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CAMBODIA

World Bank Group

COUNTRY CLIMATE AND DEVELOPMENT REPORT

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Acknowledgments

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Acronyms and Abbreviations

ABC	Association of Banks in Cambodia
ASEAN	Association of Southeast Asian Nations
AWD	Alternate wetting and drying
BaU	Business-as-usual
BCR	Benefit-to-cost ratio
CBAM	Carbon Border Adjustment Mechanism
CCAP	Climate change action plans
CCCSP	Cambodia Climate Change Strategic Plan
CCDR	Country Climate and Development Report
CGE	Computable general equilibrium
CHIRPS	Climate Hazards Group InfraRed Precipitation with Station data
CHIRTS	Climate Hazards Center InfraRed Temperature with Stations
CSFP	Cambodian Sustainable Finance Principles
DHRW	Department of Hydrology and River Works
DOM	Department of Meteorology
DRF	Disaster risk financing
DRM	Disaster risk management
ELC	Economic land concession
EOC	Emergency operation center
ESCO	Energy service companies
ESG	Environmental, social and governance
ESM	Ecosystem services modeling
EV	Electric vehicles
FDI	Foreign direct investment
LULUCF	Land use, land-use change, and forestry
FTT	Future of Technology Transformations
GCM	General circulation model
GDP	Gross domestic product
GHG	Greenhouse gases
IEEM	Integrated Economic-Environmental Model
IFC	International Finance Corporation
IMF	International Monetary Fund
LCOE	Levelized cost of electricity

LTS4CN	Long-term Strategy for Carbon Neutrality
MOWRAM	Ministry of Water Resources and Meteorology
MPWT	Ministry of Public Works and Transport
MRD	Ministry of Rural Development
NCAP	National Cooling Action Plan
NDC	Nationally Determined Contributions
NEEP	National Energy Efficiency Policy
NPV	Net present value
NR	National and provincial roads
PDP	Power Development Plan
PDSI	Palmer Drought Severity Index
PPA	Power purchase agreements
PPAP	Phnom Penh Autonomous Port
PPP	Public-private partnership
PV	Photovoltaics
PWO	Private water operators
RCP	Representative Concentration Pathway
REDD+	Reducing Emissions from Deforestation and Forest Degradation
RGC	Royal Government of Cambodia
RS-IV	Rectangular Strategy Phase IV
SDG	Sustainable Development Goals
SOP	Standard operating procedure
SRSPF	Shock-Responsive Social Protection Framework
SSP	Shared Socioeconomic Pathway
UNDP	United Nations Development Program
UNFCCC	United Nations Framework Convention on Climate Change
VRE	Variable renewable energy
WASH	Water, sanitation, and hygiene

1
Introduction

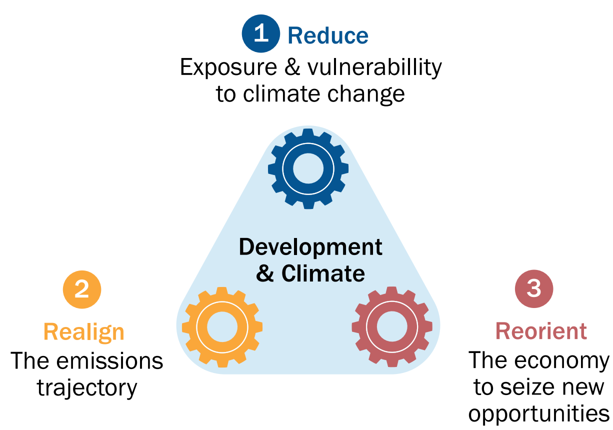
1. Introduction

The Cambodia Country Climate and Development Report (CCDR) provides analysis and recommendations on how Cambodia can achieve sustained development while responding to climate change and the low-carbon transition. Cambodia has high development aspirations, aiming to become an upper-middle-income country by 2030 and a high-income country by 2050. Achieving these goals will not be easy and will require a more inclusive, diversified, and productive economy. Climate change could amplify existing development challenges, with potentially sizable impacts on growth, trade, debt, and poverty reduction, as Cambodia faces one of the world's highest levels of exposure to floods and extreme heat. However, building climate resilience also offers an opportunity, not only to mitigate climate risks, but also to concurrently further development outcomes, as this report finds that adaptation measures in Cambodia have large development co-benefits. Moreover, Cambodia has made ambitious pledges in its Nationally Determined Contributions (NDC) and in its Long-term Strategy for Carbon Neutrality (LTS4CN). Delivering these commitments will require careful policy choices to mitigate transition risks and seize development opportunities. Finally, as a small, open economy highly dependent on trade and foreign direct investment (FDI), Cambodia will be highly affected by the accelerated decarbonization and changing consumption and production patterns in the rest of the world. With the right policy choices and a vibrant private sector, this could offer opportunities for export diversification, job creation, and growth.

While successful at achieving rapid growth and significant poverty reduction, Cambodia's current development path has increased, rather than reduced, vulnerability to both physical and transition risks from climate change. Current land-use patterns have led to high deforestation rates, with a 30 percent loss of forest cover over the past two decades, although there are recent signs of improvement. This has reduced the ability of ecosystems to regulate climate shocks, while also curtailing natural carbon sinks. Exposure to floods has also been exacerbated by building in high-risk flood locations. Cambodia has also lost almost 45 percent of its natural wetland area, which has increased exposure to floods, droughts, and wildfires. While energy-based emissions are still low, they have been rising faster than gross domestic product (GDP), locking in carbon-intensive infrastructure and making the economy more dependent on fossil fuels.

This report identifies actions to steer Cambodia's economy onto a more climate-compatible development path. First, Cambodia needs to *reduce* exposure and vulnerability to the physical impacts of climate change. At the same time, Cambodia will need to *realign* its emissions trajectory through a targeted policy response to achieve climate mitigation goals in ways that benefit development. Finally, Cambodia will need to *reorient* its economy to seize opportunities from trade, investment, and technological progress and to avoid transition risks. This CCDR will focus on these three *R's—reduce, realign, reorient*—to help Cambodia achieve its ambitious development vision, compatible with climate change and the low-carbon transition, both globally and at home (Figure 1). Doing so will necessitate mobilizing significant private and public investments, estimated by this report to require 1.7 percent of GDP over the next three decades.

Figure 1. This CCDR will address three interrelated climate and development priorities for Cambodia



The remainder of the report is structured as follows: Chapter 2 provides background on how development and climate interact in Cambodia and on the microeconomic and macroeconomic implications. Chapter 3 provides an overview of Cambodia's climate change policies and institutions. Chapter 4 provides policy recommendations and investment needs for specific sectors. Chapter 5 outlines options for mobilizing financing, and Chapter 6 concludes with priority actions and the path forward.

2

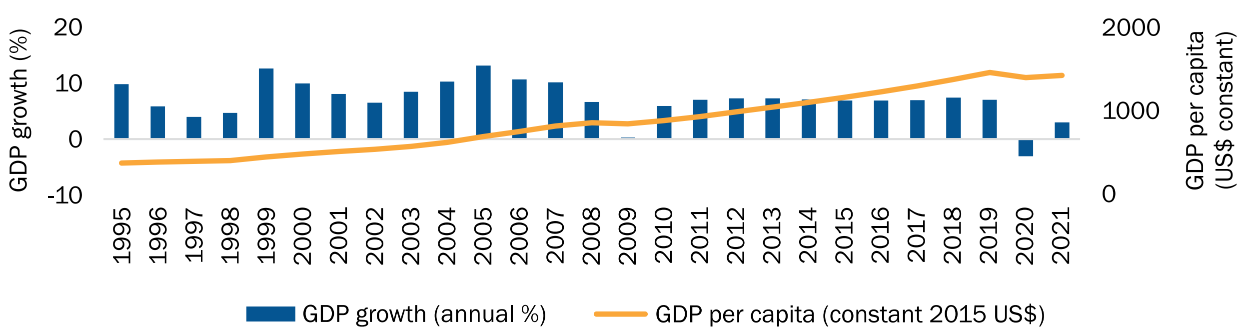
Understanding how development and climate interact in Cambodia

2. Understanding how development and climate interact in Cambodia

2.1. A strong development track record and high aspirations, but challenges ahead

Over the past three decades Cambodia has seen rapid inclusive growth and significant declines in poverty, underpinned by structural and spatial transformation. Cambodia achieved an average growth rate of 7.1 percent between 1995 and 2021 (Figure 2), accompanied by a large reduction in poverty, with the headcount rate falling over 50 percent between 2009 and 2019. Cambodia has also seen life expectancy rise from 57 years in 1998 to 71 years in 2018. A major engine of Cambodia's growth has been the structural transformation from lower-productivity agriculture into higher-productivity manufacturing and services. Cambodia's export-oriented garments and footwear manufacturing took off in the 1990s, and today garments, travel items, and footwear account for over two-thirds of goods exports and contribute nearly one-third of GDP. The country has also experienced spatial transformation, with about one-third of Cambodians migrating from rural areas between 2008 and 2019, driven by economic opportunities in cities and improved connectivity. Rapid physical capital accumulation was also a major contributor to growth, as was strong productivity growth within the agricultural sector.

Figure 2. Cambodia saw rapid economic growth of 7.1 percent on average from 1995 to 2021



Source: World Bank World Development Indicators.

The COVID-19 pandemic posed a temporary setback to progress, and the growth outlook remains lower than its pre-pandemic trend. The COVID-19 pandemic led to a 3.1 percent contraction in 2020, followed by a relatively subdued recovery with 3.0 percent growth in 2021. This was the first economic contraction in 25 years and was among the most pronounced in East Asia. The impact was exacerbated by the country's dependence on a narrow range of products, markets, and factor inputs, which were all disproportionately hit by the collapse in external demand. In 2022, GDP growth is estimated to have accelerated to 5.2 percent, but the longer-term projection is roughly 6 percent—below the growth rate of the past two decades. The deteriorating global environment also continues to pose challenges to Cambodia's open, export-driven economy.

Cambodia aspires to become an upper-middle-income country by 2030 and a high-income country by 2050. Reaching these goals would require sustained average annual growth rates of 13 percent between now and

2030 or 9 percent between now and 2050.[1] Cambodia's key development goals are articulated in the Royal Government of Cambodia (RGC)'s Rectangular Strategy for Growth, Employment, Equity, and Efficiency, currently Rectangular Strategy Phase IV (RS-IV) (2019–2023), and the National Strategic Development Plan. The Cambodia CCDR will focus particularly on the following priority elements of Cambodia's development vision:

1. **Transformative economic growth:** The RGC has laid out a vision for further *structural transformation* into higher value-added manufacturing. The Industrial Development Policy (2015–2025) aims to transform the country's manufacturing sector from labor-intensive to highly skilled by 2025. *Technological transformation*, through innovation and enhanced firm productivity, also features prominently in this strategy. The RGC has also prioritized further *spatial transformation* through urbanization and improved transport networks.
2. **Closing the critical infrastructure gap in water, sanitation, transport, and energy:** Currently, 78 percent of the population has access to the water supply, but only 69 percent can access basic sanitation. Only 11 percent of people have access to sewerage and wastewater treatment. The Ministry of Rural Development (MRD) has set a target to provide 100 percent clean rural water supply and sanitation services throughout the country by 2025. About 70 percent of provincial roads and more than 90 percent of rural roads remain unpaved and are in poor condition. The Cambodia Rural Road Policy 2020–2030 aims to provide all-season road access to 75 percent of all villages by 2030. Ensuring reliable, affordable, and improved energy security is also a priority, as stated in the Power Development Plan (PDP).
3. **Human capital formation:** The Education 2030 Roadmap targets an upper secondary completion rate of 45 percent by 2030. Currently, human capital indicators in Cambodia lag behind other lower-middle-income countries, underscoring the importance of this vision. For example, in 2020, a child born in Cambodia would be expected to be only 49 percent as productive when grown as they could be if they enjoyed quality education, good health, and proper nutrition. While overall school enrollment has risen across all levels, children are still not progressing from primary to secondary education in sufficient numbers.
4. **Diversification and resilience:** Cambodia's economy is highly concentrated in terms of sectors, export products, export destinations, and financing sources. It is highly exposed to shocks, as was revealed during the pandemic, when demand for tourism and garments dropped sharply, significantly impacting growth and reversing poverty reduction. As such, diversification is a high priority for the RGC and features prominently in the RS-IV and Cambodia's Trade Integration Strategy, which focuses on export diversification.
5. **Sustainability:** Cambodia's economy relies on its rich and diverse natural capital. However, these resources are degrading rapidly due to unsustainable economic activities, with significant declines in forest cover and losses of original natural wetlands. Recognizing this, sustainability is another rectangles in the RS-IV.

To achieve this vision, Cambodia can no longer rely on the same factors that drove strong growth and poverty reduction over the past two decades. Physical capital accumulation has been responsible for nearly two-thirds of Cambodia's real GDP growth since 1995, while the labor force has made only modest contributions to GDP growth (at only 8 percent, far lower than that of peers in Southeast Asia). Total factor productivity explained 28 percent of Cambodia's real GDP growth between 2004 and 2010 but has since

[1] This calculation uses the World Bank's population projections and the 2022 World Bank definition of a high-income country (gross national income per capita higher than US$13,205, Atlas method). Becoming an upper-middle-income country requires gross national income per capita higher than US$4,256 (World Bank, 2023a).

declined to just 5 percent, underscoring the need to reinvigorate productivity growth. Cambodia's eventual graduation from being a least developed country will also bring a progressive decline in donor financing and an erosion of preferential trade treatment. This change will require new efforts to diversify financing and improve competitiveness. While some nascent higher-value export products have emerged in recent years, most of the activities located in Cambodia still involve labor-intensive assembly and occupy a segment in global value chains that has relatively low added value. With tourism accounting for 70 percent of total services exports, there are opportunities to enhance value addition, especially in ecotourism.

Cambodia will need to both address structural constraints to growth and tackle new challenges. Several institutional, human capital, and infrastructure constraints continue to hamper competitiveness as well as the creation of a vibrant private sector in Cambodia. Cambodia's international integration could be strengthened by tackling costly trade-related regulatory barriers and insufficient trade-related infrastructure. Cambodia also has low domestic investment stemming from low savings. Even though it has maintained macroeconomic stability and remains at low risk of debt distress, public capital investment has declined and rapid growth in private debt and credit pose a growing risk to macro-financial stability. Improvements in the business environment will be necessary to increase private sector competitiveness and technology diffusion.

Climate change and the global net-zero transition will add to these challenges, but could also create opportunities, with significant implications for achieving Cambodia's development vision. Cambodia is highly exposed to climate change and physical risks are expected to grow. Sections 2.2 to 2.3 will lay out these physical climate risks and how they could impact Cambodia's development vision. Cambodia's recent development model has exacerbated these risks through rapid deforestation and the depletion of natural capital, while also increasing emissions and hindering productivity, as will be discussed in Section 2.4. However, adapting to climate change offers an opportunity to not only reduce the adverse consequences of climate change but also to achieve development objectives, as will be discussed in Section 2.5. Cambodia remains a minor contributor to climate change but has made ambitious mitigation pledges. The economic implications of achieving these pledges will be discussed in Section 2.6. The global low-carbon transition could offer Cambodia opportunities to diversify the economy and increase value addition, while globally declining costs of clean energy technologies also offer new opportunities for a lower-carbon growth path. These implications for development will be discussed in Section 2.7. After laying out these key implications of climate change for development, the remainder of the report will then present the solutions and path forward.

2.2. Cambodia faces high exposure to climate change and risks are projected to grow

Cambodia already faces high exposure to present-day natural hazards, with poorer households exposed to compound risks from floods, droughts, and heatwaves. Flooding is Cambodia's most common and recurring disaster. The Inform Risk Index ranks Cambodia as the world's fourth most flood-exposed country. It is highly exposed to riverine floods, particularly along the Mekong and Tonle Sap floodplains—home to 80 percent of the country's population. Cambodia is also highly exposed[2] to flash flooding after extreme rainfall, especially during tropical cyclone events and the monsoon and typhoon seasons. Major flooding events in Cambodia recur on average every five years. Analysis undertaken for this CCDR shows that built-up areas in Phnom Penh and large urban settlements along the Mekong Valley (Stung Treng, Kratie, Kampong Cham)

2 ”Exposure” is defined as the presence of people and physical assets in places that could be adversely affected by natural hazards. “Vulnerability” is defined as exposure that results in a negative outcome because people cannot cope.

are particularly exposed. Similarly, the highest mortality risk from flooding is along the Mekong River Valley, especially in the densely populated capital of Phnom Penh and the upstream Mekong Basin. Agricultural land is most at risk in the Tonle Sap region, particularly in Battambang, Banteay Meanchey, Kampong Thom, and Siem Reap, where more than 7,500 hectares of agricultural land is exposed to floods (Essenfelder et al. 2022).

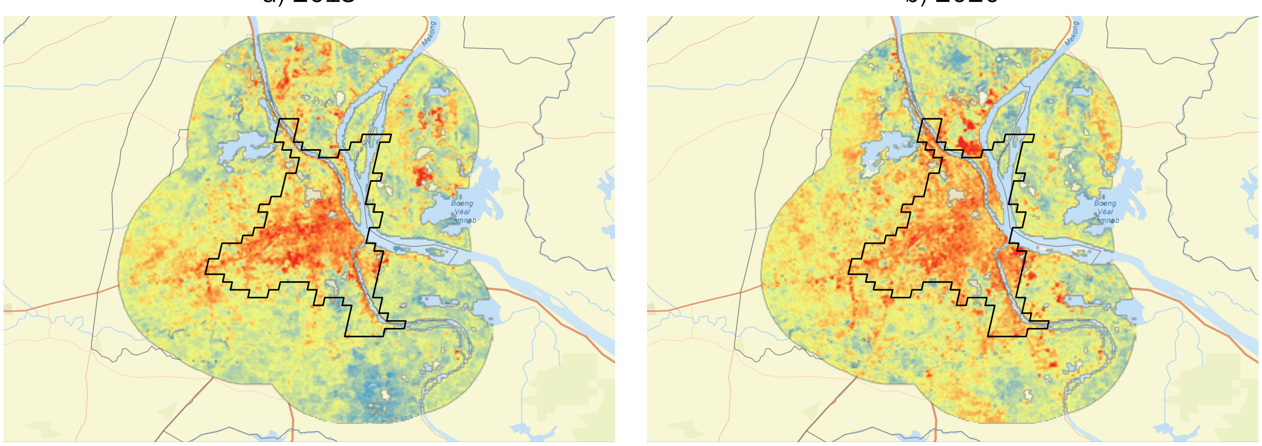
Variability in rainfall causes frequent droughts in Cambodia, with the southeast regions and Pailin province the most exposed. Cambodia's annual probability of severe drought is around 4 percent (CCKP, 2023). The most exposed provinces (Phnom Penh, Svay Rieng, Prey Veng, and Pailin) are severely affected every five to six years, with more than 30 percent of cropland experiencing drought stress. Maize and rice, Cambodia's two main crops, are equally exposed, thus compounding the risk of crop failures and food insecurity. Unfortunately, this risk materialized in 2015–2016, with a drought severely affecting 18 of 25 provinces and impacting over 2.5 million people. The event damaged crops and caused a loss of livelihoods in poor agricultural communities (CFE-DMHA, 2017).

Cambodia also faces high exposure to heat stress, and cities suffer from urban heat island effects, whereby urban areas face amplified high temperatures due to the built environment. Cambodia also experiences some of the highest temperatures in the world, averaging an estimated 64 days per year when the maximum temperature exceeds 35°C, placing it in the top 23 countries with acute exposure to extreme heat. In 2020, four cities in Cambodia–Poipet, Siem Reap, Phnom Penh, and Battambang—had mean urban temperatures of 36.7, 35.5, 35.2, and 35.2°C, respectively. This compares to 31.9°C in a sample of 100 cities in East Asia and the Pacific. In Phnom Penh and Siem Reap, urban heat island effects are strong; in 2020, the urban areas of these cities were 1.16 and 1.19°C hotter than the non-urban areas. Urban temperatures have risen rapidly in Phnom Penh (Figure 3).[3] The construction of roads and buildings increases the heat island effect as these infrastructure types absorb and re-emit the sun's heat more than natural landscapes (EPA, 2023). The urban poor are especially vulnerable to heat stress and associated health and productivity impacts as they often work outdoors and tend to live in overcrowded housing without adequate ventilation or cooling.

Figure 3. Phnom Penh suffers from the greatest urban heat island effect, with central urban temperatures 1.16°C higher than those on the outskirts of the city

Urban heat index (red = hotter, blue = cooler)

a) 2013 b) 2020



Source: World Bank analysis and 4EarthIntelligence (2023). These figures display the spatially disaggregated heat index for Phnom Penh over time. The black line denotes the city boundary. The urban heat island effect refers to the difference in temperature between the central urban area and the temperature 5 km outside the center.

[3] The construction of roads and buildings increases the heat island effect as these infrastructure types absorb and re-emit the sun's heat more than natural landscapes (EPA, 2023).

To a lesser extent, Cambodia also faces exposure to cyclones and landslides. Cambodia experiences tropical cyclones (typhoons) an average of six times a year between April and November. In September 2022, Tropical Cyclone Noru (Category 5) passed through northern Cambodia and caused 16 fatalities due to flooding along the Mekong River (AHA Centre, 2022). Analysis for this CCDR shows that agricultural land is particularly exposed in the provinces of Svay Rieng and Kampot, where approximately 230 hectares of agricultural land are expected to undergo some degree of destruction due to yearly tropical cyclones. Landslides occur in areas with porous soil and high soil moisture content, usually following prolonged heavy rainfall. The population and built-up areas in Koh Kong, Battambang, and Kampong Chhnang are particularly exposed to landslide hazards.

