3 Transportation

According to assessments by the International Energy Agency, aligning transportation with its net zero emissions scenario will require emissions to decrease by around 25%[40] while demand will inevitably increase simultaneously as the population grows and travel becomes increasingly accessible. Reaching this goal requires overhauling both travel habits and logistics as well as supply chain practices.

Within the transportation industry, **digital can enable electrification and shared transport** through the software that is needed to run electric vehicles, the optimization of charging infrastructure, and of course digital based systems for **mobility as a service** with shared vehicles (including driverless cars in the future), ride sharing and last-mile solutions for shipping that may involve AI.

Digital technologies also **reduce fuel consumption in non-electric solutions by optimizing fleets and logistics** to create **eco-friendly routes** and through **car-to-infrastructure and car-to-car communication.** Digital solutions for parking may also decrease time spent with the engine running while **digitally enabled congestion tolls** that reduce fuel consumption may further promote the use of public transportation.

39. (ROI-EFESO, 2021)
40. (IEA, n.d.)

Google Maps: fuel-saving routes[41]

Polluted air and crowded roads: The negative aspects of motorized transport are undeniable. Nevertheless, the car remains the undisputed means of transport within our society in the EU. This results in 64% of the carbon dioxide emissions from road traffic coming from cars and motorcycles. A fundamental change in consumer behavior is crucial for climate protection. Digital technologies can trigger this shift. One example is the new feature in Google Maps, introduced in Europe in 2022. It shows eco-friendly and fuel-saving routes. In this feature, a leaf-marked fuel-saving route is displayed as an alternative. It includes information on the fuel savings of taking a route that is often only marginally longer. Besides environmental benefits, the cost savings from fuel efficiency also provide an incentive for behavior change.

Thinking Outside the Farm

Adaptive measures will need to be applied as climate change transforms the realities of farming, prompting most countries to design creative solutions to feed their population. For countries with limited land space, this implies relying on new farming techniques such as vertical farming, which increasingly require digital technologies to monitor growth, increase crop yield, and in general enable farming in new areas.

'Precision agriculture' encompasses multiple uses of digital technologies in farming. This includes the use of sensors to observe, measure, and respond to changes during agricultural production, using the resulting data to make, execute or even automate decisions, not to mention operate related farming tasks through robots, drones, and other machines of varying complexity.

Companies like **Agripredict in Zimbabwe** use machine learning to offer information to all farmers about weather, connection to agri-service providers, and crop disease diagnosis.

Cutting-edge technologies can go as far as identifying and designing novel genes in plant DNA and use machine learning to predict their future success, even editing the genomes to breed and improve for next-generation crops.

4.4 Food

Climate change is drastically changing weather patterns and crop growing conditions around the world. This **affects crop yields and poses the challenge of ensuring food security to a growing population in increasingly volatile and uncertain circumstances.** Moreover, disrupted food systems threaten the livelihood of those employed in agriculture, highlighting the importance of ensuring a just transition and adaptation of all communities.

Looking at mitigation, **the food industry is one of the highest producers of emissions, with about one quarter of global emissions attributed to the food industry either directly from changes to land uses, livestock, and fertilizer use, or indirectly through energy and transportation emissions.[42]** More specifically, reducing food waste can provide vast benefits for both people and the planet. Estimates suggest that 8-10% of global greenhouse gas emissions are associated with food that is not consumed.[43] Digital technology can help this sector **find sustainable operating models** by reducing waste via better distribution channels such as direct-to-consumer, which enables purchasing closer to home and reduces distribution impact, or through excess re-distribution. Precision agriculture can assist in improving resource efficiency through analytics, sensor data fed into AI, and demand forecasting. Meanwhile, digital solutions can also encourage and enable engagement with growers, especially in remote areas.

Digital technology can also **enable resilience through prediction and forecasting systems** that project and manage disruptions. AI solutions support precision agriculture that monitors yield to better support watering and fertilizer use. Innovation can also play a role in the exploration of novel plant varieties, efficient organization and distribution of seeds, and promotion of smart urban agriculture through digitally enhanced management of growing conditions.

41. (Google, 2022)
42. (WRI, n.d.)
43. (UNEP, 2021bis)

5. Summary

Climate change is one of the most pressing concerns of our time, impacting people and ecosystems worldwide. Governments sit at the epicenter of this crisis, charged with helping chart a path forward and find a way for society to **mitigate** further impact, **adapt** to the realities we all are soon to collectively face, and build a **foundation** to assist others in joining the fight. Digital technologies are a critical lever that governments can utilize as they develop national strategies to take action on climate change. Digital technology can help advance climate action through four key **impact drivers:** Helping us better **connect and communicate,** enabling improved monitoring and tracking, providing us with software that can **analyze, optimize and predict,** and assisting us through **augmentation and autonomation.** Together, these digital solutions can help maximize our progress, minimize negative consequences, and enable **up to a 20% reduction in emissions in energy, materials, and mobility by 2050.**[44]

Each of these functions of technology can be applied to aid governments in the three goals of climate action **(Mitigation, Adaptation & Resilience and Foundational Capabilities)** through the four core axes governments operate within: Infrastructure, People, Market Environment and Technology Innovation.

