Heat and High Water

Nine Pathways to Climate Resilient Development

Hipólito Talbot-Wright
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IDB

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Foreword

This year is the warmest on record, with temperatures rising more than 1.4°C above pre-industrial averages for the first time. The resulting heatwaves, droughts, wildfires, hurricanes, floods, landslides, and epidemics, to name only a few disasters, are taking a steep toll. In Latin America and the Caribbean alone, we suffer thousands of lives lost and significant setbacks in economic growth and fiscal health. Those most affected are the poorest countries, the poorest households, and those already marginalized.

Greenhouse gas reductions must be made as quickly as possible: the climate will only stabilize when we reach net-zero emissions. The transition to a carbon-neutral economy, far from being a sacrifice, will create much-needed economic growth and prosperity. But climate impacts are already here and will continue to worsen for decades regardless of our actions. Adaptation is essential.

The good news is that the evidence shows we can adapt. Over centuries, human settlements have thrived under a variety of climates. The challenge for governments is that they must push through structural changes in only a few decades and chase a moving target. After all, it is impossible to predict how global warming will affect local weather.

This book intends to facilitate the design of adaptation policy. It provides tools that enable governments to coordinate their actions better so that each agency has clarity on how climate change affects its mandate, what the solutions are in each sector, and what governments can do to adapt, either directly or by empowering private sector efforts. The book stresses that adaptation requires action by everyone, from households and firms to all segments and levels of government.

Many solutions are readily available. As we show in this book, one of them is reducing communities' exposure by locating or relocating them away from danger or building protection—be it with brick-and-mortar or by leveraging the power of nature-based solutions, such as urban parks and wetlands.

Adaptation does not mean eliminating all risks. No amount of investment can wipe away the risk of a natural disaster. Instead, adaptation means building resilience. We need to prepare evacuation and business continuity plans. We need to stockpile essential medicines and reconstruction materials. We need to guarantee diverse sources of water and energy. We need redundancy in transport and telecommunications networks to guarantee the provision of essential infrastructure services. Investing in early warning systems is the most cost-effective way to save lives, allowing governments to anticipate disasters, inform people, and help them act.

While inflicting widespread economic and social disruptions, climate change will disproportionately affect marginalized communities. Effective adaptation thus calls for improving financial inclusion. It also requires more robust social protection programs that can respond to climate shocks. Explicitly targeting support to excluded households is critical. For example, informal settlements would benefit immensely from better housing design and stronger materials. However, construction codes are often not enforced in such places. Governments must address these deficiencies, designing plans in consultation with all stakeholders and insisting they cater to the needs of even the most disenfranchised.

Solutions will depend on the local context. Each country and each municipality has priorities and development strategies consistent with their external commitments. Adaptation plans must start from an analysis of risk and vulnerability and focus on the territorial level. Our hope in this book is to help design such plans based on up-to-date and strategic knowledge.

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EXECUTIVE SUMMARY

Heat and High Water: Nine Pathways to Climate Resilient Development

As we write these lines, 2023 is on track to become the warmest year on record, reaching 1.4°C above pre-industrial averages for the first time ever. A strong El Niño this year has added to the impact of slow-onset global warming to give us a preview of what the future could look like. Forest fires have burned 363,000 hectares in Chile, causing nearly US$3 billion in losses and damage in just 72 hours. Strong rains have destroyed 50,000 homes in Peru, as an accompanying heatwave exacerbates the dengue epidemic, infecting 150,000 people and killing 400. Landslides triggered by torrential rains in Haiti have harmed one in every 5 communities, killing 48 people and resulting in the loss of 3,000 livestock and 30,000 hectares of farmland while boosting cholera cases.

There can be no doubt that adaptation is a priority, and this book shows how it can be accomplished. The book begins with an observation: while technical solutions are available, knowledge is scattered across technical reports that each focus on a different issue, such as adapting the power sector to winter storms, or upgrading farming practices in the face of higher temperatures and droughts. Publications that give an overview on adaptation tend to either offer a conceptual framework or examples of scattered initiatives. Our goal here is to explain in a systematic but simple way why climate change is a problem, what solutions can be implemented, and what governments can do to help. We tried to write in an accessible fashion that appeals to a wide audience of policymakers, analysts, and citizens concerned about climate change.

The book is organized in nine chapters. Six of them focus on a specific system: food and biodiversity (that are linked because they often compete for land), water, energy, transport, cities, and health. Each chapter explains how climate change is a threat, lists adaptation solutions, and suggests government interventions that can enable the transition to a climate-resilient economy. Three other chapters present issues to be considered across sectors: disaster risk management and techniques to support decision-making under conditions of uncertainty, the social implications of climate change, and fiscal and financial aspects of adaptation policy. We have prioritized examples from Latin America and the Caribbean, but we hope the book, and each chapter individually, will be of interest to a global audience.

Climate Risks Threaten Lives and Prosperity

Global temperatures will keep increasing as long as countries emit greenhouse gases into the atmosphere. Current emissions projections paint a bleak picture, with temperatures projected to rise over 2°C or even 2.5°C by the end of the century if countries do not act more decisively to reach a carbon-neutral economy by 2050.

A Slow-Motion Movie with a Fast-Paced Soundtrack

A warming climate brings gradual changes and violent shocks. Gradual changes include impacts that accumulate over time, such as rising temperatures and sea levels, changes in precipitation patterns, ocean acidification, glacier melting, species migration, and biodiversity loss. Violent shocks include extreme weather events such as floods, storms, droughts, and heatwaves, and other disasters such as pandemics, pest invasions, wildfires, and landslides.

Climate change may exacerbate existing hazards or bring them to new areas. For instance, changes in precipitation and glacier melt can bring water insecurity and increased risk of drought to places that used to have plenty of water. Some coastal areas that are already prepared for floods may experience them more frequently and face higher storm surges.

A useful way to analyze the risks that climate change brings is to decompose them into hazard, exposure, and vulnerability (Chapter 1). Hazard is the climate threat, exposure is the condition of being located in threatened areas, and vulnerability determines how severely exposed elements are impacted. For instance, rising seas are a hazard, coastal cities are exposed, and infrastructure quality determines vulnerability.

Predictions Are Difficult, Especially About the Future

Climate change also brings *deep uncertainty,* a situation generated when decision-makers and stakeholders do not know or cannot agree on the likelihood of different scenarios. In our case, deep uncertainty arises because local impacts of climate change are unknowable (Chapter 1). The same atmospheric dynamics that make it impossible to predict the weather a week in advance in one's hometown make it impossible to predict how much rain to expect in Valparaiso in 2040, the length of the bean growing season in Colombia in 2045, or the incidence of heatwaves in Mexico City in 2050.

The historical record is no longer a good picture of current and future hazard. In most places, climate models cannot even agree on whether it will rain more or less in 30 years. We will only know for sure after the fact. Furthermore, climate change itself is not the only uncertain factor. Technology, social, and economic trends are as uncertain, and they play a key role in shaping exposure and vulnerability to climate impacts. Adaptation must therefore consider many possible climate futures and give priority to flexible, low-regret options that work across them.

Economic and Social Losses

Climate change causes economic losses by destroying assets, disrupting the provision of services, and reducing productivity. For instance, unfavorable weather and species migration destroy ecosystems and decrease the productivity of agriculture. In South America, the average duration of the growing season for key staples such as wheat and corn has already decreased by 1.6% to 2.5% (Chapter 2). Rising sea levels engulf tourist destinations such as hotels and beaches. In the Caribbean, the influx of tourists falls by a third after hurricanes (Chapter 2).

Extreme weather events interrupt or decrease the productivity of essential infrastructure services. In Lima, Peru, heavy rains and subsequent landslides in 2017 filled the rivers with mud, forcing the main water treatment plant to shut down and cutting off water supply to the city (Chapter 3). Across Latin America and the Caribbean, droughts threaten to dry up the reservoirs of hydropower plants and force operators to shut down natural gas power plants that cannot be cooled. Wildfires cut power lines, while heatwaves increase demand for air conditioning (Chapter 4).

When infrastructure is damaged, the biggest issue is the loss of service. In the Dominican Republic, hurricanes, river surges, earthquakes, and tsunamis cause about US$1 million in damage to the network every year, but losses to users, measured by valuing time lost to the disruptions, are almost three times as large (Chapter 5). A key concern arises when weather obstructs access to essential infrastructure, such as ports used to export merchandise or import reconstruction materials.

Most of the impacts of climate change will be felt in cities (Chapter 6). The majority of people in Latin America and the Caribbean live in cities, and cities are where the wealth of the region is concentrated. The rapid rural flight that most countries in the region have experienced means that the urban population has jumped from 50% of the total population in 1960 to 81% in 2020. Unfortunately, much of this rural migration has been absorbed by informal settlements, located on steep hills, riverbanks, or coastal areas prone to landslides and flooding; containing homes that are poorly designed and built with substandard materials that cannot withstand hurricanes; and with little access to public services such as waste collection and firefighting, exposing inhabitants to the danger of conflagration.

Climate change also has health impacts (Chapter 7). In an aging and warming South America, heat-related casualties increased by 160% between 2000 and 2021. Heat stress also reduces productivity and has already caused a kidney disease epidemic in Central America. Crop failure and droughts bring malnutrition and disease. Between 2030 and 2050, 95,000 children could die yearly from climate-change-induced undernutrition. Insect migration is also an issue: the climate suitability of dengue in South America increased 35% between 1951 and 2021.

Finally, climate change exacerbates inequality and poverty (Chapter 8). Poor households tend to have flimsier dwellings, live in riskier areas, and, when denied access to bank accounts, put most of their savings into assets such as livestock that are vulnerable to climate impacts. When Hurricane Mitch hit Honduras, the poorest fifth of households lost 18% of their assets, compared to only 3% for the highest quintile. Poorer households also have less capacity to cope with losses; having little luxury spending to cut, they may be pushed to drop out of the educational system, postpone health treatment, or reduce food intake.

The Same, But Different: Common Adaptation Solutions

Immediate action is required to prevent devastating consequences and ensure that everyone, regardless of socioeconomic status, can adapt and thrive in a changing world. While each economic sector and location is different, our review reveals common solution types to consider.

Identifying Hazards and Reducing Exposure

The first common solution is to reduce exposure to climate change impacts, as some areas will be more affected than others. For instance, low-lying coastal regions or areas near rivers and lakes are more prone to flooding than areas located away from such places. Adaptation means avoiding these exposed areas or relocating to safer ones.

Identifying hazards is an essential prerequisite. While climate impacts cannot be predicted with certainty, numerical simulations and deliberations with local stakeholders are key to anticipating which areas could be exposed to the elements.

Protecting Valuable Areas

Withdrawing from risky areas is not always possible or desirable. Exposed areas may have significant assets or be of cultural interest, and relocation through massive migration brings other challenges. Protecting exposed areas is thus crucial. Building grey infrastructure is one way to do so, for instance using dikes and seawalls. Nature-based solutions, also known as green infrastructure, are often cost-effective alternatives: mangroves can break waves, parks can provide buffers against floods and landslides, and urban trees substantially reduce temperatures during heatwaves—all while providing cultural amenities and promoting biodiversity. Grey and green solutions work best together: in Asunción, Paraguay, restored wetlands and enhanced drainage infrastructure protect 1,500 dwellings against floods (Chapter 6).

Ask the Engineer: Reinforcing Structures and Improving Efficiency

Relocation and protection will not eliminate risk. Designing stronger and smarter structures is key to reducing damage when impacts materialize. For instance, roads can be built to higher standards, use more robust materials, include more culverts, and feature a slope that protects them against growing rain and landslide hazards (Chapter 5). In the food sector, technical solutions to preserve yields include switching to heat-resistant crops, improving irrigation systems, and building reservoirs (Chapter 2).

Improving efficiency is also vital. Design choices that use less water, land, or energy moderate the stress on these resources from climate change. For instance, better insulated homes need less energy for cooling during heat waves, increasing the chance that the energy system can cope (Chapter 6). In the food system, reducing waste and loss, which currently affects up to 30% of food production globally, is a way to achieve efficiency.

Diversification, Redundancy, and Decentralization

Adaptation is most effective at the system level. The key concepts here are diversification, decentralization, and redundancy. Diversification means establishing alternative sources of goods and services, such as sourcing water from a portfolio of solutions including reservoirs, groundwater, desalination plants, restored or maintained wetlands, and recycled grey water (Chapter 3). Similarly, farms that produce multiple foods and leverage the repellent properties of some plants are less vulnerable to pest devastation than monocultures. In Colombia, Nicaragua, and Honduras, supplementing traditional crops such as soy, wheat, and maize with cassava and yam would improve food security (Chapter 2).

Decentralization means distributing critical infrastructure and services geographically, reducing single-point failures in the process. For instance, solar panels and windmills scattered throughout a territory are less likely to all be flooded at the same time than one single coal power plant (Chapter 4). With redundancies, multiple parts of the system serve similar purposes and provide backup solutions, for instance when multiple routes and means of transportation are available to connect residential neighborhoods to jobs, health centers, and recreation (Chapter 5).

Forewarned is Forearmed: Building Resilience

Not all risks are avoidable. Adaptation also means preparing for disasters and building resilience, which is the capacity to cope and recover from adverse events, before the hazards hit (Chapter 1). With monitoring, early warning, and response plans in place, households, firms and authorities can move valuables and stocks away from flood areas. They can reinforce windows and doors in advance of a hurricane, prepare alternative routes to procure inputs or supply products, or evacuate before a wildfire approaches. Surveillance of climate trends also allows health professionals to identify and respond to new health hazards and farmers to choose better crops to plant (Chapter 7).

Preparing for reconstruction is key. Saving through financial institutions and contracting insurance allows households and businesses to fund repairs in a disaster's aftermath (Chapter 9). Keeping stocks of critical parts, medicines, and reconstruction materials is important in some industries. And providing households with social protection, such as cash transfers, and access to health and sanitation services means they will have a safety net if they are affected by climate change impacts (Chapter 8).

The Role of Government Policy

To address the challenges posed by climate change, governments need to use a range of policy instruments. Indeed, while many technical adaptations can be implemented directly by a government, many others require the involvement of the private sector in accordance with government policy.

Zoning and Standards

Zoning plays a crucial role in reducing exposure to the impacts of climate change. In Barbados, buildings cannot be constructed within 30 meters of the high-water mark, thus avoiding zones exposed to erosion and flooding (Chapter 6). Zoning also serves to protect nature, safeguard critical ecological functions, and promote nature-based solutions (Chapter 2). A case in point is the mandating of space to restore mangroves in tropical coastal areas, which reduces flooding risks for new development. In Medellin, the government planted urban parks on mountain slopes to avoid informal settlements, reduce landslide risk, and provide local recreation

Standards can be used to require the use of essential adaptations. Construction codes often establish standards for withstanding extreme wind, temperatures, or rainfall. Energy regulations dictate the building of reinforcements around power plants to withstand flooding events (Chapter 4). Enforcing regular audits can help ensure adequate maintenance (Chapter 5). Workplace regulations are key to accommodating labor conditions, for instance, by prohibiting outdoor work during peak hours of heat or making special clothing, sunscreen, and access to drinking water mandatory (Chapter 7).

The Carrot and the Stick: Economic Instruments

Governments also have economic instruments at their disposal to promote adaptation. These include subsidies, taxes, tariffs, and grants. For instance, water tariffs can be designed to promote water conservation and cost recovery for utilities (Chapter 3). Government grants can provide direct financing to enable power utilities to reinforce the grid or invest in batteries to avoid blackouts when extreme weather events hit (Chapter 4). Congestion taxes in urban centers can be used to promote dense, more adaptable cities (Chapter 5).

Reforming agriculture and energy subsidies is also essential. Governments spend nearly $540 billion per year globally to support agriculture, and 87% of that support has been found to be inefficient and inequitable. Moreover, this support creates health risks linked to the agricultural impact on the environment and the impact of unhealthy diets on people's wellbeing (Chapter 2). In 2020, Latin America and the Caribbean spent US$60 billion, or 1.3% of GDP, on fossil fuel subsidies. Beyond their impact as incentives, these put a burden on public finances; reforming them while protecting poor households and vulnerable businesses should be a priority (Chapter 9).

The Value of Data and Capacity Building

Collecting and publishing real-time data and forecasts is crucial for helping decision-makers prepare for extreme weather events. Early warning systems that directly and efficiently deliver instructions to the population (such as text messages instructing people to urgently leave a flash flood zone) are among the most effective ways to save lives. Governments should invest in the technology and skills needed to provide this essential service. Long-term weather forecasts are also important, for instance to help farmers adjust their seasonal crops if a drought is expected.

Governments must also conduct and publish climate change impact and vulnerability assessments that anticipate how climate change will affect economic activities or the environment locally. And they need to establish sector- and location-specific education and training programs to build the adaptation capacity of their agencies, subnational governments, and private sector.

Government agencies and the private sector have to deal with deep uncertainty in their decision-making. To do so, they can explore different scenarios, look for no-regret options that perform well under multiple conditions, and generate plans that bake in the ability to adjust course as new information becomes available (Chapter 1). Training decision-makers, civil servants, and academia to use such tools is an important part of the government adaptation policy mix.

Bringing Stakeholders Together

Climate change manifests differently in every geographic area and affects all economic sectors at the same time with social and financial implications. Adaptation strategies should thus be created by bringing together the perspectives of all stakeholders affected at the territorial level.

The Territorial Approach

Institutional fragmentation is a significant challenge when designing adaptation policy. Coordinated action is complex because expertise, responsibilities, and decision-making power are distributed among various private and public actors and between agencies that report to more than one ministry. For instance, the government response to a severe drought might depend on water, agricultural, health, and environmental policies.

Adaptation plans can promote coordination between actors and clarify responsibility as to who must act on what. The main planning instruments for adaptation are climate change laws and national adaptation plans. In Chile, the Climate Change Framework Law delegates the responsibility to act in the face of climate change to line ministries, requiring them to develop adaptation plans for their respective sectors. Adaptation plans should diagnose risk, identify solutions, and give responsibility to specific government agencies to act and promote them. Governments should strive to streamline adaptation planning into other planning instruments, such as sector development plans and the nationally determined contributions that they communicate to the UN in the framework of the Paris Agreement.

Governments must also consider climate change at a territorial level. A territorial approach ensures that local realities are considered, and sector policies are tailored to the territory's specific needs. This means empowering local governments and administrations to define their own adaptation needs and policies. Promoting public participation and consultation with local communities and involving all stakeholders in the decision-making process to ensure that marginalized and vulnerable groups have a voice is crucial.

Money Talks: Adapting Finances to Finance Adaptation

Well-designed fiscal policies also have a major role to play in adaptation (Chapter 9). Government interventions depend on allocating budgetary resources to fund public infrastructure and providing financial incentives, such as subsidies or tax cuts. At the same time, fiscal balances are themselves vulnerable to climate change. Natural disasters and relief efforts cost money. In the region, experiencing at least one extreme event per year can increase the fiscal deficit by 0.8% to 0.9% of GDP. Most public funds will come from the general budget, but governments can also use contingent credit, green bonds, and environmental tax reforms to manage climate risk and fund adaptation.

The financial system is also vulnerable to the risk of climate change impacts creating stranded assets—for instance if sea levels rise enough to engulf an expensive resort (Chapter 9). Large stranded assets could lead to cascading losses that are transmitted and amplified throughout the financial system. Providing definitive assessments of the system's climate preparedness is challenging because of the opacity of financial institutions' risk exposure, the complex connections within the financial system, difficulties predicting climate impacts and market reactions, and limited data availability. Governments should mandate assessments of climate-related risks. They should require climate-related financial disclosures and enforce precautionary practices to reduce risk.

Adaptation Through a Social Lens

The poorest households are often the most affected by extreme weather events (Chapter 8). Governments should identify households at risk and establish ways to support them with shock-responsive social protection programs. Recovery efforts should focus on building back communities better. This means reconstructing homes in safer locations, reinforcing structures, and investing in measures like thermal insulation and ventilation to increase communities' resilience to future climate-related challenges.

Financial inclusion reduces the need for government relief and investment. Bank accounts and financial assets help keep savings out of harm's ways when a disaster strikes. Insurance, savings, and loans help households recover from disasters. However, access to financial instruments is often limited. Governments can promote financial inclusion to build resilience. This includes removing barriers, such as the distance to bank branches, or the minimum requirements for accessing bank accounts and insurance. For instance, implementing weather-indexed insurance, which makes payouts based on easily observed variables such as rainfall, can bring risk transfer coverage to smaller and poorer farms by lowering administration costs (Chapter 9).

Finally, good governance must ensure that no one is left behind. Governments must pay attention to how the benefits and losses of adaptation policy are distributed across society, avoiding inequalities in access to protection, relief, and basic services. Zoning regulations and the displacement of informal settlements can negatively affect the access to health and education of the settlements' inhabitants, regardless of the risk. At the same time, climate change will drive more migration, as people abandon areas damaged by climate impacts and move to ones with better opportunity, typically within the same national borders. The best way to ensure that climate policy is equitable is to give a voice to all stakeholders, including the poor and marginalized segments of society.

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CHAPTER 1.

Decision-Making for a Future with Climate Change

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Decision-Making for a Future with Climate Change

Climate change causes slow-onset events, such as higher temperatures and sea level rise, and extreme weather events, such as floods, droughts, and hurricanes. Disaster risk management is a vital tool for adapting to climate change. It involves identifying possible extreme weather events (hazards), limiting the affected population and assets when natural disasters hit (exposure), reducing the immediate consequences for affected people and businesses (vulnerability), and improving the ability to cope and bounce back (resilience). But risk management approaches need to account for deep uncertainty, that is, cases in which data are scarce or when experts disagree about possible risks and outcomes. Indeed, climate change causes uncertain changes in the frequency, intensity, and geographical distribution of extreme weather events. The historical record is no longer a sound basis for predicting hazard. The decision-making under deep uncertainty (DMDU) toolset considers a variety of scenarios, looks for good-enough and no-regret options that perform well across possible futures, and bakes flexibility into the planning process so that decision-makers can adapt the course of action as information becomes available. Disaster risk management and DMDU approaches can be used to adapt to both uncertain extreme weather and slow-onset events. Governments should conduct hazard and vulnerability assessments; design risk management strategies that define clear responsibilities across ministries, subnational government levels, and the private sector; ban the riskiest areas and activities; and set standards for infrastructure and continuity plans. They should also promote access to early warning systems and plan ex-ante ways to provide direct support after major disasters, particularly to poor households. Finally, they should promote financial inclusion and insurance, allocate ample budgets for disaster preparedness, and set special budgetary rules to funnel relief funds.

Whatever Will Be: Climate Risks and Informed Decision-Making

Climate risks come from two types of events: extreme weather events, such as floods and hurricanes, and slow-onset events, such as sea-level rise and reduced annual rainfall. To reduce the impact of climate change on lives and prosperity, countries should adapt to both types of events.

Understanding Hazards, Exposure, Vulnerability, Resilience, and Adaptive Capacity

A good lens for viewing the risks of climate change and how to adapt is the identification of hazards, exposure, and vulnerability (Hallegatte et al., 2017). *Hazards* are extreme weather events such as storms, floods, and droughts, as well as slow-onset events such as higher temperatures and sea level rise.

Exposure is the presence of populations, ecosystems, and economic assets in areas affected by one or more hazards. Climate change exposes communities to hazards to which they were previously not exposed. For instance, as sea levels rise, areas located farther inland become exposed to flooding, particularly in low-lying coastal regions such as river deltas.

Exposure by itself does not imply risk from a hazard. The degree to which hazards impact populations, ecosystems, and human systems depends on how *vulnerable* they are to them. For example, a heatwave will have a greater effect on a household located in a neighborhood without tree cover, away from bodies of water, without proper ventilation, and with inadequate insulation than a household surrounded by trees, close to water, and with good ventilation, insulation, and access to air conditioning.

Two elements are critical to reducing the long-lasting effects from hazards when there is exposure and vulnerability to climate change impacts: *resilience* and *adaptative capacity*. Resilience is the capacity to cope and recover from adverse events. Adaptative capacity is the ability to reduce exposure and vulnerability to hazards. A resilient household has access to savings and insurance to repair or rebuild its assets after an extreme weather event. The same household has adaptive capacity if it has the information and financial resources it needs to move away from the exposed area.

Poor and excluded households tend to be the most exposed, most vulnerable, and least resilient. They also have the lowest capacity to adapt to climate change impacts (Hallegatte et al., 2017). The poorest often lack the means to avoid exposure to events by, for example, moving from low-lying floodplains. They often live in weaker structures, like self-made housing in informal settlements.[1] Additionally, they often lack access to risk management measures, such as insurance schemes. Following extreme weather events, the asset losses of the poorest households will account for a small fraction of overall damages but a higher proportion of their total assets. In addition, smaller impacts on assets, when measured in financial value, often take a significant toll on poor people's welfare, as they are forced to cut spending on education, nutrition, and healthcare. [2]

Disaster Risk Management to Improve Lives

Disaster risk management approaches are tools for governments, firms, and private individuals to identify the risks from extreme weather events and reduce them to acceptable levels. A disaster risk management strategy aims at identifying hazards and developing emergency preparedness instruments, disaster response and relief strategies, and post-disaster recovery plans. Policymakers can also use the principles of disaster risk management to plan a response to slow-onset events, such as sea level rise and desertification (Hallegatte et al., 2017; UNDRR, 2021).

Reducing risk is achieved by reducing exposure (e.g., moving people away from coasts or restoring mangroves to protect against flooding and sea level rise) or by limiting vulnerability (e.g., reinforcing buildings). Risks that are not addressed by reducing exposure or

1 Chapter 6. Adapting the Urban Environment

2 Chapter 7. Wellness Check: Climate Change and the Health Sector

vulnerability are called residual risks. Because residual risk cannot be avoided, disaster risk management should also build resilience. Financial instruments are a key way to do so: they help mitigate the impacts of unavoidable risks. Insurance spreads some of the cost of extreme weather events to the pool of its subscribers, instead of letting those directly affected foot the bill alone. Similarly, government-funded relief effectively transfers some of the costs of climate change to a large pool of taxpayers (IPCC, 2022). Designing emergency response plans in advance, for instance to establish evacuation, rescue or rehabilitation routines, is essential to minimize residual risk.

Early warning systems are a critical way to reduce risk, save lives and safeguard property (IPCC, 2022). Warnings give households and firms time to prepare for incoming extreme weather events by evacuating, moving valuables away from flood areas, or reinforcing windows and doors. Sufficient time to prepare a house before a hurricane, for example, reduces the damage by up to 50% (Williams, 2002). Emitting warnings 48 hours before flooding events allows for similar damage reductions (Carsell, Pingel, and Ford 2004). An IDB survey called *Riskmonitor* found that at least 16 Latin America and Caribbean countries use early warning systems (Lacambra et al., 2014; IDB, 2023). A typical example is Barbados's Emergency Management Act, which established in 2017 a National Alert System that enables the government to broadcast emergency announcements directly to the public using mobile and fixed lines, fax, SMS, television, or email announcements.

Climate change and risk management have welfare implications. Climate change's impacts on assets are not the same as its impacts on wellbeing (Hallegatte et al., 2017). An adaptation approach that aims to reduce the impact of climate change on assets risks excluding poor people. An alternative approach is to aim at reducing the risk to welfare rather than the risk to assets. For instance, a city can decide to spend money on an expensive seawall that protects a poor neighborhood rather than a rich one, even though the financial value of protected assets would be lower in the poor area. It could decide to do so because the destruction of poor people's property would have a greater impact on their wellbeing.

Baking Uncertainty into Decision-Making

The traditional approach to risk management is based on identifying hazards, their probability, and their possible consequences and weighing the benefits and costs of measures to reduce such risks or their consequences. For instance, many countries use historical records to determine the likelihood that any area could become flooded, usually expressed as a return period. If the return period of a one-meter flood is 100 years, that means that every year there is a 1% chance that a flood of one meter or more will occur in that area. Countries may then set a safety standard. They could, for instance, ban development in areas where floods are expected at least every 20 years and require that structures be able to withstand events of a specific strength. Eight countries in the region report a regulation that defines acceptable risk levels for at least two natural disasters (Lacambra et al., 2014; IDB, 2023). For instance, the Bahamas Building Code establishes that facilities should follow standards set by the American Society of Civil Engineers and buildings in coastal zones should follow higher standards than buildings further inland.

Climate change, however, induces changes in the frequency, intensity, area of influence, and duration of hazards (IPCC, 2022). The historical record no longer provides a good picture of future hazard. In the Bahamas, category 5 hurricanes, such as Dorian, which in 2019 left 70,000 people homeless and caused more than US$5 billion in damages, used to happen once every 50 to 100 years. With climate change, they may now happen once every 25 years (IDB, 2020). Assessing future hazard now requires using simulation models.

Complicating matters, risks induced by climate change are *deeply uncertain*. *Deep uncertainty* refers to situations, often associated with complex systems and long-time horizons, where scarce data and disagreement among experts makes it impossible to quantify the possible risks and outcomes in a precise way (Marchau et al., 2019). A key uncertainty is how much global climate change will occur. We know that climate change will worsen, but not by how much and how fast. Depending on the willingness of countries around the world to curb greenhouse gas emissions to reach net-zero emissions by around 2050 (Fazekas et al., 2022), the effectiveness of their efforts, and the response of the complex climate system, global warming by 2081-2100 will likely be between 1.4°C and 2.7°C (IPCC, 2023). This will directly affect both extreme weather and slow-onset events. For instance, we know that by 2050, sea levels will be higher, but not precisely by how much: they could rise anywhere from 15 to 30 cm above current levels.

The second uncertainty involves how global warming affects local climates. The equations that govern the behavior of the atmosphere are famously chaotic: it is said that a butterfly flapping its wings in Europe can change the path of a hurricane days later in the Caribbean ("Butterfly effect", 2023). This means that no model can precisely predict how temperature, precipitation, or the frequency and intensity of extreme weather events will change in any given area. Often, we cannot even predict the direction of changes, such as average annual precipitation (Hallegatte et al., 2012).