While the wealthy regions around the capital are expected to cope better with climate shocks, poorer regions along the Mekong, Tonle Sap River valley, and the Northwest are at greater risk. Analysis for this CCDR, shown in Figure 4, which overlays climate hazard and exposure maps with poverty maps from the National Institute of Statistics (2022), suggests that there is a high vulnerability in the areas along the Mekong and Tonle Sap, where a high share of poorer households are exposed to natural hazards. The adverse impact of flooding on agricultural land in poor communities is expected to be highest in the northwestern parts of the country. High poverty rates in the northern and western Cambodian provinces also coincide with significant population exposure to heatwaves. Recurring droughts affect large areas of Cambodia, particularly the central regions around the Mekong River and Tonle Sap, which are also considerably impacted by floods and heat stress. The compounding effect of frequent agricultural drought poses a significant risk to the poorest and most vulnerable households in these regions, who suffer disproportionately from livelihood-related shocks, such as crop and livestock losses.

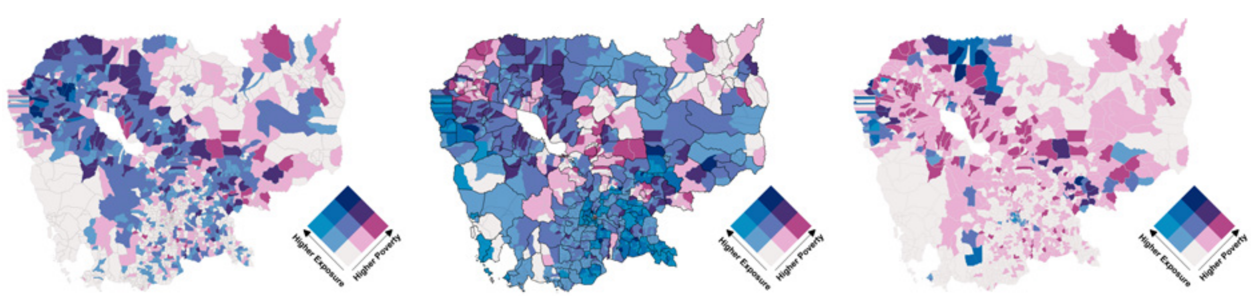
Figure 4. Exposure of poor households to extreme weather events is highest in the Mekong, Tonle Sap Valley, and the Northwest

Overlap between poverty and exposure to extreme weather events

a) Exposure of poor households to agricultural losses from floods

b) Exposure of poor households to agricultural losses from droughts

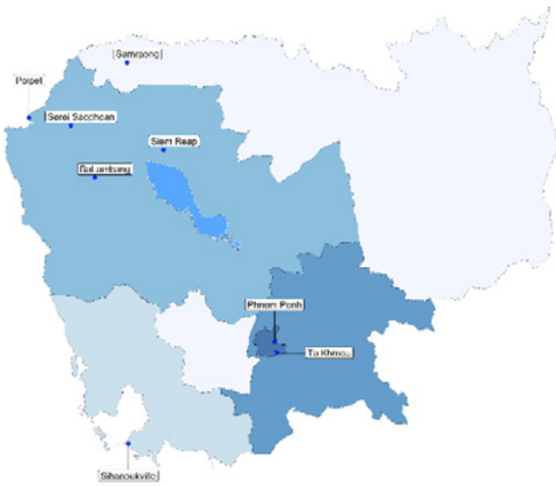
c) Exposure of poor households to heat stress



Source: Essenfelder et al. (2022). The authors calculated the expected exposure of agricultural land and population to floods, drought, and heat stress by overlaying population and agriculture maps with the Fathom probabilistic flood data set (Fathom, 2023), the FAO's Agricultural Stress Index (FAO, 2023), and VITO's extreme heat probabilistic data set (Fraser, 2017). Then, they overlaid the resulting maps with poverty maps from the National Institute of Statistics (2022).

Women and persons with disabilities are the most vulnerable to climate change impacts, especially those living in northeastern and southwestern rural areas. In Cambodia, women are less resilient to climate impacts than men (ActionAid Cambodia, 2018). Women have fewer adaptation possibilities, less access to human capital resources, and lower empowerment. More women than men live below the poverty line, limiting their access to resilient housing, safe water, and sanitation. Women's adult literacy is also 11.5

Figure 5. Social inclusion is lower in the northeastern and southeastern rural regions
Social inclusion index (darker=more inclusion)



Source: Pecorari et al. (2022). Note: The authors define social inclusion as the process of creating opportunities for all people. Their index estimates the population share having access to key markets and services, including labor force participation and access to water, sanitation, electricity, internet, healthcare, administrative services, and school enrollment. The calculation relies on the LSMS (2019) and Asian Barometer surveys.

percentage points lower than men's (UN Women and CDRI, 2021), likely hampering their ability to understand and act on critical information and adopt adaptation solutions, such as early warning systems and access to safe places (Setyowati et al., 2023). Analysis for this CCDR shows that this gender gap is likely higher in the southwestern and northeastern rural areas, where women's empowerment and social inclusion indexes are lower (Figure 5). Persons with disabilities are particularly at risk of food insecurity in the aftermath of disasters, as they are often not able to work and have limited mobility, making them dependent on community and outside support for food aid and evacuation (ActionAid Cambodia, 2021).

Climate change is projected to increase the frequency and intensity of flooding, sea level rise, and heat stress. Climate projections, including rainfall over 10 millimeters, maximum five-day precipitation, and extreme wet-day precipitation, suggest that the intensity of precipitation events is likely to increase. Increased intensity of precipitation is likely to increase flood risk considerably. Along the coastlines of Cambodia, sea level rise could also have sizable implications, particularly for the Koh Kong and Preah Sihanouk provinces. This region faces the highest risk of sea level rise by the midcentury, increasing by at least 19 centimeters under all climate change scenarios. Under high-emission scenarios, sea levels could rise by 40 to 80 centimeters. The implications of sea level rise need further analysis. Climate projections also suggest that heat stress will significantly worsen in Cambodia. The Cambodia Climate Country Risk Profile (2021) projects that average daily temperatures will rise by 0.9–1.7 degrees under RCP2.6-8.5 scenarios by 2040–2059 compared with the 1986–2005 baseline. The projected days with a Wet Bulb Global Temperature—a combined measure of humidity and heat—over 30°C could increase by around 4–7 percent by midcentury under different scenarios. Uncertainty remains high for drought projections, but all emissions pathways modeled in the risk profile indicate an increase in the median annual probability of droughts from 4 percent to 9 percent.

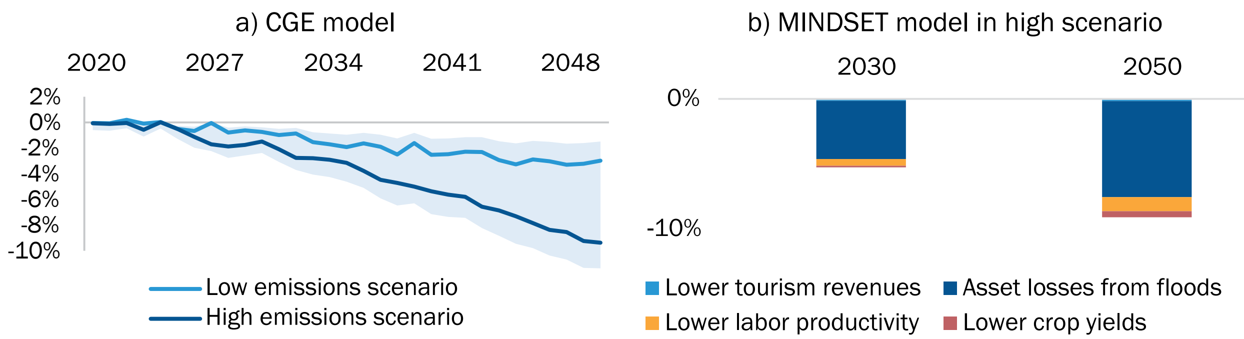
2.3. Climate change could have wide-ranging social and economic consequences

2.3.1. Climate change could have macro-critical implications

Macroeconomic modeling suggests that, without action, the impacts of climate change could lower Cambodia's GDP by around 3 to 9 percent by 2050. Figure 6 provides estimates of the annual impacts of climate change on GDP from two macroeconomic models: CGE and MINDSET. The models and climate scenario are described in Box 1 and more detailed technical information on the models is provided in the Technical Appendix. Results are relative to a business-as-usual (BaU) scenario without climate change impacts explicitly modeled. Both models incorporate estimates of asset losses from floods and estimates of the impact of climate change on labor productivity, crop yields, and tourism, with each of these impact channels discussed in more detail in Section 2.3.3 below. The MINDSET model, which is for a single year only, includes asset losses from a one-in-ten-year flood (of which three could be expected between 2020 and 2050). The CGE model takes average annual asset losses from floods. Both models show similar aggregate impacts from climate change by 2050. In the CGE model, the impacts range from 3.0–9.4 percent in the low and high climate change scenarios, respectively. In the MINDSET model, impacts reach a similar 9.1 percent in the high scenario. In the MINDSET model, it is possible to disaggregate effects by impact channel. The results demonstrate that the asset losses from floods have the greatest impact, accounting for 7.4 percentage points of the total 9.1 percent loss. A sensitivity analysis included in the Technical Appendix shows that this impact from floods would fall to 2.9 percentage points for a one-in-a-two-year flood, and therefore impacts in any given year depend on the magnitude of the floods that occur.

Figure 6. Climate change could lower GDP by 3.0–9.4 percent by 2050

GDP impacts of climate change relative to a no-climate change baseline, without adaptation (%)



Note: Panels a) and b) include asset losses from floods, impacts of heat on labor productivity, impacts of climate change on tourism, and impacts of climate change on agriculture crop yield losses, without adaptation measures. In panel a), asset losses are the average. In panel b), asset losses are based on losses from a 1 in 10-year flood, excluding supply chain effects. Panel c) includes the direct effects of the floods, knock-on supply chain effects, and demand-side multiplier effects, with limited adaptation possibilities. Supply chain flexibility is the length of time that companies can continue producing without receiving new inputs, for example by holding reserve stocks; the maximum on the x-axis is six weeks.

In a year with a high-impact flood, the knock-on effects from flooding could be even higher but depend heavily on how businesses anticipate and prepare for floods. The foregoing results excluded the indirect economic disruption from floods. To further understand the potential macroeconomic consequences of high-impact floods and how they vary depending on how businesses prepare, the MINDSET model is also used to estimate the impacts of floods of different return periods including their knock-on supply chain effects and demand-side multiplier effects. The modeling estimates the impacts under a range of scenarios of business preparation, in terms of the amount of stock held by businesses. The impacts of smaller floods can be mostly offset by businesses preparing adequately. However, even for floods that occur once every ten years, losses could reach up to 7–11 percent of GDP, with lower impacts where businesses are more prepared. A one-in 83-year flood could knock off 20–23 percent of GDP in one year. In the 30 years between 2020 and 2050, there is a 33 percent chance of such an event occurring. These results highlight the macro-criticality of adaptation measures and disaster risk financing (DRF).

Box 1. Macroeconomic and microsimulation modelling frameworks used in this report

As macroeconomic models have different strengths and weaknesses, this CCDR uses several macroeconomic models to evaluate the impacts of climate change and low-carbon policies on Cambodia's economy. The two primary macroeconomic models used (CGE-BOX and MINDSET) are based on recent social accounting matrices that show economic interactions between sectors at a high level of detail, but have different assumptions about how the economy works. As both models are limited in their ability to study the forestry and other land use (LULUCF) sector, it is separately modeled using the Integrated Economic-Environmental Model (IEEM) + Ecosystem Services Modeling (ESM) model, which incorporates ecosystem services. The following models and methodological approaches are used in this report:

- **CGE-BOX** is a dynamic recursive Computable General Equilibrium (CGE) model that focuses on supply-side factors and assumes that the economy always operates at full capacity; results, therefore, represent a redistribution of the available resources. It is a global CGE model based on the Global Trade Analysis Project (GTAP) database (Aguiar et al., 2019).
- **MINDSET** is a post-Keynesian single-year model developed by the World Bank that focuses on the demand side and assumes that the economy is always operating below full capacity, meaning that more resources (such as labor) may be brought into production when needed.
- **IEEM + ESM**: For modelling the impacts of Cambodia's LULUCF policies, the IEEM linked with spatial land use, land cover, and ESM (IEEM+ESM; Banerjee et al., 2019a; Banerjee et al., 2020). IEEM is also a dynamic recursive CGE model but for a single country only.
- **Results for the impacts of climate change on poverty** are estimated in two separate ways. The first "general equilibrium" approach uses microsimulation modelling in conjunction with results from CGE-BOX. The second "partial equilibrium" approach directly estimates the relationship between climate hazards and consumption and combines it with estimates of how consumption affects poverty. Both approaches have strengths and weaknesses. Due to the assumptions on market clearing, the general equilibrium approach is expected to describe long-term outcomes better and typically represents a lower bound of effects, while the partial equilibrium analysis performs better on short- and medium-term outcomes.

This report primarily focuses on two sets of Shared Socioeconomic Pathway (SSP) and Representative Concentration Pathway (RCP) emissions scenarios:

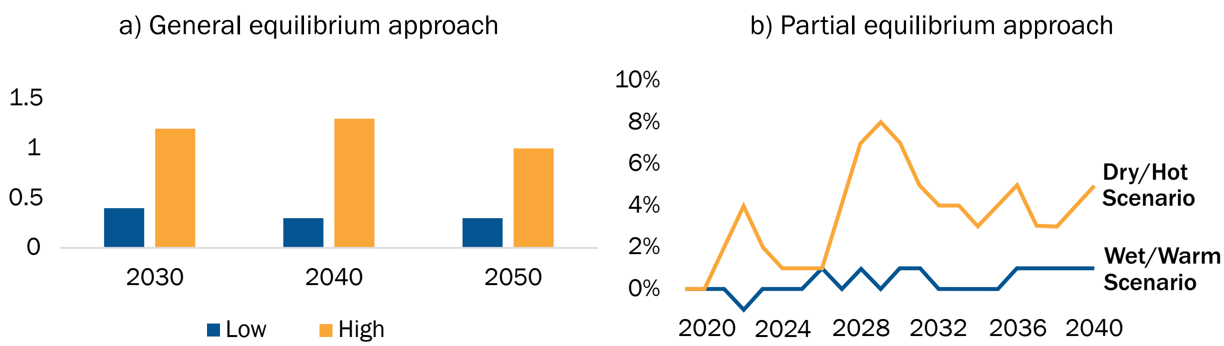
- **Optimistic/low climate change scenario**: SSP1-1.9 or RCP2.6. Represents reductions in greenhouse gas emissions in line with limited 1.5°C of warming by 2100.
- **Pessimistic/high climate change scenario:** SSP3-7.0 or RCP8.5. Scenario in which warming reaches 4°C by 2100, due to lax climate policies or a reduction in ecosystems and oceans' ability to capture carbon.

In some cases, however, the CCDR built upon prior modelling efforts, and it was not possible to harmonize scenarios. In addition, to capture the broadest range of climate change effects across GCMs, some of the modelling also considers impacts under possible wet vs. dry and hot vs. warm GCM outcomes. The modelling approaches and specifications are discussed in more detail in the Technical Appendix.

2.3.2 Climate change could reverse progress in poverty reduction

Without adaptation, the impacts of climate change on poverty could range from 0.3 to 6.0 percentage points by 2040, depending on the climate scenario. Panels a) and b) in Figure 7 provide estimates of the annual impacts of climate change on the poverty rate using two different methods, as outlined in Box 1. Panel a) presents the results using the general equilibrium approach, which combines the CGE results with microsimulation modeling. Using this method, climate change translates into a 0.3 percentage point rise in the poverty headcount rate by 2040 in the low climate change scenario and 1.3 percentage points in the high scenario. This impact is primarily driven by stronger declines in earnings in the service and agricultural sectors, which disproportionately affect poorer households. This approach is only able to pick up longer-term impacts on the poverty of average climate change scenarios driven only by the impact channels included in the CGE modeling, so could be seen as the lower bound of the potential impact. Panel b) in Figure 7 presents results using an alternative approach that picks up shorter-term impacts for a wider range of climate scenarios. This approach combines survey data with a satellite-based measure of drought and uses the estimated drought-consumption relationship to forecast the change in poverty rates. The results show that in a best-case (wet-warm) scenario, poverty would only increase by 1 percent by 2040 since drought patterns would change very little. However, in a worst-case (dry-hot) scenario, poverty could increase by six percentage points. Results are higher using this approach, reflecting the worst-case scenario and thus the six percentage point impact could be seen as the upper bound of the potential impact on poverty.

Figure 7. Climate change could increase the poverty rate by up to six percentage points by 2040
Impact of climate change on poverty rates (percentage points relative to baseline)



Source and notes: Panel a) combines the CGE Box estimates with microsimulation modeling to obtain impacts on poverty. Panel b) (Roy et al. (2023)) combines Cambodia's socioeconomic surveys with satellite-based measures from ERA, TerraClimate, and CHIRPS to estimate the impact of weather shocks, including drought, on consumption. The negative relationship estimated for drought (PDSI<-2.7) is then used to forecast poverty rates. The dry/hot scenario in red relies on the cmcc-cm2-sr5, cnrm-esm2-1, and kace-1-0-g climate models. The wet/warm scenario in red relies on the inm-cm4-8, mpi-esm1-2-hr, and mpi-esm1-2-lr climate models.

2.3.3. Climate change could have a wide range of knock-on effects on development outcomes

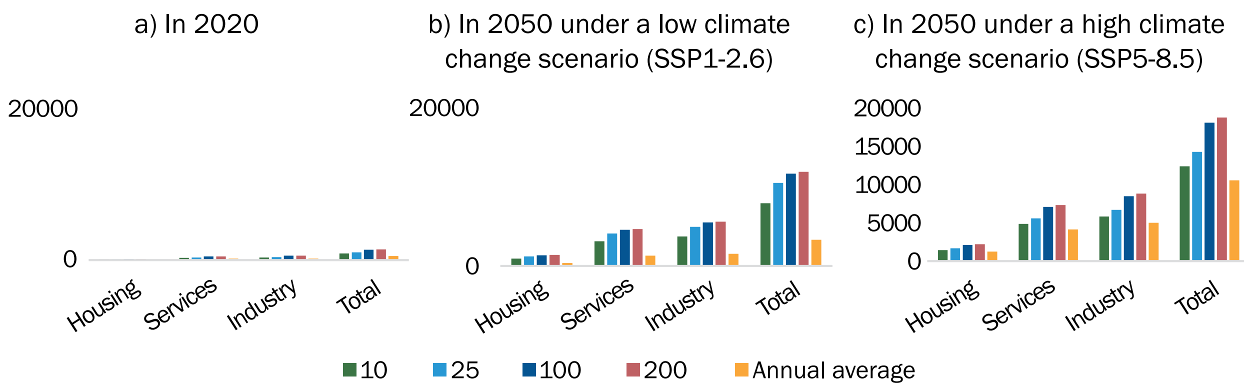
Underpinning these macroeconomic impacts are a wide range of direct and indirect knock-on effects of climate change throughout the economy, which have implications for each element of Cambodia's development vision. This section provides new modeling or empirical evidence on the microeconomic impact channels from climate change in Cambodia, which underpin the foregoing macroeconomic results. There are a wide range of potential knock-on or cascading impacts of climate shocks. This report does not attempt to cover all potential impacts, but rather highlights some of the most important prospective or quantifiable ones.

Climate change is projected to increase the frequency of high-impact floods, with losses to physical infrastructure

Without adaptation measures, physical assets in manufacturing, services, and housing face high losses from floods. Probabilistic modeling for this CCDR shows that the estimated asset losses from a 1-in-25-year flood in 2020 already total US$412 million in manufacturing, US$344 million for services, and US$108 million for housing (Figure 8). Annual average losses in 2020 are estimated to be approximately US$530 million. Climate change is projected to increase the frequency of high-impact floods, resulting in higher average losses. By 2050, annual average losses are projected to increase to US$3.3 billion under an optimistic climate change scenario.[4] Under a pessimistic climate change scenario, annual average losses stand at around US$10.6 billion. This is assuming a worst-case scenario with no risk-informed land-use planning and thus high construction levels in flood risk areas.

Figure 8. Climate change is projected to substantially increase asset losses from floods

Asset losses from floods of different return periods (US$, millions)



Source and notes: World Bank modeling. This optimistic low scenario takes a lower tail risk of the scenario closest to the 20th percentile from SSP1-RCP2.6. The pessimistic high scenario takes the upper tail risk of the scenario closest to the 80th percentile from SP5-RCP8.