The first is governmental approach to **Infrastructure.** Governments can leverage technologies that Monitor & Track (such as sensors and warning systems) in order to build more resilient infrastructures, thus allowing us to be better equipped for damage caused by climate change. Furthermore, the data created can help provide insight through the "Analyze, Optimize and Predict" function of technology. One application of this is the Tapestry project, which aims to create a single, virtualized view of the electricity system. By developing computational tools that can predict and simulate future scenarios on the electric grid, ranging from the immediate future to decades ahead, Tapestry is facilitating the transition to a carbon-free, reliable electric grid. Meanwhile "augmentation and autonomation" tools that take advantage of these new digitally connected infrastructures can **optimize resource consumption.** Therefore, it is important for governments to ensure they are maximizing internet access

44. (George, 2022)

and standardizing data. **Standardizing data and encouraging its sharing** also helps governments fulfill the task of "building foundations" as it increases the amount of data in the world, which can then be used by others to better understand our world or build new solutions.

Governments can also look to the function of "connect and communicate" to **spread awareness and promote action** among people. The role of digital technology in building a strong foundation not only helps promote activities that reduce emissions (mitigation) but can also **educate and re-skill citizens** in jobs that are set to be disrupted by climate change (a form of adaptation).

Governments themselves can also leverage the additional data provided when creating **public policies.** Governments can help the world mitigate damage by encouraging the internalization of negative externalities. This means including the cost of the harm done to the environment in the price of everyday things, which is fueled by the additional data available. This **encourages consumers to make more environmentally friendly decisions while also driving businesses to adopt other digital solutions,** increasing the demand and adoption of many climate solutions. Policy can also help increase the supply of available solutions by 'cutting' red-tape and making it easier for new climate solutions to do business.

Finally, increasing the supply of solutions requires increasing the amount of **technological innovation** itself. This of course leads to solutions that utilize all functions of digital technology across all actions to fight climate change. To support this innovation, governments can find ways to encourage it, such as promoting the flow of capital market funding into climate solutions and building a landscape that is conducive to new businesses and innovation. Additionally, governments can adopt these solutions internally. In particular, both "Optimize, Analyze and Predict" as well as "Augment and Autonomate" solutions can help **quicken the pace** or improve the accuracy of governmental models.

As governments invest in these arenas, the interconnectedness and complexity of society, matched with the possibilities of digital technology, begin to truly make a difference and produce a **flywheel effect.** For example, these policies aimed at promoting adaptation amongst people by using technology to 'connect and communicate,' may catalyze diverse and cross-disciplinary innovation, leading to novel uses of any and many other uses of technology, to solve all three needs in all four domains.

When governments utilize the power of digital technologies across the four domains, they can build an unstoppable foundation that together mitigates continued damage to the environment and adapts to realities in order to save lives.

Summary of areas for government engagement

Theme	Subtopic	Recommendations for governments
Infrastructure	Data availability	• Expand IoT into future grids, buildings, highways, and energy management • Enhance AI capabilities through real-time data integration and integrate AI solutions into new infrastructure projects • Establish a national climate and resilience center for standardized climate data • Facilitate data sharing through regulatory frameworks for data security and privacy
	Build adaptive infrastructure	• Evaluate new infrastructure investments under the lens of both climate change and digital technology by empowering relevant experts as part of the decision-making process • Explore partnerships between emerging countries and multilateral development banks (MDBs) and development finance institutions to equip new infrastructure projects with forward-looking technologies • Establish partnerships with online platforms to share critical information for early warning systems as climate becomes more and more extreme
People	Public education and academia	• Build digital engines and systems to educate young children and other stakeholders such as job seekers about climate change • Identify knowledge gaps related to climate and digital issues in academia and address them through international and regional collaboration and training programs • Guide policymakers to integrate climate courses into existing curricula to create a workforce well-versed in both climate science and digital technology
	Cross-collaboration	• Promote collaboration between researchers and industry innovators by facilitating platforms, initiatives, climate summits, and open-source digital technologies • Support public-private partnerships in the area of climate and digital in order to strengthen an innovative culture in public administration around climate change and maximize the impact and deployment of climate initiatives
Market environment	Establish standards to encourage adoption	• Establish protocols and frameworks for calculating and labeling the environmental footprint of products to allow for more informed decisions using digital tools • Leverage digital technology to facilitate the standardization and product labeling process in order to empower consumers to make sustainable decisions • Strike the right balance between privacy laws and the benefits of data-driven digital solutions for climate
	Integrate digital technology into market functionality	• Use digital tools to support enforcement of existing regulations that impose increased traceability requirements on businesses (EU Deforestation Regulation) • Employ digital tools to monitor real-time use and tailor prices, taxes, and subsidies to encourage climate-friendly policies
Tech Innovation	Encourage digital innovation	• Create innovation hubs and accelerators and host national and international challenge events to nurture new digital innovations for climate change • Encourage entrepreneurs to share IP rights to promote innovation and open data development • Support early stage businesses in the climate and tech field by reducing red tape, providing trade incentives, and facilitating global market access
	Assist with Adoption	• Encourage governments to employ AI solutions to identify critical areas of concern and then make informed decisions on how to counteract them • Encourage accountability by collecting and publishing data on the climate performance of state-owned and state-controlled companies and incorporate climate criteria into public tenders • Encourage municipalities and governments to adopt digital climate tech solutions, serving as pilot clients to demonstrate feasibility and improve government initiatives • Employ AI or digital twin solutions to identify critical areas of concern, or offer holistic perspectives on climate strategies (e.g. optimize public transportation stops)

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