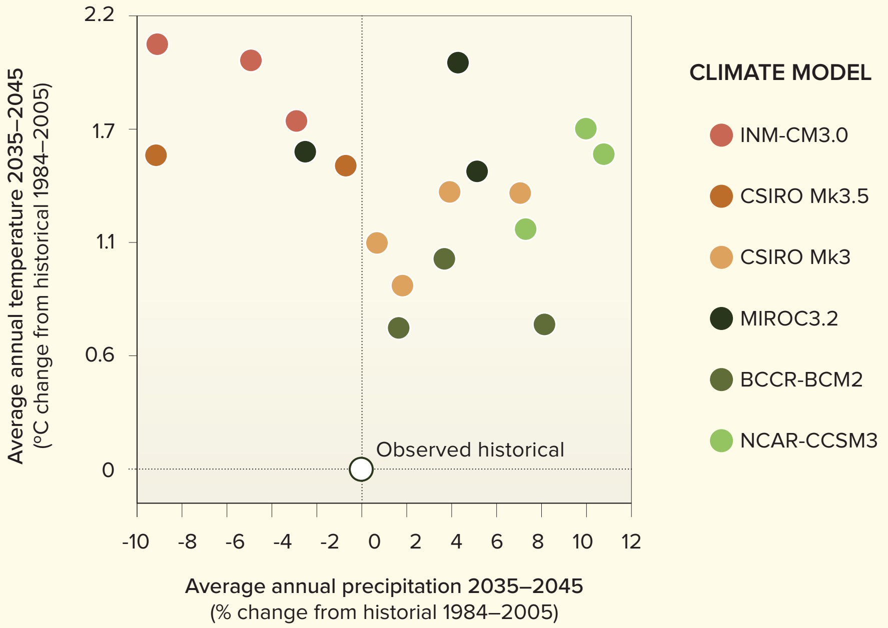
Figure 1.1 illustrates *deeply uncertain* climate change impacts. It shows simulations of temperature and precipitation changes in Maryland, USA, by 2045 according to six different climate models that were calibrated on three different greenhouse gas emissions pathways (Fischbach et al., 2015). Temperatures could increase by little less than 1°C or little more than 2°C, while precipitation could be reduced by more than 8% or increase by more than 10%. While it may be tempting to pick a "best model," for instance choosing the one that best replicates the climate in Maryland when calibrated on historical data, this would be a mistake: as far as climate modeling is concerned, past performance does not guarantee future results (Hallegatte et al., 2012).

In these conditions, the so-called *Decision-Making under Deep Uncertainty* (DMDU) toolset helps decisionmakers design robust plans by generating many different scenarios, comparing approaches, using safety margins, finding no- or low-regret options, emphasizing reversible strategies, and making contingent plans that can be adjusted over time as new information becomes available (Hallegatte, 2009; Marchau et al., 2019).

After analyzing the implications of various precipitation and water demand scenarios, a DMDU study found that the Mexican city of Monterrey should invest in water-saving measures, a reservoir, and various groundwater projects by 2026 (Molina-Pérez et al., 2019). These no-regret options are useful in virtually all scenarios and guarantee water security in 91% of the scenarios analyzed for less than US$0.5 billion. The study also puts forward a contingent plan to guarantee there is enough water if one of the remaining 9% of scenarios turns out to be true (Figure 1.2). If water demand exceeds a given threshold (around 15 cubic meters per second), the next step to take depends on the state of groundwater levels: with high levels, existing wells would be enough, and no

FIGURE 1.1

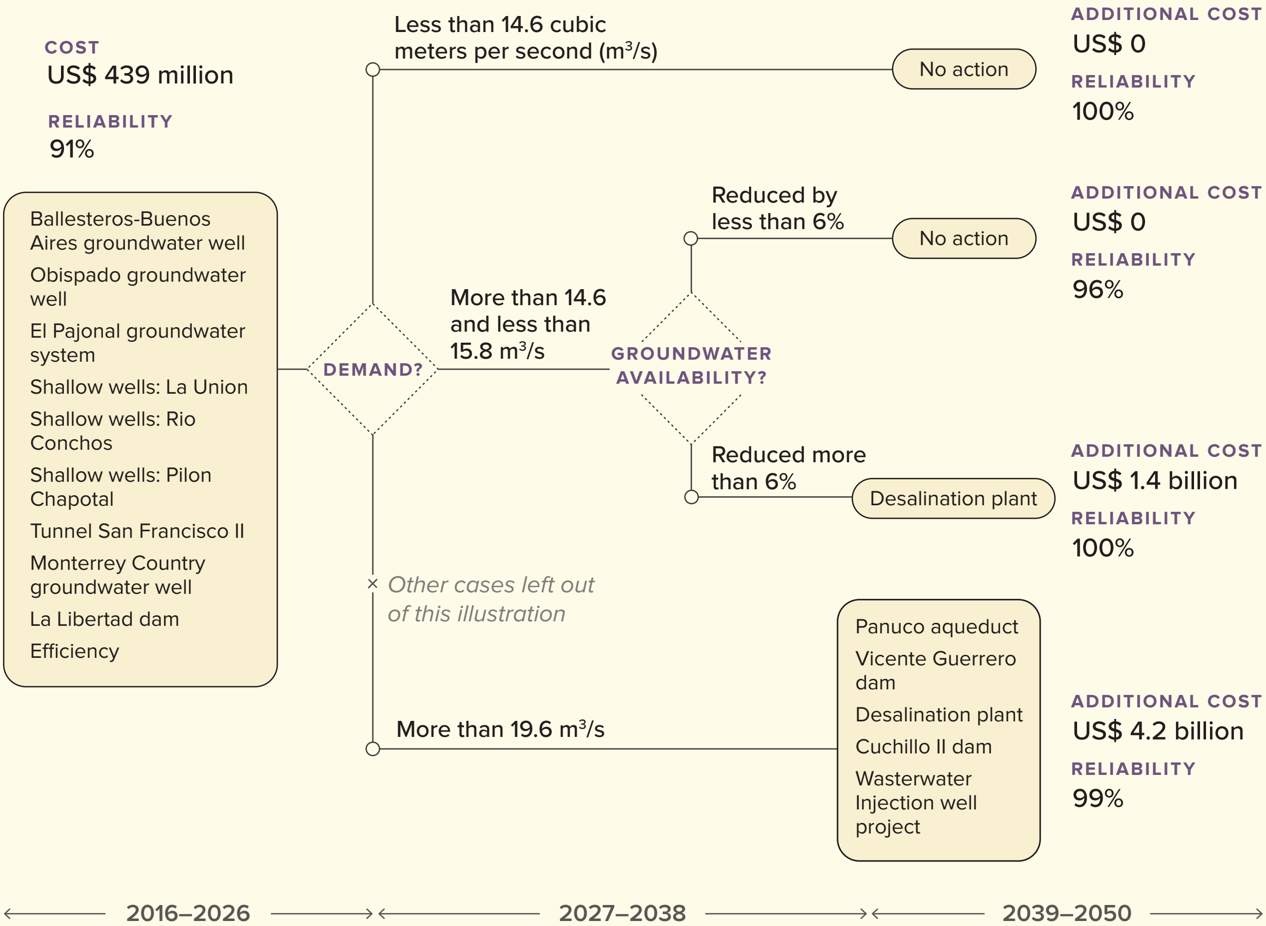
Simulations of Temperature and Precipitation Changes in Maryland by 2045 in Three Climate Scenarios and According to Six Climate Models.



Source: adapted from Fischbach et al. (2015).

FIGURE 1.2

No-regret Investments and a Contingent Plan to Ensure Water Security in Monterrey, Mexico



Source: Simplified excerpt, adapted from Molina-Pérez et al. (2019).

additional action is required. But with low levels, a desalination plant would be needed by 2039, for an additional US$1.4 billion. For even higher demand levels (around 20 cubic meters per second), investing in the desalination plant makes sense regardless of groundwater levels, and additional dams and aqueducts would also be required, bringing the cost to more than US$4 billion.

Effective decision-making around climate change, beyond scientific and technical expertise, requires engagement with stakeholders and consideration of social and ethical values (Kalra et al., 2014). By incorporating the concerns and knowledge of a broader interest group, stakeholder engagement in the decision-making process can contribute to (i) ensure that diverse perspectives and concerns are taken into account, which is particularly important for indigenous peoples and local communities who are most vulnerable to the impacts of climate change; (ii) build trust and legitimacy around the process, which contributes to a more effective implementation; and (iii) foster innovation and creativity.

The Monterrey study mentioned above helped build consensus among local stakeholders (Molina-Pérez et al., 2019). Initially, they experienced difficulties working together as they disagreed on what projects to prioritize: some preferred conservation, other favored large infrastructure. The analysis started by gathering stakeholders to agree on objectives (reliability and cost) and showed how conservation and infrastructure development projects could work as a portfolio towards these goals. For instance, conservation is always useful, so it should be promoted. But it is not enough to guarantee water security. On the other hand, the largest investments would be very effective, but they are expensive, and smaller projects are adequate in most scenarios. The largest investments can safely be delayed to when (and if) more information establishes that they are indispensable.

A Better Response to a Big Problem

Climate change presents enormous challenges, and governments must be up to the task. Promoting a governance framework aligned with climate change risks is their first step in improving decision-making and building resilience (IDB, 2023).

A key action is designing disaster risk management strategies. The United Nations decided in Sendai on a Framework for Disaster Risk Reduction (UNDRR, 2015). It outlines seven targets for 2030: on the one hand it aims at reducing casualties from disasters, the fraction of people affected by disasters, disaster costs as a fraction of GDP, and damage to critical infrastructure and disruption of basic services. On the other hand, it calls on countries to develop national and local disaster risk management strategies, cooperate internationally, and promote available and accessible early warning systems. All countries in the region have adopted it and regularly report progress.

Risk management strategies should set actionable targets, encourage the development of hazard and vulnerability assessments, consider how climate change may affect future hazard, and integrate disaster risk management considerations into land-use planning, infrastructure development, and policy frameworks. Colombia's risk management plan, for instance, aims to reduce fatalities to 3.5 per 100,000 and have fewer than 6,215 people affected per 100,000 inhabitants by 2030 (UNGRD, 2022). It points to the existing territorial development plans as an instrument to ban construction in risky areas, and it emphasizes the importance of taking climate change into account when evaluating disaster risk.

Accountability Breeds Responsibility

Governments must clearly define responsibilities, liabilities, and the extent of protection to effectively respond to climate change risks and guide private actors' decision-making (Halegatte et al., 2020). Interventions for defining clear responsibilities include laws and mandates, land use zoning, and construction codes. In the Netherlands, the government is legally required to provide a certain level of flood protection to the population, allowing individuals and firms to make informed decisions about where to live and invest and what additional flood management measures they may need to invest in.

Governments should establish organizations, inter-ministerial commissions, or working groups that facilitate the implementation of quick responses and coordinated action against disasters (Lacambra et al., 2014). They can also help firms develop business continuity plans. National authorities should monitor, audit, and evaluate ex-post and ex-ante disaster risk management processes, with the goal of continuously improving them and then update them when more information about risk or the effectiveness of mitigation measures becomes available. They can also establish a territorial approach to disaster risk management to tackle localized risks using territorial planning, decentralized decision-making, and citizen participation.

Ultimately, a lot of disaster risk management will need to happen at the sectorial and sub-national levels. To reduce exposure and vulnerability, governments must, for instance, set incentives in favor of risk-conscious agricultural practices; build levees, restore mangroves, or use zoning regulations to steer urban development away from flood zones; and set safety standards and good practices in the power generation sector. Chapters 2 to 7 dive into what risk management and adaptation to climate change mean for different parts of government and the economy.

Solidarity in Times of Crisis

No amount of preparation can reduce risk to zero, and very large but very rare events will always strike. The more significant and destructive the extreme weather event, the fewer the number of households and firms with sufficient wealth and access to the financial instruments necessary to recover. Governments are expected to help in case of force majeure.

In the aftermath, they can help firms recover by providing direct support, such as by replacing expensive equipment if it is destroyed (Hallegate et al., 2020). They should particularly help the poorest and most vulnerable households. Designing social protection programs that are responsive to shocks is one of the most cost-effective options for doing so (Hallegatte et al., 2017; Costella et al., 2023). Chapter 8 analyzes the issue of disaster risk reduction and adaptation through the lens of inclusion and poverty reduction.

Disaster support should always align with long-term adaptation objectives and promote migration and alternative economic activities when these are the best options. For instance, disaster relief to households affected by flooding should incentivize relocation to less exposed areas, when possible, to avoid locking affected families in flood-prone areas (Hallegate et al., 2020).

Risk Financing

Finally, financial instruments are important tools to improve firms' and households' resilience and capacity to adapt. Governments should thus promote access to savings, credit, and insurance (Hallegate et al., 2020). They can promote the inclusion of poor and vulnerable households in financial markets by subsidizing or acting as guarantors for insurance markets or credit eligibility.

Disaster preparedness also requires governments to have readily available resources with which to act (Lacambra et al., 2014). They must establish ample budgetary margins, decide on contingent credit lines, and contract insurance with international financial institutions to fund relief and repairs. They should also design special rules that allow them to quickly allocate and spend resources immediately after disasters hit. Chapter 9 discusses risk finance in more detail.

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CHAPTER 2.

Land of the Living: Rethinking Food and Biodiversity Together

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Land of the Living: Rethinking Food and Biodiversity Together

Biodiversity is crucial to human and planetary health. It provides free ecosystem services like food, pollination, nutrient recycling, soil formation, pest control, protection against erosion, and clean and steady water flows. Losing these services makes it harder to grow plants for food and materials, breed livestock, and farm or catch fish. Food production is the main driver of biodiversity loss. But climate change creates an additional danger: it affects both ecosystems and food production. Changing weather patterns, heatwaves, drought, and other extreme weather events destroy ecosystems, damage crops and livestock and disrupt supply lines and the cold chain. The results are lower incomes for farmers and threats to food security. Adaptation means enhancing the efficiency of land and ocean use, expanding conservation and restoration efforts, changing diets, and adjusting agricultural practices, including diversifying production, enhancing water management, and promoting drought-resistant varieties of certain crops. Governments should manage land and water in a more integrated fashion, considering productive, conservation, and recreational purposes together. Spatial planning, zoning, and land titling are key instruments, as is the establishment of protected areas with sound management plans and sustainable financing. Promoting access to insurance reduces the vulnerability of farmers to extreme weather events. Regulations that ban unsustainable practices, such as fish trawling, help protect natural resources. Reforms to agricultural subsidies can incentivize crop choice and agricultural practices that pollute less and leave more room to nature. Finally, government funding of research and development, capacity building, and communication campaigns helps local actors implement the necessary adaptations.

An Assault on Biodiversity and Food Security

Land, oceans, and clean air are key to both food production and biodiversity preservation. Half of global economic activity depends on land and marine ecosystems that provide the food, water, clean air, and materials needed for daily living. Three-quarters of the world's food crops depend at least in part on pollination. Moreover, the volume of agricultural production dependent on animal pollination has increased by 300% over the past 50 years (IPBES, 2016). The soil hosts tens of thousands of underground species of invertebrates, bacteria and fungi that are needed to filter water, recycle nutrients that enable plant growth, and regulate soil diseases. They also create humus and sequester carbon (Gunstone et al., 2021).

Latin America and the Caribbean is a biodiversity superpower. It represents 16% of the Earth's surface but harbors 40% of the world's biodiversity. It holds half of the tropical forests, is the largest reserve of freshwater, and hosts 12% of the world's mangroves (UNEP-WCMC, IUCN, and NGS, 2018).

Man's Inhumanity to Nature

However, human activities threaten the ability of nature to continue providing these ecosystem services. Latin America and the Caribbean is at the forefront of the current sixth mass extinction. It has lost 94% of its vertebrate population in 50 years and hosts the highest number of threatened mammals, plants, fish, and birds in the world (IDB, 2019a, WWF, 2020).

The food system is the primary driver of biodiversity loss. Agriculture is the main threat to more than 85% of the 28,000 species at risk of extinction globally (Benton et al., 2021). The greatest drivers of habitat loss have been the conversion of natural ecosystems for crops, and, even more importantly, deforestation for livestock production (IPBES, 2019). In Latin America and the Caribbean, beef is responsible for nearly two thirds of deforestation while only providing 12% of the region's protein intake (Dumas et al., 2022).

Habitat fragmentation further weakens ecosystems. Habitat fragmentation and loss prevent species from migrating to places with more suitable conditions or regenerating after losses from forest fires, drought, or other extreme weather events (Parmesan et al., 2022). The Amazon has experienced some of the most severe forest fragmentation in the world over the last two decades (Ma et al., 2023). Mangroves menaced by sea level rise are especially at risk as adjacent land is often occupied for activities such as agriculture, complicating their resettlement.

Monoculture can be an issue. Historically, 6,000 plant species have been cultivated for food. But today only nine of them account for 66% of total crop production on the planet (FAO, 2019). In Latin America and the Caribbean, 75% of the calories consumed by the region's population come from just 12 crops and five animals. Without the natural shield that genetic diversity provides, agriculture is less resilient to dangers, such as disease, pests, extreme weather, and climate change.

The massive use of pesticides for food production also generates serious problems for nature and people (UNEP, 2022). Central America uses an average of 5.5 kilograms of pesticides per hectare of crops, compared to the world average of only 1.8 kg/ha. Costa Rica and Belize are among the highest users, at 34 and 11 kg/ha respectively. Pesticides are largely responsible for the mass disappearance of birds and insects (Sánchez-Bayo and Wyckhuys, 2019; Rigal et al., 2023). They also accumulate in the soil, kill underground life, contaminate water, and cause chronic and acute illnesses, accidentally poisoning 12 million people each year in Latin America and the Caribbean (Boedeker et al., 2020; Pathak et al., 2022).

Water use for agriculture, energy, industry, and human consumption further stresses ecosystems. Increased human demand for water reduces how much is left to preserve ecological flows (IPCC, 2019). More than 70% of all freshwater withdrawals are currently used for agriculture and livestock. Beef is the largest water user, representing 21% of average water consumption in Brazil alone (Da Silva et al., 2016). At the same time, climate change is increasing variability in the water cycle and causing extreme weather events—including drought.[1]

1 See Chapter 3. Riding the Adaptation Wave in the Water and Sanitation Sector

Overfishing stresses the marine ecosystems. In 2019, 35% of the world's fishery stocks were below levels of biological sustainability (FAO, 2022). In the Southeast Pacific, 67% of the stocks are fished unsustainably, partly due to overfishing by non-regional fleets around or even within the exclusive economic zones of the region's coastal countries (Kadie, 2018). In Chile for instance, almost 60% of fisheries are overexploited, with 28% of them classified as exhausted (Subpesca, 2023).

Threats to Terrestrial and Aquatic Ecosystems

Climate change further endangers ecosystems. Extreme weather events, such as heat waves, drought, and wildfires, can result in mass mortality. Changing weather and rain patterns affect flowering and insect emergence. Plants and animals are increasingly subject to pest outbreaks, exposing them to new risks and mortality. As climate change continues to impact ecosystems, some of their functions, such as pollination, are also affected.

Rising sea levels threaten coastal ecosystems, including mangroves and marshlands. Those are rich habitats for fish, mollusks, reptiles, amphibians, birds, and mammals. They provide essential ecosystem services such as water regulation, which includes flood control and water purification (Leal & Spalding 2022). As oceans warm, they lose oxygen, become more acidic and rise in level. Among the most vulnerable ocean ecosystems are coral reefs. Their skeletons weaken with ocean acidification, and they bleach during heatwaves. Rising sea levels increase sedimentation and smother them.

Hotter conditions increase tree mortality and make wildfires more frequent and extensive. In the Amazon Rainforest, a rise in temperature of 1.2°C can boost tree mortality by almost 40% (Parmesan et al., 2022). In Chile, the 2016-17 summer was the hottest in almost 40 years and brought wildfires that affected 14 times more land than the average for previous years (Bowman et al., 2019). Wildfires can multiply tree mortality rates by seven times or more, compared to non-burned areas, with the higher mortality persisting for up to a decade after a fire (Silva et al., 2018).

Melting glaciers and shifting precipitation patterns make arctic and mountain regions among the most exposed ecosystems (Parmesan et al., 2022). In Peru, glaciers in the Cordillera Blanca have lost up to 64% of their mass since 1970 (Taylor et al., 2022). Ice melt brings more runoff in the short term. But in the long term, streams fed by glaciers in the Cordillera Blanca will decline by as much as 30% (Baraer et al., 2012).

These processes reduce the suitability of the natural habitat for many species and thus affect their abundance, distribution, and seasonal activity. In the tropical Andes, species must move half a kilometer per year poleward to keep pace with climate change. Many protected areas are only a few dozen kilometers wide and are surrounded by farmland or plantations, trapping species in narrow areas (Fuentes-Castillo et al., 2020).

Smaller Yields, Bigger Problems

Just as climate affects wild plants and animals, it also affects crop yields, livestock, farmed and caught fish, fiber, and timber.[2] In South America, the average duration of the growing season for spring wheat, winter wheat, maize, soybean, and rice has already decreased by 2.5%, 2.2%, 1.6%, 1.3% and 0.4%, respectively, compared to a 1981–2010 baseline. This has brought with it commensurate impacts on yields (Hartinger et al., 2023). Climate projections suggest that on average agricultural yields and output in the region could further decline 7.5 and 5.2 percentage points, respectively in 2050 (Prager et al., 2022). The average price of staples such as soy, maize, beans, rice, and wheat could go up by 15%.

Higher temperatures also affect the productivity of agricultural workers: the equivalent of 2.5 million, full-time equivalent jobs could be lost to heat waves in Latin America and the Caribbean by 2030, most of them in the agricultural sector (Saget et al., 2020). The combined effects of climate change on yields and the productivity of farmers could cost around 0.5% of GDP worth of agricultural production to the typical country in the region, according to one climate projection for 2050 (Banerjee et al., 2021).

Warmer temperatures shift the zones for crop suitability poleward and to higher elevations, impacting food, fiber, and wood production. In Nicaragua, the

2 Agricultural productivity is generally expected to decrease under the impact of climate change, even though the direct effect of warmer temperatures and higher carbon dioxide concentrations in the air may increase productivity for some species in some regions, particularly for irrigated crops (Bezner Kerr et al.,, 2022; Prager et al., 2022). The net effect of climate change depends on many other factors discussed below.

optimal altitude for coffee farming will increase 400 meters, to 1,200–1600 meters above sea level by 2050 (Laderach et al., 2009). In El Salvador, 30% of the current coffee production areas will no longer be suitable for Arabica coffee by 2050 (Fernandez-Kolb, 2019). Some areas will be flooded by the ocean, others will become deserts. Up to 30% of exploited areas globally will no longer be apt for food or materials production by 2030 (Bezner Kerr et al., 2022).[3]

Heatwaves, drought, excessive rains, flooding, and the delayed onset of the rainy season result in crop failure and in food loss–harvested food that goes bad before being sold to a final consumer (Bezner Kerr et al., 2022). Climate change increases the risk of simultaneous crop failures in multiple, major crop producing regions (Hasegawa et al., 2022). These so-called *multi-breadbasket* failures can reduce global production by as much as 20% when they occur.

Impacts on food also impact poverty and hunger (Hartinger et al., 2023). Almost half of rural households in Latin America and the Caribbean are poor, and their income often depends on agriculture, fishing, or forestry (IDB, 2021). Undernourishment affected 6.5% of both the rural and urban population in the region in 2022, including nearly 20% in Bolivia, Honduras, Nicaragua, and Venezuela, and up to 45% in Haiti (FAO, 2023).

Food is not the only economic activity that depends on nature. Sea level rise and environmental degradation will impact the tourism sector as they affect landscapes, beaches, coral reefs, or hotspots for animal watching. The Caribbean is particularly vulnerable in this regard, as receipts from international tourism provide 33% of its export revenues–and up to 80% in the Bahamas (WDI, 2023). The arrival of tourists, for example, falls 30% in the aftermath of hurricanes. While most of this reduction comes from the destruction of transportation and hospitality infrastructure, natural capital is also affected (Rozenberg et al., 2021).

Living Better with Nature: Adaptation Options

Safeguarding Land and Oceans

Protecting land and ocean areas is crucial to enhancing the capacity of ecosystems to sustain climate impacts. At the 15th United Nations Biodiversity Conference, countries globally committed to protect 30% of the world's lands, inland waters, coastal areas, and oceans by 2030. These are ambitious goals: only 17% of terrestrial areas and 10% of marine areas were under protection in 2022 (Convention on Biological Diversity, 2022). Protected areas in Latin America and the Caribbean cover 19% and 24% of oceans and lands respectively, even though many are still lacking funding and management plans (Álvarez Malvido et al., 2021). Maintaining existing ecosystems and forest cover by creating protected areas and redirecting the growth of cities and farmlands away from native ecosystems is a first step. Rehabilitating degraded land is a close second, achieved by restoring dunes, marshlands, riverbanks, grasslands, and forests.

Establishing corridors to connect protected areas and allow species to disperse and migrate is also important (Costello et al., 2022). In Ecuador, the recently established "Hermandad Marine Reserve" protects 60,000 kilometers and sets a transnational corridor between the exiting Galapagos Marine Reserve and the maritime frontier of Costa Rica (IDB,2023). Highways and roads are a key factor in causing fragmentation as plants and animals are cut off from each side. In Costa Rica, wildlife underpasses allow several native species, including ocelots, armadillos, and opossums, to cross the highway that runs through the Hacienda Baru National Wildlife Reserve, significantly reducing collision-induced mortality (Villalobos-Hoffman et a., 2022). In Quintana Roo, Mexico, wildlife underpasses and culverts similarly help jaguars and 12 other species safely cross the highway that bisects two Jaguar Conservation Units (González-Gallina et al., 2018).

3 While other regions may become more apt for food production, these tend to be far from human settlements, such as in Northern Canada or Siberia, and tend to be at higher latitudes, where there is not much land in South America.

Avoiding practices with particularly negative environmental impacts and fostering more sustainable ones across economic activities is key. This means, for example, banning fish trawling and dredging and controlling overfishing to allow marine ecosystems to recover (FAO,2022). Lower-scale adaptations can also help. In Peru, enforcing a standard of using hexagonal instead of square nets greatly reduces unsustainable bycatch when fishing for anchovies (IDB, 2019b). On land, environmental practices in agricultural and industrial activities, such as controlling pesticide use, help reduce pollution. On the contrary, crops grown to produce biofuels risk worsening ecosystem degradation and food security—solar and wind are much better sources of energy (See Box 2.1).

Similarly, the impact of harvesting forests to produce firewood (for heating and cooking) and construction materials should be carefully assessed (Peng et al., 2023). There is only so much land; the priority should be using it for food production and biodiversity conservation (Searchinger et al., 2023).

Nature-based solutions for adapting to climate change in different economic sectors also help restore ecosystems. For instance, increasing urban tree cover promotes biodiversity while reducing vulnerability to heatwaves. Restoring mangroves along coastlines also promotes biodiversity while protecting against flooding (Hallegatte et al., 2016; IPCC, 2019; Parmesan et al., 2022).

BOX 2.1

Out of the Frying Pan, Into the Fire: The Dangers of Biofuels

Biofuels are often proposed as a way to reduce greenhouse gas emissions from the transport sector. But rigorous analyses of their economic and environmental performance shows that biofuels worsen food security and destroy ecosystems.

Indeed, while many biofuel technologies exist, the only commercially mature ones to date are bioethanol produced from fermenting sugar or starch crops, biodiesel from oil crops and waste oil, and biomethane from residues (Jaramillo et al., 2021). As such, most of the biofuel used in transport comes from dedicated crops, such as sugar cane, corn, and soybeans (IEA, 2022). Waste-based biofuels use cooking oil or animal fats as feedstock, but they only comprised 8% of biofuels in 2021 because of limited technology readiness and feedstock availability (IEA, 2022).

Biofuels are not cheaper than fossil fuels, and not less subject to international market price variations. Biodiesel and bioethanol produced in the United States and Brazil cost 80 and 60 US cents per liter respectively in 2017, compared to 40 to 60 cents for diesel and 50 to 60 cents for gasoline (IEA, 2017). In the aftermath of the COVID-19 pandemic and the Russian invasion of Ukraine, agriculture price shocks caused biofuels prices to increase 70%-150%, while crude oil increased only 40% (IEA, 2021). However, countries like Brazil, Canada, India, and Indonesia subsidize or mandate biofuel use (IEA, 2022). In the EU, the mandatory blending of biofuels costs taxpayers €17 billion per year (Marahrens, 2022).

Analysts often treat biofuels as carbon-neutral, as they falsely assume that combustion emissions are offset by the carbon captured by plants when they are growing. Yet, burning biofuels creates methane and black carbon emissions from imperfect combustion, with a much higher impact on global warming than the carbon dioxide captured by growing biomass. Biofuel crops also emit nitrous oxide from synthetic fertilizers. Land clearing for them causes deforestation.

Accounting for deforestation and fertilizer use, biofuels release 35% to 230% more emissions than diesel and gasoline (Searchinger et al., 2018). Importantly, even if they are not produced on land that was recently cleared of native vegetation, biofuel crops displace food crops. As a result, they increase food prices, promote the expansion of agriculture, and cause deforestation somewhere else. The question is not where biofuel crops are grown, but how much land they use.

By contrast, using land to install solar panels and charge electric vehicles results in 91% less emissions than using fossil fuels (Searchinger et al., 2018). Solar panels and transmission infrastructure have a negligible impact on land use and deforestation. Electric vehicles, in contrast to biofuels, also do not emit local air pollution from combustion. In addition, batteries are quickly becoming cheaper and able to sustain longer ranges, while the cost of biofuels has remained disappointingly high (Witcover and Williams, 2020). This helped the market share of electric vehicles to reach 14% of new road vehicles sold globally in 2022, up from only 9% in 2021 (IEA, 2022).