Floods cut off access to critical services, delay supply chains, and harm competitiveness

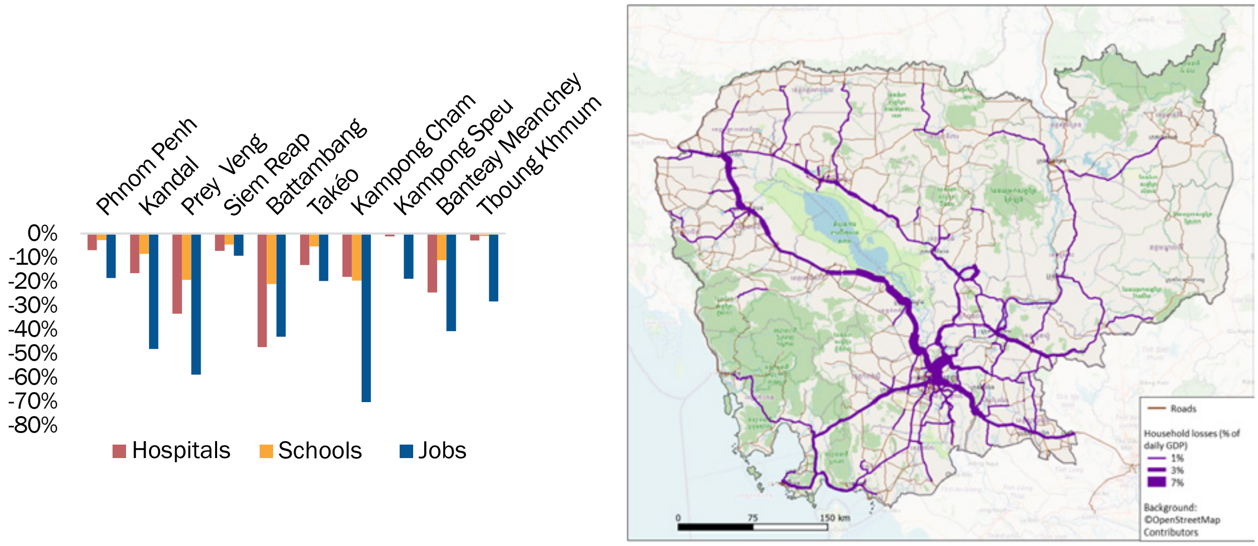
Flooding of roads in Cambodia has been shown to substantially increase travel times, cutting off access to hospitals and schools and causing critical delays to supply chains and freight transport. A 1-in-50 year flood lowers the share of people with access to a referral hospital within 60 minutes' travel time by 47 percent in Battambang, 34 percent in Prey Veng, and 25 percent in Banteay Meanchey (Alegre et al., 2020). Likewise, it lowers the share of people with access to a high school within 30 minutes' travel time by 21 percent in Battambang, 20 percent in Kampong Cham, and 20 percent in Prey Veng. These disruptions to education could have cumulative and compound effects on human capital accumulation in these provinces. Flooding can also cause critical delays to supply chains and freight transport. Cambodia relies heavily on key road corridors for its cross-border trade and logistics. A seven-day closure of key road corridors by a 50-year flood would result in a 5 percent indirect cost increase for international trade partners for each day of disruption from freight rerouting or blockage. The economic impact increases nonlinearly as the duration of the flood disruptions increases (Figure 9).

[4] This optimistic scenario takes a lower tail risk of the scenario closest to the 20th percentile from SSP1-RCP2.6. The pessimistic scenario takes the upper tail risk of the scenario closest to the 80th percentile from SP5-RCP8.

Figure 9. Flooding cuts off access to schools, hospitals, and work (left) and disrupts supply chains (right)

a) Accessibility loss from a 1 in 50-year flood

b) Losses from a 1-week road closure



Source and notes: Alegre et al., (2020). In panel a), "accessibility to schools" is defined as the percentage of people with access to high schools within 30 minutes, "accessibility to hospitals" is defined as the percentage of people with access to referral hospitals with 60 minutes, and "accessibility to jobs" is defined as the number of jobs accessible within 60 minutes. In panel b), the thickness of a road is proportional to the estimated indirect losses incurred by Cambodian households if that road gets disrupted for one week, expressed as the loss of daily consumption triggered by its disruption.

Climate change is projected to lower crop yields, with implications for nutrition, food security, and poverty

Without adaptation measures, climate change is projected to lower yields for rice, maize, and cassava, with particularly strong negative impacts for rainfed rice. Analysis for the CCDR suggests that average yield losses of 21 percent could be experienced for rainfed rice under an optimistic climate change scenario by 2030–2060 and up to 30 percent in a pessimistic climate change scenario (Figure 10a). Climate change will have negative impacts on dry season irrigated rice yields, albeit less severe than for wet season rice production. Dry season rice in Cambodia is irrigated, thus less dependent on rainfall variability. Yield losses of 2–3 percent could be expected under the same climate change scenarios. Rainfed maize and cassava production will also be affected, with yields for rainfed maize projected to fall by 6–9 percent in these scenarios and rainfed cassava by 5–11 percent. The provinces with higher climate hazards are the most productive ones in terms of agriculture, situated in the Mekong River Basin, which could have implications for food security. CCDR analysis also shows that adverse impacts are disproportionately higher for the poor and small landholders, who have less access to adaptation solutions such as storage facilities or irrigation (Monin, 2021).

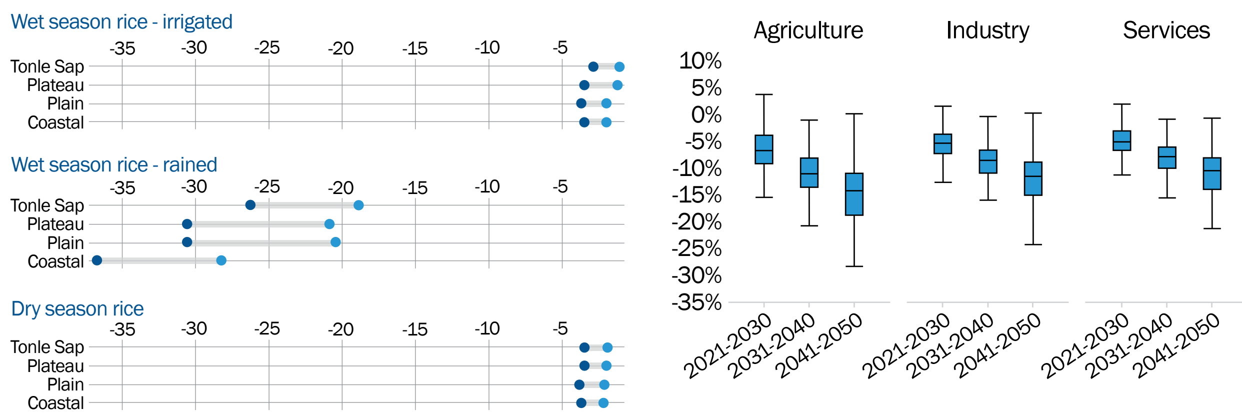
Climate change is projected to lower labor productivity and tourism revenues

Climate change could lower labor productivity, potentially slow growth, lower competitiveness, and lower tourism inflows, with implications for the current account balance. Analysis for this CCDR finds that climate change could lower labor productivity by 8 percent in an optimistic climate change scenario by midcentury or up to 20 percent in a pessimistic climate change scenario. Across macroeconomic sectors, agriculture is expected to experience the highest labor productivity decline from 2041–2050, followed by industry and services (Figure 10b). Analysis conducted for the CCDR also shows that high temperatures or drought during the growing season decrease yields and, in turn, the share of workers in manufacturing and services, likely through a strong drop in local demand for non-agricultural goods and services (Liu et al., 2023; Roy et al., 2023). Analysis for this CCDR also estimates the potential impact of changing climatic conditions on leisure tourism inflows in Cambodia, following the approach developed by Hamilton et al. (2004). Results show that tourism revenues on average could decline by around 8 percent by 2050 in a low climate change scenario and by up to 17 percent in a high climate change scenario, compared to the baseline scenario. For domestic tourism, these impacts range from 4–11 percent in 2041–2050. For international tourism, these effects range from 12–33 percent in 2041–2050 relative to the baseline.

Figure 10. By the midcentury, climate change is projected to lower crop yields and labor productivity by up to 30 percent and 20 percent, respectively, under a pessimistic high climate change scenario
Climate change impacts relative to baseline (%)

a) Crop yield losses in 2031–2060 under optimistic (●) and pessimistic (●) scenarios

b) Impacts on labor productivity for optimistic and pessimistic scenario ranges



Source and notes: World Bank and FAO modeling. For panel b) the lines reflect the GCM range, while the shaded box shows the range between the wet/cool mean (with the lowest impacts) and the dry/hot mean (with the highest impacts).

Climate change could have adverse implications for health, with compound impacts on human capital

Climate change could adversely impact Cambodians' health through many climate-sensitive channels, from nutrition to vector- and water-borne diseases and heat-related morbidity and mortality. Analysis for this CCDR shows that average daily precipitation of 20 millimeters instead of 5 millimeters increases diarrhea incidence in the following month by 56 percent (Aguilar-Gomez et al., 2023). A monthly temperature of 35 °C instead of 28 °C increases cough incidence by 55 percent and diarrhea incidence by 83 percent. Projections conducted for this CCDR find that diarrhea incidence in children could increase by four percentage points by 2050 due to the rise in temperature. All provinces would be affected, from a 3.1 percentage point increase in Siem Reap to a 4.4 percentage point increase in Mondulkiri. In addition, modeling for this CCDR also projects that these health impacts from climate change could lower the number of hours worked by each person in a year by 1.1 percent to 1.7 percent in low and high scenarios, respectively. Stunting and undernutrition are major climate-sensitive concerns in Cambodia, where the average stunting rate is 22 percent, according to the 2021–2022 dynamic health survey. Climate change also has a direct influence on the spread of vector-borne diseases circulating in Cambodia, including malaria, dengue, and Japanese encephalitis (Kulkarni et al., 2022).

2.4. Cambodia's recent development model has increased both emissions and climate risks

While Cambodia has low per capita and absolute greenhouse gas (GHG) emissions, it has the fastest emissions growth rate in Southeast Asia, exposing the economy to transition risks. Cambodia's per capita GHG emissions of 4.3 tons of carbon dioxide equivalent (tCO_2e) in 2019 were under half of the OECD average of 10.8 tCO_2e, and Cambodia's share of global GHG emissions was only 0.14 percent in 2019 (Table 1). Yet GHG emissions grew at an average annual rate of 8 percent from 2010–2019, outstripping GDP growth. Today, Cambodia's economy is among the most carbon-intensive in Southeast Asia, emitting more carbon per unit of GDP than all peer countries except Myanmar. The fastest growing sources of GHG emissions over the past decade have been electricity and heat generation, which grew by 20 percent annually from 2010–2019, due to an increasing use of coal power generation, and industry, with an annual growth rate of 17 percent. This partly reflects rapid development and rising incomes, but also reflects the growth model that is increasingly carbon-intensive and reliant on construction and real estate. Motorization and the limited expansion of public transport networks are also driving up emissions, with the number of registered vehicles in Cambodia increasing by 31 percent in 2018. Finally, urbanization is increasingly following a low-density path, with the emissions intensity of cities growing rapidly. These patterns of development are creating lock-in effects that increase transition risks, while also depleting natural capital and holding back productivity growth.

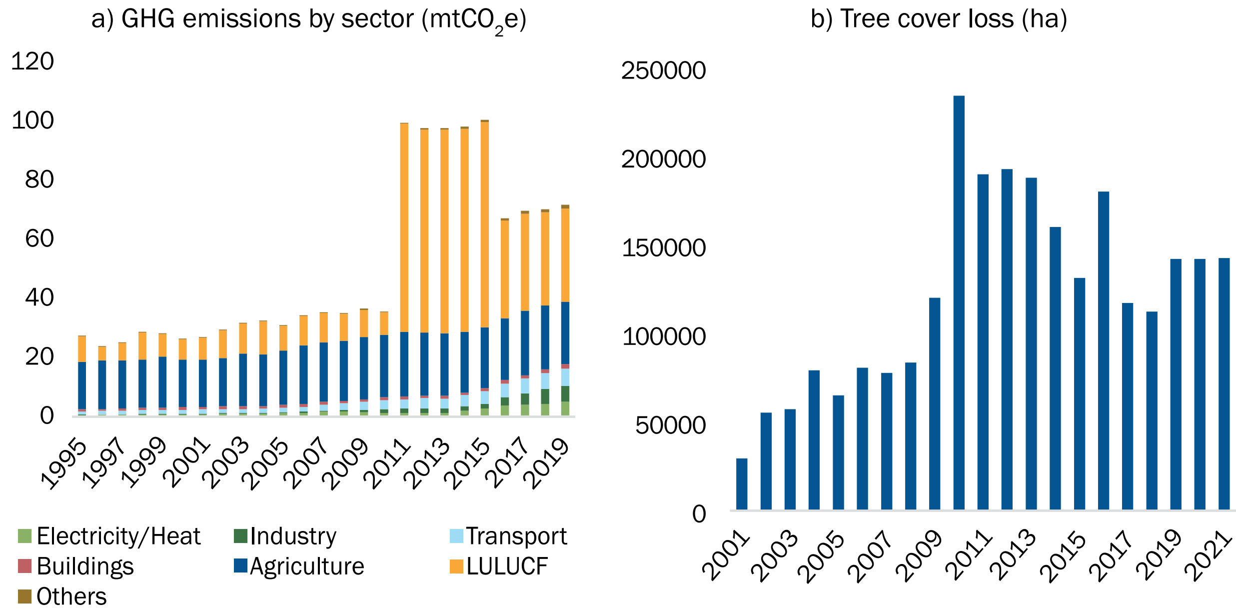
Table 1. Cambodia has low but rapidly rising GHG emissions

	GHG emissions per capita (tCO_2e per person)	Carbon intensity (tCO_2e per US$ million of GDP)	Total GHG emissions ($mtCO_2e$)	Annual emissions % growth rate (2010–2019)
United States	17.6	270	5771	-0.5
Malaysia	12.4	1081	396	0.8
OECD members	10.6	258	13797	-0.6
China	8.6	844	12055	2.2
Indonesia	7.2	1751	1960	6.3
Thailand	6.3	804	437	4.4
Lao	5.5	2104	39	3.6
Vietnam	4.5	1326	438	5.2
Myanmar	4.5	3537	243	0.5
Cambodia	**4.4**	**2649**	**72**	**8.2**
Philippines	2.2	628	237	3.5

Source and notes: Climate Analysis Indicators Tool. Emissions are all GHG emissions and estimates for 2019. Annual emissions growth is calculated as the compound annual growth rate.

Cambodia has seen rapid rates of deforestation, which has both been a major driver of emissions and has exacerbated physical climate risks. Cambodia has had one of the world's highest deforestation rates, experiencing a 30 percent loss of forest cover over the past two decades, according to satellite data from Global Forest Watch (2022). Data from the Climate Analysis Indicators Tool , which is based on the RGC's emissions inventories, shows that the land use, land-use change, and forestry (LULUCF) sector was the greatest contributor to GHG emissions in 2019, accounting for 44 percent of gross emissions, as is shown in Figure 11a. This inventory uses land-use matrixes for four-year intervals, and hence this emissions series exhibits large discontinuities around these matrix years. According to this inventory, deforestation accelerated in the early 2010s, as will be discussed in detail in Chapter 4.2.1. Box 2 outlines these data sources and methods for measuring LULUCF emissions in Cambodia. As well as raising emissions, deforestation has led to the loss of valuable ecosystem services, resulting in higher soil erosion, lower water regulation, and increased risk of floods and landslides. Cambodia's second largest source of GHG emissions in 2019 was agriculture, contributing 30 percent of the gross total, followed by transport at 8 percent, industry at 8 percent, and electricity and heat at 7 percent.

Figure 11. LULUCF is the largest contributor to Cambodia's gross GHG emissions (left), with the country experiencing significant tree cover loss over the past decade (right)



Sources: Panel a) Climate Analysis Indicators Tool emissions data; Panel b): Global Forest Watch satellite data. Notes: The discrepancies between the satellite data and official emissions data reflect the fact that the emissions data is collated as part of a government-led inventory process that estimates potential forest loss, with estimates differing from satellite-based data. Government-led forest cover inventories are published every five years, and GHG emissions are estimated by interpolations over those five-year periods and by projections.

Box 2. Measuring LULUCF emissions in Cambodia

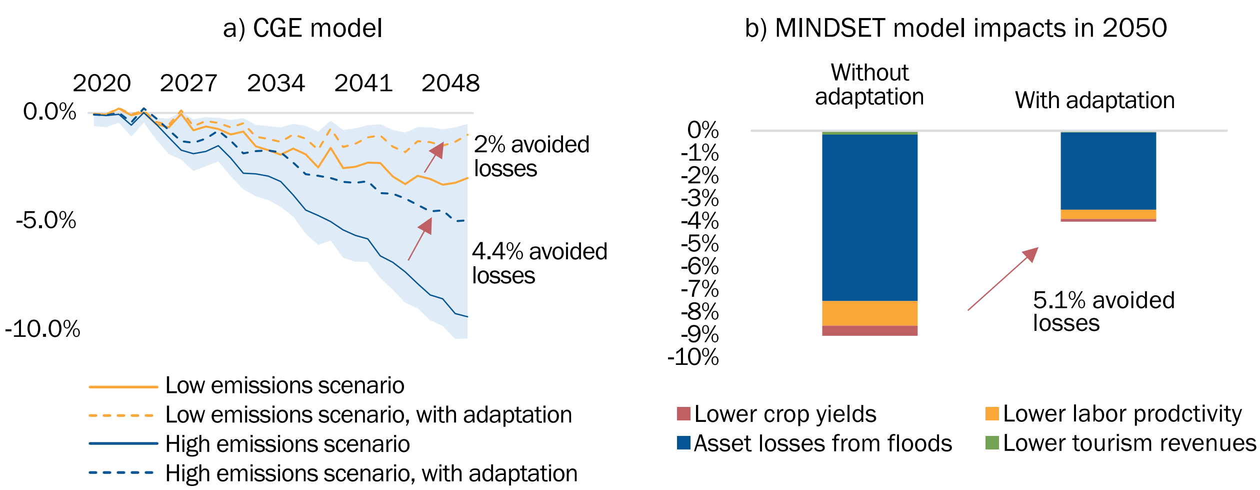
The primary emissions data source used in this report is from the Climate Analysis Indicators Tool (ClimateWatch), which is used across World Bank CCDRs. For Cambodia this dataset is constructed from the RGC's National GHG Emissions Inventory Report (2019) along with Cambodia's submissions to the UNFCCC. The 2019 edition of Cambodia's GHG inventory includes emissions for 1994–2016 of the gases CO_2, CH_4, N_2O, and HFC and follows the 2006 edition of the IPCC Guidelines for estimating the GHG emissions and removals of the inventory. For the land-use categories, data is taken from the report on forest reference level (FRL) provided by Cambodia to the UNFCCC within the REDD+ framework. This includes a set of land use matrixes for 2006, 2010 and 2014, which estimate forest area and different types of land-use conversion. Emissions factors for different forest area types are estimated based on different scientific references and national expertise and are estimated for above ground and below ground biomass. As this data relies on land-use matrices, which are constructed for four-year intervals, the estimates differ from satellite-based measures of forest cover, which capture annual fluctuations.

The loss of natural wetlands and patterns of urban development have exacerbated potential physical climate risks. Wetlands are also crucial to building climate resilience, sequestering carbon, and providing ecosystem services. However, Phnom Penh's urban expansion has come at the cost of critical natural wetlands—mangroves, streams, ponds, swamps, and marshes—with the country having lost almost 45 percent of its natural wetland area. Recent patterns of urban development that put people "in harm's way" have also increased physical climate risks. With scarce land and limited planning controls, new urban residents are increasingly located in flood-prone areas, such as river basins and flood plains. According to a recent World Bank study, the number of settlements defined as "very high risk"—the highest flood risk category—increased by 251 percent between 1985 and 2015 (Rentschler et al., 2022).

2.5. Adaptation measures could lower the economic impacts of climate change

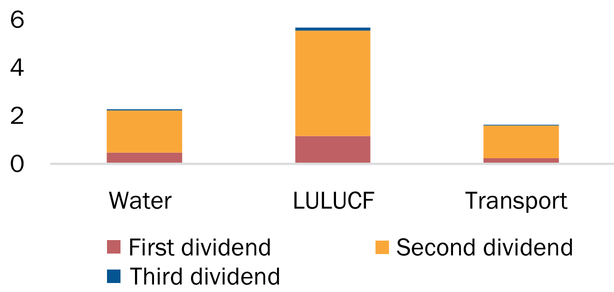
Model-based estimates indicate that well-targeted adaptation measures could at least halve the GDP losses from climate change. Climate adaptation refers to changes in processes, practices, and structures to moderate potential damage or benefit from opportunities associated with climate change (UNFCCC, 2022). Although adaptation measures can never fully offset the wide-ranging impacts of climate change, they can attenuate many of the negative effects. This CCDR identifies a range of measures that both the government and private entities could take to lower the impacts of climate change, which will be discussed in Chapter 4. This section evaluates the macroeconomic consequences of a select number of adaptation options that were feasible to incorporate into the macroeconomic modeling frameworks. These include the benefits of building infrastructure that is resilient to flooding, risk-informed land-use planning, increased irrigation, and cooling measures to protect the health of indoor workers. The results in Figure 12 show that, overall, these measures could reduce the impacts of climate change on GDP by 52–66 percent. In the CGE model GDP losses in 2050 could be reduced from 3 percent to 1 percent (a 66 percent reduction) in the low scenario or from 9.4 percent to 4.9 percent (a 52 percent reduction) in the high scenario. In the MINDSET model, GDP losses in 2050 are very similar, declining from 9.1 percent to 5.0 percent (a 55 percent reduction).

Figure 12. Adaptation measures could at least halve the GDP loss from climate change
Impacts of climate change on GDP relative to a no-climate change baseline, with and without adaptation (%)



Note: Panels a) and b) include asset losses from floods, impacts of heat on labor productivity, impacts of climate change on tourism, and impacts of climate change on agriculture crop yield losses, without adaptation measures. In panel a), asset losses are the average. In panel b), asset losses are based on losses from a 1 in 10-year flood, excluding supply chain effects. Adaptation measures include risk-informed land-use planning, resilient transport infrastructure, climate-smart agriculture, and air conditioning.