Electricity produced from wind or solar energy is thus the favored fuel to decarbonize short-and-medium-distance road transport. Proposed new technologies could use non-food feedstock to produce biofuels or synthetic fuels for long-haul transport in the future, including so-called sustainable aviation fuels, but they require substantial research and development to become mature (NREL 2022).

Building Resilience to Shocks

The most obvious intervention to reduce food production's vulnerability to drought and rainfall variability is increasing water management efficiency. In an extreme example, rainfed bean yields could decrease by more than 30% in Bolivia under the influence of climate change, while irrigated bean yields would decrease less than 5% (Prager et al., 2022). Importantly, adding reservoirs and improving traditional irrigation can only accomplish so much if climate change reduces total precipitation, demand for other water uses increases, or soils are too degraded to hold water. Investments should only be made after considering all water uses, sources, and grey and green techniques to improve soil health and water efficiency (IDB, 2019a).[4] Technologies to improve water management include drip irrigation, terracing, and rainwater harvesting (Sova et al., 2018).

Agricultural health services can boost resistance to animal and plant-related pests and diseases. Options to improve them include implementing sanitary and phytosanitary vigilance measures, -and, if prevention (and other measures such as diversification of farming systems) fails, using control measures that minimize impacts on the ecosystem (FAO, 2021).

Reinforcing transport infrastructure also builds resilience of the food system in case of crop failure (Hallegatte et al., 2016). Redundancies in the transport network help avoid disruption and ensure the timely delivery of food or, in the case of significant food losses, the quick rerouting of supply routes to compensate.[5]

Strength and Diversity

To create a sustainable food system while preserving ecosystems, a key strategy is to increase agriculture yields, measured in terms of food production or value added created per unit of land. For a given food demand, higher yields mean more land available for ecosystems (Searchinger et al., 2019). One step is matching crops to changing local climates — a process that involves relocating or switching crops (IPCC, 2019). In Colombia, Nicaragua, and Honduras, supplementing traditional crops such as soy, wheat, and maize with cassava and yam could improve food security in the face of a changing climate (Prager et al., 2022).

Increasing diversity on the farm is good for nature and for yields (Snapp et al., 2021; Dittmer et al., 2023; Ewer et al., 2023). Mixed production systems such as double-cropping or agroforestry, crop rotation, and the use of hedgerows can increase land productivity, improve water efficiency, sequester carbon, and host richer and more abundant biodiversity than simpler systems (Estrada-Carmona et al., 2022). Plant diversity also helps to regulate crop pests, such as pathogenic fungi, weeds, and harmful insects, while reducing or eliminating pesticides (IPCC, 2019; INRAE, 2022). It is also demonstrated that large natural habitat blocks, surrounded by diversified farming systems at both field and landscape scales, best support biodiversity, ecosystem services and crop yields (Kremen and Geladi, 2023).

Agroecology principles can also help tackle desertification and help build resilience against climate change impacts. These aim at promoting biodiversity, overall diversity, and healthy soils on the farm and emphasize co-creation and sharing of knowledge with local farmers (Leippert et al., 2020). Agroforestry, for instance, is the practice of mixing trees with other crops. It is commonly used in the region for coffee and cocoa plants. Erosion control techniques—e.g., matching crop varieties to land and soil types and selecting deep-rooted crops that help reduce the breakdown and slippage of soil—also help minimize yield loss (IPCC, 2019; Bioversity International, 2017).

Silvopastoral systems, in the case of cattle, can promote resilient food production and biodiversity preservation (Peri et al., 2016; Chará et al., 2019). Silvopasture involves planting trees and shrubs on grazing land or integrating pastures in existing woodlands or orchards. Trees and shrubs stabilize forage availability throughout the year. They do so directly by producing food for cattle and indirectly by promoting soil and water retention, in turn favoring fodder production. In Colombia, Mexico, and Argentina, conversion to silvopastoral systems brought increased forage production and better yields of meat and milk while contributing to forest conservation, the restoration of degraded areas, and the enhancement of biodiversity (Chará et al., 2019). One farm sample in Colombia reported increases of 300% in birds, 60% in ants and 100% in dung beetles. Silvopasture also provides shade that limits thermic stress for livestock, increasing productivity.

4 See Chapter 3. Riding the Adaptation Wave in the Water and Sanitation Sector

5 See Chapter 5. Driving Adaptation in the Transport Sector

Other options for making cattle more resilient include providing feed supplements, implementing rotational grazing to allow sufficient recovery of grasslands, and using improved varieties of fodder (Sova et al., 2018).

Better Diets and Less Waste

Changing what people eat is essential to reducing pressure on ecosystems and adapting to climate change. In Latin America and the Caribbean, beef consumption patterns are heterogenous. Countries in the Southern Cone are the global beef eating champions— consuming three times as much beef per capita as Europeans and 50% more than North Americans (Dumas et al., 2022). But a lot of a tasty thing[6] can sometimes be too much: overconsumption of red meat killed 66,000 people in Argentina, Brazil, and Colombia in 2018 alone (Romanello et al., 2021). In Central America and the Caribbean, meanwhile, many households still suffer from inadequate levels of animal protein intake (IDB, 2019a).

Diets that rely less on beef and dairy can be healthier, drastically reduce pressure on land and water use, and promote the diversification of the food system. Dumas et al. (2022) show that the regional consumption of beef could be halved by 2050, while nutritional outcomes improved in all countries. In their scenario, beef consumption increases in the poorest countries of the region, especially in Central America and the Caribbean but is reduced 45% to 85% among the highest consumers in South America. The result is that deforestation is halted in the region, and food production leaves room for massive reforestation.

Finally, reducing food waste and losses increases the efficiency of the food system. Up to 30% of the food produced globally is lost before it reaches markets or is wasted by final consumers (IPCC, 2019). Improved harvesting techniques, on-farm storage, investments in the cold chain, transport infrastructure, packaging, retail, and education are options to reduce food loss and waste (IPCC, 2019).

Ducks in a Row: Improving Food Production and Nature Preservation Policy

Food production and nature preservation depend on each other. To promote both goals, governments must reduce institutional fragmentation and better distribute responsibilities and decisions among public and private actors. Involving stakeholders, including local and indigenous communities, in decisions and planning processes around biodiversity and food production improves both development and execution (IPCC, 2019).

A Regulatory Feast

Zoning regulations can promote conservation and help prepare for climate changes' effects, such as sea-level rise (Hallegate et al., 2016; IPCC, 2019). In Belize, any intervention involving mangroves requires prior authorization from the forest department and the payment of a fee (WWF, 2021). This recent rule is designed to support the conservation of the country's 742 square kilometers of mangroves, which are threatened by development, particularly on foreign-owned land dedicated to tourism. Similarly, part of the solution for making aquaculture more sustainable is to avoid environmentally sensitive areas, match species composition to local conditions, or relocate species to suitable conditions (FAO, 2022).

Land titling policies can promote adaptation and sustainability. In 1994, Guatemala issued a 25-year concession for community-owned forest enterprises within the Maya Biosphere Reserve. The concession gave rights to sustainably manage and harvest timber under the supervision of NGOs, donors, and government agencies. The ownership model provided more than 10,000 farmers with almost US$5 million in combined revenue between 2006 and 2007. It also increased the diversity of birds, animals and insects and reduced forest fires, illegal logging, and hunting (WRI, 2008).

6 Two authors confess to enjoying cookouts.

Urban development can also be integrated with the local ecosystem, minimizing its destruction, and reducing pollution by improving waste management (Parmesan et al., 2022). The city of Curitiba, Brazil, implemented an "Urban Master Plan" in the 1960s to direct the development of the city along a radial linear-branching pattern, protecting the green spaces between (WRI, 2011).

Government policy should also aim to increase the genetic diversity of food. Reforming credit and insurance rules, which are often biased towards a few species, is one way to do so (Bioversity International, 2017). Reforming property rights that limit the use, storage, exchange, and duplication of seeds is also important (Prieler, 2022). Current rules are often at odds with ancestral practice and international law, such as the International Treaty on Plant Genetic Resources for Food and Agriculture and the United Nations Declaration on the Rights of Peasants.

Governments can also increase food variety and reduce waste by promoting dietary changes, instituting public health guidelines, and streamlining public procurement (IPCC, 2019). Governmental health and eating guidelines that promote traditional food production can increase the genetic pool of food sources (Bioversity International, 2017). Nutrition education is an effective strategy for influencing diets. Public procurement actions, such as changing the food menus in public schools, can also promote a change in diets and food diversity.

Seeds of Change: Information and Communication

Governments should enhance the dissemination of information regarding climate change, extreme weather events, and best practices. Improving the quality, the quantity, and access to information (including early warning systems) can make a significant difference. It can help decision makers adjust their activities, particularly those related to agriculture and biodiversity protection, so they factor in climate changes, such as decreased precipitation or risks of pests and extreme weather events (IPCC, 2019, WFP, 2021).

Proven measures with respect to information include extending the use and precision of climate services and forecasting and increasing the availability of knowledge of land and water resources. They also include expanding biodiversity monitoring and instituting early warning systems against natural disasters and pests (IPCC, 2019). Even low-budget solutions can have a significant impact. In El Salvador, a low-cost early warning system called "Estación Verde" disseminates weather and climatic information through radio and a podcast (WFP, 2021).

Decision makers also benefit from information on the future viability and availability of food sources, alternatives for substitution, and regionally specific adaptations that can be implemented (Prager et al., 2022). Governments can fund studies that help local actors implement the necessary adaptations, as the lack of regionally specific information is often a barrier. Relevant studies include impact assessments and research on climate change in their respective countries, possible adaptations, and technology improvements for local activities.

Monitoring by governments of fish stocks in oceans and seas allows them to anticipate the impact of climate change and set fishing quotas accordingly (FAO, 2022). In Peru, the government recently installed computational hardware and developed models that allow it to account for climate change in updating fishing quotas and developing adaptation plans (IDB, 2019b). Quotas should ideally be set after analyzing multiple scenarios of future ocean conditions, assessing how climate change, fisheries, and other human activities might affect marine stocks.[7]

Capacity building is also needed to promote more resilient and nature-positive farming systems. More diversity on the farm means more complexity, including in terms of research and development, farmers' knowledge, and skills development. Farmers' ecological literacy correlates with agricultural green production behavior (Wyckhuys et al., 2019). New approaches to rural advisory services, such as Living Labs (MACS, 2019) and Farmers Field Schools (Berg et al., 2023), are being experimented with (Davis et al., 2021).

Spending that Bears Fruit

Climate change makes agriculture a riskier investment. Enhanced insurance schemes combined with risk reduction policies are key to reducing the impacts of droughts and other unfavorable climatic conditions on the livelihood of farmers and improving food security (Hansen et al., 2019). Boosting access to credit is also important. While access to

7 See *Decision Making Under Uncertainty* in Chapter 1. Decision-Making for a Future with Climate Change

credit increases yields and reduces risk, farmers in the region have limited access to it because of the risks and cycles inherent in agriculture, the dearth of physical assets that may be used as collateral, and the difficulty of obtaining reliable information on the repayment capacity of borrowers (IDB, 2019a). Governments can also protect poor households against the consequences of these events by providing them with social safety nets such as cash transfers indexed to food prices (Hallegate et al., 2016).[8]

Governments can pay farmers to conserve ecosystems instead of producing food or fiber. Costa Rica designed a *payment for environmental services program* that compensates landowners for forest conservation. The payment is funded principally through a fuel tax and is part of a broader law that banned deforestation. Together, these policies have been instrumental in helping Costa Rica raise forest cover to 52% of its land in 2021, from just 25% in 1987.

More generally, governments should allocate public funds to biodiversity preservation. Globally, conservation projects receive only between US$77 billion and US$87 billion per year, when an estimated US$200 billion to US$300 billion is needed to preserve and restore ecosystems (Deutz et al. 2020). New financial instruments are being piloted in the region for biodiversity preservation. In Barbados, the government recently swapped old debt with new, cheaper debt, obtained after pledging to redirect savings to the funding of its new marine protected area. The deal, brokered by The Nature Conservancy and the Inter-American Development Bank, allowed the government to dedicate US$50 million to biodiversity protection (IDB, 2022). Similarly, Ecuador recently realized the largest nature debt swap ever, allowing it to dedicate US$323 million to conservation in the Galapagos and La Hermandad Marine reserves (IDB, 2023).

Finally, reforming agricultural subsidies is crucial. Current production and trade-distorting domestic support of agriculture negatively impacts climate and the environment (Ash and Cox, 2022). Governments globally spend nearly US$540 billion per year to support agricultural producers, chiefly in the beef and dairy sectors. But 87% of that support has been found to be inefficient and inequitable, while creating risks linked to pollution and the promotion of unhealthy diets (FAO, UNDP, and UNEP, 2021). Repurposing subsidies to incentivize diversity and nature-friendly practices, such as agroforestry and silvopasture, would improve food security and rural incomes. They would also protect or restore millions of hectares of ecosystems (Ding et al., 2021). Redirecting about $70 billion a year would yield a net benefit of over $2 trillion in 20 years (Gautam et al., 2022).

8 Chapter 8. Double Jeopardy: The Economic and Environmental Risks for the Poor

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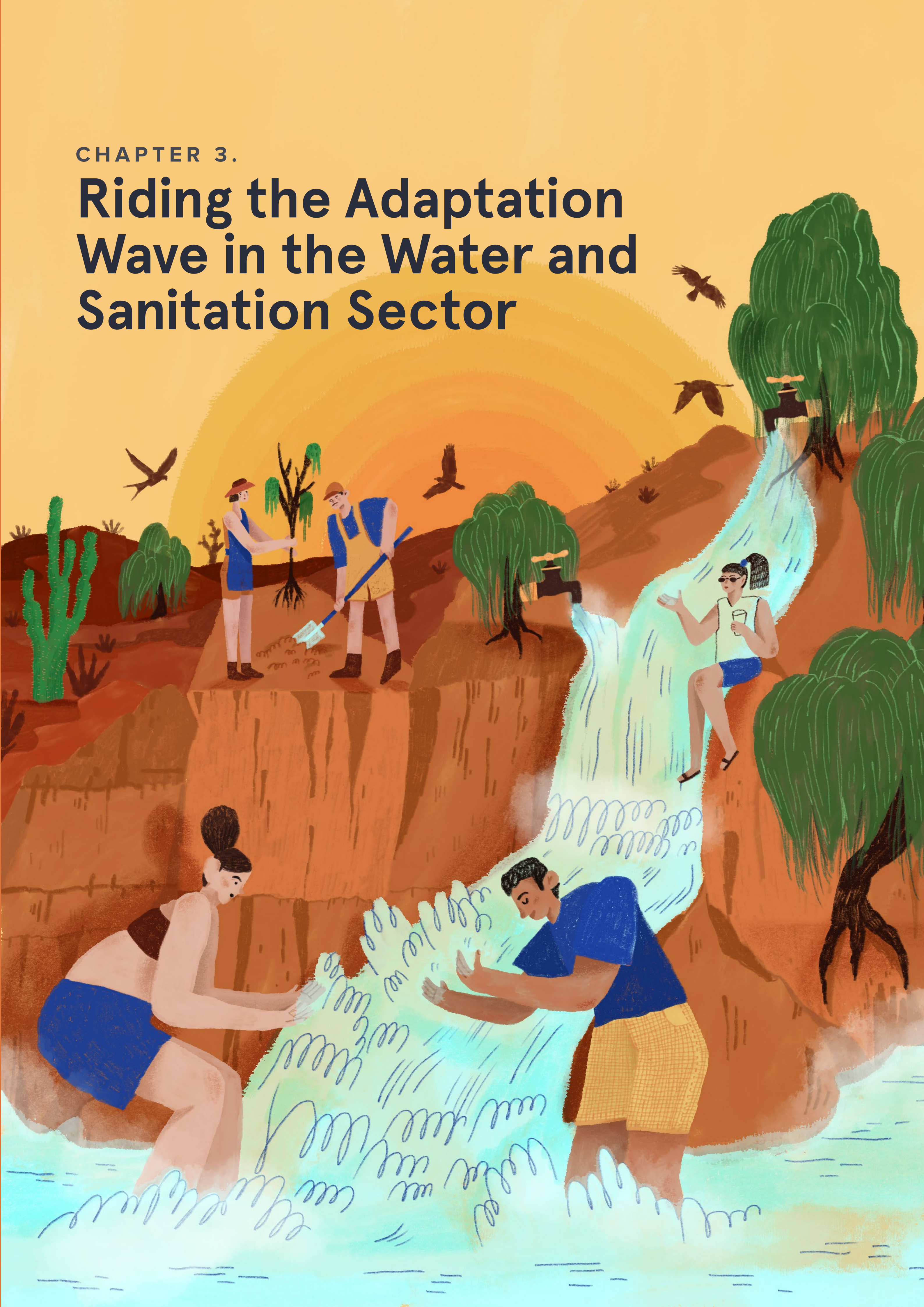
CHAPTER 3.

Riding the Adaptation Wave in the Water and Sanitation Sector



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Riding the Adaptation Wave in the Water and Sanitation Sector

Climate change affects water security. Changes in temperature and precipitation impact water availability. Extreme weather events, such as hurricanes, destroy water supply infrastructure. These changes present risks to water security by increasing scarcity, pollution, and water-borne diseases. Reduced water security also harms households indirectly through its impact on productive sectors such as agriculture, energy, and industry. Adapting means planning under uncertainty, increasing the number, diversity, and quality of water sources, and building resilience to extreme weather events. Options include reducing wasteful water consumption, improving and expanding sanitation infrastructure, diversifying freshwater sources, including by recycling and reusing water, and leveraging nature-based solutions to improve the quantity and quality of freshwater sources. Governments can improve water governance by fostering an integrated water management approach at the basin level, and enhancing coordination among government agencies, the private sector, and the public at large. They can also advance regulations on water consumption, extraction, and pollution; tax pollution or consumption; and subsidize the adoption of new technologies.

Climate Change Effects on Water Security

Water is fundamental for food production, energy generation with thermal and hydropower plants, sanitation, health, industrial processes, and human consumption (Bretas et al., 2021). Climate change jeopardizes water availability and brings new and more water-related health hazards. It increases the variability and uncertainty of water availability, exacerbates disparities as wet regions become wetter and dry regions become drier, and increases the frequency and severity of extreme weather events such as floods and droughts.

While water abounds in Latin America and the Caribbean, regional and temporal disparities mean that more than half its population (53%) is at risk of suffering from an imbalance between water demand and supply, as measured by the World Resources Institute's physical water risk indicator (Libra et al., 2022).[2] The Amazon basin, the northeast of Brazil, the north of Mexico, the Caribbean, and Central America are at particular risk (Map 3.1).

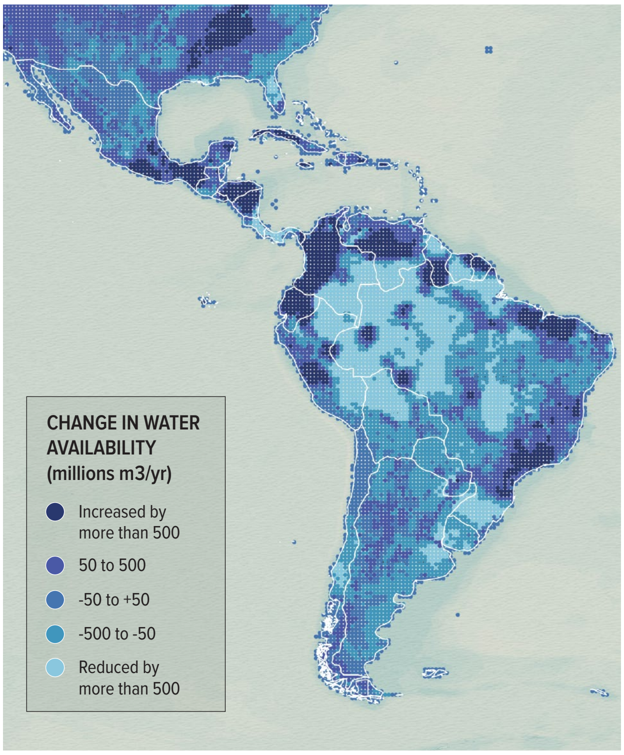
A Threat to Water Availability

In Latin America and the Caribbean, annual precipitation patterns are expected to change, and interannual variability will likely increase throughout the region (Libra et al., 2022). The Caribbean is especially susceptible to damage as tropical cyclones and sea level rise cause more extreme flooding and saltwater intrusion, harming already degraded water distribution networks and further deteriorating water quality (Masson-Delmotte et al., 2021). In the Andes, glacier retreat threatens water availability. During drought years and dry seasons, major South American population centers supplement deficiencies in precipitation with glacial melt. However, glaciers are in retreat, making areas that rely on glacial melt increasingly vulnerable. This vulnerability is particularly worrisome as climate change is altering the El Niño oscillation and increasing the frequency and intensity of droughts, thereby raising dependency on glacial melts (Wang et al., 2019).

Population growth, urbanization, and energy needs are boosting the global demand for freshwater, which is projected to increase between 30% and 50% by 2050 (Damania et al., 2017).[1] Climate change will aggravate water insecurity worldwide, affecting more than half of the world population and possibly displacing up to 700 million people (Damania et al., 2017).

MAP 3.1

Projected Changes in Water Availability, 2015-2050, in a Moderate Climate Change Scenario



Source: Bretas et al., 2020

1 Since 2017, energy investors have decidedly shifted to solar and wind as the main new sources of energy, alleviating future water demand growth in the energy sector somewhat, as these source use virtually no water compared to thermal and hydropower plants.

2 Quantity-based physical water risk, the indicator used here, considers baseline water stress, seasonal variability, water depletion, interannual variability, groundwater table decline, riverine flood risk, coastal flooding, and drought risk using data from the WRI's Aqueduct 3.0 Water Risk Atlas (Hofste et al., 2019) and 2020 population estimates from the WorldPop datasets (WorldPop, 2018).

The Impact on Water Quality

Quality is also an issue. When water quality is also considered, 60% of the population in the region is at risk (Libra et al., 2022). As the quality of available freshwater becomes compromised, new health hazards arise (WHO, 2017):[3]

- Increased temperatures and precipitation generate conditions ripe for the proliferation of pathogens, microorganisms, water algae, plants, and bacteria on both surface and underground sources of water (e.g., by increasing the nutrient load).
- Lower water levels increase the concentration of toxicants and biological contamination, while lower total rainfall reduces the capacity of surface water to dilute and remove pollutants.
- Excessive precipitation during extreme weather events increases pollutants in freshwater as wastewater facilities become overwhelmed and sources are contaminated.
- Sewers lose some of their self-cleaning capacity during droughts.
- Exhaustion of existing freshwater sources leads to the use of new, less safe alternatives.

Extreme weather events also damage or destroy the freshwater supply infrastructure. *Dry outs*, events when infrastructure becomes unable to provide freshwater, lead to business interruptions worth $6 billion per year in developing countries globally (Rentschler et al., 2019).

In Latin America and the Caribbean, climate change exacerbates a toll that aging pipes and insufficient maintenance are already taking on infrastructure. For instance, in Lima, Peru, intense rains and subsequent landslides during March 2017 filled the rivers with mud, forcing the main water treatment plant to shut down and interrupting the supply of water to the city (Stip et al., 2019).

A Flood of Adaptation Options

Adaptation goals include securing access to water resources, ensuring the quality of freshwater, and building resilience to new climate hazards. The sector can adapt by improving the efficiency of water systems and freshwater quality, adapting existing and new infrastructure to adverse effects, diversifying the portfolio of water sources (including by reusing and recycling water), and considering nature-based solutions.

Circular economy principles can be applied to water management. These principles suggest minimizing water losses in the system, reducing water consumption, and reusing water to meet demand (Delgado et al., 2021). Indeed, the dominant, linear approach is vulnerable to climate change, as it tends to depend on new water withdrawals from increasingly scarce surface or groundwater. Centralized sewage systems also miss the opportunity to treat different kinds of pollution from different activities in a separate, more effective manner. Moreover, the linear approach does not include resource recovery and reuse, which are fundamental in a scarcity context (Cavallo et al., 2020).

A More Efficient System Is a Less Stressed System

Increasing the efficiency of existing water systems and wastewater treatment is one of the most cost-effective adaptations (Delgado et al., 2021). Improving maintenance to reduce leaks is important as water utilities suffer significant losses in their distribution systems. Leakages, for instance, represent 41%, 36%, 43%, and 40% of water in the distribution network in the metropolitan areas of Buenos Aires, Belo Horizonte, Valparaíso, and Mexico City, respectively (OECD, 2017; OECD, 2019; Gutierrez, 2019). Smart meter infrastructure technologies can help identify leaks and solutions. In Brazil, these technologies have cut leaks from 60% in 2012 to 17% in 2019 (Blackman, 2019; IDB invest, 2019).

Reducing demand is also important. Demand for freshwater can be curbed by switching to water-efficient industrial processes, using water-efficient appliances, and increasing the water efficiency of agriculture by deploying drip irrigation, using saline water when possible, or improving crop selection

3 See also Chapter 7. Wellness Check: Climate Change and the Health Sector

(Delgado et al., 2021).[4] Water conservation habits, such as planting native vegetation that does not require irrigation in gardens, taking shorter showers, or washing clothes only in full loads, can also be promoted in the residential sector (Pérez-Urdiales and García-Valiñas, 2016; Attari, 2014).

Reusing and Recycling

Reusing water is a key option. Investments in new sources of freshwater must be complemented with sufficient capacity to handle its wastewater. In Latin America and the Caribbean, only 60% of the population has access to a sewage system, and only 30% to 40% of wastewater is treated (Rodríguez et al., 2020). Consequently, water reuse is uncommon in the region, even though its market potential is estimated at between US$3 billion and US$62 billion (World Bank, 2019).

Wastewater can be treated and reused for various economic activities such as irrigation, gardening, cooling of energy power plants, cleaning, or industrial processes (Delgado et al., 2021). With minimal treatment, graywater—that is, water from showering or washing—can be reused directly, or used to recharge groundwater (Delgado et al., 2021). In San Luis Potosí, Mexico, the Tenorio wastewater treatment plant processes up to 45% of the total wastewater generated by the city and uses it for such purposes as cooling of energy facilities and agricultural irrigation. Moreover, the installation itself serves as a wetland (World Bank, 2018).

Reducing the pollution of all water sources is key to enabling water reuse (OECD, 2021). Measures to do so include minimizing agrochemical and disinfectant use, optimizing and enhancing existing water treatment methods, establishing new ones, and improving infrastructure to reduce sewage runoff (WHO, 2017).

Diversification is Key

Diversifying water sources is a key part of adaptation strategies (Cathala et al., 2018). Having a variety of sources that respond differently to shocks and stresses helps hedge risk (WHO, 2017; Delgado et al., 2021). For example, to avoid risks to water security due to declining precipitation and dam levels, Australia opted to diversify its sources of water by investing in seawater desalinization and recycled water plants (Muñoz and Crisman, 2019). Innovative technologies help improve the quantity and quality of water resources and freshwater availability. Unconventional water sources include fog water harvesting, deep groundwater, desalinated water, and ballast water (Carvajal et al., 2022; UN-Water, 2020). Building redundancy in sources and distribution networks, such as by duplicating equipment, also helps to make water supply more resilient (Klasic et al., 2022).

Nature's Bounty

Nature-based solutions, also called green infrastructure, can help secure water availability, reduce pollution, and protect infrastructure and ecosystems against extreme weather events (Muñoz and Crisman, 2019). Forests and wetlands can help guarantee the provision of freshwater in the face of climate change. Restoring watersheds, wetlands, and mangrove forests can improve the quality of freshwater. Wetlands can retain nutrients, avoid water contamination on catchment, filter polluted water and wastewater, reduce sediment inflows after heavy rainfall, and protect against flooding and drought (Delgado et al., 2021; WHO, 2017). Table 3.1 lists several nature-based solutions that have the potential to address water security issues, either individually or in conjunction with grey infrastructure.

Options to increase water storage should be considered under a holistic approach that goes beyond building reservoirs and considers leveraging natural solutions, for instance by recharging groundwater and restoring wetlands (Delgado et al., 2021). Managing, recharging, and preserving aquifers is an example of how to ensure water security sustainability in cities. Regenerative agriculture—a set of agricultural practices that boost the ability of soil to perform its functions, thereby regenerating biodiversity, ecosystem health, and water retention—may also foster the resilience of water systems. This approach has been successfully implemented by small- and medium-sized cattle ranches in the Gran Chaco, which spans Argentina, Bolivia, Brazil, and Paraguay (The Nature Conservancy, 2021). Integrating green infrastructure with grey infrastructure can help reduce the costs of freshwater. For example, "bofedales" in the Central Andes Mountains and "paramos" in the Northern Andes Mountains are high altitude wetlands with significant water retention capabilities that, combined with existing water reservoirs, can maximize water storage (Muñoz and Crisman, 2019).

4 See Chapter 2. Land of the Living: Rethinking Food and Biodiversity Together

TABLE 3.1.

Some Benefits of Nature-based Solutions on Water Availability and Water Quality

	Improved Sources		Protection against extreme weather		Water Quality				
	River	Aquifers	Flood	Drought	Nitrates and phosphates	Sediments	Pesticides	Ground water	Wastewater
Land protection	✓	✓	✓	✓	✓	✓	✓	✓	
Reforestation	✓	✓	✓	✓	✓	✓		✓	
Riverbank buffers		✓	✓	✓	✓	✓			
Invasive species removal	✓								
Flood plains connected to rivers		✓	✓						
Wetlands preservation and restauration	✓	✓	✓	✓	✓	✓	✓	✓	✓
Artificial wetlands									✓
Parks and green areas		✓	✓	✓					
Permeable paving		✓	✓	✓					
Flood bypasses	✓	✓	✓	✓					

Source: author elaboration based on Bretas et al. (2018) and additional research.

How Government Interventions Can Turn the Tide

Water Management Needs Good Governance

Governments can improve water governance to promote coordination of water policy. One key improvement is to establish an integrated water management approach at the basin level. The goal is to promote horizontal and vertical coordination. Horizontal coordination means coordination among relevant government ministries and agencies, to cover all sectors that are affected by, or that affect the quality or quantity of freshwater, including, for example, agriculture, energy, health, cities, mining, and construction. Vertical coordination, that is between the national and local levels, is also relevant (OECD, 2021). Horizontal coordination is already promoted by most governments in the region via planning departments, in countries such as Bolivia, Brazil, Chile and Costa Rica; or technical public agencies in Colombia, Guatemala and Paraguay (Bellfield, 2015). Vertical coordination is, however, challenging since policymaking on water is highly fragmented across agencies. Moreover, while water governance is commonly decentralized with decision-making assigned to local authorities, regulation tends to occur at a higher administrative level (Bellfield, 2015).

Allocating collective water entitlements is also important. Well-designed entitlements alleviate the natural tendency of markets to foster inequalities (Villamayor-Tomas et al., 2022). The process for allocating water rights should pay special attention to include communities that usually have low financial and technical capacity for participating in the market, such as indigenous communities. When water was privatized in Chile's 1980 Constitution, Mapuche communities were mostly excluded (Wissmüler, 2021). In the United States, the Supreme Court ruled in 1908 that tribes should have water rights "sufficient to fulfill the need of the reservation as a homeland" and has since ruled several times in favor of reserving water for indigenous people (Sanchez et al., 2020).

Considering transboundary coordination for international water streams is also important (OECD, 2021). No country in Latin America and the Caribbean has ratified the 1992 Convention on the Protection and Use of Transboundary Watercourses and International Lakes and the 1997 Convention on the Law of the Non-Navigational Uses of International Watercourses, which set a framework for transboundary water cooperation. Moreover 11 of the 67 international drainage basins in the region lack operational arrangements for water cooperation (Muñoz Castillo et al., 2021). The road towards equitable and reasonable sharing of water resources by several countries is still long and challenging.

Making Information Flow

Communication is important to coordinate with the private sector. Communication should always be clear, aiming to build public trust, and inform the population of the risks to water security, its implications, and the actions and policies implemented (Ortiz et al., 2021).

Communication strategies should also aim to generate behavioral changes in freshwater consumption (Ortiz et al., 2021). For instance, moving from collective to individual meters can incentive households to reduce consumption. In Quito, Ecuador, water consumption dropped by 8% after the introduction of individual metering (Contreras et al., 2021). But residential consumers often lack information or awareness about their water bill (Pérez-Urdiales et al., 2022), which affects the impact of pricing policies on water conservation. Water companies should adequately communicate water consumption and tariff structures to consumers.

Moreover, it is important to raise awareness about the need to conserve water. The 2018-2019 *AmericasBarometer* survey, which captures public opinion throughout the region on several topics, found that less than 10% of respondents in the region say it is a salient issue (Pérez-Urdiales et al., 2023). In São Paulo, Brazil, authorities distributed films and flyers to inform communities and social leaders about the risks of water stress and promote the efficient use of water (Cathala et al., 2018).

Informing Decision-Making with Better Data and Better Methods

Gathering and sharing data is critical to inform policy-making. In the case of water, this requires improving groundwater measurements, monitoring new sources of water or the quality of watersheds, and adopting new technologies and tools such as modeling, mapping, and image technologies using satellites and drones. Data can be made available directly or communicated to the public through reports (OECD 2021). Analytical models such as Hydro-BID—an integrated, quantitative system created by the Inter-American Development Bank to simulate hydrology and water resources management in the region under a variety of climate, population, and land-use change scenarios—can help evaluate the quantity and quality of water, infrastructure needs, and strategies to adapt to these changes (Moreda et al., 2014; Olaya et al., 2020).

A key issue regarding data and capacity is that climate change is deeply uncertain. In some places, for instance, we do not know if it means that precipitation will increase or decrease. The same uncertainty applies to socioeconomic trends that affect water demand, for instance urban development, population and GDP growth, and technology development in cities and rural areas. To deal with these situations, government agencies and the private sector can use decision-making under deep uncertainty tools that are based on exploring different scenarios, looking for no-regret options that perform well under many different conditions, and building plans that bake in the opportunity to adjust course as new information becomes available.[5] Such methods have been used across the region, including to plan water investments in Lima, Peru, Monterrey, Mexico, or in the Province of Mendoza in Argentina (Kalra et al., 2015; Molina-Perez et al., 2019; Groves et al., 2021).

Creating and Enforcing Regulation

Governments can use regulation to protect green infrastructure, incentivize the adoption of more efficient water uses, and encourage water savings. Examples include establishing quality standards and mandatory measures and enhancing water allocation regimes. Establishing minimum ecological levels of streamflow or protecting basins' ecological status can directly protect green infrastructure (OECD, 2021). Denmark, Greece, and Hungary grant groundwater permits conditional on conserving the ecological status of the water source (OECD, 2021). Protecting slopes and forests can be an effective measure to guarantee water provision (Ortiz et al., 2021). Governments can also reform their water allocation regimes or design a dynamic and flexible system to promote the efficient use of resources (OECD, 2021). They can mandate the adoption of water conservation technologies and activities. In California, the government sets limits on the irrigation of gardens during droughts, strictly regulates plumbing fixtures to avoid water losses, and sets water efficiency minimums on all new toilets and urinals (Cathala et al., 2018). Given the sizable investment required to adopt adaptation practices and the limited fiscal space, attracting private investment by reforming the regulatory framework or using public-private partnerships is key (Castrosin et al., 2021; García et al., 2021).

Economic Instruments

Governments can also intervene with economic instruments designed to incentivize water conservation or its efficient use. Water abstraction charges are fees levied to extract water directly from a shared natural source (rivers, aquifers) by sanitation entities, industry, agriculture, or power plants. Countries where they are applied include Argentina, Bolivia, Brazil, Colombia, Costa Rica, Ecuador, El Salvador, Panama, and Peru. Pollution charges that tax polluters directly (e.g., on the source) or indirectly (e.g., measuring the number of pollutants or taxing products responsible for pollution) are also used. In the water and sanitation sector, tariffs are designed considering, among other objectives, water conservation and cost recovery, which may include the overall costs of new water infrastructure (OECD, 2021).

Subsidy schemes can improve water availability and efficiency on both the supply and demand sides. Such schemes include conditioning irrigation subsidies on water saving objectives, subsidizing infrastructure whose costs are not fully covered by revenues, and establishing replacement or rebate programs on items such as showers, toilets, rainwater harvesting, or water reuse systems (Moreno et al., 2021; OECD, 2021). In addition to saving water, these measures improve public health (WHO, 2006). Subsidies can also incentivize investment in efficient household technologies. In California, a program subsidized the purchase of efficient washers, efficient toilets, the elimination of water-intensive turfs, and the adoption of weather-based irrigation controllers that automatically adjust the irrigation schedule to account for changing weather (Pérez-Urdiales and Baerenklau, 2019).

5 See chapter 1. Decision-Making for a Future with Climate Change

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CHAPTER 4.

Powering Adaptation in the Electricity Sector

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Powering Adaptation in the Electricity Sector

The power sector is vulnerable to climate change. Changes in weather patterns, such as hotter summers, can create peaks in demand and alter generation potential. For instance, demand for air conditioning increases and the efficiency of cooling systems in power plants declines. Extreme weather events can damage production, transmission, and distribution infrastructure. Energy disruptions propagate to the most productive sectors, including industry, and threaten wellbeing by interrupting health, education, and other services. Adaptation options include: (i) choosing better sites and reinforcing critical infrastructure, such as by burying distribution lines; (ii) using better technology to cool down power plants—in particular, using less water—and to manage the grid (iii); decentralizing and diversifying energy production; (iv) increasing efficiency to reduce energy demand; (v) improving forecasting, early warning systems and representation of climate impacts in energy modeling; and (vi) planning and preparing for disruptions to minimize social and economic costs. Governments can use pricing schemes and modify regulations to incentivize adaptation; establish clear responsibility among producers, transporters, and consumers of energy; and improve information on threats, vulnerabilities, and cost-effective adaptation options.

Climate Change: A Threat to Energy Security and Infrastructure

Energy is the lifeblood of a functioning economy. Households rely on electricity for simple day-to-day tasks, from cooking their meals to heating their homes. Businesses use energy to literally keep the lights on. And critical services, such as traffic lighting or respirators in hospitals, rely on electricity. Climate change threatens all these activities. Higher temperatures can cause demand to outstrip power generation capacity, extreme weather events disrupt electricity supply, and demand for energy shifts geographically and seasonally.

Power Generation: Vulnerable on Multiple Fronts

Climate change impacts renewables and thermal power plants differently. For renewable energy—solar, wind, and hydropower—changes in weather patterns are disrupting, at best. Changes in the availability and variability of runoff water impact the output of hydropower facilities. Altered wind patterns and air density impact wind farms. Solar energy productivity is affected by changes in cloud cover and higher mean temperatures, which hinder the performance of photovoltaic modules (IAEA, 2019; IEA, 2021a).

Climate change increases the competition between water uses, including electricity production. In Brazil, existing mechanisms follow a first-come, first-served approach that does not effectively reallocate water resources among multiple uses when faced with water scarcity. This competition for water poses potential risks to energy generation in a country with 644 hydropower plants that represent 12% of the energy mix (Dutra, 2020).

For thermal plants—coal, fossil gas, diesel, nuclear, wood pellets—a key issue is cooling. Higher temperatures reduce the efficiency of thermal plants. At a fundamental level, thermal plants generate electricity by moving energy from a hot source—usually fire— to a cold source—air or water. If climate change makes air or rivers hotter, less energy is created. Moreover, heatwaves risk overheating thermal power plants, leaving no choice but to reduce output or turn plants off entirely (IAEA, 2019).

Climate change can also damage power plants. Sea level rise can flood low lying installations—for instance, a sea-cooled gas power plant. Greater windiness can destroy wind turbines. Stronger winds can also carry more salty airborne material, increasing corrosion in some power generators (IAEA, 2019). In the case of large hydropower plants, increased precipitation and more frequent storms can accelerate sedimentation: dirt progressively builds up in the reservoir and eventually renders the installation unusable (Annandale et al., 2016).

Extreme weather events can damage generation infrastructure. Heatwaves hurt photovoltaic solar panels. Ice and hail interfere with hydraulic and wind turbines (IAEA, 2019). Map 4.1 shows the proportion of total energy generation capacity exposed to hazards. Many countries in the region, including Chile, Dominican Republic, and El Salvador, are among the most exposed in the world (Hallegatte et al., 2019).

Networks Feel the Heat

Hotter days mean more energy losses. As transmission and distribution lines become hotter, they become more resistant to electricity currents, according to a law of physics (IAEA, 2019; IEA, 2021a). For the United States, increased average air temperatures projected for the 2040-2060 period are estimated to decrease average summertime transmission capacity by 1.9%–5.8% relative to the average between 1990 and 2010 (Bartos et al., 2016). Transmission and distribution lines are also vulnerable to extreme weather events such as flooding, storms, and heatwaves (IAEA, 2019). Wildfires are a particular risk: they can be ignited by sparks from the grid or dilated lines when they overheat and touch trees. In turn, wildfires destroy transmission lines (IAEA, 2019). Disrupted lines become a financial burden and can unleash cascading crises. Unprepared systems that struggle to quickly restore the system can result in prolonged spells without electricity. In Puerto Rico, many localities not directly hit by Hurricane Maria in 2017 suffered from the disaster as energy transmission was cut for months (Hallegatte et al., 2019).

MAP 4.1

Exposure of Power Generation to Multiple Hazards

Note: Values above 100% signify that assets are exposed on average to more than one hazard, for instance, flooding and hurricanes. Source: Hallegatte et al. (2019)

Demand: On the Rise

Climate change also brings shifts in energy demand that can challenge the capacity of the sector to reliably supply electricity. One prime issue is temperature, which is directly linked to the demand for cooling and heating. Higher temperatures or humidity translate into greater demand for cooling in places where people use air conditioning (IEA, 2021a). Air conditioning is an important adaptation option. By 2050, each 1°C rise in global temperatures will boost the demand for cooling globally by about 25% (IRENA, 2021). Climate change will also occasionally generate cold spells, increasing the local demand for heating (IEA, 2019a).

Under current trends, electricity demand is expected to increase 48% by 2030 in Latin America and the Caribbean (Lopez et al 2022). Climate change could boost that, as could climate policy, which will result in more electricity use, for instance in replacing gasoline cars with electric vehicles (Fazekas et al., 2022). A key driver of demand growth in electricity is more households graduating to the middle class and consuming more energy services. In 2018, only 70% of households in the region had hot water, 62% had washing machines, and 38% had heating or air conditioning. Enforcing energy efficiency standards and practices across the economy will be key to delivering new energy services and moderating growth in energy demand. It will help make the power sector more resilient (Ravillard et al., 2019).

Another issue is that some of the measures used to adapt to climate change will increase electricity demand. For example, water pumps and desalinization plants designed to deal with declining precipitation or salinization of aquifers are energy intensive and would thus increase the demand for electricity (IEA, 2021a). In 2016, desalinization in the Middle East accounted for 5% of energy consumption and delivered 3% of water supply (IEA, 2019b).

Renewable energy can often power the adaptation strategies of other sectors. Some renewables can even deliver non-energy adaptation measures. Solar shading, for example, can reduce evaporation in agriculture. Hydropower dams can deliver water harvesting and flood control benefits (IRENA, 2021). Table 4.1 shows how renewable energy can contribute to the adaptation to climate change in the water and sanitation sector.

TABLE 4.1

Renewable Energy Solutions for Adaptation in the Water Sector

Climate impacts	Adaptation needs	Energy-related measures	Renewable energy solutions
Water scarcity	• Stable freshwater supply • Effective water resource management	• Desalination • Distillation • Groundwater or aquifer pumping	• Renewable energy systems to power underground pumping • Renewable energy system to power desalination plants • Hydro dam to increase water reservoir capacity • Floating photovoltaics to reduce evaporation
Increased water pollution and contamination	• Water quality enhancement	• Water purification and sanitation	• Renewable energy systems to power water clearing pumps • Remote and small-scale water purification through renewable energy systems
		• Wastewater, sewage, and sludge treatment	• Biogas plants for wastewater treatment and recycling
Flood or drought disruption	• Flood control and drainage • Water conveyance and distribution	• Water distribution and drainage control	• Hydro dam to control flooding • Solar or wind pumping

Source: IRENA, 2021

Adaptation Options: Helping the Energy Sector Weather the Future

Adapting the energy sector means guaranteeing continuous service despite climate change and building resilience against extreme weather events (Grunwaldt et al., 2020). This can be done by reinforcing infrastructure, enhancing the power system to avoid disruptions when certain parts of the system fail (*absorptive capacity*), and minimizing response times to restore energy when disruptions happen (*responsive capacity*).

Climate change often brings different weather patterns to new places. However, these weather patterns may be common in other parts of the world that have already tried, tested, and implemented measures to adapt to these phenomena. Many feasible adaptation options consist of implementing practices and technologies that are already in use around the world.

Finding Strength in Numbers and Diversity

Diversifying energy sources can reduce the vulnerability of the system to climate change. Generating energy from a variety of sources reduces the likelihood that all power plants are affected at the same time by the same event (IPCC, 2021). Consider a prolonged anticyclone that leaves a country with little wind, but lots of sun, for several days. Diversifying through wind, solar, biogas, and small-scale hydroelectric plants also means that power is generated from numerous locations.

Interconnection is key for diversification, especially in vast Latin American countries. Brazil has one of the largest interconnected systems in the world, allowing it to balance different sources of renewables. This strong network has been key to the massive adoption of solar and wind power. By the same logic, countries in this region should grow and strengthen their own electricity networks and establish connections with nearby nations. This will facilitate greater incorporation of renewable energy sources into their power systems (Paredes, 2017).

Diversification also means re-assessing the size of power plants. Traditional power plants were designed to leverage economies of scale. But with consolidation comes risks. A country that depends on one large-scale coal power plant is more likely to experience a complete blackout due to a flood than one with multiple solar panels and windmills spread throughout its territory. Decentralization can also place production closer to demand, thereby reducing the risks associated with transport networks, and allowing communities to implement their own adaptations at the local level (Hallegate et al., 2019; IRENA, 2021).

Energy storage can help guarantee the continuity of electricity services when natural disasters disrupt production or demand spikes. Technologies such as batteries, pumped hydro, flywheels, and supercapacitors can also help integrate intermittent wind and power to the grid or make them reliable off-grid sources (Graham et al., 2020). When bundled with storage, renewables can better meet demand through the day and increase the resilience of the energy system by removing the need for transmission lines. Microgrids powered by renewable power and batteries can help establish essential services, such as clinics or schools, in remote areas.

Existing water reservoirs can also be used for energy storage (IEA, 2021d). Pumped hydropower storage means using excess energy during times of low demand to pump water from a lower reservoir to a higher reservoir (Saravia et al., 2022). The Andes mountain range provides Latin America with enormous potential to install pumped storage—a potential that is largely untapped for now, as the region hosts only about 1% of global pumped storage capacity (Saravia et al., 2022). Despite its low energy efficiency, green hydrogen also has the potential to store large amounts of energy for a long time—for instance, over seasons— or to function as a backup in isolated systems (Graham et al., 2020).

Creative Solutions to Protect Infrastructure

Better design is key to adapting to climate change impacts (IAEA, 2019). For example, wind turbines can be modified to resist extreme temperatures. Blade heating can protect them against icing damage, and reinforced support structures can help them withstand extreme windiness. Existing thermal plants can switch to dry cooling and apply recirculating water systems to reduce vulnerability to droughts and diminished water availability. New thermal plants should be avoided, since meeting climate stabilization goals means phasing out fossil fuels (Fazekas et al., 2022). Photovoltaic panels can be upgraded with cooling facilities for hot spells or use tracking systems that allow for rotating panels out of wind and sandstorms.

In Latin America, adapting hydropower is key. The region currently generates almost half of its power from dams (Ubierna et al., 2020). Increasing the water storage capacity of hydropower plants can help with water variability. At the same time, reinforcing dams and turbines can improve their resistance to extreme precipitation events (IAEA, 2019). To prevent increases in sedimentation, dams and reservoirs can be designed and maintained so they account for sediment inflows and outflows. Erosion control, flow management, and regular removal of sediment can be effective ways of dealing with sediment (Annandale et al., 2016). Maintenance is also important. In Latin America, more than 130GW worth of hydropower plants is more than 20 years old. More than $30 billion would be needed to modernize those plants' electrical and mechanical parts and install digital sensors to allow remote monitoring and control of the installations (Ubierna et al., 2020).

Nature-based solutions can safeguard infrastructure against natural hazards and reduce maintenance costs. For instance, planting vegetation along a dam or the banks of a reservoir can limit sediment flow caused by surface runoff, lessening the need for regular dredging. Strategically placed vegetation can also decrease the demand for energy by providing freshwater and cooling, thus reducing the need for desalination and air conditioning (IPCC, 2022).

Transmission and distribution systems should also be upgraded. Clearing the tree cover around transmission lines can lower the risk of igniting forest fires during heat waves or peak demand (IAEA, 2019). Burying transmission and distribution lines can protect them against heat waves and cyclones (IEA, 2021a). Improvements, like better insulation design and greater line tension to prevent sag, can help reinforce transmission and distribution lines against extreme weather events (IAEA, 2019). Increasing the system's transmission capacity can help compensate for decreases in energy generation and transmission efficiency (IAEA, 2019).

A key adaptation lies in choosing optimal sites to reduce or eliminate exposure to the elements. Selecting better locations for new infrastructure is crucial to avoid future climate change impacts, such as sea-level rise, stronger winds, higher temperatures, and flooding (IAEA, 2019). Better routing or re-routing transmission and distribution lines can mitigate or eliminate many of the most critical hazards including heavy winds, storms, and forest fires (IEA, 2019).

The Power of Preparedness

Weather forecasting and early warning systems are key to reliable operations in the electricity sector (IEA, 2021a; Steinbuks et al., 2017). When an extreme event is approaching, utilities need to acquire and properly evaluate high-quality weather and damage forecasts so they can predict system impacts and tailor their responses accordingly. Accurate weather data, for example, allow power plants to minimize damage by curtailing their facilities before a hurricane strikes (Hallegatte et al., 2019). The Australian Energy Market Operator anticipates and reduces the risks of simultaneous flaws at specific points in the grid by identifying credible contingencies, constantly reevaluating them with real time weather forecasts, and taking corrective action (IEA, 2021a).

Some outages and damage to infrastructure are unavoidable. For that reason, adaptation also means controlling the consequences, reducing the areas affected, and quickly restoring or redirecting power (NASEM, 2017). Establishing response and readiness strategies before extreme events occur is fundamental to the ability to quickly repair damaged infrastructure and restore the energy system in a disaster's aftermath.[1] In 1954, typhoon No. 15 led to a power outage in parts of the Kanto area of Japan that lasted over 12 days. A month later, improved preparedness cut the outage generated by typhoon No. 19 to only four days (IEA, 2021a).

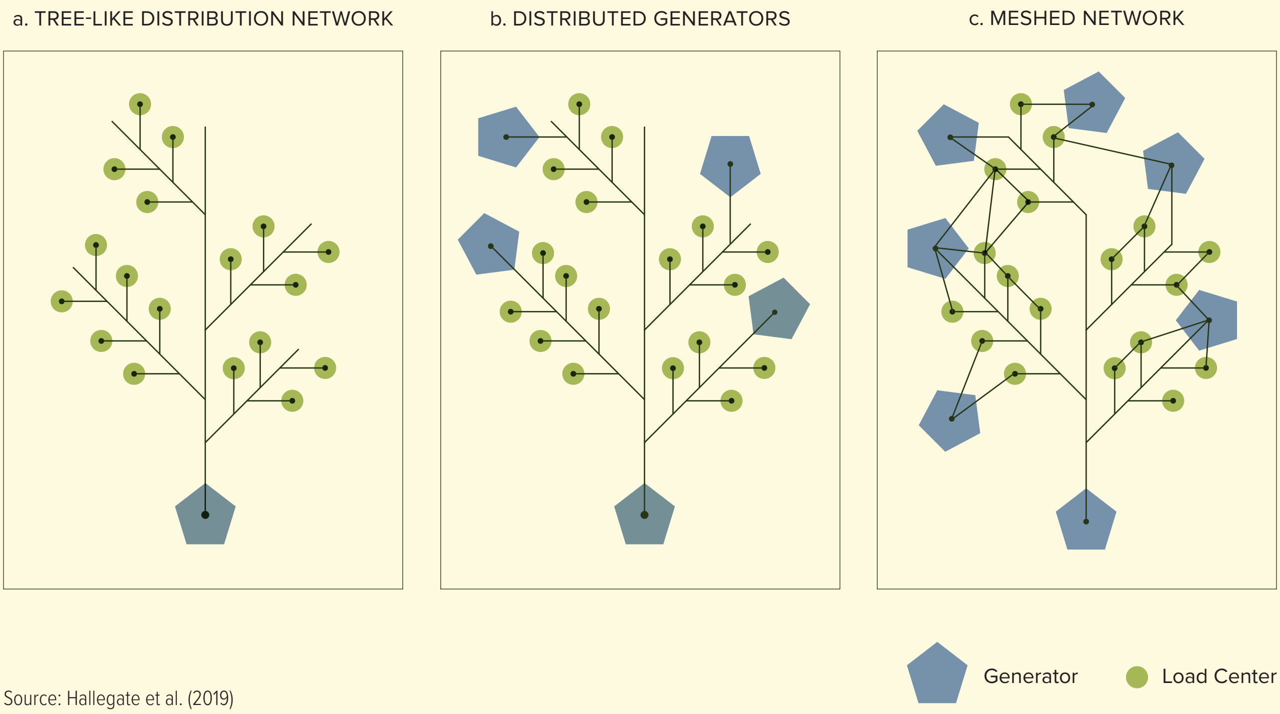
Smart grids boost monitoring capacity and facilitate the response to extreme weather events. They allow energy operators to respond to disruptions remotely, rapidly, and safely (IEA, 2021a; IEA, 2021c). With these smart grid technologies, operators can remotely measure energy consumption, operate the grid, adjust the output of power plants up or down accordingly, and reconfigure transmission and distribution systems to react to extreme weather events or demand peaks, all without risking their safety (IEA, 2021a; IEA, 2021c).

A "meshed" network with multiple interconnected supply points and redundant transmission and distribution lines boosts resilience by minimizing disruptions when segments of the energy system infrastructure are damaged (Hallegatte et al., 2019; IEA, 2021a). Adaptive island schemes—which are planned grid separations—and microgrids—a section of the grid that can operate separately from the main grid—help keep portions of the grid up and running during power outages (Figure 4.1).

1 See Chapter 1. Decision-Making for a Future with Climate Change

FIGURE 4.1

Distribution Network Design and Resilience



Source: Hallegate et al. (2019)

Government Interventions to Fuel Adaptation

Many barriers prevent private and public actors from investing in adaptation. One issue is that infrastructure owners and operators have no incentive to account for risk: They know that the government will provide help when needed. Compounding matters, power operators only bear a fraction of the total social costs caused by the disruption from extreme weather events. They do not, for example, bear the cost of interrupted health services (Hallegatte et al., 2019).

Visibility is also an issue. Underinvestment may not have consequences in normal times and become apparent only once a natural disaster hits and it is too late to act. Moreover, depending on how the market is designed and infrastructure regulated, a lack of competition may discourage investment, especially in building excess capacity to increase the resilience of the system (IEA, 2021a). Finally, adaptation measures can increase design, construction, or maintenance costs, even when they save money in the long term (Hallegatte et al., 2019).

Incentives drive economic decisions. Linking pricing schemes to adaptation investments or reliability outcomes can help (IEA, 2021a). Examples of incentivizing policies include performance-based ratemaking that links utilities' revenues to measurable performance on key metrics (IEA, 2021a), establishing mechanisms for rewards and penalties, such as those providing compensation for power outages, or establishing paying schemes for ecosystem services provision (Hallegatte et al., 2019). But pricing policies can do little to nudge private operators to invest enough to protect the electricity sector against rare events with large and costly consequences.

Part of the solution is to make some adaptations mandatory. Governments can use zoning rules to prohibit construction in at-risk areas (Hallegatte et al., 2019). They can also establish minimum infrastructure standards for resistance to extreme weather events. However, the costs of some adaptations often act as a barrier to their adoption. Regulators can support utilities with grant programs that encourage investment (NASEM, 2017). So-called "cost-trackers" used to update fees paid to grid operators are another funding mechanism. Traditional tariff schemes based on cost of service typically present long lags between investments and government-approved rate increases. Trackers can solve this issue by fast-tracking tariff adjustments to reflect invested capital in pre-approved adaptation options. However, they must be used with caution to avoid giving grid operators an incentive to overinvest.

Disaster preparedness is essential. Adaptation cannot prevent all disruptions, and when extreme events do cause disruptions, timing and coordination are central to recovery. Setting clear responsibilities among the players, including different government agencies, local governments, utilities, and regulators during good times is critical for coordination and recovery in the aftermath of a disaster (Hallegatte et al., 2019). Where actions and roles can be defined in advance, governments can also include climate-resilience criteria in national energy plans and strategies (IEA, 2021a). The foundation of disaster preparedness is anticipating what could go wrong. Governments should thus conduct (or mandate the realization of) impact and vulnerability assessments for power sector assets, considering climate change impacts as well as other hazards, such as the ageing of installations.

Governments can share best practices and monitor the preparedness of energy companies. This means gathering knowledge from industry peers and consultants to establish the best protocols for emergency response and restoration. Governments can also mandate or ask energy companies to prepare emergency plans and clearly define roles and responsibilities, as well as standard operating, mutual assistance, and communications procedures. For example, Japan requires companies to develop risk management practices and recognize their roles during disasters that might affect their industry (Hallegatte et al., 2019). In New York, after Hurricane Sandy, the Public Service Commission designed a scorecard to assess electric utility responses to significant outages. This scorecard quantifies preparedness, operational capacity to restore service, and information-sharing performance (PSC, 2013).

Improving basic market design is another part of the solution. Energy markets are often designed around incumbent technologies and must be updated to spur new activities consistent with climate change adaptation. For instance, Chile had to update the rules surrounding connections to the grid and participation in the energy market to make battery use possible for energy storage (Saravia et al., 2022). Modifying the concession periods for hydropower can improve dam operators' incentives to make costly investments with long pay-back times to reinforce dams or remove sediment (Ubierna et al., 2020). Another example is billing rules to incentivize distributed generation of electricity using rooftop solar. Net metering allows consumers to inject self-generated electricity back into the grid and be charged only for the balance between what they consume and what they produce (Hallack et al., 2018). Other billing rules, more appropriate in countries where solar power is more prevalent, pay consumers the market price for the energy they inject back into the grid.

Finally, access to financing is fundamental. Governments can increase utilities' ability to recover quickly from damage by providing direct support or by promoting access to financial markets. They can provide direct financing or support to promote adaptation in the sector. And they can enhance access to financial instruments that increase the sector's resilience and adaptive capacity, for example, through insurance. Promoting greater transparency of climate risks and measures through financial disclosures and developing taxonomies to classify adaptation activities and green financial markets can help attract private capital flows to adaptation in the sector.[2]

2 See Chapter 9. Adapting Public and Private Finances to Finance Adaptation

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CHAPTER 5.

Driving Adaptation in the Transport Sector

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Driving Adaptation in the Transport Sector

Transport provides most of the resources and services that sustain communities. Extreme weather events and the slow-onset effects of climate change can disrupt or destroy transportation infrastructure, which in turn interrupts supply lines and value chains, increases travel times, and impedes access to critical areas and services such as health and education facilities, homes, or workplaces. Building resilience in the transport sector means siting infrastructure away from danger. It involves reinforcing assets, improving connectivity, and increasing the redundancy of available routes and transportation modes.
To prioritize investments and build resilience, planners can analyze the vulnerability and criticality of key transportation assets such as roads and bridges. This means evaluating how each link would lose functionality if affected by a climate hazard, the overall consequences for system users if any link goes down, and the advantages of reinforcing infrastructure, providing maintenance, or developing local redundancies.
Making transport resilient requires mobilizing government agencies, companies, and construction firms to plan, design, build, maintain, and operate transportation infrastructure with a risk management approach. Governments need to define clear roles and responsibilities. They have to develop hazard and vulnerability assessments that consider future climate and socioeconomic uncertainty; ban development in the riskiest areas; establish mandates, incentives, and financial mechanisms for high quality construction and maintenance; and design contingency plans to quickly restore service and reconstruct infrastructure after climate events.