Figure 13. Every US$1 of adaptation spending provides US$3 of returns from its "triple dividend"
BCR of existing adaptation projects in Cambodia



Source: World Bank analysis.
Note: First dividend refers to avoided losses from climate change, second dividend refers to induced economic benefits, and third dividend refers to environmental and social benefits.

Complementing these macroeconomic estimates, cost-benefit analysis shows that adaptation measures generate strong induced development benefits, making them worthwhile investments even if climate risks never materialize. A "triple dividend" analysis conducted for this CCDR shows that climate-related spending in Cambodia has substantial development benefits, above and beyond the benefits of avoided climate change impacts. The "triple dividend of resilience" approach includes a "first dividend" of resilience that measures avoided losses from climate change, a "second dividend" that includes induced economic benefits, and a "third dividend" of wider environmental or social benefits (2022). Using data on existing investment projects, this CCDR calculates these dividends for adaptation investment in three sectors in Cambodia: land use, land- use change, and forestry (LULUCF), water, and resilient roads (Figure 13). In all cases, the benefit-to-cost ratio (BCR) far exceeds 1, suggesting these are worthwhile investments. The second and third dividends accrue whether or not the climate risk materializes and are four to six times greater than the measured avoided losses. For example, measures to upgrade and improve rural roads can lower the disruptions from flooding and increase economic activity and access to jobs in rural areas. Both improved irrigation and water management increase crop yields and agricultural productivity and lower the potential negative impacts of climate change. Improved forestry management lowers the effects of floods and droughts, benefiting rural communities through improved agricultural productivity and water resources. Benefits are particularly high for the LULUCF sector, underscoring its importance in adapting to climate change in Cambodia.

It will be crucial to engage the private sector in climate adaptation, and targeted policies by the government could catalyze private adaptation. Despite high induced economic benefits (the second dividend), private sector investment in adaptation is lagging. There are several barriers in attracting private finance. One set of barriers is the nature of adaptation investments themselves. They are often long-term, complex, comparatively small, have high transaction costs, and lack clear cash flow—all factors that discourage private investment at scale. Another set of barriers relates to the poor investment climate, including poor information and weak institutions. These barriers lead to poor understanding of risks and the complete costs and benefits of investing in risk reduction and prevent investors from prioritizing their resources to such investments. Use of the triple dividend approach by governments and investors can help lower these barriers by improving the understanding of both the public (economic) and private (financial) benefits of investing. Furthermore, a private benefit mapping by investment type can form the basis for increasing private participation in adaptation investments through blended finance and de-risking mechanisms.

Government-led adaptation measures with large positive externalities and public good elements, such as information about spatial climate risks and emergency preparedness plans, could catalyze private sector adaptation investments. In addition, measures that address other market imperfections that affect the economy's functioning could also spur private adaptation. For example, credit market constraints often hamper opportunities for farmers to invest in and adopt new crops that are more suitable to the new climate. The government can also implement regulations that help avoid underinvestment in adaptation and excessive risk-taking by the private sector because they do not fully internalize risks. Examples include land-use planning that prohibits construction in flood zones, improved building codes, and mandatory insurance.

Blended finance and concessional financing can also increase the attractiveness of climate adaptation investments for the private sector, which is discussed below in Section 5.1.1.

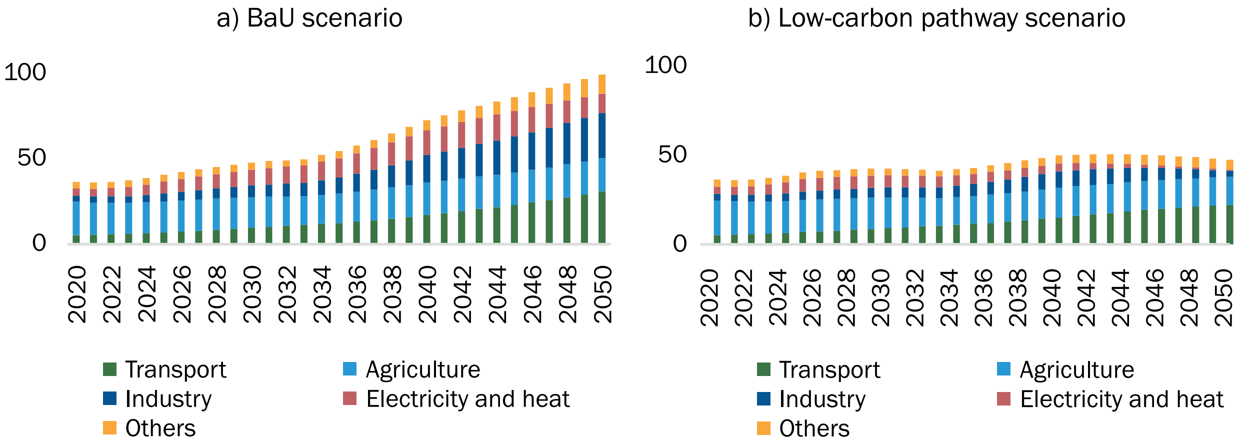
2.6. With the right policy mix, achieving Cambodia's climate migitation goals could benefit development

Cambodia has pledged to achieve carbon neutrality by 2050, and achieving this goal will require a decoupling of GDP growth from emissions growth. On December 30, 2021, Cambodia submitted its LTS4CN to the Secretariat of the United Nations Framework Convention on Climate Change (UNFCCC). The LTS4CN largely builds on existing commitments and proposes a trajectory considered to be consistent with the updated NDC from 2020, which included the target to lower emissions in 2030 by 41 percent relative to a BaU scenario. Achieving Cambodia's carbon neutrality goal will require a rapid policy shift to reverse deforestation and steer the energy, transport, and industrial sectors onto a lower-carbon growth path. The largest component of Cambodia's LTS4CN will be to reverse deforestation and increase afforestation and reforestation. Impacts of LULUCF policies are modeled separately in Chapter 4.3, where results show that meeting the LTS4CN targets could have positive impacts on GDP, wealth, and ecosystem services. The positive GDP impacts are driven primarily from the benefits of restoring degraded, unproductive forests, which outweigh the negative GDP impacts of reversing deforestation on the availability of agricultural land, particularly if restoration efforts are carefully spatially targeted.

Under a BaU scenario of current policies, emissions (excluding those from LULUCF) are projected to nearly triple between 2020 and 2050. This section models a low-carbon development scenario, excluding the LULUCF sector, which includes emission reduction measures in line with Cambodia's NDC and LTS4CN climate pledges. The mitigation policy package closely follows the policies outlined in the LTS4CN. It includes policies to incentivize energy efficiency in line with the National Energy Efficiency Policy (NEEP), accelerate the electrification of transport, accelerate the scale-up of renewable energy relative to the BaU, and introduce a moderate carbon price. In the MINDSET model, the energy sector is modeled using the Future Technology Transformations (FTT) bottom-up energy model. More details are provided in the Technical Appendix. In the MINDSET model "no finance" scenario, investments are financed using a combination of carbon and income taxation. The BaU scenario models existing policies already in place. In the BaU, non-LULUCF emissions would nearly triple between 2020 and 2050, as is shown in Figure 14, Panel a). The most rapid emissions growth would be from the transport sector, in which emissions would be nearly six times higher in 2050, and industry, in which emissions would be more than seven times higher. Figure 14, Panel b) summarizes the impacts of the low-carbon development scenario on emissions in the CGE model. This scenario results in non-LULUCF emissions that are 52 percent lower than the BaU by 2050. With the LTS4CN target of a 50 $mtCO_2e$ carbon sink from the LULUCF sector, these policies are sufficient to achieve carbon neutrality by 2050. The lower emissions in this scenario stem particularly from lower power sector emissions and industrial emissions.

Figure 14. Under a BaU scenario, emissions (excluding LULUCF) are projected to nearly triple between 2020 and 2050

CGE model emissions ($mtCO_2e$), excluding LULUCF

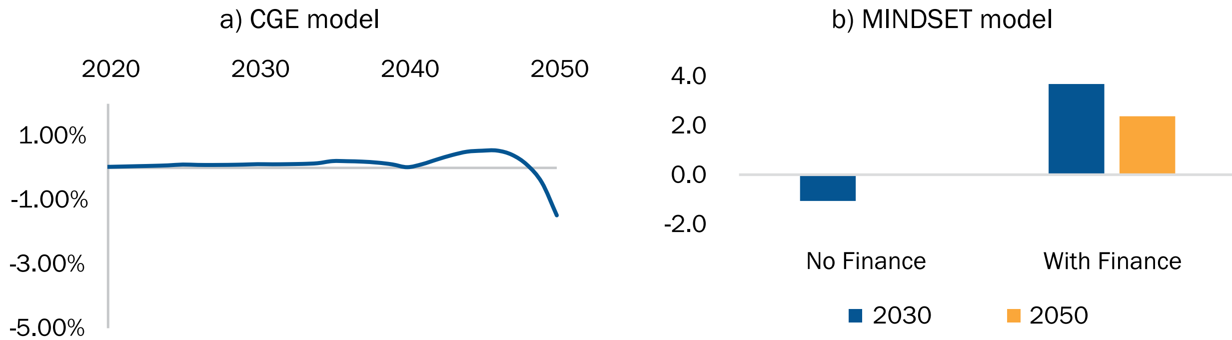


Source: Panel a) and b) CGE Box modeling of a bundle of low-carbon development policies to meet LTS4CN emissions targets, excluding LULUCF policies. These scenarios do not explicitly include the losses from climate change, or any adaptation measures. The BaU includes current policies already in place, such as the PDP for the energy sector.

Model-based estimates indicate that the macroeconomic impacts of achieving carbon neutrality in Cambodia may depend heavily on how energy transition investments are financed. In the CGE model, the GDP impacts relative to the BaU are expected to be negligible or positive until the 2040s, given the backloaded nature of the LTS4CN. By 2050, however, GDP impacts could reach a loss of 1.5 percent of GDP relative to the BaU. This model does not allow for investments to generate demand-side stimulus effects, and so this 1.5 percent could be interpreted as a lower-bound negative effect. The MINDSET model results are shown in Figure 15, Panel b), which demonstrates that they could be either strongly positive at 3.7 percent of GDP by 2030, or slightly negative at 1.1 percent of GDP, depending on whether private sector or external financing is mobilized to pay for the necessary upfront investments or whether investments are instead financed by taxation. Most of the impacts arise through the investment channel, reflecting the need for large amounts of investment in renewable electricity generation, transport electrification, and energy efficiency. In the MINDSET model, impacts are frontloaded as the model allows for investments this decade to spur a more rapid energy transition. By 2050, GDP impacts would be -0.01 percent without financing or 2.4 percent with financing. This 2.4 percent impact could hence be interpreted as an upper bound positive effect if conducive and targeted policies can catalyze sufficient investment in the low-carbon transition. Chapters 4 and 5 will discuss ways in which this can be achieved, including by lowering barriers to private sector participation in the clean energy transition, incentivizing investments in energy efficiency (particularly in cooling and agriculture), and mobilizing climate finance.

Figure 15. The impacts of achieving Cambodia's NDC and LTS4CN emissions targets depend on how investments are financed

Low-carbon development scenario GDP impacts (% compared to BaU), excluding LULUCF sector



Source: Panel a) CGE Box modeling of a bundle of low-carbon development policies to meet LTS4CN emissions targets, excluding LULUCF policies. Panel c) MINDSET model impacts for a single year of a bundle of low-carbon development policy scenarios to meet LTS4CN emissions targets, excluding LULUCF policies. These scenarios do not explicitly include the damages from climate change, or any adaptation measures. The BaU includes current policies already in place.

Decarbonization measures could benefit certain sectors and high-skilled job creation, but targeted support would be needed to ensure they do not increase poverty. In the MINDSET model in both financing scenarios, there are positive benefits for several sectors, including engineering services and equipment, and the construction sector, where output increases by 3–5 percent by 2030. In the scenario with finance, there would also be positive effects on employment, particularly for the occupation groups of technicians, associate professionals, and service and sales workers. Job creation in the MINDSET model would also be highest for the highest paid roles. Relative to the BaU, poverty rates are expected to decline until 2030 as the early stage of decarbonization reflects efficiency gains. These gains should positively impact labor income and prices. These results underscore the importance of targeted measures to ensure decarbonization policies are not regressive by providing support to lower-income households, which will be discussed more in Chapters 4 and 5.

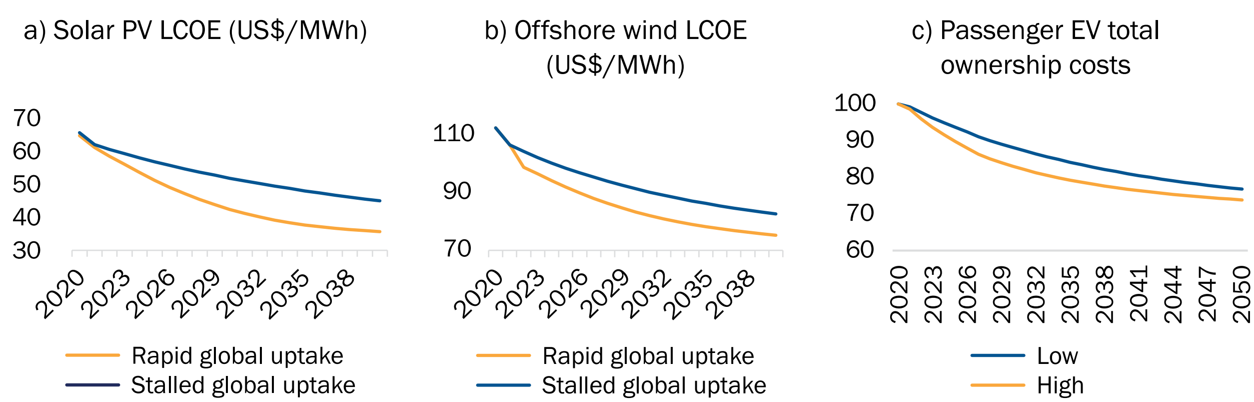
2.7. The global net-zero transition offers new opportunities but also poses risks

The global net-zero transition will also have ripple effects on Cambodia's economy through trade, investment, and technology availability, with major implications for exports and job creation. Cambodia is one of the world's most globally integrated economies, with an exports-to-GDP ratio in 2021 of 65 percent and inward FDI accounting for 54 percent of gross fixed capital formation (World Bank, 2022; UNCTAD, 2022). Growth and poverty reduction have been closely tied to export-oriented garments manufacturing, which currently accounts for nearly one-third of GDP. Cambodia's energy sector is also highly import-dependent, with the country currently importing all fossil fuels consumed domestically and importing nearly one-third of electricity from the Lao People's Democratic Republic. The net-zero transitions in Cambodia's major trade and investment partners—the EU, US, and China—will hence have ripple effects in Cambodia's economy.

The net-zero transition globally offers new manufacturing and export opportunities, while low-carbon competitiveness could become increasingly important for maintaining the existing manufacturing base. The low-carbon transition in the world's major economies is driving rapid growth in demand for low-carbon goods and services. Certain opportunities are already being seen in Cambodia today and others will likely accelerate later in the decade. For example, exports of solar panels, modules, and accessories increased from zero one decade ago to just under US$1.2 billion in 2022 (5 percent of the total), although this was likely at least in part driven by trade diversion related to trade restrictions in bilateral US-China trade. The RGC is also developing measures to attract electric vehicle (EV) manufacturers to the country, and the Chinese company BYD has recently announced plans to install 200 EV charging stations across Cambodia in 2023. At present, however, a range of trade, investment, and regulatory barriers are impeding the country from seizing such new opportunities. In addition to new opportunities, assisting (and not hindering) existing firms from achieving their emissions pledges could also become increasingly important for competitiveness in garment manufacturing. Many international brands that source from Cambodia, including H&M and Adidas, have corporate net-zero targets, implying that Cambodia's future comparative advantage may depend on facilitating companies to lower emissions. In addition, while Cambodia is not currently highly exposed to the EU's Carbon Border Adjustment Mechanism (CBAM), this could change later this decade when CBAM is expanded to a wider set of products than those currently covered. At present, Cambodian firms lag behind their peers in adopting green technologies and practices, while Cambodia still imposes several barriers to the adoption of green technologies, as will be discussed in Chapter 4.

Rapid cost declines for low-carbon technologies driven by the net-zero transition in major markets also offer new opportunities for technological upgrading or "leapfrogging" in Cambodia. Global climate policies are leading to rapid declines in the costs of clean energy technologies. Over the past decade, the levelized cost of electricity (LCOE) from solar energy has more than halved in Association of Southeast Asian Nations (ASEAN) countries (NREL, 2020). Reflecting these rapid cost declines, an analysis of Cambodia's revised PDP in June 2023 found that the scenario involving the greatest increase in the share of renewable energy throughout the modeling period (2022–2040) was now as affordable as one involving building new coal plants (ADB, 2022). In addition, the most recent auction of a 60 MW solar power project in Cambodia achieved a price of less than 4 US cents/kWh, less than half the cost of the prevailing power purchase prices for coal of about 7 US cents/kWh or more. Modeling of different scenarios for global clean energy technology deployment for this CCDR shows that even under a "stalled global uptake" scenario, the cost for solar energy in Cambodia could decline by 31 percent between 2020 and 2040, and the cost for offshore wind could decline by 25 percent (Figure 16). Similarly, reflecting rapidly declining costs globally, EV sales in Cambodia have started to grow rapidly, and modeling for the CCDR shows that passenger EV costs could decline significantly over the coming decades (Figure 16c). Falling costs of other technologies, such as energy-efficient cooling systems, also offer opportunities for Cambodia to leapfrog to lower emissions technologies, while also potentially raising productivity.

Figure 16. The global net-zero transition is driving rapid cost declines for clean energy technologies
Projected cost declines for clean energy technologies in Cambodia



Source and notes: Panel a) and b) CCDR modeling using Future of Technology Transformations (FTT) energy model. The stalled uptake scenario involves higher global inflation, investments in fossil fuels, segmented supply chains, and barriers to deployment of renewables. The rapid global uptake scenario includes the US Inflation Reduction Act, China's 14th Five Year Plan renewable targets, and the EU's REPowerEU. Panel c) CCDR modeling using FTT transport model, extending the work of Lam and Mercure, (2022) for Cambodia.

3

Climate policies, institutions, and regulatory framework

3. Climate policies, institutions, and regulatory framework

3.1. Ambitious targets and policy planning, but some gaps in implementation

The RGC's climate change regulatory framework is guided by an abundance of strategic plans and policy documents. As of January 2023, the Cambodia Climate Change Strategic Plan (CCCSP) 2014–2023 is the country's overarching climate policy framework; it is aligned with the National Strategic Development Plan 2019–2023 and RS-IV goals. Concurrently and in support of CCCSP, some line ministries have developed frameworks known as sectoral climate change strategic plans and climate change action plans to enhance their own responsiveness to climate at the subnational level.

Cambodia's key climate adaptation strategy documents and legal instruments include the updated NDC, the National Adaptation Plan, and the National Action Plan for Disaster Risk Reduction. The updated NDC includes 86 adaptation actions across nine sectors which span key areas such as agriculture, energy, and infrastructure. The National Adaptation Plan Financing Framework and Implementation Plan identifies 40 short-term priority climate change actions as well as medium- and long-term recommendations for climate change adaptation. The National Action Plan for Disaster Risk Reduction 2019–2023 is the government's primary disaster resilience strategy, emphasizing the importance of improved policy guidance around construction of resilient public infrastructure and mainstreaming disaster risk reduction and climate change adaptation into planning and development processes by line ministries. The Law on Disaster Management, passed in 2015, represented a significant milestone in the country's disaster risk management (DRM) landscape, broadening the scope of DRM to encompass pre-disaster, during disaster, and post-disaster contexts.

Cambodia's key climate mitigation commitments are in the updated NDC and the LTS4CN. The NDC outlines targets to reduce GHG emissions by 64.6 million tCO_2e/year by 2030, from 155 $mtCO_2e$ in a projected baseline to 90.5 $mtCO_2e$. On December 30, 2021, Cambodia also submitted its LTS4CN to the Secretariat of the UNFCCC. The LTS4CN largely builds on the RGC's existing commitments and proposes a trajectory it considers to be consistent with the updated NDC. The LTS4CN suggests that carbon neutrality by 2050 can be achieved through continued efforts to address forest sustainability and land use; decarbonize the power sector and pursue higher energy efficiency; and promote low-carbon agriculture, transport, industrial processes, and waste management. The LTS4CN places heavy reliance on reversing deforestation by 2030 through the REDD+ program and forest sector reform, relying on the LULUCF sector to provide a total carbon sink of 50 $MtCO_2e$ by 2050. For the energy sector, the LTS4CN focuses on enforcing the NEEP and limiting new coal generation capacity, while expanding generation from natural gas and increasing renewable energy only moderately to make up about 35 percent of the generation mix by 2050. Plans for the transport sector are also backloaded, with rail development after 2030 and only 40 percent of cars and urban buses targeted for electrification by 2050 despite an ambitious target of 70 percent electrification of motorcycles.

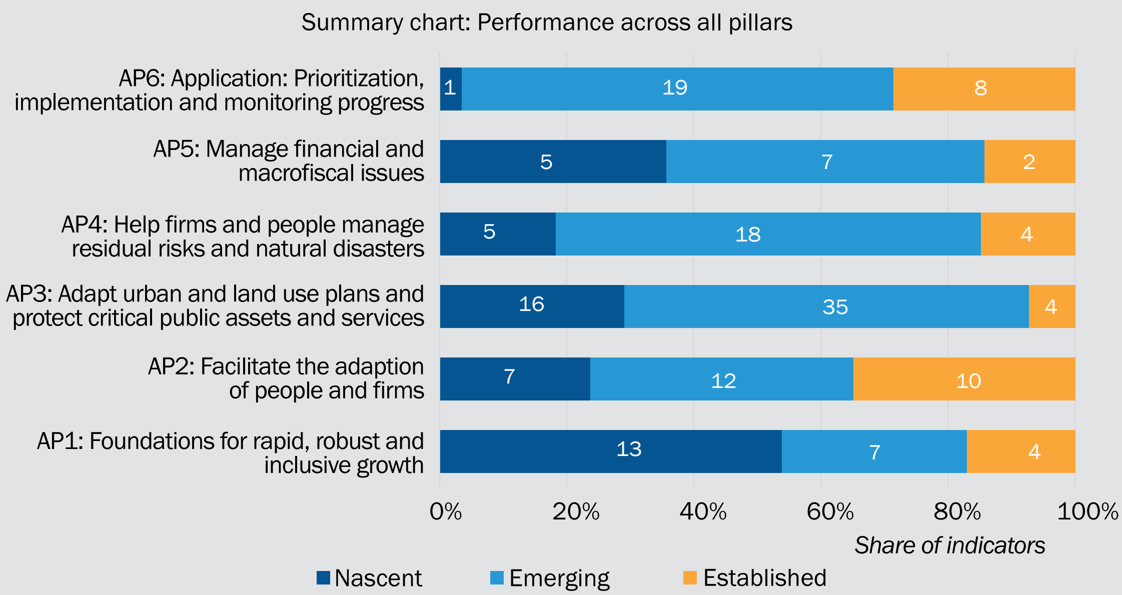
Plans for the energy sector have been updated since the LTS4CN, with the new PDP being endorsed by the Ministry of Mines and Energy in late 2022 and revised in June 2023, which will now guide power sector development in Cambodia. The PDP (2022–2040) provided more detailed generation and transmission expansion plans to fulfill its decarbonization commitments in the power sector. Following the revised PDP, the share of renewable generation will be 36 percent by 2040, which exceeds the committed 2050 target in the LTS4CN. To prepare the energy sector for achieving its NDC, the RGC has committed to (1) no new coal generation capacity beyond projects that were already committed; (2) not to build hydropower stations on the mainstream of the Mekong River; and (3) scale up energy efficiency to manage energy demand growth and improve competitiveness.

Box 3. Adaptation principles assessment for Cambodia

This box provides an assessment of Cambodia's adaptive capacity, building on the conceptual framework proposed by Hallegatte et al. (2020). It is a flexible framework that allows for evaluating effective national climate and disaster adaptation and resilience policies and strategies. It is organized around six pillars; these pillars are centered around actors and responsibilities within governments, grouping actions under "foundations" for rapid and inclusive development, which offers protection against shocks, and five priority pillars to build resilience and adapt to shocks. Cambodia's overall scoring is provided in Figure 17. Cambodia is benchmarked against countries in Southeast Asia.

Figure 17. Cambodia's adaptation principles assessment highlights that Cambodia lags behind other Southeast Asian countries on several metrics of climate adaptation

Share of indicators by category (%)



Source: World Bank Adaptation Principles Assessment for Cambodia.

- **Cambodia lags behind its peers in Southeast Asia in terms of pillar 1: "Foundations for rapid, robust and inclusive growth".** Cambodia's low score on this pillar is driven by its relatively low performance compared to other countries in Southeast Asia on the human capital index, access to health services, safe drinking water, telecommunications infrastructure, and ability to mitigate welfare losses from natural disasters.
- **Cambodia also underperforms in terms of pillar 3: "Adapting urban and land-use plans to protect critical public assets and services".** It does not yet have temperature control in school buildings and a high share of schools are still in disaster risk prone areas, while less than 40 percent of schools are resistant to disasters. Cambodia also performs poorly in terms of the health security and food security metrics. Cambodia sits in the bottom third among Southeast Asian countries in terms of the share of arable land equipped for irrigation. Cambodia also underperforms in terms of construction standards and codes for buildings and disaster risk

reduction in urban planning. It also performs poorly relative to peers in terms of construction standards and codes for buildings.

- **Cambodia also underperforms in terms of pillar 5: "Managing climate-related financial and macro-fiscal issues".** In contrast to peers, climate and disaster impacts are not yet included in Cambodia's debt sustainability assessment or financial sector assessment program. Regulations for banks, insurers, and large investors do not yet include specific disaster and climate risk requirements. Currently there are no specific requirements for disaster and climate risk considerations in policy and regulations for banks, insurers, and large investors. Quantified estimates of exposure to natural hazards are also not yet required for banks, insurers, and large investors. Banks, insurers, and large investors do not yet conduct stress tests for climate and disaster risks.

The NEEP (2022–2030) was endorsed by the RGC in 2022, and a sub-decree on GHG emissions reduction mechanisms and a Roadmap for the Deployment of EV Charging Stations are also under preparation. Cambodia's NEEP aims to reduce energy consumption by at least 19 percent vis-à-vis the BaU scenario by 2030. Specific targets have been defined for each key sector: 20 percent for the manufacturing industry, 34 percent for the residential sector, and 25 percent for the commercial sector. In the power sector, a 17 percent relative reduction in electricity consumption by 2040 (from 66 TWh to 55 GWh) is required as part of the new PDP. In early 2023, the RGC was in the process of establishing a sub-decree on GHG emissions reduction mechanisms with the goal of establishing a permanent national authority for GHG emissions reduction and thus providing rules and procedures regarding participation in GHG reduction mechanisms. In early 2023 a Roadmap for the Development of an EV Charging Station Network in Cambodia was also under preparation.

Despite this abundance of policy planning frameworks, institutional gaps in capacity, financial management, and accountability mechanisms persist. A review of CCCSP effectiveness in March 2019 found that 40 percent had only been partially achieved and 31 percent had not been achieved at all as of March 2019. Currently, climate action is guided by a network of policy frameworks, which lack integration with development policy frameworks. The LTS4CN does not mention the 2014–2023 CCCSP or the 2018 RS-IV. Many ministries do not yet appear to be on track to meet their yearly reduction targets. A harmonized framework with integrated development and climate goals could improve monitoring and accountability. In addition, whether climate commitments are reflected in legally binding or non-binding documents makes a difference in terms of the clarity, predictability, accountability, and enforceability of such commitments, and that also affects the private sector's investment decisions and operations. Cambodia's climate ambitions and aspirations need to be reflected not only in strategy and policy documents but also in its legal framework.

The government and development partners have made a concerted effort to conduct hazard and risk mapping, although efforts remain fragmented. Cambodia developed a Vulnerability Index to track the annual number of communes deemed vulnerable to climate change. Additionally, at the subnational level, Cambodia's Vulnerability Reduction Assessment process was developed to help communities quantify their perceptions of vulnerability to climate change, and their capacity to adapt. The UNDP has worked with the Ministry of Water Resources and Meteorology (MOWRAM) to assess the impact of climate-related flood and drought hazards in the Mekong River Basin. Similarly, the World Food Programme and the National Committee for Disaster Management have developed an interactive web-based dashboard called Platform for Real-time Impact Situation Monitoring, which provides the latest available hazard information along with vulnerability data. Additionally, the Mekong River Commission is working toward improving data sharing and modeling for hazard risks in the Mekong River Basin. Nevertheless, the Department of Meteorology (DOM) and the Department of Hydrology and River Works (DHRW)—the two departments within MOWRAM that play a crucial role in providing information for decision-making related to hydrometeorological-related disasters—have had limited resources for hazard mapping. The DHRW developed flood and drought hazard maps in 2020–2021, although they were not updated, by the DOM has yet to develop hazard maps or assessments or climate projections.

Ministries are not required to identify climate change-related expenditures in their yearly budgets, causing reluctance for climate spending, and climate public expenditure management also remains limited. These circumstances may, however, change with the introduction of Sub-Decree 41, which sets a standard operating procedure (SOP) for public financial management to integrate climate finance. This is a positive development; however, it will only come into effect for the 2024 budget and does not incorporate climate change spending for individual ministry budgets. In addition, there is currently no requirement to include climate change information or tagging in Budget Strategic Plans. A recent International Monetary Fund (IMF) Climate Public Investment Management Appraisal in 2022 noted that guidance on project appraisal and selection for externally or domestically financed capital projects or for public-private partnerships (PPPs) does not include requirements for consideration of climate-related issues. By strengthening public investment management (including developing project selection and implementation manuals), investment can be allocated to high-return projects and address long-term sustainability issues such as disaster and climate risk.

Several laws and regulations governing insurance and other market-based financial services have been promulgated and enacted in Cambodia, but these instruments remain nascent. Market-based financial instruments such as credit, insurance, and guarantees can play an important role in strengthening the financial resilience of governments, households, and businesses. The Insurance Law was approved by the National Assembly of Cambodia in June 2020 with the purpose of regulating insurance, protecting the rights of the parties to insurance, strengthening supervision, and contributing to the development of the insurance industry.

Sustainable government procurement policies can drive a more inclusive and green public procurement framework with significant environmental and socioeconomic outcomes. Many countries have recognized the benefits of bringing in green public procurement regulations for integrating resilience standards. This is particularly relevant in the context of Cambodia, where natural calamities such as floods occur frequently. By considering resilience standards in procurement decisions, the government can enhance the resilience of infrastructure and promote DRM and disaster response. Likewise, efficiency gains from introducing electronic government procurement will provide faster turnaround, which is critical in responding to emergencies. The Ministry of Economy and Finance is currently revising its public procurement law and has confirmed the inclusion of modern methodologies such as sustainable and green public procurement and the use of an electronic government procurement system. These will support the government in developing policy actions to achieve positive environmental and socioeconomic outcomes from public spending. In addition, environmental and social impact assessments are also a key component of mainstreaming climate considerations in development plans and projects, and the new draft Environment and Natural Resource Code requires incorporating climate change risks and impacts in environmental impact assessments and strategic environmental assessments.

4

Steering the Economy Onto a Resilient, Dynamic, And Low-Carbon Path

4. Steering the economy onto a resilient, dynamic, and low-carbon path

This chapter provides more detailed context and policy options for achieving Cambodia's climate and development objectives. It focuses on the three Rs (*reduce*, *realign*, and *reorient*) as outlined in Chapter 1. First, for continued development it will be crucial for Cambodia to *reduce* exposure and vulnerability to climate change. Second, Cambodia will need to *realign* the country's emissions trajectory with targeted responses that can achieve climate mitigation goals in ways that benefit development. Finally, Cambodia will need to *reorient* the economy to seize new opportunities from the net-zero transition globally in terms of trade, investment, and technological progress.

4.1. *Reduce* exposure and vulnerability to climate change

This section provides detailed analysis and recommendations for adapting to climate change in specific sectors or themes. Chapter 2 highlighted the various economic consequences of climate change, showing that, without adaptation measures, climate change impacts could lower GDP by up to 9.4 percent by 2050, but that even a select few adaptation measures could at least halve this impact. Moreover, analysis in Chapter 2 also showed that, in many cases, adaptation measures are worthwhile investments even if climate risks never materialize. This chapter provides more detail on the context of climate adaptation in specific sectors or themes in Cambodia and outlines the best policy options, along with their investment needs. Investment needs are identified as incremental investments that would be needed to adapt to climate change, above and beyond existing policies or investments already in place. They are measured in net present value (NPV) terms, with a 6 percent discount rate used. Together these investments add up to 1 percent of cumulative GDP from 2023–2050, as will be outlined in Chapter 5. This section aims to identify not only policy recommendations with adaptation benefits, but also those with the greatest potential for achieving Cambodia's development vision and those with win-wins for climate adaptation and mitigation. It focuses on six areas that will be critical for successfully reducing exposure and vulnerability to climate change in Cambodia—building resilience in agriculture, water, transport, health and education, urban planning, and DRM and expanding social protection.

4.1.1. Increase climate resilience in agriculture

Agriculture is a major contributor to economic growth, employment, and livelihoods, although its share of GDP and employment is declining. More than 5 million people in Cambodia still depend on agriculture and fishing for their livelihoods, income, and food security. The percentage of total employment in agriculture has fallen dramatically in recent decades from a high of 73 percent in 2000 to 35 percent in 2019 (Ministry of Agriculture, Forestry and Fisheries, 2020). The agriculture sector is highly fragmented and dominated by smallholder farmers and oriented toward subsistence, rather than commercialization. With limited diversification, the sector remains highly concentrated in rice and cassava production. Rice contributes to about 60 percent of agriculture GDP and is grown on over 3.2 million hectares of Cambodia's agricultural land (about one-third of the total).

Climate change is projected to cause substantial losses to crop yields, livestock, and fisheries. Climate change is projected to lower yields for rice, maize, and cassava, with particularly strong negative impacts for rainfed rice. Chapter 2 presented modeling results for this CCDR, showing that rainfed rice could experience yield losses of 21–30 percent on average between 2030 to 2060 under different climate scenarios. This represents one of the most negative climate change impacts on rice in Southeast Asia. Rainfed maize and cassava production will also be affected, with yields for rainfed maize projected to fall by 6–9.2 percent in these scenarios and rainfed cassava by 5–11.2 percent. In addition, although quantitative impacts of climate change on livestock are unavailable, analysis of relevant climate indices shows that climate change will likely have negative consequences for livestock production. Climate change is also projected to negatively affect fisheries, posing challenges for nutrition and food security as fish accounts for about 80 percent of animal protein in household diets. The 2009 El Niño caused low water levels in the Mekong River, leading to saltwater intrusion and affecting fish stocks. Reduced water levels in 2009 also lowered fish productivity in Lake Tonle Sap and in inland fisheries. This was also observed during the 2015 drought, which led to lower water levels and reduced fish production.

Cambodia is drafting plans and strategies to solidify its efforts to make Cambodian agriculture more climate-resilient. The formulation of the Climate Change Priority Action Plan for the agriculture sector (CCPAP III) is currently underway, with the vision to make Cambodia's agriculture resilient by 2030 as it moves toward a sustainable agrifood system using climate-smart technology and innovations. It also aims to ensure sustainable management of natural resources to boost prosperity and well-being. The Ministry of Agriculture, Forestry, and Fisheries is drafting the Agricultural Sector Master Plan, which represents the long-term strategic framework for a comprehensive roadmap to lead the Cambodian agriculture sector. Its additional mission is to provide high-quality agricultural support services with scientific methods, regulatory compliance, and clearly defined policies to develop the Cambodian agriculture sector effectively and sustainably.

Climate-smart agricultural practices, and notably irrigation, have sizable potential to lower the impacts of climate change, but adoption rates are still low. The adoption of climate-smart agriculture, and particularly irrigation, has been identified as a major opportunity to change production practices and attain farming efficiency, higher productivity, and higher incomes among farmers in Cambodia. Irrigated lands produce 60 percent greater yields than rainfed agriculture (Burke et al., 2023). Indeed, analysis conducted for the CCDR shows that the adverse effect of drought on yields is entirely mitigated by households that irrigate their plots or rely on crop-rotation practices (Roy et al., 2023). However, no more than 20–26 percent of farmers are currently known to apply improved climate-smart technologies and practices (such as resilient crop varieties) to address climate risks (Thomas et al., 2013). The main reasons for low adoption are: (i) lack of capital for initial upfront investment to purchase climate-smart agricultural technologies; (ii) lack of awareness of and limited access to extension services; and (iii) lack of financial services. Constraints to adaptation are even higher for poor households and small landholders with limited capital and no spare land to allocate to diversified production, storage, or water management infrastructure (Monin, 2021).

What we recommend

1. **Develop programs and introduce incentives to modernize and expand irrigation.** Address current challenges with irrigation schemes through interventions to lower the costs of pumping water, improve irrigation design, and build capacity for irrigation operation and management. Accelerate irrigation expansion targets, particularly in climate-vulnerable regions. Digital solutions such as precision farming, remote sensing, and weather forecasting can help farmers increase yields during droughts and optimize water and fertilizer usage, promoting climate adaptation and reducing environmental impacts.
2. **Support alternate wetting and drying (AWD) production.** A shift from continuously flooded irrigation to irrigation with just one single drainage (AWD) can present multiple benefits. In Vietnam, AWD has featured in rice production since 2005. Demonstrations on large-scale paddy fields showed productivity increases, resulting in higher rice yields during both the dry and rainy seasons. AWD in Cambodia will need to be combined with effective agriculture water management, controlled irrigation systems, and improved water supply to farmers. In Cambodia, the absence of field channels and the plot-to-plot nature of irrigation will require that all farmers within an area (100s to

1000s farmers) adopt AWD at the same time.

3. **Introduce incentives and expand extension services to diversify from high-risk crops toward climate-resilient, high-value, marketable crops.** Cambodian farmers will need to diversify away from the dominant rice and cassava cropping systems toward climate-resilient high-value marketable crops, especially those with high nutritional value. For instance, cashews, vegetables, and fruits have higher marketability. This should also include the promotion of agro-ecological practices, which will have multiple co-benefits (economic co-benefits, by helping to regenerate soils and productivity; mitigation co-benefits through carbon storage in soils; environmental co-benefits, by reducing pollution; disaster prevention co-benefits through better water retention; etc.).
4. **Support farmers and small landholders in adopting climate-smart agricultural practices with improved financial instruments and insurance products.** Cambodian farmers should use high-yielding, early-maturing, water-stress tolerant, and pest-resistant varieties. Access to financing is a major constraint on investments. Policy interventions could support these sorts of investments without land-based collateral requirements or through other financial innovations. The provision of low interest loans, carbon credits, and blended finance could help farmers purchase equipment and inputs used in sustainable practices. A national plan to improve farmers' awareness on sustainable agricultural practices and to benchmark and measure these practices could also be considered.
5. **Fund community-level investments that improve the capacity of poor and smallholder farmers to cope with natural disasters.** In communities where landholding size is a driver of vulnerability, climate change adaptation efforts could focus on community-level investments that improve the collective ability to cope with natural disasters. This could include shared agricultural storage facilities, collective rainwater harvesting facilities, and flood protection infrastructure.
6. **Improve fisheries management, promote climate-resilient aquaculture, and protect critical mangrove habitats.** To improve fisheries management, it is important to reverse the open access nature of the sector, reduce illegal and destructive fishing practices, scale up healthy and selective fishing harvest methods, and protect critical habitats (mangrove, seagrass, etc.) to help recover fish stocks. To reduce exposure to increasing climate variability, it is necessary to promote climate-resilient aquaculture intensification through integrated water zoning and infrastructure establishment such as canals, integrated aquaculture and floating solar deployment, improved access to electricity and quality water, and by providing technical assistance to improve the quality of hatcheries and nurseries to reduce climate-induced disease risks.

Incremental investment needs

- **Building a climate-resilient agriculture sector would require an investment of US$3.6 billion (NPV) cumulatively from 2023–2050.** This includes sustainable irrigation modernization, stable and enhanced water supply, improved soil and water management practices and cropping technologies, strengthened crop/farm systems resilience, and improved animal husbandry and animal waste management.

4.1.2. Improve water resource management

Cambodia's water resources endowment is above the global average, but water supply and management are insufficient to meet agriculture's growing needs. Agriculture accounts for 94 percent of annual freshwater withdrawals in Cambodia. However, agricultural water supply is still insufficient to fulfil farmers' needs, especially during droughts, because irrigation development in Cambodia is still limited. Close to 80 percent of irrigation schemes need to be fully rehabilitated. Water delivery is inefficient and does not reach all farm plots in the irrigation schemes. Irrigation performance is also affected by: (i) high costs of pumping water; (ii) inadequate irrigation canals; (iii) poor design for a changing climate; and (iv) low operation and management capacity of water user groups. As a result, dry season rice crops only account for about 18 percent of total rice production in Cambodia as farmers only have water for wet season rice and are not willing to invest in higher-value crops due to unreliable water supply (Resosudarmo and Chheng, 2021). Irrigation schemes that are not protected from flooding also suffer adverse impacts on wet season yields, while lack of storage limits dry season cropping.

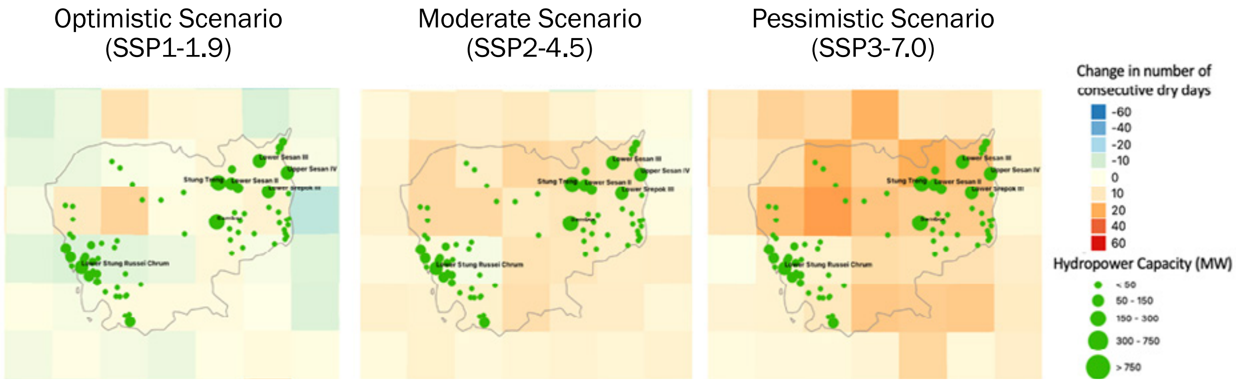
Increasing irrigation requires cross-sectoral coordination and efficiency improvements to meet the increased water demand. As discussed above, irrigation has substantial potential to lower climate change impacts and increase productivity. Cambodia is aiming to expand the area of irrigated land by 50 percent over the next decade. This planned expansion will increase current water withdrawals by up to 80 percent—a significant increase which, in turn, necessitates dialogue across the food-energy-water nexus, including the agricultural, fisheries, hydropower, water supply, and sanitation sectors, as well as environmental issues. Similarly, to meet this target Cambodia will need to increase the efficiency of water use.