On a Collision Course: Climate Change and Transport Systems

Transportation is an essential component of inclusion, quality of life, and sustainable development. It provides access to jobs, healthcare, and education. But infrastructure assets in the transportation sector are vulnerable to the vagaries of weather. Their failure can bring an entire transport system to a screeching halt. These failures can take various forms: damaged infrastructure, temporary disruptions, and reductions in the lifecycle of assets. In all cases, the consequences are far reaching.

The Vulnerability of Infrastructure

Extreme weather events and slow onset events, such as rising sea levels, temporarily disrupt or, in some cases, destroy transport infrastructure (ITF, 2016). By 2050, climate change may increase the number of roads exposed to extreme weather events worldwide by 19%, from 200,000 to 237,000 kilometers (Hall et al., 2019).

Flooding and landslides compromise the structural integrity of roads, bridges, tunnels, and other transport infrastructure. Wind and storms can damage bridges and ports. Sea-level rise can engulf ports, low-lying airports, and roads. In the Caribbean, over 60% of all roads and bridges are exposed to flooding, hurricanes, or landslides. Sixty-three percent of ports and 82% of airports are exposed to hurricanes, and 25% and 27% respectively are exposed to landslides (Rozenberg et al., 2021). River levels can also rise, due to melting glaciers or heavy precipitation, threatening bridges.

Changes in precipitation affect earthworks and geotechnical structures. Drier conditions bring subgrade shrinkage and cracks in roads. Increased rainfall can lead to hydraulic-induced failures in foundations and embankments. Culverts placed under roads or railways can collapse under increased precipitation. Heavier levels of rain strip asphalt from its binding materials. Greater humidity and atmospheric CO_2 intensify corrosion of steel structures such as bridges and railway lines (ITF, 2016).

Higher temperatures are also a major stressor for transport infrastructure, decreasing the life span of vital assets. Heat causes cracking and curling and accelerates the deterioration of asphalt used on roads, airports, and ports. Higher temperatures also negatively impact bridges and compromise the ventilation of tunnels. They prevent laborers from working in open areas and at peak times of the day, which boosts the costs and difficulty of maintaining roads and train tracks (ITF, 2016).[1]

Even when climate events do not destroy infrastructure, they can be extremely disruptive. Flooding can disrupt tunnels or roads and increase the chances of accidents and casualties. Water saturation reduces the loading capacity of bridges, while lower levels of precipitation negatively impact inland waterways (ITF, 2016). The Panama Canal can usually accommodate ships with a draft of 15.2 meters—a measure of how deep below the waterline the bottom of their hull lies. But after prolonged periods with little or no rain, the water level in the canal can decrease, setting the limit to only 13.4 meters and restricting cargo capacity (Kaufmann, 2023). Deteriorated transport infrastructure can force vehicles to travel at lower speeds. Storms and gale-force winds can interrupt services in ports and airports (ITF, 2016).

An Economic and Social Threat

Disruptions to the transportation network can have dire economic and social consequences (Hallegatte and Vogt-Schilb, 2019a; Colon et al., 2020). They can hamper evacuation measures and relief efforts, causing fatalities. In their aftermath, supply lines are interrupted, threatening export revenues and impeding imports for domestic production and consumption. Access to economic opportunities, education or health is cut short, magnifying the macroeconomic cost of extreme weather events.

Transport disruptions are costly for households as they limit access to jobs, markets, critical services, and leisure. They also result in longer travel times, higher costs, and related pollution, which have potential health consequences as well (Hallegatte et al., 2019b). In the Caribbean, a disruption affecting 20%

1 See chapter 7. Wellness Check: Climate Change and the Health Sector

of the roads reduces user value between 24% and 95% due to longer travel times and decreased access (Rozenberg et al., 2021). Such disruptions have a disproportionate impact on poorer households, as, in Latin America and the Caribbean, such households often settle in areas further from jobs and services and have access to fewer means of transport (Oviedo et al., 2019; Vender et al., 2018).

Disturbances in the transport system also impact firms: decreasing production capacity results in lost sales and delivery delays. In Argentina, the exposure of national roads to 50-centimeter-deep floods is expected to increase by 10% to 20% by 2050. An analysis of the network suggests that the worst flooding events could disrupt supply chains conveying 100,000 tons of freight per day (Kesete et al., 2021).

Finally, building roads or highways in hazardous areas can exacerbate climate risk in the rest of the economy, because transport infrastructure induces development. A highway may be constructed with standards of high resilience. But it may attract new settlements and commercial activities to its surroundings that may or may not be built to sustain climate risk. This is particularly relevant as transport infrastructure can attract informal settlements, which tend to be more vulnerable. Moreover, due to their long design life, transportation assets may be constructed in areas that, while safe today, are exposed to future climate hazards.

Adaptation Options to Keep Countries Moving

Adaptation of the transport sector should aim to provide more reliable service under adverse conditions following two broad approaches. Considering climate risks in the early stages of infrastructure development and planning can be critical (Hall et al., 2019). One goal is reducing disruptions by reinforcing and improving individual assets, new and old, against climate change effects. An even more important one is to minimize the loss of functionality of the network under negative conditions. That means increasing the transport system's capacity to absorb disruption and maintain its services.

Shoring Up Critical Infrastructure

Siting new infrastructure away from danger is the most obvious adaptation option. A seaside road, for instance, is more exposed to water surges than a road further inland. Infrastructure located in less exposed areas will suffer reduced impacts and, consequently, less damage and fewer interruptions. In Vietnam, the social gains of limiting investments in roads in districts where more than 40% of the land is below one meter above sea level is 9.3% higher relative to a strategy without limitations (Balboni, 2021). Identifying current and future risk areas and avoiding the placement of infrastructure assets in zones with high exposure to flooding, storm surges, extreme heat, or forest fires, is an effective adaptation.

Exposure, however, cannot always be avoided: alternatives may be lacking, and current infrastructure cannot simply be moved. Reinforcing infrastructure is thus also crucial. Strengthening roads by establishing positive cross slopes, soil improvements, additional culverts, retention walls, and paving gravel can prevent standing water and avoid road collapse. Porous asphalt improves road safety in areas subject to increased rainfall or snowfall. Several measures can protect tunnels against flooding: establishing passive rainwater drainage and management systems, emergency pumping, and raising subway entrances. Against heatwaves, flexible joints on roads help avoid damage while reflective coating helps protect the structural integrity of bridges (ITF, 2016; Hallegatte et al., 2019b).

For design options to be effective, they need to be adapted to a changing climate. A key issue is that traditional methods for establishing infrastructure design standards are based on historic weather data. They may be designed, for instance, to sustain a flood depth that has historically occurred every 100 years. But under a pessimistic scenario, with 2°C warming by mid-century, more than 40% of transportation assets globally are expected to experience at least a 25% decrease in the return period for extreme rainfall. In other words, a flood that used to occur every century would now occur every 75 years on average (Wang et al., 2022). In Haiti, 45% of bridges analyzed by the IDB may see higher river flows in the next decade due to climate change. Numerical modelling allows authorities to explore what the future climate may be and set construction and maintenance standards accordingly (Olaya et al., 2020).

Focusing on Maintenance

Climate change decreases the lifespan of infrastructure assets and damages their components. For that reason, regular maintenance is vital to ensure the durability and resilience of transport infrastructure and minimize disruptions (Hallegatte et al., 2019b). Lack of proper maintenance can increase infrastructure capital costs by 50% (Rozenberg and Fay, 2019).

Proactive maintenance is an effective asset management strategy that enhances assets' resilience and capacity to respond to climate hazards. For instance, regular drainage system clearance mitigates the risk of flood hazards on roads and surrounding infrastructure (UNOPS, 2021). Uruguay is rehabilitating and enhancing the maintenance of a national road to increase the redundancy of the transport network, protecting food producers' supply lines during increased rainfall events (IDB, 2021).

Nature-based solutions are also an option for safeguarding infrastructure against climate hazards and reducing the cost of maintenance. For instance, parks in urban areas create natural drainage systems that reduce road flooding (UNOPS, 2021).

Strength under Stress

Resilient infrastructure is cost-effective: even if the upfront costs are higher, it is more resistant to extreme weather events, causes fewer disruptions, and increases the life expectancy of assets (Hallegatte et al., 2019b). However, the strength of individual assets is a poor proxy for the resilience of the overall transport system. An interconnected network is only as strong as its weakest link.

A key concept in analyzing and designing resilient infrastructure is the redundancy of the system (Koks et al., 2023). Redundancy refers to the presence of alternative transport routes and modes of transportation for reaching a destination. Options include adding alternatives routes and making the system more diverse by having multiple modes of transportation (Hallegatte et al., 2019b). For instance, re-mobilizing airports that were bound for decommissioning can help maintain a diversified system better able to respond to natural disasters (UNOPS, 2021).

Decision Support Systems

When defining or prioritizing adaptation measures, the sector must consider uncertain climate change impacts. Future climate conditions are impossible to predict, and future changes in technology and social trends amplify the uncertainty around the consequences of applying, or not applying, adaptation measures.

New methods to support decision-making under deep uncertainty, such as the so-called *blue spot analysis*, allow policymakers to analyze the risks that climate change imposes on transport systems and prioritize adaptation actions (Lempert et al., 2021; Koks et al., 2023).[2] A blue spot analysis helps officials i) pinpoint transportation assets, such as sections of road networks or bridges, that are exposed to extreme weather events, across different scenarios; ii) estimate the degree of vulnerability of these assets, for instance whether they would be destroyed by a given flood; iii) estimate the criticality of each asset, depending on the economic consequences of it being disrupted; iv) anticipate the results of interventions and v) use a visualization tool to help decisionmakers prioritize investments to increase safety and resilience. It is important that planners periodically re-evaluate adaptation measures against evolving climatic and socioeconomic conditions, for instance if they state of the network changes, if economic activity changes what links are most critical, or if climatic condition evolve and new hazard maps become available. Another important feedback loop is on the

2 See also Chapter 1. Decision-Making for a Future with Climate Change

effectiveness of specific interventions and design choices: governments should monitor their efficacy after extreme weather events and reflect what they learned in the next planning stage.

The Dominican Republic recently developed a blue spot analysis to prioritize investments and improve the resilience of its road transport network (Olaya et al., 2022). The government conducted research to determine which roads, bridges, and drainage systems to reconstruct or reinforce to reduce loss and damage due to natural disasters. Damage was assessed using the financial value of destroyed transportation assets. Loss, meanwhile, was assessed as the impacts of disruptions on travel time, which was valued based on average economic productivity. The analysis considered hurricanes, river surges, earthquakes, and tsunamis under a variety of climate change scenarios. It found that natural disasters currently cause about US$1 million in damage to the network every year, but losses to users are much larger, at $2.7 million per year. In the worst-case scenario, with high growth in traffic and high climate change impacts, loss and damage could jump to almost $40 million per year by 2050—more than 13% of what the country currently spends on building and maintaining the road network. The analysis then prioritizes investments that can reduce loss and damage (Map 5.1). The government has successfully used the tool to guide its maintenance and post-disaster reconstruction efforts and to select projects presented to international development banks interested in financing adaptation (Olaya et al., 2022; IDB, 2022a).

MAP 5.1

Prioritizing Investments to Reduce Loss and Damage from Natural Disasters in the Dominican Republic

Source: Olaya et al. (2022)

Being Prepared

An effective way to prepare for different climate scenarios with limited resources is to have response strategies and contingency plans to manage service interruption.[3] For firms, boosting inventories and changing the locations of factories or stocks in response to disaster risk is also an option (Hallegatte et al., 2019b).

Governments can develop institutional arrangements to centralize information related to the road network and coordinate quick response actions. (e.g., Olaya et al., 2022). They can design contingency plans to accelerate post-event reconstruction and rehabilitation and to generate temporary solutions that can quickly restore service, if only partially. In Santiago de Chile, as in many other cities globally, the government quickly deploys a substitute bus service to replace a malfunctioning metro line.

Improving access to climate data and implementing early warning systems are key to reducing disruption to transport systems. Early warning systems are important in anticipating extreme weather events and mitigating their impacts on infrastructure systems. For instance, before Hurricane Sandy hit New York City in 2012, the city's Metropolitan Transit Authority was able to move its trains out of flood-prone areas, thereby minimizing damage to its assets and allowing service to be restored relatively quickly (Hallegatte et al., 2019b).

Government in the Driver's Seat

A key step to enhancing the transport system is to improve governance by defining clear roles and responsibilities in institutional and legal frameworks. Ministries and agencies responsible for the transport system need a clear mandate on adaptation, for instance from a climate change law or an international commitment. Overarching bodies should ensure coordinated action among transport authorities, disaster risk management agencies, and institutions dependent on the transport system. Infrastructure master plans should evaluate the vulnerabilities of the system and be updated (Hallegatte et al., 2019b). Governments should mandate local authorities to consider climate change effects in their urbanization plans by, for example, using hazard maps, and prohibiting the development of infrastructure in at-risk areas (Hallegatte et al., 2020).

Mapping the Road to Adaptation

Developing adaptation plans for the transport sector is critical, with key actors and adaptation options identified and assigned their place in a strategy. Adaptation plans can focus on the whole sector or on a specific area.

Colombia has developed a National Adaptation Plan specific to ports (MADS, 2016). The plan establishes that ports enable 93% of international trade in the country and that more than 80% of them are vulnerable to climate change impacts, such as hurricanes, floods, erosion, sea-level rise, and tidal surges. It then puts forwards adaptation options specific to each port, such as growing mangroves or building protective walls; raising existing infrastructure; expanding drainage areas; using permeable pavement; strengthening road connectivity; updating standards, codes, and regulations applicable to port infrastructure; and mandating more frequent maintenance. The operators of the port of Manzanillo, Mexico have similarly recognized that the area is highly vulnerable to sea level rise and developed an adaptation plan that includes increasing drainage capacity, establishing early warning systems, increasing maintenance, and reinforcing vulnerable assets and their surroundings (Connell et al., 2015).

Planning for emergencies with an integrated risk management approach is another efficient way to minimize the impact of disruptions. Governments can identify vulnerable infrastructure in the transportation network, establish contingency plans and evacuation procedures, and define clear roles for all transport system stakeholders in the event of a disaster (UNOPS, 2021). Examples of strategies for disruptions or evacuations include bus services that can be quickly

3 See Chapter 1. Decision-Making for a Future with Climate Change

deployed in the event of rail system failure and contraflow strategies in which road lanes are reversed (ITF, 2016).

Training of stakeholders and capacity building within government agencies is also key to effective responses. In Uruguay, civil servants of the Ministry of Transport and Public Works are trained to use models that inform the rerouting of cargo in the event of temporary disruptions in the road network (IDB, 2021).

Incentivizing Investments

Governments can also boost the resilience of the transport system using financial mechanisms that align the incentives of asset owners with the public interest (Hallegatte et al., 2020). Current financial arrangements are often inadequate: budget allocations for public agencies are often set as lump sums that do not take into account the occurrence of climate hazards; the duration of contracts with private builders is shorter than the technical life of assets, reducing the incentive to invest upfront in quality; and separate construction and maintenance contracts do not account for the social cost of disruption or the full value of maintenance (Hallegatte et al., 2020). Another issue is that local governments are often in charge of part of the transport infrastructure but lack the resources to repair or maintain their assets (ITF, 2016).

Solutions to promote investments include eliminating budgetary barriers for maintenance, penalizing infrastructure operators if yearly disruptions exceed a specified threshold, and establishing performance-based contracts for construction agencies or operators that link payments to the performance of the assets. Governments can also introduce and enforce regulations, construction codes, and procurement rules, for instance, to establish minimum standards for resistance against extreme weather events (Hallegatte et al., 2019b, 2020).

Governments can also promote densification. Densification has the potential to reduce traffic, minimize transport disruptions, and reduce the barriers to implementing redundancies, diversification, and multimodality–including by making walking and biking viable options (Hallegatte et al., 2019b). In contrast, urban sprawls often offer fewer transportation alternatives and involve longer distances to critical services such as hospitals. To promote dense cities, governments can consider city growth and infrastructure development together, and place services and public infrastructure, such as social housing, hospitals, schools, roads, and metro stations, strategically.[4] They can also use fiscal incentives, such as congestion charging.

Access to Information

Governments can improve decision-making among all relevant stakeholders by investing in accessible data, modeling natural hazards and climate change, and establishing early-warning systems. International cooperation can address information bottlenecks by making data and models broadly available, especially in low- and middle-income countries. In Bolivia, an airport modernization plan includes installing meteorological equipment for early detection of electrical storms, in addition to engineering upgrades, such as building roofs prepared for hailstorms, deploying new drainage systems, and paving and raising parking areas and access roads to prevent flooding (IDB, 2022b).

Investments in building skills and technical capacity, including in decision-making using the deep uncertainty methods mentioned above, can help maximize the utility of these tools and mobilize the know-how of the private sector (Hallegatte et al., 2019; Lempert et al., 2021).

4 See also chapter 6. Adapting the Urban Environment

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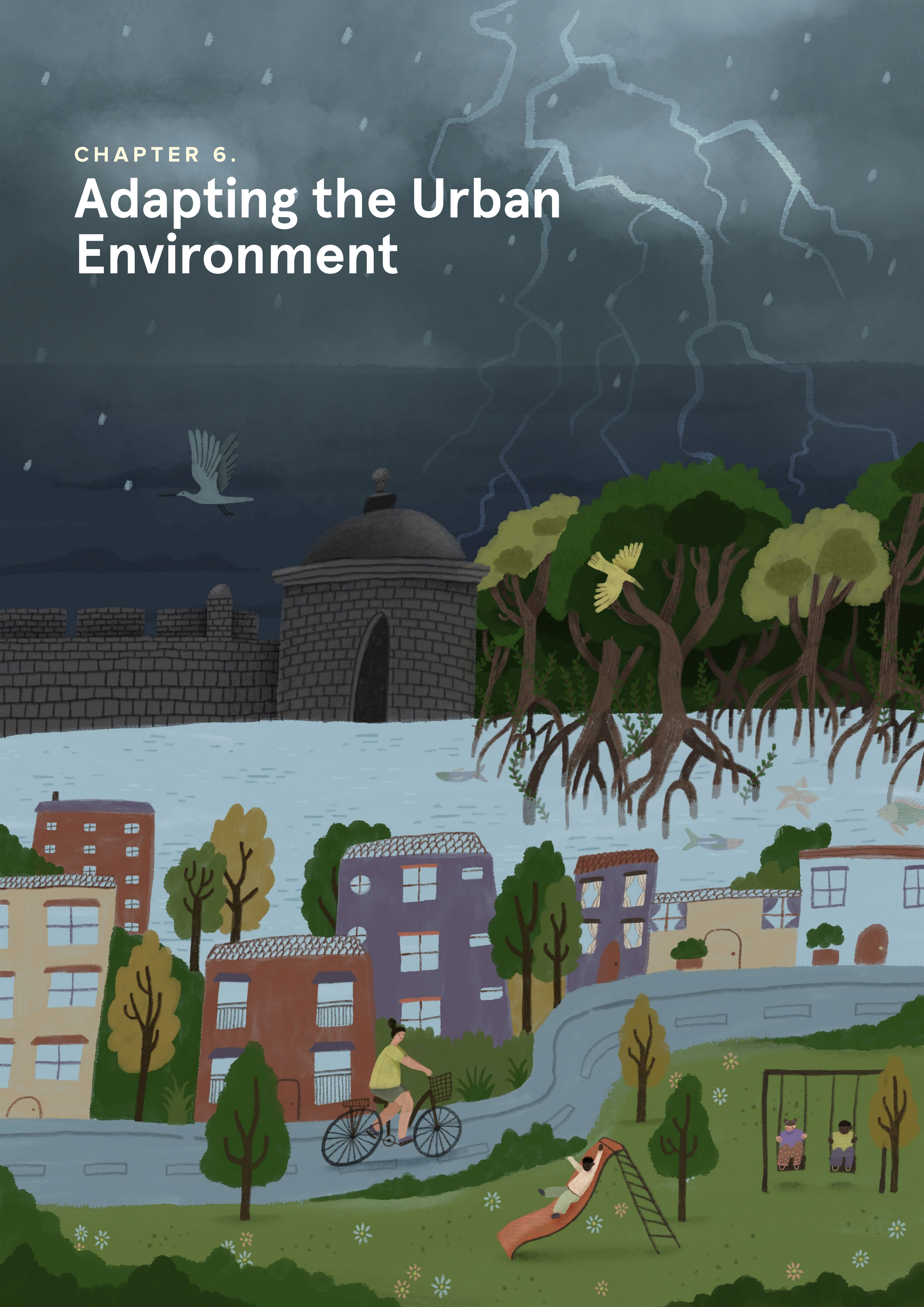
CHAPTER 6.

Adapting the Urban Environment



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Adapting the Urban Environment

Most people in Latin America and the Caribbean live in cities, which also hold most of the region's wealth and economic activity. Yet, climate change presents cities with growing risks—water scarcity, heat waves, and sea level rise—that cause fatalities, make people sick, push families into poverty, force them out of their homes and compel them to move, often to ill-prepared neighborhoods in other cities. A key adaptation is to reduce exposure by banning development in high-risk areas, e.g., by prohibiting construction along coasts that are or may become risky as sea level rises. But reducing exposure can be unfeasible or undesirable if it displaces close-knit communities. Constructing protective infrastructure and upgrading buildings is also necessary. Dikes, sewers, and cooling centers can provide protection against the elements, and so can nature-based solutions. These include mangroves in coastal areas to absorb storm surges and trees to cool down cities and make heat waves more tolerable. Governments can use risk assessments, zoning, and regulations to contain development in risk-prone areas and support development in safe areas. They can also mandate, incentivize, or allow implementation of nature-based solutions. Standards for building and maintenance can guarantee that buildings are fit for current and future climatic events. Financial instruments can encourage households to adapt, as well as cope with and recover from extreme weather events. However, governments face two crucial barriers: informality and institutional fragmentation. Climate change strategies will be more effective if they help improve governance, coordination, planning, and formalization.

A Strike at the Heart: The Impact of Climate Change on Cities

Cities are engines of development, concentrating critical infrastructure, key assets, and economic, social, administrative, and cultural activities. Urban areas are home to most of the world's inhabitants: by 2018, 55% of the world's population lived in urban centers (United Nations, 2018). Given current demographic trends, more than 86% of the population in Latin America and the Caribbean will be living in cities by 2050—the highest rate among developing regions in the world (UN, 2018).

Cities are critically vulnerable to climate change and face growing risks of water scarcity, sea level rise, and extreme weather events such as heatwaves and floods. These climate events increase mortality and morbidity, cause asset and economic losses, push households into poverty, and displace communities (Boland et al., 2021; Dodman et al., 2022; Vera and Sordi, 2020).

When Climate Change Hits Home

Higher temperatures and heat waves make urban areas less livable. Cities are subject to the heat island effect: buildings and roads absorb the sun's heat, typically increasing surface temperature by 0.5°C to 4°C (Boland et al., 2021), and up to 3 to 8°C in Latin America and the Caribbean's eight largest cities (Oliver et al 2021). By 2050, South America's largest cities will see five to ten times more extremely hot days: in some of the worst-case scenarios, temperatures that used to occur less than 20 days per year could occur six months per year (Kephart et al 2022). Heat waves bring health hazards, productivity loss, and economic disruption (Dodman et al., 2022). Heat disproportionally impacts poorer households, who tend to reside in less insulated buildings and in hotter areas of the city and who cannot afford air conditioning. Heat has particularly negative impacts on people aged 65 and older—the fasting growing demographic segment of the coming decades (Jiménez et al., 2021).

Changes in precipitation patterns raise the risk of water scarcity in some cities.[1] A growing population, combined with poorly maintained, insufficient water supplies and incomplete neighborhood infrastructure increases the threat to water security. Cities such as Mexico City and La Paz, Bolivia already suffer from freshwater stress due to climate change and house some of the 350 to 411 million urban dwellers worldwide that will be become threatened by water scarcity under a 1.5°C–2°C warming scenario (Dodman et al., 2022). In Montevideo, Uruguay, an extreme drought in 2023 left the only freshwater reservoir almost dry, giving authorities little choice but to tap into the brackish water from the Rio de la Plata estuary, which is too salty to drink (Tocár, 2023).

Climate Change Increases the Risk of Urban Fires

Lower precipitation, higher temperatures, and drought increase the occurrence of wildfires. Urban sprawl near wildlands boosts exposure (Boland et al., 2021). Valparaiso, Chile, suffered the largest urban fire in its history in 2014 when a forest fire spread to the city. One thousand hectares burned, including 2,900 homes; 12,500 people were displaced; 500 were injured, and five were killed. The fire started in a forest of pine and eucalyptus, which are fire-prone species exotic to Chile, and spread into adjacent low-income neighborhoods. Contributing to the disaster was the fact that many affected dwellings were built with substandard methods in illegally occupied neighborhoods. As a result of poor access to public services in those neighborhoods, flammable trash accumulated on empty lots (Reszka and Fuentes, 2015). Over three million people living in wild-urban interfaces are still exposed to forest fires in Chile (Sarricolea et al., 2023).

The Vulnerability of Urban Assets

Sea level rise and storm surges threaten coastal and low-lying urban areas. Globally, the population exposed to a 100-year coastal flood event will increase by about 20% if sea levels rise 15 cm relative to 2020 levels (IPCC, 2022). Compounding matters, coastal urban areas compete for space with wetlands, estuaries, and mangroves, which are crucial for protecting

1 See Chapter 3. Riding the Adaptation Wave in the Water and Sanitation Sector

against surges. Latin America and the Caribbean is particularly exposed, as it is the region with the highest proportion of its metropolitan population living close to the coast. In addition, sea level rise poses an existential threat to some Caribbean islands.

Excessive precipitation leads to additional flood risk. Pavement and buildings in cities block water drainage. Channeled rivers and drained wetlands stop water flow capacity from adjusting (Boland et al., 2021). In the region, 160 million people across 70 major cities are exposed to urban floods (Tellman et al., 2018).

Extreme Weather Events May Destroy Valuable Urban Assets

Strong winds from tropical storms, cyclones, and hurricanes can cause structural damage to buildings, particularly if they have not been designed to withstand such climatic events. Climate events can also damage a city's infrastructure and interrupt the essential services it provides. Flooding overruns unprepared water treatment facilities. Interruptions to the transport system, including roads and services, potentially disconnect parts of the city from critical services. Climate change threatens the energy system as it decreases efficiency or destroys energy generation, transmission, and distribution, while demand increases for cooling and adaptation solutions such as desalinization. These issues are discussed in chapters 3 to 5.

Fuel on the Fire: Rapid Growth and Informality

The effects of climate change multiply with rapid and unplanned city growth (Vera & Sordi, 2020). Each month more than half a million move to cities in Latin America and the Caribbean to take up residency there, many of them in informal settlements (IDB, 2021). Between 1990 and 2015 urban informality in the region grew from 6% to 26% (Vera et al., 2023). Climate change itself may increase migratory flow to urban areas as it impacts livelihoods in rural areas. In Mexico, each additional month of drought increases rural-to-urban migration by 3.6%. Periods of three or more years of above-normal temperatures also increase migration (Nawrotzki et al., 2017).

Cities' rapid sprawl brings with it numerous problems that exacerbate climate change vulnerabilities. These problems include poor planning, lack of metropolitan coordination, inadequate zoning, poor enforcement of construction codes, insufficient infrastructure, and the destruction of ecosystems vital for risk reduction (Boland et al., 2021; Vera and Sordi, 2020). For instance, long commutes add vulnerability to road disruptions, while deficient infrastructure and lack of redundancies further disrupt service. New settlements often arise in exposed areas: between 1985 and 2015, the global footprint of all settlements increased by 85%, while the footprint of settlements exposed to the highest flood hazard level rose by 122% (Rentschler et al 2022). The overcrowding of dwellings, neighborhoods, and public transportation creates a hotspot for disease outbreaks, including those from air- or water-borne diseases that are more likely to spread during heat waves, droughts, and floods (Vera and Sordi, 2020).[2]

Unplanned urban growth also brings housing informality as local governments fail to provide adequate levels of basic services (IDB 2021). Some 21% of all urban dwellers in the region live in informal settlements, which are often located in areas exposed to natural hazards, such as landslide-prone slopes or river floodplains (World Bank, 2022). Structures in these areas are often built with low-quality materials, putting their residents at greater risk from extreme weather events such as heat waves or floods (Dodman et al., 2022; Satterthwaite et al., 2020). Finally, informal settlements are often overcrowded and lack adequate, if any, access to basic services.

2 See chapter 7. Wellness Check: Climate Change and the Health Sector

Building Better Cities

Location, Location, Location

When adapting cities to climate change impacts, and especially to floods and wildfire risk, location is critical. Cities can develop relocation strategies to avoid occupying the places most exposed to climate change. However, withdrawing from the most exposed areas is not without challenges; communities and assets in at-risk sites can suffer material and cultural losses (Dodman et al., 2022). Alternatively, land reclamation strategies aim to reduce the risk to coastal areas by landfilling, building levees, draining the remaining water, or planting vegetation that promotes land accretion. Raising existing land can also protect cities from flooding.