Climate change will put pressure on water resources, alter the hydrology of the Mekong River, and could make much needed irrigation systems less reliable. Hotter days in the future could drive more water demand for human consumption, industries, crops, and livestock. Climate change is expected to cause a later onset of the monsoon and make the wet season shorter in general but also wetter. On the other hand, the dry season is likely to grow drier. This increased variability in precipitation will likely cause more severe floods and droughts and will change the hydrology of the Mekong River. In the downstream area of the Tonle Sap Basin, an increase in pests and diseases is expected, which will further increase agrochemical use and put further pressure on human, agricultural, and ecological systems (Box 4). Irrigation systems may be less reliable due to increased uncertainty in rainfall and water flow.

Climate change also poses risks to water infrastructure and could exacerbate water quality concerns, posing impacts on health and well-being and further delaying access to safe water and sanitation. More intense and frequent floods increase the risks of damage to water treatment and supply infrastructure, which can lead to service disruptions. Water and wastewater infrastructure in coastal low-lying cities are more prone to severe flooding. Increased variability in rainfall intensity and patterns caused by climate change could have a significant impact on the performance of urban drainage systems, with an increase in combined wastewater and stormwater overflows during heavy precipitation and flooding. As floods and droughts are likely to increase due to climate change, there are further risks of water pollution and pathogenic contamination caused by flooding or by the higher pollutant concentrations during drought. Deteriorating water quality and water pollution poses impacts on health and well-being and further delays access to safe water and sanitation. As discussed in Chapter 2, through adverse health impacts, climate change is projected to lower the labor supply by 1.1–1.7 percent per year by 2050.

Water infrastructure and hydropower systems are highly vulnerable to future changes in hydroclimatic conditions. Hydropower provides almost half of the country's installed electricity and 95 percent of renewable energy. Only 20 percent of estimated hydropower technical potential is developed, and it is set to play an important role as a source of renewable energy in the future. The results of a hydroclimatic stress test show that historical mean annual flow conditions are at serious risk of not being met while historical peak flow could be surpassed in some periods. Only 18 percent of climate projections estimate that historical mean annual flow conditions will be met at the 30 September Dam (San Sep Kanha) and Ott reservoirs of the St. Staung catchment. This indicates a high vulnerability of the hydropower system to decreasing flows and an increasing risk of the reservoir not being able to meet its delivery targets in the future. The intensification of droughts could also lead to shocks in energy production as well as more intense competition for water resources, and thus potential conflict. In fact, in a moderate climate scenario, about 60 percent of the current hydropower capacity in Cambodia would already be in areas that will see an increase of at least 10 consecutive dry days (see Figure 18).

Figure 18. Climate change poses risks to hydropower capacity
Exposed hydropower capacity to change in number of consecutive dry days



Sources: World Bank analysis.

The private sector is heavily involved in water provision, yet it lacks incentives to increase investment. About 50 percent of Cambodians receive water through private water operators (PWOs), principally through small-scale piped water supply systems. Investments by PWOs are held back by high infrastructure costs, an inability to obtain financing for capital expenditure, and pressures to lower tariff rates. Suppliers face issues in obtaining financing due to high collateral requirements and relatively short tenures on available loans. As a result, PWOs tend to rely on relatively small grants to fund growth and focus on areas of investment with a higher short-term return on investment, such as urban areas, thereby restricting growth in rural areas and reducing investment in system upgrades.

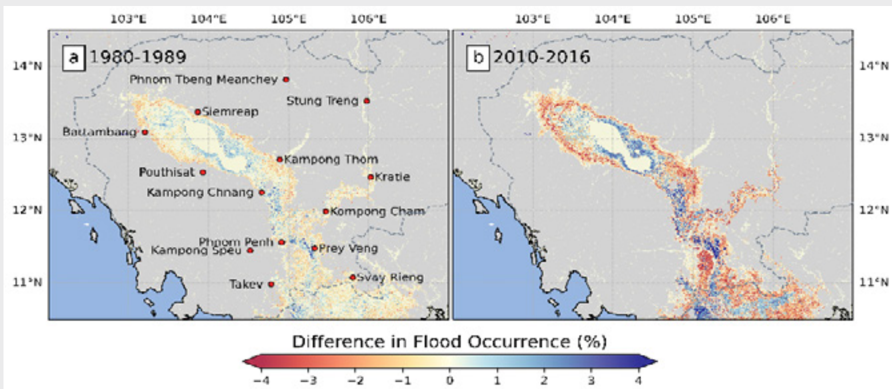
Box 4. The Mekong and transboundary coordination on tackling climate impacts

The Mekong River flows through six countries and the transboundary nature of the basin requires supra-national coordination. The Mekong River Commission is an inter-governmental organization that works directly with the governments of Cambodia, Thailand, the Lao People's Democratic Republic, and Vietnam to facilitate the adoption of a regulatory framework and tools to improve the safety of dams and infrastructure and the safety of downstream communities, environments, and assets. Climate change poses significant challenges to water resources in the Lower Mekong basin and climate strategies implemented by one country pose significant cross-border implications for other countries. The Mekong River system also serves as a key source of hydroelectric power in the region. The total installed hydropower capacity along the Mekong is projected to nearly triple by 2040 (Mekong River Commission, 2021). Dams have been amplifying flooding patterns, as shown in Figure 19. Dams in the upstream Mekong are reducing the Tonle Sap lake's intra-annual water-level rise and fall. Elevated dry season water levels may threaten flooded forests, while reduced wet season flooding could adversely impact the potential for flood-recession rice farming and aquatic productivity. In general, the upstream floodplain may benefit from lands no longer flooded in the wet season, while the downstream floodplain may experience the loss of arable land due to higher dry season water levels.

A variety of actions will be needed to better manage risks posed by climate/dam impacts, including:

- *Mandating dam planning to take into consideration flood dynamics in distant downstream locations.*
- *Conducting detailed examinations of the changes in onset, magnitude, and duration of the rise and fall of water levels, which affect ecology, agriculture, fisheries, and local livelihoods around the Tonle Sap.*
- *Monitoring, controlling, and analyzing sand mining operations as changes in the riverbed of the Tonle Sap River and the Mekong due to extensive sand mining may result in less water exchange between the lake and the Mekong.*

Figure 19. Dams on the Mekong have amplified flooding patterns on the Tonle Sap
Mekong dam impacts on the Tonle Sap Lake's decadal-average flood occurrence (%)



Source: Reproduced from Figure 6 in Dang et al. (2022).

What we recommend

1. **Increase investments in water storage, built in the form of dams, reservoirs, in-field storage, and tanks.** Water storage enables the management of variability and then increases the amount of water available for human, environmental, and economic use, reduces the impact of floods, and provides a variety of ancillary services by regulating water flows. The identified vulnerability of reservoirs in Cambodia to both not meeting its annual flow conditions and exceeding historical high flow peaks also requires comprehensive operational and planning strategies. Such strategies include, for example, updating the operational rules of reservoirs, improving weather forecasting, and promoting flood (and flow) forecast systems, which accommodate and manage excess flows. This also includes revising and constantly updating historical flow return periods and revising structural designs.
2. **Increase data collection and monitoring to better understand and address water challenges, specifically floods and droughts.** One of the major barriers to designing plans and programs to effectively manage water resources in Cambodia is the lack of water data and understanding of catchment-wide water supplies and demands. Filling these data and knowledge gaps requires catchment-level studies, the results of which could be used to design science-based strategies to improve water resources management and increase water security.

3. **Expand and enhance investments in drainage.** Changes in rainfall intensity associated with climate change have the potential to overburden drainage systems, which may lead to flood damage, disruptions to local transport systems, discharges of untreated sewage to waterways, and increased human health risks. There is therefore a need to improve the efficacy and targeting of current initiatives in urban drainage, particularly in climate-vulnerable areas such as the Mekong and Tonle Sap valleys.
4. **Launch new initiatives to enhance coordination with countries in the Mekong River Basin.** This should enhance information sharing on the rivers' flow regimes and on the building and maintenance of infrastructure for water supply, hydropower, mining, and irrigation. Establishing effective mechanisms to exchange and share information on flood situations is essential to reduce climate vulnerability in riparian countries and better respond to climate change impacts on existing, proposed, and planned water infrastructure.
5. **Develop water allocation plans and agreements to help avoid and resolve international, regional, and local conflicts over access to water.** While objectives and approaches have evolved over time, ultimately water resources allocation has fundamentally remained the process of determining how much water is available for human use and how that water should be shared between competing regions and users. The allocation process typically culminates in the granting of water entitlements to individual abstractors. The process can involve allocating water at a variety of administrative and geographic levels, including at a national, basin, sub-basin, or regional level. Basin-level water allocation needs to consider: i) national-level water allocation planning, which can determine how water will be shared among basins (for instance, through inter-basin transfers) or between provinces; ii) regional or sub-basin plans, which may be required and give effect to basin-level allocation decisions; iii) individual water users within a basin, which can affect the required levels of reliability of supply; iv) other water-related plans, such as those related to flood management, hydropower development, and water resources protection, which may link closely to water allocation decisions.
6. **Improve incentives for private sector investment in water provision.** Catalyze private sector investments by analyzing the potential for private sector engagement in providing water supply services through a PPP in areas where piped water supply is currently unavailable. In-depth studies and provincial investment plans could help identify potential PPP-suitable water supply sites.

Incremental investment needs

- **Building a resilient water sector would require an investment of US$0.7 billion (NPV) cumulatively from 2023 to 2050.** The largest component is for improved water storage (US$544 million), including rehabilitation, repurposing, and retrofitting of existing reservoirs and dams and adding additional functions, such as flood control and additional storage. For water, sanitation, and hygiene (WASH), the total amounts to a lower NPV of US$148 million assuming an annual increase in expenditure by 5 percent to meet more ambitious WASH targets.

4.1.3. Improve resilience of transport infrastructure

Increasing the resilience of roads will be critical for avoiding disruptions from floods, yet design standards in Cambodia are not currently tailored to adapt to climate risks. Chapter 2 presented estimates of the impacts of floods in cutting off access to critical services and delaying supply chains, underscoring the importance of resilient roads in reducing exposure and vulnerability to climate change. Cambodia's design standards for national and provincial roads date back to early 2000–2003. The existing standards do not incorporate flood levels to inform embankment, drainage, or pavement designs. Hydraulic structures are designed based on the historical highest daily rainfall data and are therefore not tailored to accommodate the shorter but more intense rainfall episodes expected under climate change. Large-scale riverine flood risks are also not considered by design, failing particularly to address the issue of poor outlets and downstream discharge capacity due to Cambodia's flat terrain and overall poor soil drainage capacity.

Subnational analysis shows the need for urgent resilience interventions to cope with climate risks. Pavement coverage in Kratie and Kampot provinces is 31 percent and 27 percent, respectively, far behind that of other extremely risk-exposed provinces (average 68 percent). In terms of drainage and water-crossing structures (bridges and road-crossing culverts) for effective floodwater passage, the road network in Kampong Cham is a negative outlier among extremely exposed provinces, with only 0.2 water-crossing structures per kilometer. Without prioritized interventions, roads in those provinces are expected to have a higher damage rate during flooding.

A modal shift to Cambodia's existing rail line and inland water corridor, which are substantially less exposed to flooding, could reduce disruptions from flooding and lower emissions as well. Cambodia's existing railway connects Phnom Penh with the country's major trade gates—Poipet at the Thai border in the Northwest and the Sihanoukville seaport in the Southwest. The existing rail line is considerably less exposed to riverine flood risk from the Tonle Sap River (compared with NR5) and the Mekong River (compared with NR4). Similarly, the Mekong inland water transport corridor connecting Phnom Penh with Vietnam through K'orm Samnor serves as an alternative for freight transport using NR1, but is much less vulnerable to flooding risks, particularly compared with the NR1 sections in Kandal near the Mekong River. Improving the infrastructure conditions and capacity of the railway and waterways and better integrating them with the road network could lead to a freight modal shift from road for as much as 4.6 million tons by 2030. It would considerably reduce the potential indirect economic costs from road network disruption by floods, while at the same time reducing the annual GHG emissions from the transport sector by 0.69 $MtCO_2e$.

What we recommend

1. **Align road design standards with climate risk exposure levels.** MOWRAM and the Ministry of Environment should be mandated to develop and share key climatic information with the Ministry of Public Works and Transport (MPWT) and MRD for road design updates. The most critical information includes hourly precipitation, flood depth, and duration monitoring. The MPWT should align design parameters with climate risk exposure by location instead of by road class. Further, there is a need to conduct periodic sensitivity tests in hydraulic design to ensure structures are adapted to shorter and more intense rainfall and longer large-scale flood inundation. Finally, "road for water" principals must be applied consistently to maximize normal water passage underneath roads located in floodplains by constructing dense water-crossing structures across the road network.
2. **Invest in railways and inland waterways.** The following investments could be made:

Table 2. Targeted investments could promote modal shift to railways and waterways

Mode	Potential interventions based on assessment.	Est. costs (US$, million)
Railway	Railway infrastructure upgrade and procurement of freight locomotives and rolling stock. Connecting railway line with the container terminal LM17 of the Phnom Penh Autonomous Port (PPAP).	520.0
	Finance PPAP's plan to expand the capacity of the LM17 from 500,000 TEUs at present to 900,000 TEUs by 2030.	50.0
Waterways	Finance dredging works for waterway sections in Koh Keoh Channel, Prek Kdach Channel, and Pream Rang Channel to increase vessel draft levels.	16.2

3. **Invest in critical road redundancy to reduce economic costs from flood disruptions.** The overall resilience of the road network against flood induced disruptions depends on the level of redundancy

in the network. With limited fiscal resources, the RGC needs to prioritize investing in redundancies for the most critical road corridors. Based on a network criticality analysis, it appears that most critical road links in Cambodia's road network already have redundancy in place as rerouting options during flooding. Three major opportunities are identified in Table 3 for recommended investment to reduce high economic costs from flood disruptions.

Table 3. Spending could be prioritized to increase redundancies for the most critical road corridors
Potential investment interventions to enhance network redundancy

Roads	Redundancy for	Length (km)	Condition	Recommended upgrade	Est. costs (US$, million)
PR1534	NR5, Kampong Chhnang - Pursat section	71	Unpaved	Pave with asphalt concrete	20.50
NR43	NR4, Preah Sihanouk section	79	Unpaved	Pave with asphalt concrete	22.81
NR62-3	NR6, Siem Reap - Kampong Thom section	93	Unpaved	Pave with asphalt concrete	26.85

4. **Invest in asset maintenance to reduce the physical fragility of the network and prioritize investments for climate resilience of critical rural roads.** Maintaining national and provincial roads in good condition would require a maintenance budget of US$125 million every year for the MPWT (US$55 million more than the current level) and US$63 million for the MRD (US$38 million more than the current level). Improvement is also needed in maintenance practices, including full rollout of the road asset management systems by the MPWT and MRD and increasing participation of the private sector in road maintenance. With a massive rural road network of 47,920 km, Cambodia must spend its rural road investment strategically by focusing on communes where the rural accessibility gap is most severe and where climate risks have the highest negative impacts.

Incremental investment needs

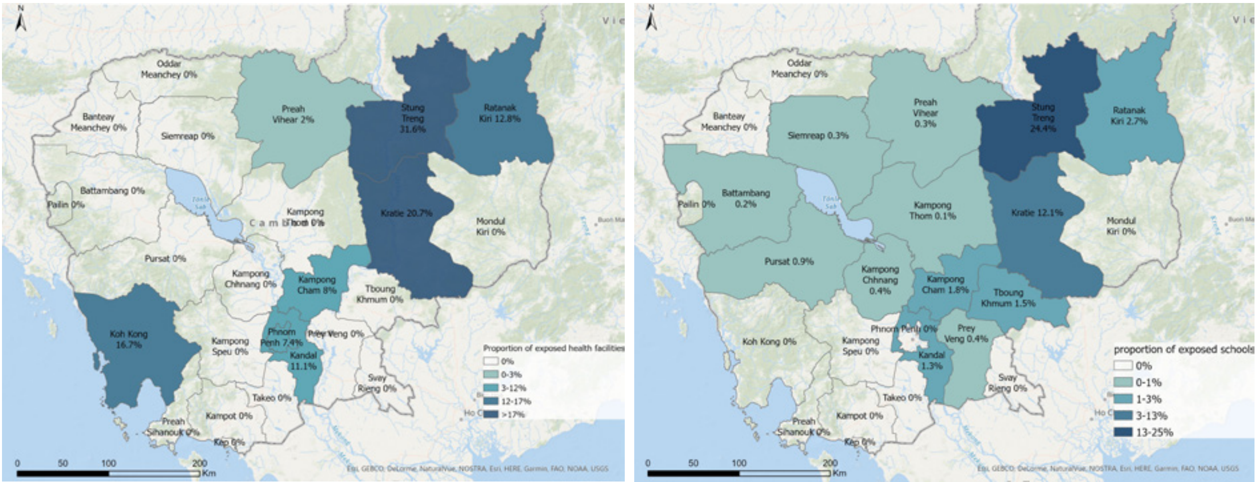
- **Building a resilient transport network would require an investment of US$7.0 billion (NPV) cumulatively from 2023–2050.** This includes the costs outlined above for increased road maintenance budget, modal shift, and enhanced network redundancy. These have a combined NPV of US$3.3 billion. In addition, it also includes an estimated incremental NPV of US$3.7 billion for raising the resilience standards of new transport infrastructure, based upon estimates from Hallegatte et al. (2017).

4.1.4. Strengthen climate resilience in health and education

Ensuring the resilience of health and education facilities is critical to mitigating the impact of climate change on human capital. Analysis for this CCDR shows that provinces along the Mekong River have the highest proportion of schools and health facilities exposed to flooding (Figure 20). The clustering of affected communes in Stung Treng and Kratie provinces calls for caution as a higher Mekong water level could simultaneously flood health facilities in 11 neighboring communes. In this scenario, on top of direct casualties and road disruptions, the simultaneous flooding of health facilities could prevent people in need from quickly reaching a non-flooded hospital. Early warning systems and action plans are vital to mitigating damage in acute situations, such as the simultaneous flooding of nearby health facilities. Some areas are also at risk of clustered flooding of schools along the Mekong River. Overall, the analysis suggests that the education of approximately 1 percent of Cambodia's students could be disrupted each year by flooding. The impact will be much higher in certain areas, with 33 percent of students affected in Kratie, 25 percent of students in Stung Treng, and 13 percent of students in Kampong Cham. This could have long-term negative implications for human capital formation, particularly in these regions, as students may drop out of school earlier following these disruptions.

Figure 20. Exposure to floods is the highest for health facilities and schools in the Mekong Valley

a) Health facilities exposed to floods (%) b) Schools exposed to floods (%)



Source: World Bank analysis.

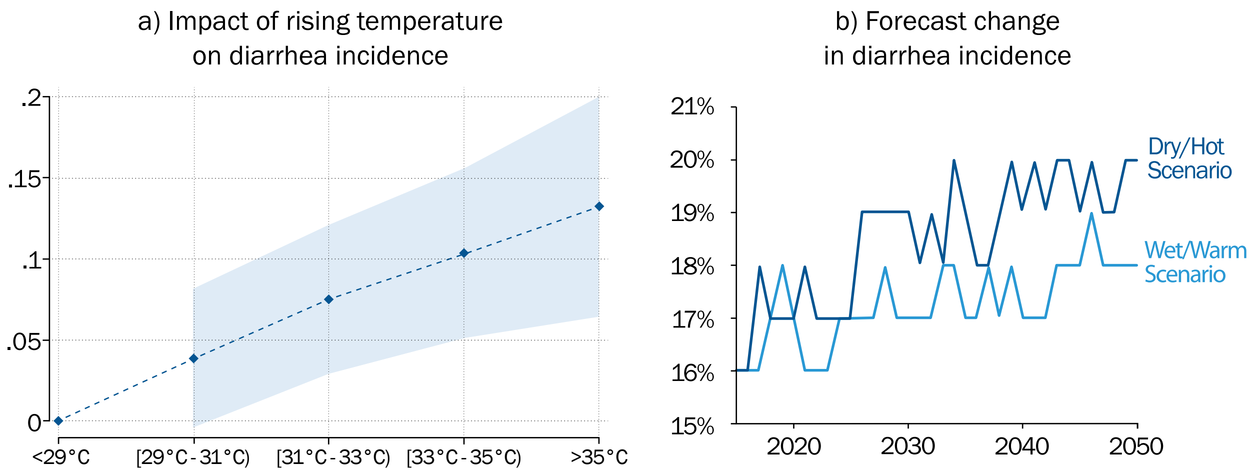
Currently, limited risk reduction expenditure for social sectors is a cause for concern. The Ministry of Health and Ministry of Education, Youth, and Sport accounted for only 1.5 percent and 0.1 percent, respectively, of total climate change expenditure in 2020, with a 24 percent decrease in the Ministry of Health's allocation from 2019, likely due to COVID-19. Analysis shows that in 2015, out of the 1,019 health facilities, 55 percent were in non-flooding areas, 12 percent in areas that experience flooding of less than two meters, and 33 percent in areas that experience flooding of more than two meters. Moreover, even non-flooded health facilities may suffer disruptions to their water supply and sanitation services in the aftermath of floods. Of the 6,929 educational facilities nationwide, 62 percent were in non-flooding areas, 10 percent in areas that experience flooding of less than two meters, and the remainder in areas that experience flooding of more than two meters (Mochizuki et al., 2015).[5] The Ministry of Health plans to strengthen and/or relocate high-risk health facilities as part of its National Strategic Plan on Disaster Risk Management for Health 2020-2024, subject to adequate financing.

Beyond climate-resilient infrastructure, protecting Cambodians' health requires funding and implementing adaptation solutions that directly mitigate climate impacts. The expected changes in climate will result in shifts in the spatiotemporal variation of diseases and increase the occurrence of infectious disease outbreaks. The World Health Organization also reported that climate variability (temperature, rainfall, and relative humidity) will be one of the public health challenges to control infectious diseases in the future, particularly in low-income developing countries. The direct impact of climate change on health will likely be higher than the damage to health facilities. Chapter 2 presented results showing that climate change through an increase in rainfall variability and temperature as well as prolonged drought could increase diarrheal incidence in children by four percentage points by 2050 (Figure 21). All provinces would be affected, from a 3.1 percentage point increase in Siem Reap to a 4.4 percentage point increase in Mondulkiri. Widespread cooling solutions will be needed to adapt to the expected increase in heat and to mitigate the resulting health, productivity, and economic losses. Improvements in urban drainage will also be critical to prevent the incidence of water-borne diseases that may flourish with the projected flood increases. Investments

5 For tropical storm risks, 64 percent of the health facilities and 69 percent of the educational facilities are situated in areas that are exposed to tropical depression with wind speeds less than 61 km/h, while 36 percent of health facilities and 31 percent of educational facilities are in areas exposed to tropical storms with wind speeds ranging from 62 to 88 km/h (Mochizuki et al., 2015).

in human development will certainly generate triple dividends by increasing people's ability to cope with shocks and their productivity (and, in turn, will yield significant economic and social benefits) and by creating healthy, educated, resilient citizens able to withstand shocks, thus generating economic benefits (regardless of whether there is a climate shock) and creating stronger societies.

Figure 21. Rising temperatures and higher precipitation increase the incidence of diarrhea (left), and climate change could increase diarrhea incidence in children by four percentage points by 2050 (right)



Source and notes: Aguilar-Gomez et al., (2023). The authors assess the causal impact of precipitation and temperature on diarrhea incidence in children under five. Health data comes from the Demographic Health Surveys and historical data on temperature and precipitation from CHIRPS and CHIRTS (Funk et al., 2019; University of California, 2023). Panel (a) shows the results from a binned regression of health outcome on temperature or precipitation bins. Points are estimates and the shaded region is associated with a 95 percent confidence interval. In panel (b) the relationship between diarrhea incidence and temperature is then used to forecast diarrhea incidence in future years. The dry/hot scenario in dark blue relies on the cmcc-cm2-sr5, cnrm-esm2-1, and kace-1-0-g climate models. The wet/warm scenario in light blue relies on the inm-cm4-8, mpi-esm1-2-hr, and mpi-esm1-2-lr climate models.

What we recommend

1. **Decrease the exposure and vulnerability of health and education facilities.** The vulnerability of education and health infrastructure could be reduced with building assessments and standards to ensure investments will be effective in the face of climate change. A nationally recognized sustainable building code is needed to codify climate mitigation and adaptation standards for education and health infrastructure, leveraging existing efforts by the Cambodia Green Building Council (CamGBC), the Ministry of Environment, and the Ministry of Land Management, Urban Planning, and Construction. For instance, the new building code could ensure that the construction and expansion of health facilities adheres to the WHO Guidance for Climate-resilient and Environmentally Sustainable Health Care Facilities. Various adaptation solutions exist to make infrastructure more resilient, from building schools on stilts to weatherizing facilities and identifying opportunities for nature-based solutions, such as restoring watersheds as a buffer against floods.
2. **Improve monitoring of climate-sensitive diseases.** Increased data collection on climate-sensitive diseases, tied to early action programs, could help better understand and respond to climate-related hazards and associated health risks. Such a monitoring system could build upon the existing data infrastructure of the Ministry of Health's National Center for Parasitology, Entomology, and Malaria Control. Data access on case numbers and potential outbreaks should be extended to stakeholders

working with health information systems, early warning systems, and communicable diseases, such as community-based organizations, development partners, and other actors within the Ministry of Health. Data on climate-sensitive diseases could also be included in the Ministry of Health's Health Database, which will contribute to making climate change-related health data available to the public (Ministry of Health Global Environment Facility Project 2020–2022).

3. **Address the health financing gap and develop insurance schemes.** Including health-sector climate adaptation in the national budget will be critical to meet the expected high increase in demand for health expenditure. Increasing the availability and affordability of health insurance schemes and better targeting of climate-vulnerable populations will be critical. More PPPs will also be needed because private providers provide a significant portion of healthcare in Cambodia. In 2019, more than two-thirds of households sought care from a private healthcare provider, and only 23 percent did so from a public provider. In 2022, there were approximately 16,000 private providers (including pharmacies) and less than 1,500 public health facilities.
4. **Improve food storage and introduce vector control measures.** Vector control measures will become increasingly important to prevent the spread of vector-borne diseases, particularly in regions that have been spared but will become suitable vector habitats under the new climate conditions. Incentivizing investments in improved food storage and expanding information and monitoring on food storage conditions can also mitigate climate-related health risks.

Incremental investment needs

- **Making health and education facilities more climate-resilient would require an investment of US$117 million (NPV) cumulatively from 2023–2050.** This estimate is based upon the spatial analysis of flood exposure outlined above and cost estimates of resilient building infrastructure. This does not consider the increased allocation needed for healthcare expenditure from the budget.

4.1.5. Improve urban planning and DRM

Cambodia faces growing challenges from rapid urbanization, with the combination of increased population, limited investment resources, and weak urban planning systems exacerbating exposure to climate and disaster risks. The number and share of urban poor are increasing in Cambodia as cities absorb rural migrants. Inequality, measured by the Gini coefficient, rose between 2014–2019 and is highest in urban areas (reaching 33.8 percent in 2019). Approximately 39 percent of urban dwellers live in slum conditions (UN Habitat 2020).

Increased incidence of extreme heat represents a major threat to human health in Cambodia, especially for outdoor laborers and urban populations for whom heat rises are compounded by the urban heat island effect. The effects of temperature rise and heat stress in urban areas are increasingly compounded by the urban heat island phenomenon. Dark surfaces, residential and industrial sources of heat, an absence of vegetation, and air pollution can push temperatures higher than those of the rural surroundings, commonly anywhere in the range of 0.1°C to 3°C for global megacities. Particularly high urban heat island levels have been reported in Cambodia's capital Phnom Penh, with the temperature differential between rural and urban areas reaching as high as 4°C during the daytime. Beyond the impacts on human health, the temperature peaks resulting from the combined effects of urban heat island, climate change, and future urban expansion are likely to damage the productivity of the service sector economy. These may occur both through direct impacts on labor productivity, but also through the additional costs of adaptation such as cooling measures.

Urban expansion on green spaces, natural lakes, and wetlands, which previously served as natural flood control and wastewater management systems, has resulted in growing flood risk and exposure. This is particularly the case in major cities such as Phnom Penh, Battambang, and Sihanoukville (World Bank Group, 2018). The adoption of comprehensive Environment and Natural Resources Code which includes provision for disaster risk reduction and climate change in April 2023, will support support Cambodia's efforts to enhance its institutional capacity and effectively address disaster risk reduction. Nature-based solutions alone are insufficient in rapidly urbanizing areas, and the loss of these ecosystem services will require additional green and gray infrastructure to compensate. Globally, cities are pivoting approaches to become sponge cities, better utilizing natural wetlands, greenspaces, and nature-based engineering solutions for storm water drainage, retention, and flood control. Cambodia's cities have historically been natural sponge cities but are quickly losing this capacity with the loss of agriculture and wetlands. This also includes encouraging use of the most space efficient and environmentally friendly forms of collective and personal transport.

Cambodia's emergency response capacity faces challenges due to broadly defined responsibilities and gaps in stakeholder coordination. To address some of these gaps, the National Center for Disaster Management has developed specific SOPs for evacuation center management and multi-hazard warning systems. Additionally, the Flood National Contingency Plan was prepared in 2021 and provides more detailed guidance on preparedness and response procedures and the roles and responsibilities of relevant government institutions. Despite these efforts, Cambodia's Mid-Term Review of the Implementation of the Sendai Framework for Disaster Risk Reduction found that further coordination between government and non-government stakeholders is needed to improve emergency response operations (RGC, 2022).

Cambodia has made efforts to upgrade its hydrometeorological observation network and communication systems, but hydrological information and services remain insufficient to meet rapidly growing needs. MOWRAM has upgraded its observation network and communication system. Furthermore, the Mekong River Commission operates a network of water level and rainfall stations along the main stem of the Mekong River and major Mekong tributaries in Cambodia, Lao PDR, Thailand, and Vietnam, which is used to calculate the flow in Cambodia. However, despite improvements over the past decade, climate and hydrological information and services remain insufficient to meet the rapidly growing needs of Cambodia's different sectors.

The quality and frequency of climate and hydrological information products and service by the DOM and the DHRW in MOWRAM is variable. Although the DOM provides 3- and 7-day forecasts, early warnings for extreme events, and monthly and seasonal outlooks, these long-range forecasts are not readily accessible to everyone and often not updated regularly. Sectoral agencies have also raised concerns about the resolution and absence of information on forecast uncertainty and accuracy. This limited availability and infrequency of updates restricts the delivery of climate services. Currently, the DOM only offers short-range forecasts for certain weather parameters, but does not offer services tailored to the transport, tourism, or marine sectors. Similarly, it does not provide regular forecasts or outlooks that are crucial for the Ministry of Agriculture, Forestry, and Fisheries to develop agro-meteorological advisories.

Cambodia ranks among the top 15 countries globally where universal access to early warning systems for natural hazards could have a significant impact on reducing the risk to the well-being of its citizens. Research has shown that Cambodia could avoid well-being losses of up to US$340 million annually and asset losses of up to US$170 million. Universal access to early warning systems could reduce well-being losses by up to 21 percent and asset losses by up to 20 percent (Hallegatte et al., 2017).

What we recommend

1. **Strengthen risk-informed urban planning and adopt a comprehensive flood risk reduction approach**: It is necessary to strengthen risk-informed urban planning regulations and practices to reduce exposure of people and assets in high flood risk areas, reduce vulnerability of the built

environment and people to flood hazard, protect remaining natural retention areas, and improve drainage and flood mitigation through green and gray protection infrastructure. A comprehensive approach needs to be developed that combines physical infrastructure improvements and nature-based solutions to address inadequate flood protection in areas of Phnom Penh and other rapidly growing urban areas. This could involve the development of integrated urban flood risk management strategies for primary and secondary cities.

2. **Improve access to early warning systems and emergency response infrastructure:** Enhancing EWS1294 coverage to last-mile communication by improving the number of subscribers and reliability is needed for better and more timely and accurate early warning messages to at-risk communities during disasters. Developing an operational and effective national emergency operation center (EOC) and building up the country's warehousing and logistics capabilities necessary for emergency response activities to reduce dependence on external organizations. Developing contingency plans linked to anticipatory actions, social protection, and other relevant emergency preparedness and response actions is necessary. Digital tools can facilitate efficient aid distribution and emergency cash transfers, bolstering the population's resilience.
3. **Incorporate cooling measures into planning and urban development to reduce urban heat island effects.** Phenom Penh's vegetative coverage is declining and already below UN recommendations. As Cambodia's cities expand, preserving green spaces and carrying out low-cost tree planting initiatives can lock in long-term benefits to reduce urban heat island effects. It will be important to introduce natural cooling methods in building design, rather than adding to energy usage with air conditioning. The vast network of public sector social service buildings offers an opportunity to forge ahead with solar installations.
4. **Manage motorization and encourage the use of much more carbon efficient modes such as walking and biking and public transport:** Fostering the use of 2- or 3-wheelers, bus, or train is fundamental to a low-carbon development trajectory while supporting sustainable development goals for livable cities, social inclusion, clean air, and road safety. Affordable, safe, and convenient urban passenger mobility systems are critical for the welfare of urban residents. In addition to connecting people to jobs, education, health care, and recreation, efficient and reliable urban mobility systems are also critical enablers of economic activity and labor markets in cities. Public transport is particularly relevant for helping people of lower income access opportunities, generate income, and gain education.

Incremental investment needs

- **Improving DRM and building urban resilience would require an investment of US$176 million (NPV) cumulatively from 2023–2050.** This includes the costs of extending and enhancing the coverage of the early warnings system, strengthening the management of the EOC, the administrative costs of risk-informed urban land-use planning, and the incremental costs of additional urban greening.

4.1.6. Develop an adaptive social protection system

Social protection systems are essential to protect the poor and vulnerable against risks from climate change. In response to the 2022 floods, the government created a temporary cash transfer program to support at-risk households. This cash transfer program came in addition to the ones targeting inflation and COVID-19 consequences. With these three shock-responsive cash transfer programs, social assistance coverage in the country currently stands at 24.7 percent, and Cambodia spent 1.13 percent of its GDP on social protection in 2022, up 1.04 percentage points compared to 2019. Still, the share of spending on social protection is much lower than in other Southeast Asia countries; it amounts to 5.3 percent in

Thailand, 2.4 percent in the Philippines, and 1.67 percent in Indonesia. Moving forward, an institutionalized shock-responsive cash transfer program is needed to replace the current temporary programs and address life cycle risks. The latter would be readily available and automatically activated when risks are triggered. Even if the final amount spent on transfers may be the same as what would be disbursed under an ex post cash transfer program, the strengthened preparedness from an adaptive social protection program would speed up disbursement. This would prevent potential long-term impacts due to inefficient short-term coping mechanisms, such as workers selling productive assets or children dropping out of school (Nishikawa Chavez and Cardona, 2023).

Building an effective adaptive social protection system requires strengthening social protection programs' financing, institutional arrangements, and program design. Cambodia has shown significant progress in its capacity to use existing social protection programs to respond to shocks in the last three years. The expansion of the Cambodia social registry's coverage (IDPoor) to include near-poor households increased the number of registered households from 700,000 to 1.1 million. This additional information is key to being able to rapidly identify poor and vulnerable households in the event of a shock. Nevertheless, additional steps remain to strengthen the adaptability of the social protection program. The Adaptive Social Protection Stress Test conducted for this CCDR quantifies the level of preparedness and identifies the gaps in adaptive social protection systems to guide the policy design process. The results highlight the need to prioritize financing mechanisms, including the government's strategy for risk financing, the capacity to analyze the country's main disaster risks and model their cost implications, and the mechanisms currently in place to finance risk response. The analysis also highlights the need to scale up social programs and their delivery and to strengthen the connection between DRM and social protection systems (Nishikawa Chavez and Cardona, 2023).

What we recommend

1. **Strengthen the social protection system to improve its capacity to respond to shocks.** Cambodia has taken large strides toward developing its social protection system in response to COVID-19, but further actions are needed to consolidate the current social protection system, including: (i) moving toward an integrated and interoperable social registry; (ii) creating a permanent, broad-based, social assistance cash transfer program that covers vulnerable households' main risks from a life cycle approach; (iii) transiting from ad hoc social assistance responses to external shocks to a pre-established adaptive social protection system; (iv) developing a risk financing strategy that can endow the financial resources required to temporarily expand cash transfers; and (v) developing coordinated door-to-door damage assessment capacity that can serve both the National Committee for Disaster Management and the social protection sector.
2. **Promote emergency cash transfer response mechanisms.** For sudden-onset climate change events like floods, emergency shock response cash transfers can help households weather the immediate impacts. For slow-onset climate events like droughts, productive economic inclusion programs can help reduce households' vulnerability ex ante by helping diversify livelihoods, while cash transfers triggered by timely early warning systems can help households weather the crisis.

Incremental investment needs

- **Building a broad-based adaptive social protection system would require investments of US$4.1 billion (NPV) cumulatively from 2023–2050.** This is based on the historical costs of the social protection system in Cambodia and future requirements for its expansion as estimated from the modeling of poverty impacts in Chapter 2.

4.2. *Realign* the emissions trajectory to achive mitigation goals in ways that benefit development

This section provides detailed analysis and recommendations on four topics that will be critical for achieving both Cambodia's climate mitigation goals and development vision. Cambodia has made ambitious climate mitigation pledges in its LTS4CN and NDC but at present the country's emissions are growing rapidly—by 8 percent annually over the past decade. The LTS4CN relies heavily on rapid improvements in the LULUCF sector. Thus, active afforestation, resilient land management, and strong counters to deforestation need to be fully functional immediately to achieve the NDC and LTS4CN goals and constitute the first priority of this section. However, this CCDR suggests that there are numerous opportunities for Cambodia to boost ambition in other sectors in ways that would benefit development and avoid lock-ins to carbon-intensive patterns that could later be hard to reverse. One of these is the energy transition, which is the second focus of this section. Electricity and heat accounted for only 7 percent of emissions in 2019 but grew on average by 20 percent annually over the past decade, and the PDP projects a fourfold increase in power demand by 2050. The third is agriculture, given that it still accounts for nearly one-third of GHG emissions today and that upgrading practices in the agriculture sector will also have adaptation co-benefits and prove important for food security and productivity growth. Finally, this section also focuses on steering the urbanization process to facilitate more compact, productive, livable cities, which could stimulate productivity growth while also lowering emissions and freeing up space for wetland restoration.

4.2.1. Seize opportunities for win-wins in forest management

The LULUCF sector in Cambodia will play a crucial role in reducing exposure to climate change impacts, as well as lowering emissions and contributing to economic development. As discussed in Chapter 2, emissions from LULUCF accounted for 44 percent of Cambodia's total in 2019, according to data from the Climate Analysis Indicators Tool, which is based on the RGC's GHG emissions inventory. Approximately 80 percent of communities in rural areas directly depend on forests for food, potable water, medicine, building materials, and goods for small businesses. Forest resources in Cambodia also play an important role in providing valuable ecosystem services, such as carbon sequestration, erosion control, sediment retention, flood regulation, and water purification. Protecting and restoring forests can help preserve biodiversity, which acts like a safety net to keep delivering ecosystem services and help build resilience against climate change. Cambodia is among the most biodiverse regions on Earth, with many biodiversity hotspots (that is, hubs of threatened endemic species) and one of the largest areas of remaining natural forest in Southeast Asia. It is home to an estimated 8,260 plant species, more than 250 amphibian and reptile species, 874 fish species, and over 500 bird species (FFI, 2023). Climate change is projected to accelerate forest degradation, including the loss of wet and dry forest ecosystems. In fact, increased temperatures, drought, and changes in seasonal rainfall patterns alter forest productivity and distribution and influence the frequency and intensity of forest disturbances, including the risk of fires, insect outbreaks, and invasive species.

Cambodia has experienced one of the world's most rapid rates of deforestation over the past two decades, and the rate of deforestation has not yet slowed. Satellite data suggests that Cambodia has lost 2.64 million hectares (30 percent) of forest cover from 2000 to 2020 (Global Forest Watch, 2022). In response to deforestation, Cambodia introduced the Law on Environmental Protection and Management of Natural Resources in 1996 and the Forestry Law in 2002 for the management, use, harvesting, conservation, and development of all forests. The draft Code on Environment and Natural Resources was also approved in April 2023 after nearly eight years and will expand the possibility for ministries and institutions to further participate in environmental protection and natural resources and biodiversity management and preservation. Although the annual rate of permanent deforestation in Cambodia has declined slightly from 2 percent in 2017 to 1.9 percent in 2020, it remains the highest among peer countries such as Vietnam (1.1 percent in 2020) and Thailand (0.3 percent in 2020) (Sachs et al., 2022).

There have been several causes of deforestation, including agrarian expansion by smallholder farmers and illegal logging. In the 1990s, accelerated deforestation was initially linked to timber extraction for logging. To curb timber extraction, a logging ban was introduced in 2002, and the forest concession system was replaced with an Economic Land Concession (ELC) system, which sought to attract investment into industrial agriculture. However, the allocation of ELCs led to more deforestation within agro-industrial plantations, which continued until a moratorium on new ELCs was introduced in 2012 (ODC, 2015). The lack of inclusive land tenure programs for smallholder farmers has also indirectly driven forest clearances by forcing farmers to scramble for agricultural plots and move upland, encroaching on communities living adjacent to forests. Although it is illegal to grant ELCs in forested areas, this can be bypassed if the land is first reclassified as state-private land (ODC, 2015). The lack of law enforcement has also contributed to deforestation. Other secondary drivers of deforestation include exploitation for fuelwood and charcoal and forest fires during the dry season, exacerbated by land clearing and climate change (Sim et al., 2023)), as well as small-scale mining, construction of hydropower dams, and road construction and expansion (Pacheco et al., 2021). The government has been actively addressing deforestation issues, including through the zoning and demarcation of protected areas (core zone, conservation zone, community zone, sustainable use zone), and improving REDD+ programs and access to carbon markets for sustainable land management.