Color It Grey

When relocation is not possible, protection is key. New and upgraded infrastructure can reduce exposure to some extreme weather events, for instance by blocking incoming floods and storm surges, as well as by allowing for the storage of water. So-called grey infrastructure solutions include seawalls and breakwaters (which are barriers erected in the ocean to protect coastlines), dikes, floodgates, levees, and even temporary sandbag barriers (Boland et al., 2021). In Barbados, the government has turned to coastal engineering to protect the more highly developed southwest and west coasts where erosion is common. Guyana uses seawalls to address coastal flooding (Mycoo and Donovan, 2017). The understanding that flooding on a massive scale will likely take place in the country led to the elevation of pump stations (Mycoo and Donovan, 2017).

Increasing drainage capacity with sewers is critical in cities where precipitation is projected to increase in frequency or intensity. Cities can improve the drainage capacity of buildings and surface cover or adapt the transport infrastructure to act as a conduit. Barcelona, Spain, where over 90% of the city's surface is impermeable, is enhancing its drainage infrastructure by installing underground reservoirs, permeable pavement technologies, and artificial detention (Favaro and Chelleri, 2018).

Or Color It Green

Adaptation using grey infrastructure can be costly. In Latin America and the Caribbean, US$7.1 billion per year would be needed to build dikes to protect against coastal floods in a medium sea-level scenario for 2050 (World Bank, 2010). Nature-based solutions, also known as green infrastructure, provide swift and effective alternatives to traditional engineering ones by considering surrounding ecosystems as a complement, rather than a menace, to the urban built environment (Muñoz et al., 2019).

Green spaces significantly protect against flooding and strong winds. Cities can restore river basins, floodplains, and wetlands and construct new ones. Such urban ecosystems offer additional drainage, water retention during flooding and rain events, and wastewater treatment (Vera and Sordi, 2020). Buenos Aires, Argentina, created a 36-hectare national park, Parque Lugano, to restore the city's floodplain, mitigate flooding, and improve the quality of life of neighborhoods vulnerable to the riverine flooding of the Riachuelo River in the southwest area (Buenos Aires, 2021, 2022).

Grey and green infrastructure often work together (Box 6.1). Curitiba, Brazil relies on permeable pavements, urban parks, and green areas to manage water currents (IDB, 2017). In Managua, Nicaragua, a cost-effective solution to manage peak flows in areas prone to cyclones is to combine conservation and reforestation measures upstream with improved retention and channeling infrastructure downstream (Vega et al. 2015). Combining green and grey infrastructure is also an opportunity to re-envision street life. In Mexico City, the "Calle Verde" project makes streets more enjoyable to pedestrians, cyclists, and public transit users at the same time as it reduces climate risk. Calle Verde consists of repairing drainage pipes, repaving streets and sidewalks with permeable concrete, and planting trees and building green spaces (Vera et al., 2023).

Coastal ecosystems such as mangroves and wetlands can act as a barrier against storm surges, flooding, and erosion as they store water and stabilize sediment or shorelines (Figure 6.1). In the United

BOX 6.1

The Bañado Sur Neighborhood in Asunción, Paraguay

Located on the banks of the Paraguay River in Asunción, the Bañado Sur neighborhood faces periodic floods that are predicted to intensify due to climate change and upstream land use changes. These floods damage homes, streets, water systems, and electricity infrastructure: in 2018, flooding affected 23,000 people in the riverside Bañados neighborhoods. In response to increased housing needs, the Government of Paraguay and the Municipality of Asunción created a Master Development Plan for the city's riverside neighborhoods that is adaptive to the Paraguay River's periodic flooding. Using nature-based solutions to reduce flood risk for 1,500 newly constructed housing units, they restored the lagoons and wetlands that border the river and built a new linear park along it to create a buffer against floods. The plan also considers building infrastructure that enhances basic public services and reduces climate risks, including sustainable sanitation systems, an improved drainage system, and solid waste collection (Oliver et al., 2021; World Bank, 2022).

States, existing wetlands prevented an estimated $625 million in property damage during Hurricane Sandy (Narayan et al., 2017). Sufficiently wide mangroves reduce the height of waves by up to 66% and of storm surges by up to 55cm (Boland et al., 2021). More than 18 million people and $82 billion in assets globally could be protected from flooding thanks to mangroves (Losada et al., 2018).

Nature-based solutions also contribute to biodiversity and habitat protection, and clean water and air, while reducing extreme heat in cities, leading to important co-benefits for people and the environment. In the United States, the use of trees in urban settings to remove air pollution is worth $5.4 billion annually in avoided healthcare costs and lost productivity (Nowak and Greenfield 2018)

Keep It Cool

Cities should aim to reduce the heat island effect and ensure adequate facilities for protection during heat waves. Expanding green coverage with parks and tree-lined streets substantially reduces the heat island effect. In Medellin, Colombia, the Green Corridors program led to a 2°C drop in the city's average temperature (Oliver et al., 2021).

Architecture integrated with the local environment and climate can ensure thermal comfort. The proper orientation of buildings, for example, is key to minimizing heat absorption and leveraging wind patterns for ventilation. Building design can also increase passive cooling, for instance, by improving insulation or by positioning windows so they enhance air circulation (Alvear et al., 2022). In Brazil, a building standard establishes guidelines for low-income family housing according to the bioclimatic zone in which the housing is located, with recommendations on ventilation, shading, external enclosures, and passive conditioning strategies (Gonzales-Mahecha et al., 2020).

Installing air conditioning in houses and buildings is also a solution. But greater use of air conditioning is not an option for many low-income and informal households in the region. Cooling centers can provide relief to households who cannot afford it. Air conditioning also expels hot air from buildings which can increase the heat island effect (Dodman et al., 2022; Salamanca et al., 2014). District cooling systems are a technologically advanced strategy for cooling high-density urban areas. District cooling can recycle waste heat from chillers to produce hot water, increasing efficiency. They can also be paired with cool storage. In the center of Paris, France, a district cooler freezes water tanks at night when electricity is cheaper and air conditioning is more energy efficient and uses ice to chill a mall during the day (di Cecca et al 2022).

Cool surface treatments and natural vegetation reduce the heat island effect. Cool surface treatments include alternative building materials that increase sun reflection or shading and thus reduce the amount of heat absorbed (Boland et al., 2021; Dodman et al., 2022). Structures can reduce their heat absorption with the application of white paint, which reflects sunlight, or with the installation of green roofs, which provide shading and evapotranspiration (Dodman et al., 2022). These roofs lower energy consumption by up to 32% in warm climates by reducing demand for cooling. In Rio de Janeiro's Favela Green Roof pilot program, homes with green roofs were up to 20°C cooler indoors during peak heat than those with traditional roofs (Oliver et al., 2021).

Design Solutions

Upgrading building standards for climate adaptation purposes is also an opportunity to achieve other sustainable development goals. The University of Belize is building a facility that includes resilience and green building architecture principles, while designed to minimize maintenance requirements and be universally accessible to people with disabilities (IDB, 2020).

Buildings and infrastructure should be designed considering present and future climate change risks, and uncertainty surrounding future climate change.[3] Appropriately designed construction can be resistant to disasters, such as storms, for a fraction of the cost of repairing it if it fails. Existing systems can also be reinforced.

Some transformations in urban planning and housing can also support adaptation in other sectors. For instance, adopting better insulation or kitchen equipment helps decrease the demand for energy and water services that are under stress due to climate change. The risk of wildfires can be reduced by controlling rapid urban growth, avoiding new development in high-risk areas, or incorporating wildfire protection measures such as evacuation plans, vegetation management, and fire-resistant buildings (Boland et al., 2021).

The Role of Government

Urban Planning

Institutional and financial weaknesses make it difficult for cities to adapt. Cities have limited tools and resources and often lack institutions able to coordinate across expansive metropolitan areas. For instance, the forest management needed to reduce an urban area's risk of wildfires may depend not on the local urban planning authority but on a different jurisdiction or a central government institution (Boland et al., 2021). Lack of coordination between the national and subnational governments and between adjacent territorial jurisdictions hinders policy implementation and undermines the success of climate adaptation measures. This is particularly relevant when decisions on land use and infrastructure investments are not coordinated at the metropolitan level (IDB, 2021). Institutional fragmentation within a metropolitan area also complicates effective climate action. In Latin America and the Caribbean, only half of the urban areas have unified governance bodies (Gómez-Álvarez et al. 2017).

Overcoming institutional weakness requires enhancing the governance surrounding the relationship between cities and climate change. Governments can begin to assess existing institutional fragmentation and coordination issues regarding climate change adaptation by identifying critical problems (Dodman et al., 2022). Better governance can be achieved by developing strategies and coordinating urban and metropolitan plans. Climate strategies help identify relevant actions, promote coordination, and assign responsibility among institutions.

Planning is key to developing integrated and inclusive adaptation in cities. Urban planning facilitates government action, including redundancies for critical systems such as transport, power, telecommunications, and health; the diversification of services; the management of urban growth; increases in infrastructure resilience; and the avoidance of development in exposed areas (Boland et al., 2021; Dodman et al., 2022; Parnell, 2016). Providing basic urban services to underserved neighborhoods and including those neighborhoods in regional planning programs aimed at managing urban growth is equally important.

Cities can design local climate change action plans to coordinate adaptation policy. In Chile, the law mandates that all cities develop such plans by 2025. A key role for governments is publishing guidance that cities can use to diagnose their exposure to climate risk, understand possible solutions, and identify actions they can take within their legal attributions to move forward (Rakes et al., 2023).

3 See Chapter 1. Decision-Making for a Future with Climate Change

Knowledge Is Power

Increasing awareness of climate change risks enhances decision-making for policymakers, residents, and other relevant actors. Governments can develop risk assessments, which are useful for creating the risk profile of cities or urban areas. They can, for example, identify key performance indicators for monitoring progress in implementing adaptation measures (Dodman et al., 2022). Governments can also engage directly with citizens and influence climate action by educating people, promoting accessibility, and building public-private partnerships to create standards and business models.

Early warning systems are a cost-effective adaptation measure that allows timely and orderly evacuations and helps households and authorities prepare (Dodman et al., 2022). Investing US$800 million in early warning systems can prevent between US$3 billion and US$16 billion in losses (Boland et al., 2021). Early warning systems rely on constant monitoring and effective communication; unfortunately, the most vulnerable people are often the most challenging to reach. Effective communication measures include mobile apps, broadcasting, and street signs.

There is not enough information on climatic risks, especially at the city level. Modeling tools on the global climate system cover large spatial scales and long-time frames. But local governments need localized and short-term data to make effective adaptation decisions (Pitman et al. 2022). One compounding challenge is that no climate model can unambiguously predict how climate change will impact local climates. Planners must rely on scenarios that explore uncertainty.[4] Another issue is that local governments may not have the incentive to identify or disclose environmental hazards and risks in their jurisdictions as these may lower the value of real estate properties, decrease their attractiveness to businesses and households, and undermine their tax base and growth prospects (US CEA 2023).

The Value of Regulation

Regulations can effectively promote adaptation. Building codes and standards that improve flood and storm resistance, insulation, natural ventilation, and wildfire resistance are practical tools for new buildings (Boland et al., 2021; WHO, 2018). Building codes need to be revised to include future climate-related risks rather than just reflecting past data on issues such as flood levels and rain frequency. Some regulations, such as the enforcement of regular audits, management standards, and labeling, promote adaptation in both existing and new buildings (Dodman et al., 2022). One difficulty is that building regulations usually do not apply to the existing housing stock and are typically not followed by informal settlers.

Zoning is another essential adaptation intervention by governments. By banning buildings in at-risk areas with inadequate protective infrastructure, cities avoid the need for future adaptation (Boland et al., 2021). Barbados implemented a minimal coastal setback: buildings cannot be constructed within 30 meters of the high-water mark. This protects new developments from erosion and flooding (Mycoo, 2006). Zoning, as it applies to building codes, should be established considering possible scenarios of uncertain climate change.

Overcoming Informality and Inequality

A key issue is that informal settlements sprout up in areas beyond the reach of zoning regulations. In the Andes, urban expansion has reached the slopes of hills and mountains, making landslides particularly deadly (Puente-Sotomayor et al., 2021). Moreover, informal settlements tend to be built with substandard materials in violation of building codes. In Medellin, Colombia, enforcing existing standards and codes would reduce the cost of landslides by 63% (Vega & Hidalgo, 2016). Finally, poorer neighborhoods lack the resources to implement adaptation transformations.

Two elements are key for addressing the uneven distribution of adaptation efforts: a holistic approach to urban planning and tackling poverty and underdevelopment.[5] This means, for instance, involving the residents of informal settlements in land use planning. It means assisting those residents who are unable to comply with standard regulations on their own (Puente-Sotomayor et al., 2021). Other options include securing dwellers' tenure (also called formalizing), relocating communities, and improving the connectivity of neighborhoods (Nuñez and Wang, 2020).

Installing public facilities on exposed areas to deter illegal occupation is a key policy option. The Peripherical Garden of Medellin is a good example (Vera et

4 See Chapter 1. Decision-Making for a Future with Climate Change

5 See Chapter 8. Double Jeopardy: The Economic and Environmental Risks for the Poor

al., 2023). It restores ecosystems with native trees on more than 65 hectares of uphill, degraded land. The park reduces the flood and landslide risk for adjacent neighborhoods downhill, and, through its presence, controls uphill urban growth. Footpaths, bike lanes, and mobility corridors provide recreational opportunities, and there are areas for traditional orchid farming. The government also built affordable housing near the park and involved local inhabitants in the park's design and maintenance, providing employment and educational opportunities in the process.

Even if cities act to protect themselves against climate change, their policies may not reach the most disadvantaged people and, in some cases, could increase those people's vulnerability. Protective infrastructure and zoning are often unevenly distributed in favor of wealthier households. They can even increase the risk to unprotected areas or encourage already vulnerable people to relocate to higher-risk sites (Anguelovski et al., 2016; Dodman et al., 2022; Boland et al., 2021).

Uncoordinated adaptation can also be a problem. In Bangkok, inhabitants of an unregulated development built private walls to protect their dwellings from floods, but the redirected flows only worsened flooding for poorer households downstream who could not afford to build their own protection (Limthongsakul et al., 2017).

Finally, providing affordable living opportunities away from danger is critical. The most sustainable way to prevent informal growth from expanding to exposed urban areas is to ensure that regulations and public investment choices allow for the development of housing, public services, and job opportunities in safer places. But this often requires managing local opposition from already existing homeowners to development.

Funding Cities

A lack of resources or incentives often prevents households from implementing adaptation measures. Governments can provide subsidies and loans to residents in informal settlements to encourage them to move to less exposed areas. They can also provide affordable housing in safer areas.

Limited financial resources are a key barrier to infrastructure development. (Dodman et al., 2022). For instance, infrastructure in coastal areas requires upfront investments. But its benefits, which often take the form of avoided costs, are difficult to convert into revenues for financing (Hinkel et al., 2018). Since many infrastructure developments provide public goods, taxes are a key funding source. Cities in the region, however, tend to depend heavily on fiscal transfers. Local revenues in 2010 covered only about 30% of total subnational spending in Latin America (Fretes Cibils and Ter-Minassian, 2015).

Another approach is to create incentives for private developers to construct more environmentally friendly buildings. Expedited review and permitting processes, as well as density and height bonuses, are some of these incentives. Other options, used especially in richer countries, include tax credits, reduced fees, grants, and low-interest construction loans.

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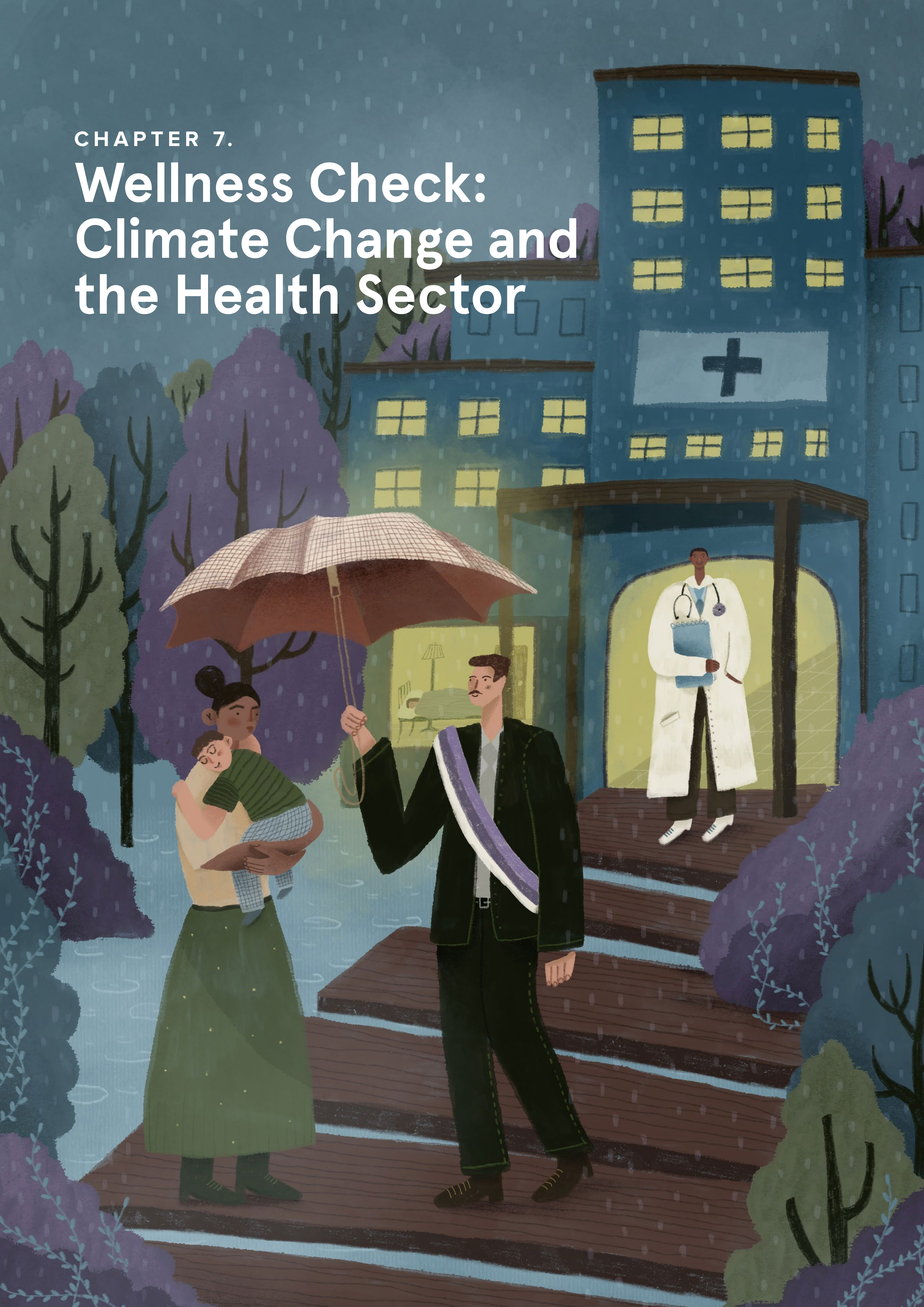
CHAPTER 7.

Wellness Check: Climate Change and the Health Sector



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Wellness Check: Climate Change and the Health Sector

Climate change affects human health and health systems. Changes in temperature and precipitation patterns induce a range of vector-borne diseases and aquatic pathogens. Extreme weather events, including heatwaves, are increasing in intensity and frequency, causing deaths, injury, illness, and deteriorating mental health. Climate change negatively affects food systems, exacerbating undernutrition and food security risks. It also threatens facilities such as health centers, clinics, and hospitals or the infrastructure that allows them to function, including water, electricity, and supply lines.

Adaptation means responding to changes in disease patterns. This includes monitoring the emergence of new diseases, sometimes over just a few months, and modifying or developing new treatments, prevention programs, and training. It also involves keeping health systems operational during extreme weather events by making health infrastructure more robust and developing emergency preparedness plans. Action in other sectors, such as water sanitation programs, and the adoption of workplace occupational and safety measures can also reduce the impact of climate change on health.

Governments can directly implement many of these adaptation measures. It may be difficult to separate climate adaptation policy from traditional health policy, as they reinforce each other. Government interventions include assessing the vulnerability of the health system to climate change, designing health adaptation plans, and integrating them with national adaptation ones. In particular, authorities should develop contingency plans for the health system against extreme weather events and outbreaks of climate-sensitive diseases. They should enhance early warning systems, based on health and climate indicators, to improve detection of disease outbreaks; develop new treatments and prevention plans in coordination with government agencies and the private sector; and advance towards universal health coverage.

Climate Change: A Threat to Human Health and Health Systems

Health is wealth, the saying goes. Good health allows people to enjoy life, manage the challenges it brings, and transmit opportunities to new generations. Yet, climate change threatens human health and health systems. Climate change brings new health problems. Extreme weather events can damage health care facilities and disrupt their operations (WHO 2021). Ultimately, the health impacts of climate change could plunge 25 to 44 million people into extreme poverty globally—including up to 4.7 million in Latin America and the Caribbean (Jafino et al., 2020).

Breeding Ground for Disease

As temperatures and precipitation patterns change, so do the distribution and frequency of diseases that are vector-borne, food-borne, water-borne, and dependent on exposure to the elements, like heat and cold. Climate change also increases the risk of cross-species viral transmission and, therefore, of pandemics of zoonotic origin such as rabies and hantavirus (Carlson et al., 2022).

One of climate change's key impacts involves heat stress. This occurs when temperatures or humidity levels are too high, or the human body is clothed inappropriately or directly exposed to the sun. The body's natural mechanisms for regulating its internal temperature then begin to falter. Heat stress can be fatal, especially among older populations and young children. In South America, the number of heat-related deaths increased by 160% between 2000 and 2021. Aging is a factor, but exceptional heat waves are clearly linked to higher death rates (Hartinger, 2023). Heat stress also reduces labor productivity, especially for outdoor workers, who tend to be poorer. This cost the region US$22 billion in 2021, with particularly strong effects on construction and agriculture (Hartinger et al., 2023). By 2030, climate change could claim the equivalent of 2.5 million jobs in the region because of the impact of heat stress on productivity (Saget et al., 2020). Heat stress can also make people sick, a phenomenon currently occurring in Central America where it is causing an epidemic of chronic kidney disease (Wesseling et al., 2020).

Higher temperatures and variations in precipitation favor pathogen vectors such as mosquitos, whose range and reproduction patterns are being altered, thereby increasing the potential for diseases such as dengue, malaria, and zika to reach epidemic proportions (Romanello et al., 2021). In 2019, the malaria transmission season was 39% longer than usual in tropical highlands globally (Romanello et al., 2021). In South America, the climate suitability of dengue increased 35% between 1951 and 2021 (Hartinger et al., 2023).

Water-borne disease risks have increased from climate-sensitive aquatic pathogens and toxic substances that originate in harmful freshwater bacteria (IPCC, 2022). Higher temperatures and increased precipitation create conditions favorable to the proliferation of pathogens, such as algae, plants, and bacteria on surface and underground water sources (WHO, 2017). Excessive precipitation causes wastewater facilities to collapse, allowing pollutants to contaminate drinking water (WHO, 2017). At the other end of the spectrum, lower water levels increase the concentration of toxicants and biological contamination, as a decline in total rainfall reduces the capacity of surface water to dilute and remove pollutants (WHO, 2017). Either way, the extremes expected from climate change, running the gamut from floods to drought, have deleterious effects on the availability of safe water.[1]

A Danger to Diets

Climate change also impacts food production and, therefore, food security (IPCC, 2022, Romanello et al., 2021). Heatwaves, rising temperatures, droughts, rainfall variability, and ocean acidification negatively affect productivity yields, decrease food output, and generate major crop losses. The growing season for key staples such as wheat, maize, and soybean in the region decreased by 2.5% to 1.3% between 1981 and 2022 (Hartinger et al., 2023). The commensurate reduction of yields worsens food insecurity, which already affects more than 200 million people in the region. Between 2030 and 2050, an average

1 See Chapter 3. Riding the Adaptation Wave in the Water and Sanitation Sector.

of 95,000 children could die every year globally from climate-change-induced, undernutrition-related deaths (WHO, 2014).[2]

When Nature is Disastrous for Health

Extreme weather events also directly affect health outcomes. Disasters, such as floods and hurricanes, can result in severe injuries and death, for example. In the aftermath of extreme weather events, food and water-borne diseases can appear or increase in frequency. Exposure to smoke from wildfires, dust, aeroallergens, and particulate matter exacerbates cardiovascular and respiratory diseases. Air pollution already kills 138,000 people every year in Latin America and the Caribbean (CODS 2019). In South America, the exposure to high levels of risk from wildfires increased by seven days per person per year on average in 2018–2021 compared to historical levels, especially affecting Argentina and Chile with 14–20 more days per person (Hartinger et al., 2023).

Finally, climate change worsens mental health. Extreme weather events, displacement, food insecurity, water scarcity, loss of livelihoods, biodiversity loss, and social unrest can cause a range of mental issues, including anxiety, depression, grief, post-traumatic stress disorder, suicidal tendencies, aggression, and intimate-partner violence, often against women (IPCC, 2022).

Hurting the Health System

Climate change also increases morbidity and mortality by threatening the structural integrity of health centers, clinics, and hospitals or the infrastructure that supports their operations, including energy and water distribution and transportation networks (World Bank, 2017).[3] Extreme weather events can rapidly increase the demand for health services and interrupt supply chains (WHO, 2020). Moreover, climate change affects the quality of health services by altering the local demand for them. For example, an increase in vector-borne or zoonotic-origin diseases changes the number and profile of health workers needed to provide services. Finally, new health hazards may arise if climate change effects cause social disruption, population displacement, economic decline, and migration (IPCC, 2022).

Adaptations to Fortify the Health System

Diagnosis, Prevention, and Treatment

The first step to curing an illness is to diagnose it. For a climate-resilient health system, this means establishing and strengthening surveillance systems for climate-sensitive disease and integrating meteorological surveillance into early warning systems for health hazards (World Bank, 2017). The best course of action is to consider all health hazards in an integrated fashion, simultaneously monitoring animal diseases, human diseases, and environmental determinants as they interact (World Bank, 2021).

When climate change entails new diseases, the health system needs to respond by training professionals to diagnose those diseases, develop treatments, and design prevention measures. Exposure to heat stress, for example, has recently become a common cause of kidney disease. Treatments for kidney disease do not depend on heat stress being the cause. But prevention programs need to be adjusted to reduce its prevalence (Box 7.1).

When defining adaptation measures, the health sector must recognize that some effects of climate change

2 See Chapter 2. Land of the Living: Rethinking Food and Biodiversity Together

3 Chapters 1, 3, 4, 5 and 6 on adapting infrastructure services and urban planning to climate change provide more insights.

BOX 7.1

Costa Rica Fights Heat Stress with Labor Regulation

Established in 2015, Costa Rica's *Regulation for Prevention and Protection of Workers Exposed to Heat Stress* aims to protect outdoor workers. The regulation came into being after numerous studies showed that exposure to heat stress is a cause of chronic kidney disease among farmworkers in Central America (Wesseling et al., 2020). Modeled after the U.S. Occupational Safety and Health Administration's "Water, Rest, Shade" campaign, the Costa Rican regulation holds that employers must provide workers with protective measures. These include training, personal protective equipment (such as hats and umbrellas), time to acclimate to the heat, rehydrating drinks, and shaded areas for rest. In addition, workers must be enrolled in a health surveillance program focused on kidney health and function.

are uncertain and can change rapidly. For instance, while the risk of dengue was contained in Argentina until recently, the country was hit by a severe dengue episode in 2023 that affected nearly 100,000 people (Ministerio de Salud de Argentina, 2023). For that reason, response strategies and contingency plans must consider a variety of climate scenarios.[4]

Ensuring Structural Fitness

Investing to prepare all elements of health services for extreme weather events is also important. Emergency preparedness, planning, and rehabilitation should be improved, taking into account all relevant hazards. Goals include establishing coordination mechanisms and information systems and disaster mitigation risk plans to ensure service continuity during extreme weather events (World Bank, 2021, Astorga et al., 2023). Health workers should be trained to operate under emergency conditions. They should be trained to care for victims of climate disasters (PAHO 2020a) and to recognize and prescribe follow-up care for all climate-related issues, including those with consequences for mental health (WHO 2022).

The health sector also needs to make sure that physical structures and medical supplies can withstand extreme weather events (World Bank, 2017; 2021). One adaptation option is to design and construct health facilities that are resilient to the impact of events such as floods, landslides, or overheating due to heatwaves.[5] Infrastructure design and construction should also contemplate the possible disruption of basic services, such as temporary interruptions in water or electricity supply during extreme weather events. Finally, infrastructure should be prepared for patient surges, and the stocks and supply chains of essential medical commodities should be managed with redundancy and resilience in mind.

Adopting digital technology can also be a way to build resilience (Astorga et al., 2023). Telemedicine can be provided even when extreme weather disrupts the transport system, as can the digital transmission of analysis results and prescriptions. Digitalized registries and digital orders can make the stocking process more efficient and easier to track. As always, digital technology has to be adopted in such a way as to minimize exposure to digital threats, such as ransomware, while securing privacy rights and ensuring that the processes are inclusive of people who do not have access to the technology (Cathles et al., 2022).

Sharing Knowledge and Enhancing Communication

Access to data is key to adapting health programming and interventions (World Bank, 2017; WHO, 2015). For instance, climate change will affect the geographic distribution of existing health hazards, such as malaria and dengue. Well-established strategies for approaching many of these hazards already exist. Mosquito nets and insecticides, for example, are proven methods for controlling mosquito-borne illnesses (World Bank, 2017; 2021). Adaptation, informed by access to correct information, includes deploying existing solutions to new geographic areas.

Importantly, the actions of other sectors impact the health sector. Cross-sector solutions, such as

4 See also Chapter 1. Decision-Making for a Future with Climate Change

5 See also Chapter 6. Adapting the Urban Environment

sanitation programs, energy security policy, sustainable food systems, active transport that emphasizes walking and biking over vehicles, and education contribute to building a more resilient health sector (IPCC, 2022). Increasing access to clean freshwater, which decreases the incidence and risk of waterborne diseases, is one such example.[6] Other examples include expanding access to urban green spaces and designing buildings with air conditioning and passive cooling features (Romanello et al., 2021).

Timely communication involving decision-makers, the media, and the public can help coordinate preventive action against health hazards such as disease outbreaks or extreme weather events (WHO, 2015). Impact-based forecasts of heatwaves informed by weather data permits the establishment of a comprehensive warning system. This can alert the population to the risk of exposure and help prepare the health system (PAHO 2021). Developing exposure forecasts for diseases and storms and thresholds (e.g., heat and sun exposure) can improve the communication of health hazards with relevant stakeholders (WHO, 2015). Digitalization is key to making early warnings effective. For instance, sending mobile phone alerts to people in affected areas gives them time to take shelter and is one of the most effective ways of saving lives when a natural disaster hits.

Government Interventions: A Lifeline for Adaptation

Governments can directly implement many of the adaptations mentioned in the previous section, as they often directly manage large parts of the health system. But the private sector also plays an important role. Private clinics provide health services, and most of prevention must take place in the workplace and in private life. Government policy should thus also aim to facilitate adaptation in the private sector.

Much of adaptation policy in the health sector mirrors traditional health policy (World Bank, 2021; Astorga et al., 2023). Indeed, a functioning system should be able to detect new health hazards and respond, regardless of whether those hazards were generated by climate change. The role of adaptation policy is to anticipate and facilitate this process.

A Preventative Posture

The so-called *climate change and health vulnerability and adaptation assessments* are a key input for designing adaptation plans (WHO, 2021). Through these assessments, governments should comprehensively investigate how climate change will impact the health sector at the national and subnational levels, identifying vulnerable populations (including any gender bias, see Box 2) and weaknesses in the system (World Bank, 2021; Astorga et al., 2023). In Latin America and the Caribbean, 26 countries report having developed such a comprehensive assessment as of October 2021 (WHO, 2021d).[7]

A key role for governments is coordinating the design of adaptation plans for the health system. Governments often use so-called *health national adaptation plans* to identify priority sectors for adaptation.

These define the course of future policy (WHO and IISD, 2021; World Bank, 2021). The plans should ideally be informed by comprehensive vulnerability assessments. So far, only two countries in the region, Brazil and Cuba, have a national health and climate change plan in place, and they struggle to implement them because of financial and human resource constraints. Nine other countries are preparing plans (WHO, 2021d).[8]

6 Chapter 3. Riding the Adaptation Wave in the Water and Sanitation Sector

7 Including Argentina, Bahamas, Barbados, Belize, Bolivia, Brazil, British Virgin Islands, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, El Salvador, Grenada, Guatemala, Guyana, Haiti, Jamaica, Nicaragua, Paraguay, Peru, Saint Kitts and Nevis, Saint Lucia, Suriname, Trinidad and Tobago, Uruguay.

8 Note that Mexico, Honduras, Panama, Ecuador, and Chile did not participate in the assessment.

BOX 7.2

Gender Matters

When identifying necessary adaptations for the health sector, it is important to consider how the impacts of climate change vary by gender. Occupations or social attitudes defined by gender and social roles often influence the way climate change impacts health (WHO, 2012). Not surprisingly, heatwaves and higher temperatures adversely affect the health of construction workers, who are predominantly male. In contrast, in rural areas women suffer greater food insecurity; the traditional gender roles that put them at a disadvantage vis-à-vis men in terms of education, income, and social status also work against them in access to food (Romanello et al., 2021). Governments can account for inequalities and differences in climate change adaptations in the sector by mainstreaming gender into sectoral policy and planning (WHO, 2012). A first step in this direction is to identify gender differences and inequalities by increasing the availability of health information disaggregated by gender (Romanello et al., 2021).

Governments should also promote and establish mechanisms for monitoring climate-related health hazards and risks, health outcomes, and the effectiveness of the health system and policy responses. A practical way to develop early warning systems for climate-related health hazards is to coordinate and share information among governmental, nongovernmental, and international agencies responsible for monitoring and implementing action, such as meteorological services and national emergency agencies (WHO, 2015). Argentina and Costa Rica are the only two countries that have implemented surveillance and early warning systems that use climate information and cover climate-change related health issues, including injuries and fatalities, from extreme weather events and high temperatures (WHO, 2021d).

A Team Approach to Governance

Health ministries should improve collaboration with other sectors whose policies affect human health (e.g., the ministries who oversee water and sanitation, education, labor, and environmental issues) at the national and subnational levels. Actions to enhance coordination include defining clear responsibilities and accountability mechanisms, incorporating climate change into the leading health policies and programs, and establishing focal points for climate change.

Unfortunately, more than half of the countries in the region have not established a working mechanism, such as a team or committee, that involves and unites all relevant parties inside and outside the health sector to respond to climate change (Astorga et al., 2023).

Finally, health authorities should take part in designing or updating climate policy (WHO, 2015). Globally, 94% of Nationally Determined Contributions (NDCs), the climate plans submitted to the United Nations as part of the Paris Agreement, mention health. But the topic tends to be covered imperfectly. Only 61% of NDCs, for example, clearly establish adaptation priorities, and less than 10% mention mental health and psychosocial support (WHO, 2021).

Regulatory Policy

Regulations can help the health sector adapt. Specific actions include changing zoning rules to avoid building hospitals that can be exposed to extreme weather events and establishing standards for health infrastructure so it can withstand disease outbreaks and extreme weather events (WHO, 2015).

Governments can also enforce climate-aware occupational safety and health measures to reduce the exposure of workers to climate-related health hazards (Saget et al., 2020). For their part, employers must inform workers about their working conditions and adjust working environments accordingly. Safety measures can be as simple as agreeing to work schedules outside the hottest hours of the day, ensuring access to water, providing air-conditioned rooms, or even just supplying hats. The best practice is to encourage workers to agree with companies and the government on these rules. Costa Rica has implemented a Regulation for Prevention and Protection of Workers Exposed to Heat Stress, which was adopted by the Occupational Health Council in 2015 (Box 1). These regulations require employers to provide shade, water, breaks, and protective clothing for outdoor agricultural workers.

Fiscal Policy and Health Insurance

Policymakers can also rethink fiscal policy. Reallocating the budget, adding specific line items to health budgets for climate emergencies and climate-related diseases (including by closing the large funding gap that exists for mental health and psychosocial support), securing funding to mitigate health risks, and considering environmental determinants of health when prioritizing investment funding can all help achieve the necessary adaptations (WHO, 2015).

Promoting universal health coverage is also critical, with improvements in health funding a key step. On average, governments in Latin America and the Caribbean spend less than 5% of GDP on health (WHO 2023), although the PAHO (2020b) estimates 6% would be needed to advance towards universal health coverage. The only countries in the region that meet this bar are Argentina (6.6%), Colombia (6.5%), Cuba (11%), and Uruguay (6.6%).

Insurance is essential to reducing financial barriers to health care and protecting people from catastrophic health expenditures. It can also be used to incentivize preventive and primary care. Twenty-six percent of all health spending in the region is paid out-of-pocket, well above the OECD average of 12%, ranging from more than 50% in Guatemala and Venezuela to less than 20% in Colombia, Cuba, Jamaica, and Uruguay (WHO, 2023). Finally, the health systems in the region tend to rely on a fragmented mix of public and private actors. This tends to divide the population by social conditions, limiting access for the most vulnerable, while costing more than government-run and single-payer options (OECD and WB, 2020). Health reforms can reduce inequities in access, provide generally better health outcomes, and make the region more resilient to climate change impacts.

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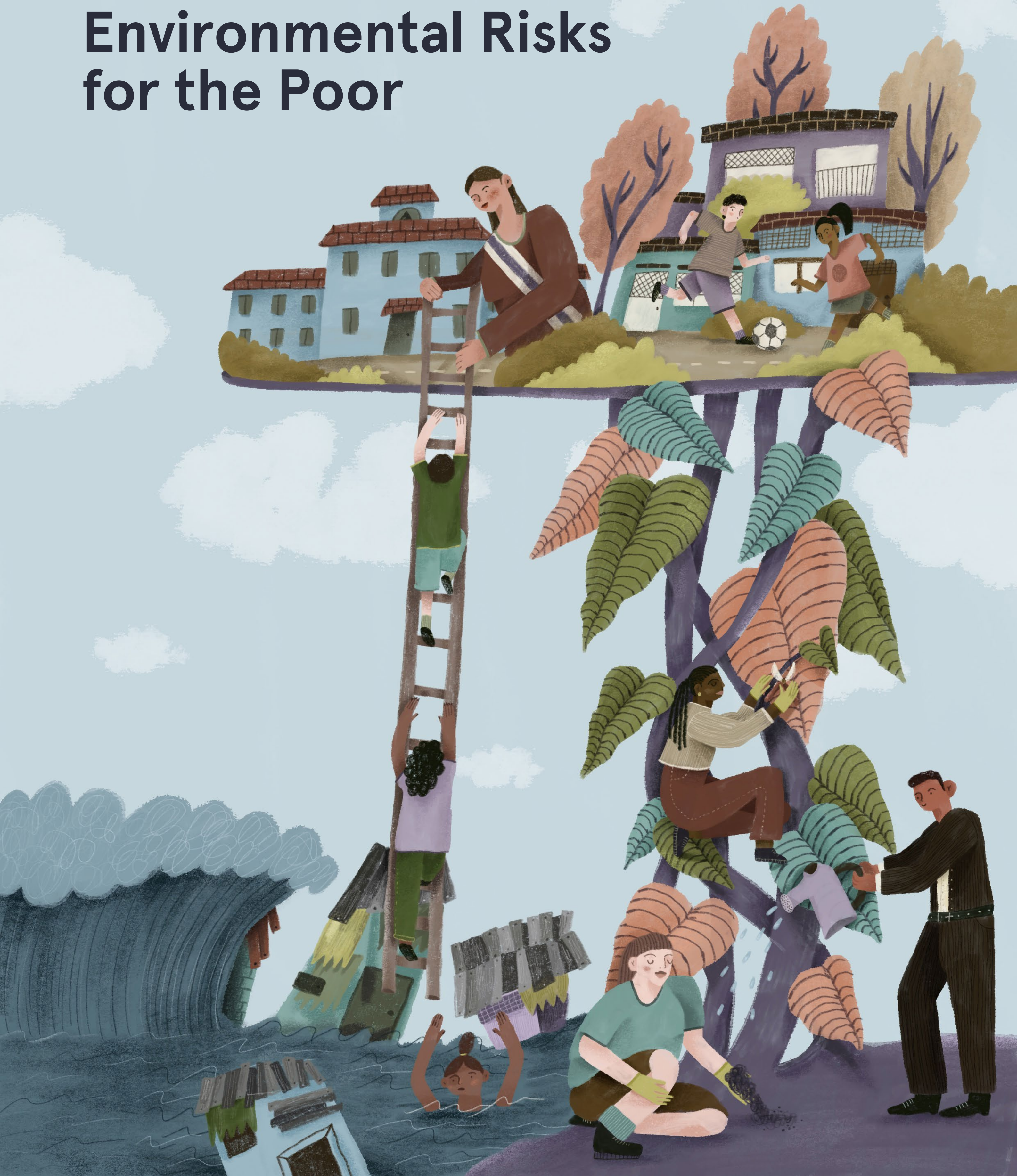
CHAPTER 8.

Double Jeopardy: The Economic and Environmental Risks for the Poor



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Double Jeopardy: The Economic and Environmental Risks for the Poor

Climate change disproportionately affects low-income households, which are more exposed, more vulnerable, less resilient, and have limited access to adaptation options. The location of these households and their reliance on at-risk assets as their main source of savings, such as housing and livestock, explain much of their greater vulnerability to the effects of climate change. Moreover, since they live close to subsistence levels, they often have to cut back on basic needs when disasters strike. In the aftermath of a disaster, low-income households are the least equipped to recover, and are subject to potential long-term consequences, such as falling into poverty. This can occur because they suffer catastrophic losses, stop receiving education, become stunted due to malnutrition, or cannot access healthcare and become incapacitated. Poorer households tend to have limited access to social protection, adaptation programs, and financial instruments like insurance and loans to help them get back on their feet. Adaptation programs must be designed across sectors to be inclusive of low-income households. For instance, zoning regulations must consider the impact on low-income housing and early warning systems must be designed to reach everyone. Social protection, income diversification, and financial inclusion are crucial ways to reduce vulnerability. Adapting existing social protection programs to ensure they can quickly expand and reach those affected by extreme weather events is particularly important. Finally, health and education services should be made resilient, improving infrastructure and using digital technology to allow them to function during extreme weather events.

When It Rains, It Pours on the Poor

Climate change disproportionately impacts low-income households. In vulnerable countries such as Nicaragua, Dominican Republic, Paraguay, El Salvador, Guatemala, Bolivia, and Honduras, between 57% and 90% of the poor live in municipalities that have experienced at least five climate-related disasters in the last decade (Bagolle et al., 2023). Greater exposure to disasters translates into more damage, which falls heavily on the poor. For instance, 20% of poor residents in San Salvador, El Salvador, and 17% in Tegucigalpa, Honduras, report suffering damages from landslides (Fay, 2005).

In cities, the relationship between socioeconomic status and exposure to climate change is particularly noticeable due to land scarcity.[1] Poorer urban dwellers are often pressured by high land prices to settle in low-rent but high-risk neighborhoods (Hallegatte et al., 2017). Low-income families may deliberately choose to live in risky urban areas because they present opportunities, despite the higher risks. For example, households in flood-prone areas of Mumbai accept flood risks because these areas also offer access to jobs, schools, healthcare facilities, and social networks (Patankar, 2015).

In rural areas, poor communities are also threatened by climate change. Drought, soil degradation, and ecosystem losses represent a growing threat, especially since the livelihoods of poor households depend disproportionately on the services and resources provided by the environment (UNEP, 2009).[2] In countries such as Honduras, Bolivia, Guatemala, and Haiti, agriculture is closely linked to the quality of soil, forests, and water sources, and the livelihoods of 30-50% of the population depend on it (Bagolle et al., 2023).

Adaptation efforts also tend to be unequal, leaving lower-income households exposed and unprotected. Decision-making for adaptation investments, such as levees and drainage, often prioritize the protection of assets, a strategy biased against lower-income households (Hallegatte et al., 2017). Informality further increases their exposure. Formal developments may adhere to land-use regulations, but lack of enforcement, combined with land prices, can drive informal settlers to hill slopes, riverbanks, or near open drains and sewers—all areas prone to natural hazards (Lall and Deichmann, 2012).

Asset Vulnerability

Poor households are more vulnerable to the impacts of climate change as they often live in structures unable to withstand natural hazards. Informal settlements are particularly vulnerable—a typical flood can destroy a typical informal house—whereas modern homes or multifamily buildings are much more resilient (Hallegatte et al., 2017). A greater proportion of the assets of poor households are exposed to climate change, and they are by and large less resilient to its effects. Typically, poor households hold a larger percentage of their assets in material forms, such as homes, construction material, or livestock, while the nonpoor have more financial access and can save in financial institutions (Hallegatte et al., 2017; Moser and Felton, 2007; Nkedianye et al., 2011). This asymmetry in asset type translates into more significant damages for the poor. For instance, the lowest quintile in Honduras lost 18% of their assets to Hurricane Mitch, compared to only 3% for the highest quintile (Morris et al., 2002).

Vulnerability is aggravated because poor households invest less in risk reduction and have little access to early warning mechanisms. Lacking resources for long-term investment, more impoverished individuals often rely on short planning horizons (Lawrance, 1991). In addition, many low-income households reside in informal settlements with unclear ownership of land and at risk of eviction. The insecurity of their living situation further disincentivizes investment in risk reduction, such as retrofitting to strengthen homes against disasters (Rentschler, 2013). In Buenos Aires, fear of eviction and low household income are the main reasons for underinvestment in housing infrastructure in informal settlements without tenure security (van Gelder, 2010).

1 See Chapter 6. Adapting the Urban Environment

2 See Chapter 2. Land of the Living: Rethinking Food and Biodiversity Together

Living on the Brink of Poverty

Poverty and vulnerability exacerbate the negative impacts of climate change. The loss of a dollar in consumption has a more significant impact on the well-being of poor people than on nonpoor people because they live closer to subsistence level and have fewer resources to cope with shocks (Hallegatte et al., 2017). Poor people's inability to reduce spending—while wealthier people can cut back on luxury items— threatens their capacity to cover their basic needs, such as food, when faced with climate shocks (Hallegatte et al., 2016; 2017).

Indeed, the impacts of climate change on food production pose a threat to poor households, which spend a larger portion of their income on food (Hallegatte et al., 2016).[3] Rising food prices can result in lower food consumption. In low-income countries, a 10% increase in food prices can reduce daily food intake by 72 kilocalories (Green et al., 2013). However, access to markets can help mitigate the impact of food shocks from climate change by diversifying the pool of food sources. Studies have shown that parts of the Philippines with low precipitation have experienced a 4% decrease in food consumption; however, this effect disappears in areas close to highways (Safir et al., 2013; Hallegatte et al., 2016).

Climate-related shocks can also push nonpoor but vulnerable people into poverty. People at the margins of the poverty line are constantly at risk of dropping below the threshold. In Latin America and the Caribbean, household surveys compiled by the IDB reveal that 37% of the population makes between US$5 and US$12.4 a day, and is therefore at risk of falling into poverty as a result of climate shocks. In India, 44% of the 12% of households in 36 Andhra Pradesh communities that fell into poverty over 25 years cited "drought, irrigation failure, or crop disease" as a reason for their income losses (Krishna, 2006).

Poor households and those at risk of falling into poverty are also more dependent on public services and infrastructure and less able to cope on their own with system failures (Hallegatte et al., 2017). Natural disasters can disrupt public infrastructure, which affects everyone to some degree. However, poorer people tend to be less able to protect themselves from these disruptions. They often rely on less developed or poorly maintained infrastructure, such as unpaved roads, which are impractical during rainy seasons, or on insufficient drainage systems that can become clogged by solid waste (Hallegatte et al., 2017).

Employment and Wages

Climate change will heavily impact labor markets and certainly have negative social consequences. In developing countries, private micro-, small, and medium enterprises—often in the informal sector—are the main source of job creation and play a significant role in reducing poverty. However, they are also the most vulnerable due to their limited ability to anticipate or adapt to the impacts of climate change (Hallegatte et al., 2016). The agriculture, livestock, fishery, forestry, and tourism sectors will be severely affected by climate change and suffer subsequent employment consequences. Climate change also negatively affects productivity: rising temperatures and heat waves decrease labor productivity as extreme heat makes it more difficult to work and workers must work at a slower pace. In Latin America and the Caribbean, this loss in productivity could cost the equivalent of 2.5 million full-time jobs, affecting informal workers in agriculture and construction the most (Saget et al., 2020).[4] Natural disasters such as hurricanes and floods also lead to labor productivity losses and increased informality (ILO, 2018; Pecha, 2017).

3 See Chapter 2. Land of the Living: Rethinking Food and Biodiversity Together

4 Chapter 7. Wellness Check: Climate Change and the Health Sector

Low Income=Low Resilience

Lower-income households are less resilient. They are the least equipped to adapt to climate change and when affected by it, the least able to recover. The potential long-term consequences include the risk of falling into poverty traps because of catastrophic asset losses or disruptions in the accumulation of human capital (IPCC, 2022, Hallegate et al., 2017).

Asset loss is indeed one of the main drivers of falling into poverty traps. If household assets go below a certain critical value, rebuilding the asset stock becomes difficult or almost impossible (Carter and Barrett, 2006). Ethiopia's 1984–1985 famine provides a vivid example of this effect; it took a decade on average for asset-poor households to bring livestock holdings back to prefamine levels (Dercon, 2004). The lack of access to risk management tools also contributes to the impact of climate change on poverty as it incentivizes suboptimal investment decisions. For example, small landholders plant low-return, low-risk crops and limit their investment in fertilizers (Cole et al., 2013).

A Difficult Lesson: Long-term Impacts on Education and Health

Climate shocks can also have significant long-term impacts on people's education and health, disrupting the accumulation of human capital. Extreme weather events can lead poor and vulnerable households to adopt negative adaptation strategies, such as pulling children out of school, increasing child labor, or interrupting medical checkups. In the rural areas of Nicaragua hardest hit by Hurricane Mitch in the late 1990s, child labor increased while secondary school retention and progression declined (Ureta, 2005; Vakis, Kruger and Mason, 2004; Baez and Santos, 2007; Baez & Mason, 2008). Infant malnutrition also increases after natural disasters, putting children at risk of experiencing "stunting," impaired growth that is long lasting and limits their future health and cognitive capacities. The negative consequences of climate shocks can thus contribute to the creation of enduring poverty traps and to the intergenerational transmission of poverty.

Extreme weather events also cause severe damage to educational infrastructure, leading to loss of school days and lower learning. In Latin America and the Caribbean, nine out of ten boys and girls are exposed to at least two types of climatic and environmental threats, jeopardizing their access to education (UNICEF, 2021a). In 2021, hurricanes and tropical storms Eta and Iota damaged or destroyed almost 1,000 schools in Honduras and Guatemala. In Honduras, the school year closed one month early (IDB and ECLAC, 2021). Hurricane Mathew damaged more than 300 schools in Haiti in 2016. Intact schools were often used as shelter, causing more than 100,000 students to miss classes (UNICEF 2016).

High temperatures negatively impact academic performance, particularly among minority and low-income students (Park et al., 2021). In the classroom, they cause children to lose concentration, leading to a lower rate of on-time high school graduation. In the region, 70% of the classrooms analyzed by the IDB a decade ago did not have adequate levels of thermal comfort (San Juan, 2014).

Climate change and extreme weather events can also make people ill, injure or incapacitate them, and result in deaths.[5] The resulting health expenditures push an estimated 100 million people worldwide into poverty annually (WHO 2013). The loss of income for the sick and their caregivers also impacts a family's well-being significantly. Poor households are largely uninsured and must bear the cost, often through debt at high interest rates, to access health care (Hallegatte et al., 2016; 2017). Access to universal health care presents a risk reduction alternative against health hazards.

In Need of a Bigger Financial Umbrella

Financial inclusion helps people affected by adverse events recover. Access to banking reduces asset risks as savings in bank accounts are less vulnerable than savings in livestock or housing (Hallegatte et al., 2017). Yet, the most vulnerable households often lack access to formal savings, borrowing, or insurance products. People may not have access to formal financial tools for various reasons: the cost of bank accounts, the distance and time required to access a branch, lack of documentation, and mistrust of banks. Additionally, some people prefer to remain in the

5 Chapter 7. Wellness Check: Climate Change and the Health Sector

informal sector or are unaware of the advantages of using financial tools for risk management (Allen et al. 2012).

Insurance is another instrument to protect assets and manage risk. When more severe disasters strike, access to credit and insurance provides resilience in affected households (Hallegatte et al., 2016; 2017).[6] Insurance also encourages investment in risk reduction. Insured farmers, for instance, tend to invest more in riskier and higher-yielding cultivation methods compared to farmers who are not insured. They also make higher overall investments in the planting stage, allowing them to balance their investment decisions with effective risk management (Emerick et al. 2016). However, insurance coverage is virtually non-existent for the poorest households in the region. When they are uninsured, people in low- and middle-income countries suffer more and recover more slowly from natural disasters (Peter, Dahlen, and Saxena 2012).

Diversifying the revenue of poor and vulnerable households is important. Many households rely on a single income source. That is because hurdles such as limited access to credit and financing, lack of technical skills, or inadequate access to markets restrict their ability to earn livelihoods from different sources. Some social programs are specifically designed to overcome these barriers (Davies et al., 2013). They typically complement cash transfers with access to training, financing, or the transfer of productive assets. In Nicaragua, an experimental program combined cash transfers with grants to spend on training or on starting a small non-agricultural activity. Two years later, the farmers who had received training or the business grant were more likely to be able to maintain their income and consumption in the face of droughts (Macours, 2022). While such programs, and evidence of their efficiency, are scarce, the evaluation of existing ones yields promising results (Andrews et al., 2021).

Migration: Blessing or Curse?

Extreme weather events are a major driver of migration and displacement, and climate change is bound to increase the pressure. Climate-related migration and displacement are primarily concentrated in low- and middle-income countries. They often originate in rural areas; destinations are mostly cities and other rural regions within a country, followed by migration to bordering nations (IPCC, 2022). The relocation of 300 indigenous families from a low-lying island in Panama is being observed internationally, as it could serve as a pilot for the much larger population waves that may come (Newsome, 2023). In Latin America and the Caribbean, up to 17 million people, or 3% of the regional population, could be forced to move by 2050 as they escape from areas with lower water availability, decreased crop productivity, or the threat of sea level rise (Clement et al., 2021).

Migration is not necessarily a negative outcome of climate change; it can also be a successful adaptation (IPCC, 2022). It is viable when adaptation alternatives are highly constrained or exhausted, and exposure and vulnerability are significant. Regardless, migration due to climate change may not always be a voluntary choice as individuals may be deeply attached to their livelihoods, economic opportunities, social networks, and cultural ties to a specific place. People living in small island states may not see relocation as a favorable or practical solution, and some individuals may wish to migrate but lack the means to do so.

Migration often changes household composition and structure as some households do not migrate as a unit. Males are often the only members to move, sending remittances to their family back. This partial household migration can increase vulnerabilities or present opportunities (IPCC, 2022). When only one adult moves from a household, the adult who is left behind (often a woman) must take on greater workloads. At the same time, households can also experience greater economic freedom, and remittances add a more diversified source of revenue for them.

Governments should prevent involuntary displacement by adapting all sectors to climate change and ensuring adaptation is inclusive. Policies should also help those who need to move. When migration is the best option, policies and practices related to people's movements across international borders are important. In locations where permanent, government-assisted relocation becomes unavoidable, the active involvement of local populations in planning and decision-making increases the likelihood of successful outcomes. Effective integration of migrants into receiving communities requires sound policy and planning decisions at the regional, national, and local levels regarding housing, infrastructure, water provision, schools, social protection, and healthcare in the recipient regions (IPCC, 2022).

6 See Chapter 9. Adapting Public and Private Finances to Finance Adaptation

Synchronizing Adaptation and Development

Standard development tools can be adaptation options. For example, new settlements in safe areas and better-quality structures reduce long-term vulnerability (Hallegatte et al., 2016; 2017). Yet, for adaptation transformations to offset the effects on the poor they must be inclusive. Flood protection infrastructure must reach low-income neighborhoods, including informal ones.[7] Early warning systems, vital for notifying the at-risk population to prepare or evacuate, must reach everyone. Insurance coverage and access to information must be widespread. Developing and connecting communities with transport networks can improve market access, increase resilience to price shocks due to local food shocks, and promote revenue diversification for inhabitants (Hallegatte et al., 2016; 2017).

Reducing Exposure

Reducing the exposure of low-income households to climate change is paramount and for this, inclusiveness is key. Zoning is a standard approach to avoid settling in the most exposed or unprotected areas, but some key problems must be addressed for zoning to be inclusive. The first issue is lack of enforcement, which leads to risk areas being informally settled regardless of restrictions (Hallegatte et al., 2017). Second, risk-informed zoning can drive up prices in safer areas and push them out of reach of the most vulnerable. Restrictive land-use regulations can have unintended consequences as low-income households often settle in risky areas. This can lead to increased housing costs, making it harder for poor rural households to move to urban areas and access better-paying jobs, healthcare, and education opportunities (Hallegatte et al., 2017).

Building solid institutions that enforce land use regulations is fundamental to tackling exposure. However, enforcement must go hand in hand with policies that provide viable alternatives for low-income households that choose to settle in risky places. To ensure that people can reside in safe locations while still having access to decent jobs and services, investments in transportation and other infrastructure should be made in conjunction with zoning regulations (Hallegatte et al., 2016). Reducing exposure can also be tackled through a positive approach by developing safer areas. A key urban planning approach is to overlay maps of secure areas with maps of high potential for development in determining priorities (Hallegatte et al., 2016; 2017). When deciding which areas to safeguard with investments like dikes or nature-based solutions, such as mangroves that protect against storm surge, authorities should not only make their decisions based on the financial value of assets that would be shielded. They might also count inhabitants or weight the losses potentially experienced by poorer households in the economic analysis of public investment projects (Hallegatte et al., 2017).

Strengthening Education and Health

Given that cutting access to education and health are key ways in which climate change pushes people into poverty traps, governments should make health and education services resilient.[8] Improving the education system's resilience to climate change demands considering measures during the design, construction, and maintenance of school buildings to allow them to operate during extreme weather events, including droughts and heatwaves, or serve as shelter when needed.

Digital technology can enable distance education during climate emergencies until the return to the classroom, but that requires poorer households have access to the internet. In 2020, 77 million rural Latin American or Caribbean people lacked such access (Ziegler et al., 2020). In addition, education programs should ensure that students have the necessary knowledge, values, and capacity to respond and adapt to climate change. They should ensure that students have more livelihood resources, are more empowered, and are able to innovate and find solutions. Education improves resilience to climate events (UNICEF, 2021b).

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Adapting Social Protection to Weather Climate Change

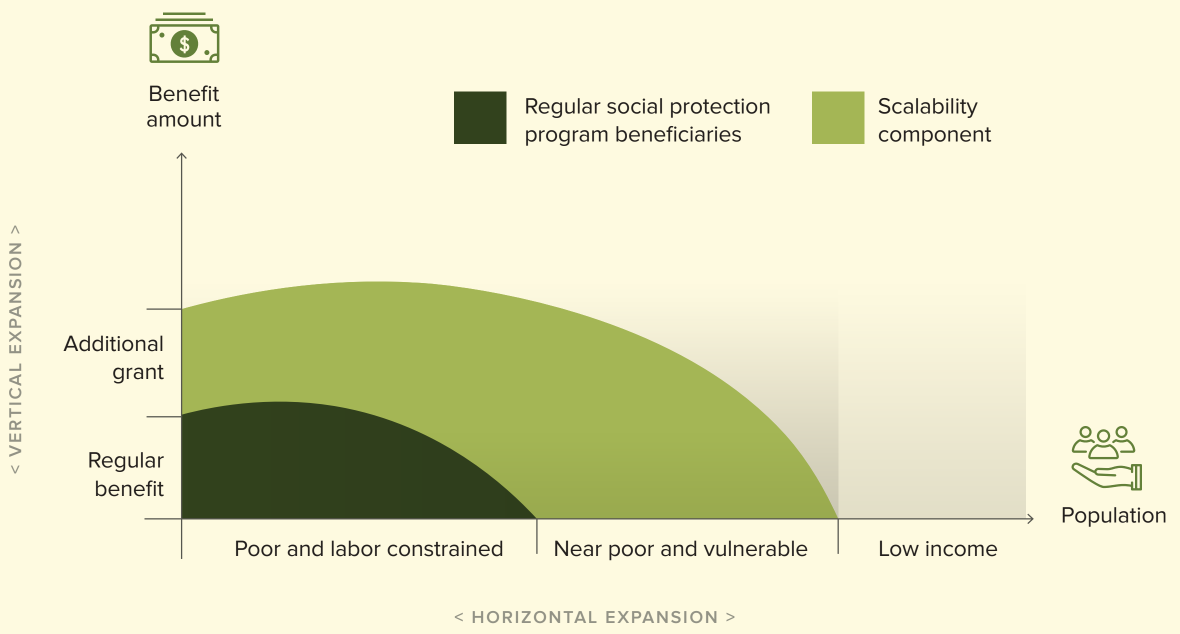
Social protection programs, such as cash transfers, are paramount to reducing the impact of climate change on livelihoods. First, regular and consistent cash transfers increase precautionary savings, prevent harmful risk-coping strategies, and improve the resilience of recipient households (Bastagli et al., 2016). Second, cash transfers delivered in the aftermath of disasters help households maintain food consumption and makes them less likely to pull their children out of school (Hallegatte et al., 2017).

At the same time, social protection systems and programs need to be improved to better serve adaptation purposes. For one, they frequently exclude poor households. Formal employment is sometimes a requirement—a formidable barrier for poor individuals in Latin America and the Caribbean, where 59% of the active population has an informal job (Saget et al., 2020). Programs aimed at alleviating poverty, such as non-contributory cash transfer programs, also suffer from bad coverage. In the region, cash transfers cover on average only 56% of the population in extreme poverty. Reaching remote rural areas, where many poor individuals live, is particularly challenging. In addition, the amounts transferred are inadequate, representing only 30% of the poverty gap–a measure of how much additional income recipients would need to receive to qualify as nonpoor (Stampini et al., 2021). Improving the coverage and adequacy of social protection is a first step to making households more resilient.

A second required improvement is making programs more flexible so they can expand rapidly and provide relief to individuals affected by extreme weather events. This means disbursing higher amounts to more beneficiaries (figure 8.1) and requires adjustments at different levels (Beazley et al., 2019; Williams and Gonzales, 2020; Costella et al. 2023; Bagolle et al. 2023). At the program level, governments should set in advance rules and criteria (such as the declaration of a natural disaster) that trigger extraordinary transfers, as well as criteria and mechanisms to determine beneficiaries (based for instance on income, economic activity, or household composition). Numerical simulations show that erring on the side of including too many people is safer than insisting on meeting exclusive criteria at the expense of leaving some households out when they most need help (Hallegatte et al., 2017). However, it is important that the amounts and duration of the emergency cash transfers are set in advance, with automatic sunset clauses, to ensure fiscal sustainability.

FIGURE 8.1

Scaling Social Protection After a Disaster with More Money to Reach More People



Source: Based on O'Brien et al 2018

At the operational level, deepening social registries is key. Existing registries should be extended beyond the traditional population of social protection programs (households in poverty) to include vulnerable populations in near poverty and other at-risk population categories (for instance farmers). The socioeconomic information contained in social registries should be integrated with other information sources related to the exposure of households to climate threats, and governments should ensure the information is updated frequently. Registries should also include bank account or mobile banking numbers when relevant to ensure the government can use a combination of digital and in-person payment channels (Costella et al., 2023).

On the financial level, governments need to ensure the availability of funds. Government reserve funds, contingent finance, and government insurance are all rapidly actionable during emergencies (Hallegatte et al., 2017).[9] More generally, governments will need to secure the budget to keep an adequate coverage of regular cash transfer programs (Galindo et al., 2022). One option is reducing energy subsidies, which cost 1.1% of GDP in the region in 2018 (Conte Grand, Rasteletti y Muñoz, 2022) and are up to six times more expensive than cash transfers per dollar disbursed to poor households (Feng et al., 2018). Another option is better targeting existing social protection programs by excluding higher income households (Vogt-Schilb et al., 2019).

Finally, on the governance level, new regulatory frameworks, processes, and procedures need to be developed (Costella et al., 2023). The frameworks should specify the roles and responsibilities of the social protection actors in the aftermath of natural disasters. They should also establish coordination mechanisms with risk management and humanitarian aid organizations.

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CHAPTER 9.

Adapting Public and Private Finances to Finance Adaptation

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Adapting Public and Private Finances to Finance Adaptation

Climate change is a risk to public and private finances. Extreme weather can increase disaster relief spending and lower tax revenues. Climate events also cause losses for firms and defaults on loans that can propagate through the economy. At the same time, adapting infrastructure, agriculture, and social systems requires major investments by both government and private actors. Governments can use fiscal tools like contingent credit, green bonds, and environmental tax reforms to manage climate risk and fund adaptation. They should also update procurement and investment rules to account for climate risk. Financial regulations, like climate risk disclosure and stress testing, can reduce propagation risk while incentivizing adaptation. Central banks should integrate climate factors into monetary policy and portfolios. Expanding financial inclusion through insurance and savings access reduces households' reliance on post-disaster aid. Enhanced coordination between financial, environmental, and sectoral agencies is key. Developing climate financial strategies, investment taxonomies, and climate spending trackers helps planning and evaluation. Finally, only an orderly transition to net-zero emissions can truly contain climate risks.

Climate Change Brings Physical and Transition Risks

Two types of climate change risks threaten public and private finances (TCFD, 2017; Delgado et al., 2021). *Transition risks* are the first kind, associated with policy changes, disruptive technology innovation, and investors' and consumers' feelings towards activities inconsistent with transitioning to a net-zero carbon global economy. For instance, as consumer preference shifts to electric vehicles and the owners of power generators favor renewable energy over fossil fuels, global demand for oil and gas will likely decrease. This will undermine profits for fossil fuel firms and fiscal revenue for governments. In Latin America and the Caribbean, one to three trillion dollars of oil and gas royalties could be lost this way by 2035 (Solano-Rodríguez et al., 2021; Welsby et al., 2021).

This chapter focuses on a second type of risk, called physical risk. These are the risks related to extreme weather events and slow-onset ones. Between 2000 and 2019, 110 storms affected Latin America and the Caribbean, causing US$39 billion in damages—mostly around the Caribbean Sea (Frisari, 2022). During the same period, floods caused US$26 billion and droughts US$13 billion in damages. This toll will likely increase under the effects of climate change. As the previous chapters show, slow-onset events will also impact agriculture, infrastructure, cities, and social systems, threatening to generate additional costs for governments, firms, and households.

Fiscal Policy to Manage Climate Risk

Extreme weather events take a toll on public finances. After large disasters, governments are expected to spend on emergency aid for their affected populations (Delgado et al., 2021). They typically must pay to rebuild infrastructure and public facilities. If state-owned enterprises or national banks are significantly affected, governments are expected to bail them out—an expectation that can extend to private firms of economic, cultural, or political significance. Governments also suffer from reduced tax revenues as output drops for a few months or years. In the region, experiencing at least one extreme event per year can increase the fiscal deficit by 0.8% to 0.9% of GDP (Alejos, 2018).

Financing the Cost of Extreme Weather Events

When assessing fiscal sustainability, the treasury should treat relief and reconstruction as a contingent liability and be prepared for it. With climate change uncertainties affecting financial systems, decision-makers need analysis to anticipate risks. By exploring various scenarios of how climate risks could materialize,[1] governments can anticipate climate repercussions and manage potential fiscal obligations rather than reactively addressing them as last-resort insurers (Delgado et al., 2021).

A range of financial instruments can help countries manage that liability. Every day, somewhere in the region, a relatively small flood damages buildings, roads, and other infrastructure. Governments can use budget (re)allocation, contingency funds, and reserve funds to absorb losses from low-impact events with a medium-to-high probability of occurring. They should pre-authorize spending for relief and reconstruction efforts in their national and subnational budgets to avoid the need to refashion a budget in the aftermath of disasters.

For lower probability and medium-to-high impact events, such as serious wildfires, additional risk retention options include contingent credit. Contingent credits are loans arranged ex-ante so they can

1 See Decision-Making Under Uncertainty in Chapter 1

provide liquidity soon after a disaster. For instance, the IDB's Contingent Credit Facility for Natural Disaster Emergencies issues loans that are triggered with predefined parametric triggers, such as the type, location, and intensity of a natural disaster (Lewis et al., 2023). Importantly, these loans also include incentives to reduce risks and improve disaster risk management, which are often more important than liquidity per se. As of November 2022, 12 countries in the region have subscribed US$2.6 billion worth of loans to cover climate risks. Other institutions, such as the World Bank and the IMF, offer similar loans.

For very low probability, very high-impact events, such as catastrophic hurricanes, risk transfer options include insurance, especially to protect critical infrastructure, as well as catastrophe bonds and risk pools (BMZ, 2022, Cissé 2021). These instruments are often expensive. The government of Chile has issued US$630 million worth of bonds and swaps redeemable with certain conditions in the event of an earthquake, for which it pays an annual premium of 4.75% (Ministry of Finance of Chile, 2023a). Similarly, the Nicaraguan government recently subscribed to the Caribbean Catastrophe Risk Insurance Facility, which quickly provides the country with resources should it be stricken by an extreme weather event.

Climate-resilient clauses in government debt, often called "hurricane clauses," can help countries manage the macroeconomic consequences of large events. They let borrowers delay repayments for a few years after a major event like a hurricane. More importantly, loans are typically conditioned on improving budgetary and sector-scale regulations to enhance disaster preparedness. The Bahamas and Barbados have contracted loans with the IDB that have such clauses (Lewis et al., 2023). Similar clauses are also used by private corporations (Meirovich et al., 2022).

At the 27th annual UN conference on climate change, a decision was made to offer financial support to the developing countries most affected by climate change. This support is specifically for losses and damages, which can be due to extreme weather events or slow-onset climate change impacts. A committee has been set up to work out the details for this funding, but how the decision will impact countries in the region is still uncertain.

Financial inclusion reduces the need for government relief. Bank accounts and financial assets help keep savings out of harm's way, while savings in kind, such as livestock and housing, can be erased by natural disasters (Hallegatte et al., 2017). Private insurance allows households and firms to transfer risk, giving them access to resources to finance reconstruction. For instance, weather-indexed insurance makes payouts based on easily observed variables such as rainfall. This can bring risk transfer coverage to smaller and poorer farmsteads by lowering administration costs (Lema al., 2023).[2] The tradeoff is that payments are not directly linked to losses, meaning that some farmers will suffer losses and not be compensated, while others will be compensated without suffering losses. Governments should establish and enforce quality standards for parametric insurance products (Cissé 2021).

The most vulnerable often lack access to formal savings, borrowing, or insurance products. Reasons include the costs of holding an account, lack of documentation, not having access to a branch, and transaction costs. By lifting such barriers, governments should play a key role in promoting financial inclusion.

Funding Adaptation

The best way to reduce the need for ex-post risk financing is to reduce risk in the first place. Private resources are crucial to funding risk reduction, but the wrong incentives, insufficient information, and burdensome regulations often hinder private spending on adaptation (CPI, 2023; Delgado et al., 2021). The previous chapters show how governments can update regulations, use economic incentives, and spend better to ease these barriers.

Governments can also update public investment rules to make sure new projects consider climate hazards. National public investment systems, through which most countries in the region regulate infrastructure projects, can be updated so they require a disaster risk analysis to greenlight new projects (Delgado et al., 2021). In Jamaica, the Public-Private Partnership Policy mandates the integration of climate risks in the different phases of the project cycle so that climate impacts that may arise during the project's expected lifetime are considered (Frisari et al., 2020). In Panama, the Ministry of Environment has published guidance to ensure climate risk and adaptation are taken into account in the evaluation, design, and financial structuring of public investments (Ministerio de Ambiente de Panama, 2020).

2 See chapter 2. Land of the Living: Rethinking Food and Biodiversity Together

Governments should include climate adaptation considerations in public procurement processes. One common issue is that public procurement rules often prioritize the minimization of purchasing costs, neglecting future maintenance and climate-related costs. To avoid that, governments can include environmental requirements in technical specifications, procurement selection, adjudication criteria, contract execution clauses, and benchmark products (Delgado et al., 2023). Two tools are being used to advance this process. The Public Expenditure and Financial Accountability Climate Module evaluates the preparedness of systems for climate-related risks, ensuring that they can adapt to potential disruptions. Meanwhile, the Methodology for Assessing Procurement Systems Sustainability Module highlights areas in procurement processes that can be made more environmentally friendly.

More generally, climate change adaptation is tied to the government budget (Delgado et al., 2021, Hallegatte et al., 2019). Many adaptations discussed in previous chapters require public spending, for example, to improve the redundancy of the transport network, to plant and maintain vegetation that protects against floods and heat waves, or to strengthen social protection schemes. While some of these may seem unaffordable at first glance, insufficient fiscal support for managing climate risk can backfire, negatively affecting the budgetary balance and public debt. Budgeting for maintenance is key: lack of proper maintenance can increase infrastructure capital costs by 50% (Rozenberg and Fay, 2019).

Governments can also promote adaptation transformations by establishing specific funds. In Colombia, 80% of the income generated by the carbon tax, roughly US$100 million in 2022, is allocated to the sustainability and climate resilience fund (Fondo para la Sustentabilidad y Resilencia). This fund supports deforestation reduction and monitoring, promotes the conservation of water sources, and advances the protection, preservation, restoration, and sustainable use of strategic areas and ecosystems (Talbot-Wright et al., 2023).

Finally, environmental tax reforms can help fund adaptation. In 2020, Latin America and the Caribbean spent US$60 billion, 1.3% of GDP, on fossil fuel subsidies (Parry, Black, and Vernon, 2021). Nearly US$540 billion is spent by governments worldwide to support agricultural producers, mainly in the beef and dairy sectors. Eighty-seven percent of that support is deemed inefficient and inequitable. It also creates risks related to pollution, the promotion of unhealthy diets, and a lack of resilience due to crop choice (FAO, UNDP, and UNEP, 2021). These subsidies disincentive climate action and put a burden on public finances; reforming them while protecting poor households and vulnerable businesses should be a priority (Ahumada et al., 2023; Missbach et al., 2023).

Reward offered? Green and Sustainability-Linked Bonds

Ultimately, funding for any public spending on adaptation comes from the general tax system, and most public spending on adaptation that requires high upfront investments will be financed by general government debt. But governments can also use specific financial instruments earmarked for adaptation.

Sovereign green bonds are an example (Delgado et al., 2021). Green bonds are issued to fund projects from eligible sectors or with eligible purposes, such as reinforcing public infrastructure against extreme weather events (CBI, 2022). Investors with appetite for climate change projects may offer slightly better terms on a green bond–*a greenium*–than for a conventional bond (Delgado et al., 2021). But greeniums are small compared to country spreads and typical day-to-day variations of market rates. For instance, Colombia simultaneously emitted green and conventional bonds in 2021 with financially identical terms, and the green bonds traded on average at 0.1 percentage point below the conventional ones (Hussain 2022). For comparison, over the last year, Colombian bonds traded between 6 and 10 percentage points above US treasury bonds.

Beyond greeniums, green bonds force governments to develop clear adaptation investment plans (Delgado et al., 2021). In Colombia, the green bond framework includes activities for the conservation of natural resources, such as water and biodiversity; climate-risk management in agriculture, including early warning systems; and sustainable buildings (Ministry of Finance and Public Credit of Colombia, 2021). Green-bond issuance in the region rose from US$14 billion in September 2019 to US$30 billion in June 2021 (Green Finance LAC Platform 2022).

Sustainability-linked bonds are another example. Instead of funding specific projects as green bonds do, these are linked to key performance indicators. When it issues these bonds, the government defines targets for years in the future. It establishes penalties to be paid to bond subscribers if it fails to achieve those targets, or, similarly, a bonus if it does achieve them. This creates a long-term incentive for using regulations and investments to advance environmental goals. Chile was the first country to issue sustainability-linked bonds in 2022. The country raised US$2 billion while committing to reducing greenhouse gas emissions and increasing renewable energy production by 2032 (Ministry of Finance of Chile, 2023b). Sustainability-linked bonds with adaptation targets are yet to be emitted; the other chapters in this document may provide inspiration to design adaptation-oriented performance indicators.

Banking on Government to Promote a Resilient Financial Sector

Surprises and Cascades

A key issue with physical risk is that it can propagate and generate cascading effects through the financial system. Firms and households can be directly exposed to physical risks, for instance if they own real estate on a waterfront threatened by rising sea levels. A bank located some distance from the coast can also be exposed to risk from sea-level rise if its portfolio includes mortgages on coastal real estate (Brunetti et al., 2021). In Brazil, the impact of climate change on droughts, floods, and heatwaves by 2050 could reduce increase non-performing loans 12%, reduce deposits by 3%-22% and shrink credit by around 23% (Asuncao et al., 2023). In Colombia, the Superintendency of Financial Institutions (*Superintendencia Financiera*) found that floods fueled by climate change could increase loan losses by 0.2% to 2.2% of total bank assets by 2080 (FSB, NGFS 2022).

The financial sector may not be anticipating the full extent of physical risks (Brunetti et al., 2021, Grippa et al., 2019). Due to changes in the intensity, frequency, and location of extreme events, such as droughts and storms, existing financial risk models may fail to identify new risk. Some assets may thus be priced higher than what an accurate understanding of their exposure to physical risks would suggest. When used as collateral, these assets could lead to more debt than would be optimal, thus increasing the risk for lenders (Brunetti et al., 2021). For instance, a bank that holds mortgages may seem as if it has healthy balance sheets when the risk of default on mortgages is assessed from past data. But if increased hurricane risk means more defaults in the future, the bank may fail.[3] These could then have cascading effects: firms and households that use that bank could lose their savings, unless the government or the central bank decides to bail the bank out, spreading the cost to taxpayers or holders of the domestic currency.

Compounding matters, physical risk may be reducing the portfolio diversification of investors, insurers, and reinsurers. That is because the risks of wildfires, floods, and rising sea levels can change quickly and affect many types of assets at the same time (Brunetti et al., 2021). This can result in systematically correlated risks across the economy and financial system, reducing the accuracy of models estimating risks in leveraged financial institutions.

In response to increased exposure from their clients, insurers may raise prices or limit coverage (sometimes knows as "insurer retreat"). In California, many providers of homeowner insurance have stopped covering wildfire risk. This leaves many businesses and households uninsured, making them more exposed to climate change impacts (Collier et al., 2021; Grippa et al., 2019; Brunetti et al., 2021). Moreover, climate change increases costs for insurance companies. Insurance companies collect premiums from policyholders and invest those funds in various assets like stocks, bonds, and real estate. But a study found that over 35% of insurance companies' investments globally are exposed to physical or transition risks (IAIS, 2021). In different climate change scenarios, insurance companies could lose between 7% and 50% of their available capital to cover claims.

3 See also Decision-Making Under Uncertainty in Chapter 1.

Finally, climate risk is an issue for central banks. It jeopardizes their goals of promoting growth, controlling inflation, and securing the system's financial stability (NGFS, 2021; Frisari et al., 2019). As is the case for insurance companies, central banks should be concerned with climate risks not only in the banking and monetary systems of the economy they supervise, but also on their own balance sheets (NGFS, 2021).

Diagnosing Financial Risk

The first step to managing risk is assessing it. The Network for Greening the Financial System (NGFS), a group of central banks and supervisors spearheading the financial response to climate risk globally, has used so-called integrated assessment models to assess transition and physical risks on the global financial system in six climate change scenarios (NGFS, 2023). One key shortcoming of these models is that they provide limited geographical coverage–for instance they often group together all countries in South America, severely restricting their ability to assess physical risk at a relevant scale.

Governments can also directly assess the risk to physical assets and pass this information on to the public (Frisari et al., 2019). In Chile, the ministry of environment developed the ARCLim platform, where data on the exposure and vulnerability of physical assets to different climate change scenarios are compiled and made available to society (Pica-Tellez et al., 2020). Since future climate change is deeply uncertain, financial and physical models will never accurately assess risk, and decision-makers should rely on a broad range of scenarios.[4]

Central banks should also incorporate climate risks into their models and their analyses of how to conduct monetary policy, including using forward-looking climate scenarios (Frisari et al., 2019; Grippa et al., 2019; NGFS, 2021). For instance, the European Banking Authority conducted an EU-wide pilot aimed at mapping banks' exposure to climate risk and estimating the ratio of assets vulnerable to climate change (EBA 2020). The European Central Bank has included climate stress testing in its annual banking supervision activities to identify banks' exposure to climate risks (ECB, 2022).

Institutionalized working groups can help broaden the financial system's understanding of these risks and identify best practices in the sector (Jaramillo and Saavedra, 2021). For instance, Chile developed a public-private green finance roundtable where private sector actors, the finance ministry, financial regulators, and supervisors identified good practices that contribute to developing meaningful guidelines. In Ecuador, the recently formed Sustainable Finance Initiative is a public-private-academia partnership that seeks to catalyze the benefits that sustainable finance and impact investment can bring to the Ecuadorian economy.

Assess, Manage, and Disclose Risk

To reduce climate risk at the firm level and prevent it from spreading, governments can require firms to frequently assess and disclose their climate-related risks and the actions they have taken to manage them (Frisari et al., 2019).

In 2017, a global task force of corporations and financial institutions, the Task Force on Climate-Related Financial Disclosures (TCFD), recommended that any publicly traded corporation or financial institution disclose 11 items regarding the governance, strategy, risk management choices, metrics, and targets that they use to assess climate-related risk and opportunities (Box 9.1).

Governments are increasingly requiring financial firms to disclose climate risks and implement practices to manage them. These firms may be required, for example, to maintain a safe level of structural liquidity to minimize bankruptcy risks. Large corporations may be obligated to implement good practices such as those recommended by the TCFD (Delgado et al., 2021, Frisari et al., 2019).

Eleven countries in the region have implemented regulatory or supervisory measures dedicated to climate change in the last few years (Frisari, 2022). In Chile and Colombia, for instance, recent regulations require issuers to incorporate climate risk in their annual report, following TCFD recommendations (CMF 2022; SFC, 2021). Other countries, such as Costa Rica, the Dominican Republic, Honduras, and Mexico have issued guidelines to encourage voluntary sustainability disclosure for issuers (Herrera et al., 2023).

Central banks should also disclose their exposure to climate risk and strategy to manage that exposure. In Brazil, the Central Bank Strategy follows the recommendations of the TCFD. It recently created

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BOX 9.1

The TCFD’s 11 recommended disclosures on climate-related risk and opportunities

The TCFD recommended disclosures aim to provide useful information to investors and other stakeholders on companies’ governance, strategies, risk management, metrics, and targets related to climate change. The recommended disclosures are:

GOVERNANCE

a. Describe the board’s oversight of climate-related risks and opportunities.
b. Describe management’s role in assessing and managing climate-related risks and opportunities.

STRATEGY

a. Describe the climate-related risks and opportunities the organization has identified over the short, medium, and long term.
b. Describe the impact of climate-related risks and opportunities on the organization’s businesses, strategy, and financial planning.
c. Describe the resilience of the organization’s strategy, taking into consideration different climate-related scenarios, including a 2°C or lower scenario.

RISK MANAGEMENT

a. Describe the organization’s processes for identifying and assessing climate-related risks.
b. Describe the organization’s processes for managing climate-related risks.
c. Describe how processes for identifying, assessing, and managing climate-related risks are integrated into the organization’s overall risk management.

METRICS AND TARGETS

a. Disclose the metrics used by the organization to assess climate-related risks and opportunities in line with its strategy and risk management process.
b. Disclose Scope 1, Scope 2, and, if appropriate, Scope 3 greenhouse gas (GHG) emissions, and the related risks.
c. cDescribe the targets used by the organization to manage climate-related risks and opportunities and performance against targets.

Source: TCFD (2017)

a committee on organizational socio-environmental responsibility and developed a socio-environmental risk report and responsibility policy. It is also including climate change considerations in its regulatory and supervisory functions (BCB, 2023). For instance, it has required since 2020 that financial institutions develop processes and roles for the management of climate risks and has introduced mandatory disclosures inspired by the TCFD Framework. Central banks can also lead by example by integrating sustainability considerations into their portfolio management (Frisari et al., 2019; Grippa et al., 2019; NGFS, 2021). This can mean avoiding investments in assets exposed to climate risks, or discounting their value when evaluating the risks and returns of different assets in their portfolios.

The government can also mandate highly regulated institutions, such as pension funds, to assess and manage climate-related risks when investing. In Chile, the government mandates pension funds to integrate climate risk considerations in their policies and investment processes, as well as in their risk assessment systems (Frisari et al., 2019; Frisari 2022).

Storm Clouds Gathering: Capacity Building, Planning and Coordination

Classifying Economic Activities and Public Spending

Finance ministries can foster transparency and improve information related to climate finance. One challenge is that there are not established definitions of what climate adaptation entails. This can lead to underfunding adaptation and to *greenwashing*, where activities are falsely presented as environmentally beneficial when they are not.

To tackle this issue, some ministries are issuing a taxonomy that classifies activities based on their contribution to environmental goals, including adaptation. The European Union pioneered this approach with their Sustainable Finance Taxonomy in 2020. Its main principle is that for an investment activity to be considered sustainable, it must substantially contribute to at least one of the taxonomy objectives, including furthering climate change adaptation, while avoiding significant harm to any of the other objectives and complying with minimum safeguards (Pettingale, 2022). Colombia, in 2022, and Mexico, in 2023, have approved national taxonomies that emphasize climate adaptation.

Governments are also developing tools to track how much of their budget is spent on climate change. The main challenge for accounting for climate change expenditures is transitioning from an economic or administrative classification of the budget—that is, according to the institution, program, or administrative purpose (staff, operations, etc.)—to a functional classification (expenditure on climate change, gender, poverty reduction, etc.). Climate change budget labelling or tagging can be a short-term solution. With budget tagging, governments identify, or "tag," expenditures according to defined criteria and allow for a parallel budget classification (Ferro et al., 2020). In Chile, a government review of 729 programs or initiatives in the 2021 budget found that 58 of them, with a combined worth of almost US$1 billion, have a climate component, with 22 related to adaptation and 16 affecting both adaptation and mitigation (DIPRES, 2022).

Budget tagging can also identify spending that works against climate change objectives. An IDB study found that Argentina, Colombia, Jamaica, Mexico, and Peru allocate between 1.1% and 3.3% of their national budgets for actions that positively combat climate change. However, these countries also invest a higher percentage, ranging from 1.9% to 8.6% of their budgets, on programs that detrimentally impact climate change efforts, such as fossil subsidies (Ferro et al., 2020).

Planning and Coordinating Climate Policy

Data cannot be acted upon without skills. Policymakers should recognize that the expertise required to adapt finances to climate change extends beyond traditional financial knowledge. They need to pinpoint critical skills, evaluate internal capabilities, identify knowledge gaps, bridge these gaps, and build their capacity to act on climate change.

Ministries of finance can develop financial strategies to outline their climate objectives and a roadmap of policies, regulations, and investments to reach them (Jaramillo and Saavedra, 2021). These strategies can be used to commit to a timeline for developing environmental tax reforms, green taxonomies, functional classifiers for public spending, and financial disclosure regulations. They can also promote international cooperation, serve as a tool for dialogue with multilateral development banks, and define instances of public-private linkage for identifying needs and actions.

Financial strategies should ideally be linked to broader national climate strategies (Jaramillo and Saavedra, 2021). For instance, the Chilean Climate Change Framework Law sets the goals for achieving a climate-resilient economy by 2050, and establishes targets and responsibilities for most ministries, including the ministry of finance. While each ministry should pursue its own adaptation targets, the ministries of environment and finance are pivotal in coordinating action, securing funds, and upholding overarching environmental and fiscal objectives.

Finally, the best way to reduce climate risk is to prepare an orderly but prompt transition to net-zero emissions (Fazekas et al., 2022). Recent simulations from financial supervisors show markets' exposure to climate risks would be manageable under orderly scenarios of transition to a low carbon economy. But continuing to produce greenhouse gas emissions would worsen climate change and produce significant economic and financial losses from the realization of physical risks. Delaying decarbonization policies would only increase transition risks (FSB, NGFS 2022). National strategies should aim at achieving low-carbon development in addition to climate resilience.

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Climate change has arrived, putting lives, ecosystems, and economies in jeopardy. *Heat and High Water* provides a much-needed primer on how countries can adapt to this harsh new reality. Written for a general audience in clear, non-technical language, the book examines climate threats and resilience strategies sector by sector, focusing on the specific challenges for Latin America and the Caribbean.

How can dense population centers use wetlands and parks, as well as other elements of urban planning, to protect against floods and landslides? What can be done to ensure the health and wellbeing of vulnerable people during heatwaves and epidemics? Are there innovations in renewable energy, food security, energy, transport, and fiscal and financial policy particularly suited to the new circumstances of the region and others likely to fail? The book engages these questions and many more with a deep analysis based on three core principles: the need for flexible solutions amid the uncertainty of climate change; the interdependence of sectors across social and economic life; and the need to reform governance to ensure coordinated, inclusive adaptation that emphasizes local communities and stakeholders.

By breaking down the complex topic of climate adaptation into digestible chapters, *Heat and High Water* offers tools for citizens, policymakers, and business leaders to build thriving, resilient societies amid climate disruptions while elucidating lessons valuable to a global audience.

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