Deforestation and the loss of wetlands exacerbate the impacts of climate change in Cambodia, with negative impacts on valuable ecosystem services. Wetlands are not only crucial to building climate resilience but are important biodiversity hotspots. They support the livelihoods of communities as a source of food and clean water, protect against wildfires, and act as sponges by storing water and releasing it slowly, which protects against floods and droughts. Protecting and restoring wetlands is the most cost-effective and efficient way to counter the impacts of climate change, but these critical ecosystems have been disappearing three times faster than forests (UNFCCC, 2018). Cambodia's wetlands cover 30 percent of the country, including five wetlands of international importance (Prathna, 2021; Ramsar, 2023). However, large areas of wetland in Cambodia have been destroyed due to rapid development, with devastating consequences to its population and wildlife.

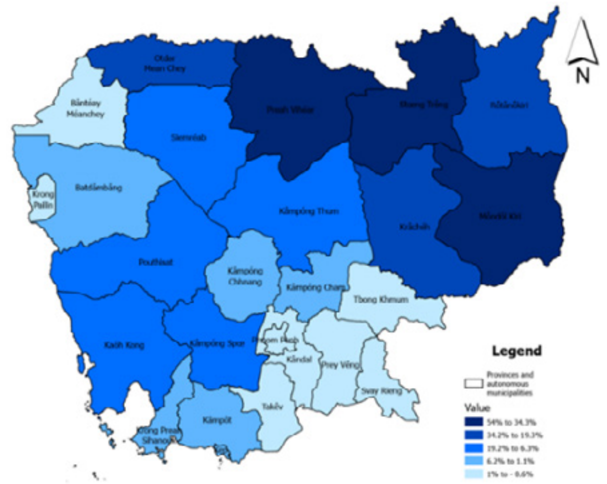
Cambodia's forests are much more valuable than alternative uses of the same land. A recent study in the Pursat River Basin in southern Cambodia found that intact forests generate benefits that are almost five times higher than those gained from cutting them down for small-scale agriculture and charcoal production (Rawlins et al., 2020). Converting these forests for charcoal production and agriculture would provide benefits worth about US$22 million. However, the loss of irrigation capacity alone would cost US$28 million, while the loss of hydroelectric power generation capacity would add another US$18 million. Flood risk would also increase, but this cost was not quantified. The loss of tourism opportunities would cost an additional US$53 million. Thus, Cambodia has strong reasons to protect its remaining forests and restore forest cover, in addition to meeting its NDCs, purely because of the national benefits this would generate.

Cambodia's LTS4CN has the ambitious target to halt and eliminate deforestation, plant 1.6 million hectares of forests, and restore 1.1 million hectares of vegetated areas to a natural forest state. Research for this CCDR has modeled the impacts of various policies for improved forestry management in Cambodia using the Integrated Economic-Environmental Model (IEEM) linked with spatial land-use land cover and Ecosystem Services Modeling (ESM), described in Box 1. This modeling framework is considered state-of-the art for integrated analysis on the impacts of forestry policies. It models several scenarios, all of which follow the measures outlined in the LTS4CN for LULUCF and the REDD+ Strategy. The first policy scenario is "NODEFOR," which represents a halving of deforestation by 2030 and its elimination by 2045. The second scenario is "AFFOR," which establishes 1.6 million ha of forest plantations on unproductive land. The third scenario, "RESTORE," restores 1.1 million ha of degraded, unproductive forests. All three policies are modeled in the "COMBI" scenario, which approximates the LTS4CN commitments. The fifth and final scenario is "COMBI+," which is similar to COMBI but includes a more ambitious commitment to eliminating deforestation, whereby the deforestation rate is reduced by 65 percent by 2030 and altogether eliminated by 2035.

These policy scenarios would all lower emissions substantially and mitigate land erosion, which in turn would positively impact agricultural productivity and potentially lower the need for the application of fertilizers. Erosion mitigation services would increase by US$1.9 billion when the portfolio of policies is implemented in the COMBI scenario. These scenarios would also result in more water being retained in forests, reduced quick flow, and reduced flood risks and damage, which would generate positive economic co-benefits. Improvements in water regulation services result in reduced run-off and quick flows to streams, particularly during high rainfall events. In the COMBI scenario, water regulation ecosystem services would improve across Cambodia with the greatest positive impacts found in Preah Vihéar (54 percent), Mondulkiri (47 percent), and Stoeng Treng (34 percent) by 2050 (Figure 22).

Figure 22. Achieving the LTS4CN targets would have a range of positive benefits for climate adaptation

Estimated water regulation ecosystem service benefits of the LTS4CN targets (% change relative to the BaU)

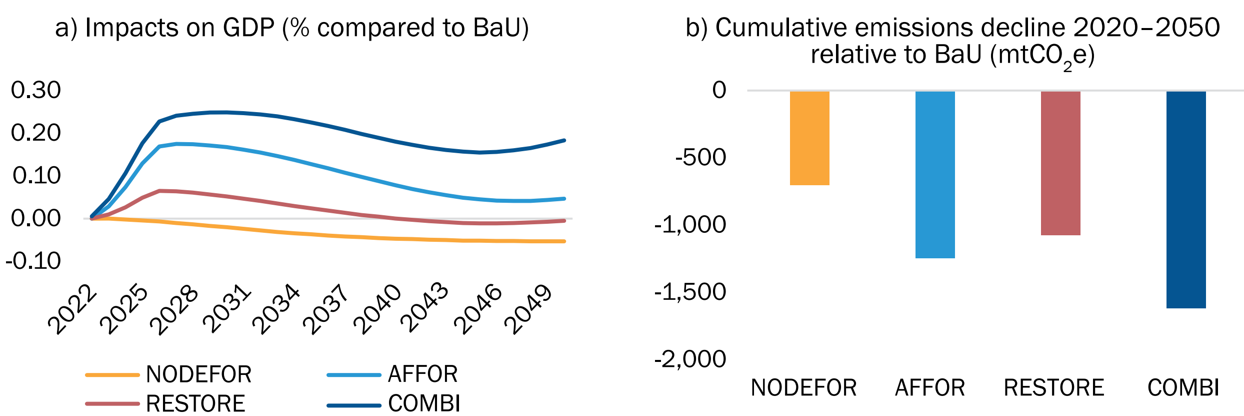


Source: Banerjee and Cicowiez (2023).

These policies could also potentially have positive impacts on GDP. The portfolio of LULUCF policies in the LTS4CN and REDD+ strategy would reduce cumulative net CO_2 emissions by 1.6 billion tons of CO_2 by 2050 (Figure 23b, COMBI scenario). While the impacts of reversing deforestation are slightly negative due to the resultant constraints on agricultural intensification and land expansion, they are outweighed by the positive impacts of afforestation and reforestation. In terms of wealth, the more ambitious program for eliminating deforestation (COMBI+) would have the greatest wealth impact while the less ambitious plan would generate the greatest GDP impact (COMBI). The reason for this distinction is that the more rapid elimination of deforestation in COMBI+ would have a more pronounced impact on the availability of future agricultural land and negatively impact GDP.

Figure 23. Achieving Cambodia's LULUCF-sector LTS4CN emissions targets would have positive GDP impacts and have the largest effects on lowering emissions by 2050 of all LTS4CN sectors

Impact of LULUCF targets in LTS4CN



Source: IEEM model impacts of LTS4CN forestry targets. NODEFOR = the target to reverse and eliminate deforestation; AFFOR = the target for afforestation; RESTORE = the target for forestry restoration; and COMBI = combination of all of these, as included in the LTS4CN.

Cambodia has a wide range of options to conserve and restore its forests. An important first step would be to identify any policies that might inadvertently create incentives to deforest, such as explicit or implicit subsidies for crops grown in forest frontier areas. Removing any such subsidies would not only reduce pressure on forests but could also free up resources that could be used for other purposes. It is also crucial to avoid exacerbating the problem by awarding new logging or other concessions in forest areas; if possible, such concessions should be rescinded in protected areas or at least strictly managed in designated conservation areas. Many remaining forests are in protected areas and can be better conserved if additional resources are devoted to protection. Loggers and small farmers typically receive only a small fraction of forest benefits and thus have no incentive to conserve them. These incentives can be changed by, for example, improving value chains or developing new markets for sustainably harvested non-timber forest products, ecotourism and nature-based tourism activities, and other means. In valuable areas where these approaches are not applicable, direct payments can be used. None of these options is a silver bullet, but together they can significantly reduce forest loss and promote reforestation.

Carbon markets could offer opportunities for Cambodia to mobilize investments. It is important to account for the significant carbon sequestration value of standing forests, and not only of reforestation and afforestation. Between 2016 and 2020, Cambodia's forest sector generated close to US$12 million with the sale of emission reduction credits (UNDP, 2022). The government has participated as an observer in the Voluntary Carbon Market Initiative (VCMI, 2022) to develop guidelines to use and claim carbon credits. Cambodia is now developing governance arrangements to efficiently drive private sector investments into high-impact mitigation by developing an institutional architecture to facilitate and incentivize site-specific carbon projects, applying national or subnational REDD+ approaches as a key instrument in halting deforestation and enabling the direct participation of communities.

The private sector must also contribute to sustainable forest management and climate change adaptation by adopting agroforestry techniques. The 2020 Cambodia Agriculture Survey estimated that 23 percent of the total 2.04 million agricultural smallholdings were involved in collecting wood for heating and cooking (National Institute of Statistics, 2020). A smaller number of agricultural households were engaged in other forestry activities, including collecting edibles and charcoal making. With sustainable agroforestry techniques, private companies and communities of farmers can increase the range and value of farming products and diversify their revenues while preserving ecosystems and combating climate change.

What we recommend

1. **Prioritize urgent reforms to implement transparent satellite monitoring of forest cover to evaluate progress against LTS4CN targets and enhance protected area management, and strengthen law enforcement to eliminate illegal logging.** Implementing Cambodia's LTS4CN commitments will be critical for climate adaptation, mitigation, and development goals and should be prioritized, with enhanced monitoring and evaluation of annual progress against targets. Doing so will require a multi-pronged approach, including conservation through improved management of protected areas, including core zones, community zones, and sustainable use zones, as well as heightened funding for the satellite monitoring of forests (for example, the satellite monitoring of clear-cut deforestation and alerts of change in forest cover). This should be complemented with heightened law enforcement, support to sustainable economic activities, and an elimination of uncertainty regarding possible changes to laws. To promote private sector participation in plantations and registration of private forests, the Guidelines on Private Forest Registration in Cambodia (AFoCO, 2021) should be published and disseminated to central and subnational governments and the private sector. Initiatives should prioritize small-scale forest users' needs in community-forestry initiatives and agroforestry and systematically include women in forestry decisions.

2. **Scale up land and natural resource management approaches that recognize the interaction across land uses across sectors.** Cambodia has experience in deploying climate-smart landscape management through REDD+, although at a relatively modest scale. Scaling up such investments will require strengthening local governance, planning, and management capacity, and improving stakeholder ownership and involvement in the governance and operationalization of landscape management. Landscape management approaches involve low capital costs and could be adapted and scaled up easily.
3. **Protect critical ecosystems, including wetlands.** Conservation, restoration, and effective management of wetlands should be appropriately valued in policies and land-use planning as cost-effective and sustainable solutions for climate change adaptation. More investments in resources and capacity building in protected areas are needed, as are continued efforts to strengthen law enforcement and increase carbon offset opportunities, including REDD+ strategies for sustainable land management.

4.2.2. Making an economic case for a lower-carbon energy growth path

Cambodia has experienced rapid growth in energy supply and power demand over the past two decades. The energy supply per capita in Cambodia in 2020 was only about 28 percent of the global average but total energy supply increased by 6.1 percent annually from 2010 to 2020 (International Energy Agency, 2020). Firewood is still the primary energy source for 3 million Cambodian households, mostly in rural areas, and it accounted for 44 percent of total final energy consumption in 2020. Cambodia has seen double-digit annual growth in electricity demand since the early 2000s, with an annual average of 17.8 percent from 2003 to 2022. Electricity consumption increased 22-fold during this period. While Cambodia mainly relied on expensive fuel oil to supply its electricity before 2010, demand since the mid-2010s has been primarily met by the expansion of coal-based energy, hydropower, and power imports from Lao PDR, Thailand, and Vietnam. Variable renewable energy (VRE) in the form of solar power and wind power accounted for only 10 percent of installed capacity and only 4.5 percent of electricity generation in 2022.

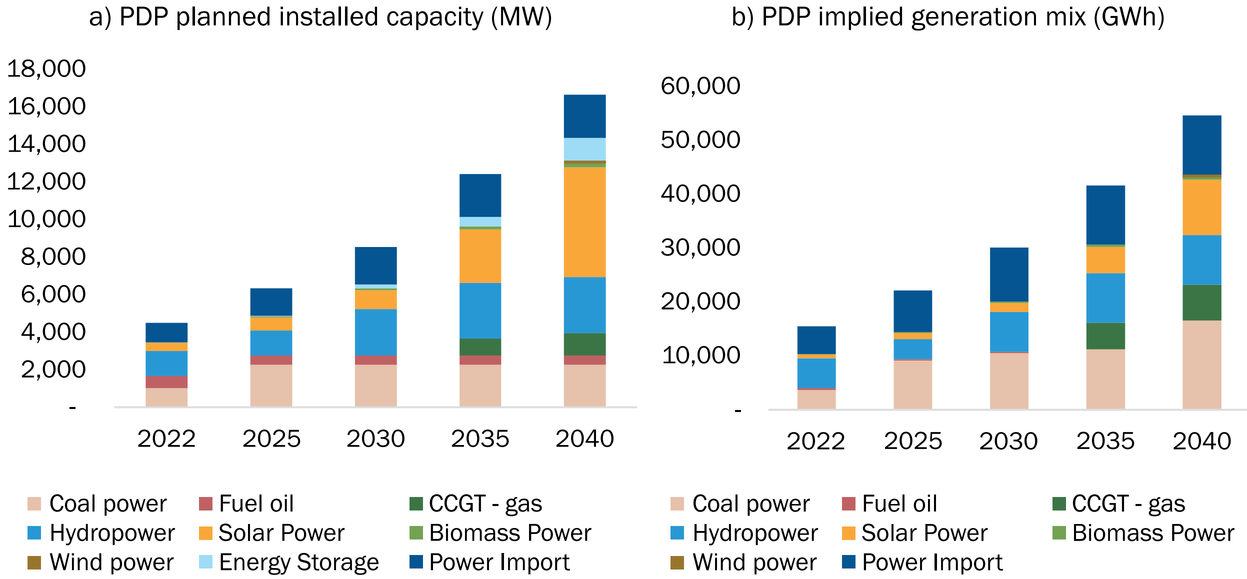
Although Cambodia has rapidly expanded access to electricity, it has one of the highest electricity tariffs in the region, which acts as a constraint to growth. While the country has rapidly expanded the coverage of grid electricity services over the past decade (achieving a village electrification rate of 97 percent by 2021), electricity remains expensive in Cambodia. Cambodia's average retail tariff of about 15 US cents/kWh is one of the highest tariffs in the region. This high tariff rate has mainly been caused by inadequate system planning, high investment costs, limited competition (especially for generation), lack of transparency on pricing and power purchase agreements (PPAs), and suboptimal power system operation with several unsynchronized small systems. The power grid is still fragmented and congested, with a weak backbone transmission network that is already overloaded.

The new PDP endorsed by the Ministry of Mines and Energy in late 2022 and revised in June 2023 will guide power sector development in Cambodia until 2040. According to the revised PDP, electricity demand in Cambodia is projected to increase from 12,400 GWh in 2020 to 54,600 GWh in 2040. The growth in demand will be met by new coal-based power, solar power, hydropower, and greater power imports from Lao PDR and Thailand. The PDP's planned capacity mix and generation mix are presented in Figure 24. The PDP includes three committed coal-based power plants (with a total of 3,5GWh added capacity), which will be built by 2025.[6] No new domestic coal-based power projects are scheduled after 2025. The share of coal in the generation mix will increase from 24 percent in 2022 to a high of 41 percent in 2025 and decrease gradually to 30 percent and 27 percent by 2030 and 2040, respectively. New gas power projects are planned

6 The three committed coal power plants are Han Seng and two plants invested in by the Cambodia International Investment Development Group and Royal Group, respectively.

from 2030 to meet the demand and balance the power system to integrate VRE and will account for around 12 percent of the generation mix in 2040.

Figure 24. Cambodia's revised PDP includes significant scale-up of solar capacity, but with limited ambition this decade



Source: Cambodia PDP 2022–2040 and World Bank analysis.

While more ambitious than previous iterations of the PDP, the revised PDP involves only moderate, backloaded scale-up of renewables resulting in CO_2 emissions in the power sector quadrupling between 2022 and 2040. The revised PDP from June 2023 now includes a planned 5.9 GW of solar capacity by 2040, up from the 3.2 GW planned in the previous version of the PDP, which included lower solar capacity but higher power imports. This brings the solar share of electricity generation in the revised PDP from 4 percent in 2022 to 12 percent in 2030 and 19 percent in 2040. However, modest solar power development (0.59GW) is planned before 2030, even though Cambodia has high solar potential and achieved a competitive price of utility-scale solar farms through the recent auction. The revised PDP also includes an increase in hydropower capacity, which will account for around 19 percent of the generation mix in 2040, bringing the total renewable energy generation share to 37 percent in 2040. The share of power import capacity is expected to decrease over time, stabilizing at 20 percent of the generation mix by 2040. The power sector will experience overcapacity in 2025/30 due to the commissioning of new coal power before 2025 and power imports from Lao PDR before 2030. Limited wind power capacity is considered (0.15 GW in total by 2040). Analysis for this CCDR estimates that the revised PDP will involve a rise in CO_2 emissions from just under 4 $mtCO_2$ in 2022 to nearly 16 $mtCO_2$ by 2040.

A more rapid scale-up of VRE this decade, along with greater hydropower imports from Lao PDR than is currently planned in the revised PDP, could offer several benefits for Cambodia. A more ambitious scale-up of solar energy this decade, and wind energy in later decades, could also have several benefits for Cambodia with the potential to: (i) technically defer or even avoid some of the planned domestic coal-powered capacity that has not yet started, reducing overcapacity in the next 10 years while maintaining a reasonable capacity reserve margin; (ii) reduce the total system generation cost of electricity, as the investment of additional renewable energy capacity could be offset by the avoided investment of part of the committed coal power capacity and associated fuel costs of coal power generation; and (iii) lower local air pollution and carbon emissions. In addition, a greater use of clean energy imports from Lao PDR than is currently planned in the revised PDP could offer an opportunity to reduce both the cost of electricity supply and carbon emissions, provided energy security risks can be minimized through enhanced regulatory cooperation on regional energy trading. Power imports from Vietnam, Thailand, and Lao PDR supplied one-fourth of Cambodia's peak load and one-third of its electricity demand in 2022 and facilitated lower costs than domestic energy generation. In the revised PDP, however, the planned power imports from Lao PDR were revised down from 3.1 GW by 2030 in the previous PDP version to 1.3 GW.

With rapid cost declines and technological progress in renewable energy, PPAs with fixed "take-or-pay" clauses also pose risks of lock-ins to using fossil fuels beyond what is the economically optimal and least cost pathway to meet growing power demand. With the acceleration in the clean energy transition globally, there is a high likelihood of continued cost declines in renewables and further technological progress in energy storage and transmission. Long-term fixed investments in fossil fuels that cannot be altered over multiple decades hence pose a risk of economically costly lock-ins to energy system costs that are higher than necessary and the possibility of some these investments becoming stranded assets. Analysis for this CCDR suggests that the utilization hours of coal power in the revised PDP will be reduced to less than 5,000 hours and utilization could fall further if declining costs of renewables makes a higher share of renewable capacity more cost-effective and economically desirable. Under these circumstances, the role of coal power plants would need to be shifted from traditional baseload to peaking plants, providing system stability services. Ensuring that PPAs for committed coal power plants provide sufficient flexibility to enable this shift is therefore important. Take-or-pay clauses with high-capacity factors could lock in higher than necessary costs and emissions in coming decades.

A more rapid VRE scale-up would require significant short-term grid investments and clear forward planning to enhance the flexibility of the power grid. Poor reliability of electricity supply and an outdated grid remain major concerns in Cambodia and hinder readiness for scaling up VRE. A successful VRE scale-up this decade would require urgent grid improvements in the short term. Forward planning with clear market signals will be needed to ensure pricing mechanisms and energy market policies are consistent in supporting this rapid scale-up. Energy market design would also need to be adjusted to allow for optimal dispatch that prioritizes VRE. It will also be imperative to conduct detailed forecasts and systems planning to anticipate and enable the grid integration of rooftop solar.

The private sector plays an important role in the electricity generation, transmission, and distribution network in Cambodia and could be supported further to accelerate the deployment of renewables. The private sector plays an important role in independent power transmission and production in Cambodia, accounting for 42 percent of the 115 kV–230 kV transmission lines and 27 percent of substations under build–own–operate–transfer arrangements (Electricity Authority of Cambodia, 2019). In addition, independent power producers generate over 90 percent of power (Asian Development Bank, 2018). The private rural electricity enterprises have been critical to the distribution network and have played a key role in providing off-grid solutions to address electricity access issues in remote areas. The participation of the private sector in utility-scale solar power development in Cambodia has demonstrated the success of cost reduction through competitive auctions, which has resulted in more transparent, competitive, and efficient prices.

Switching to clean cooking options would have multiple positive effects on health, economic opportunities, livelihoods, and the environment. The use of firewood for cooking is a major cause of deforestation and has negative impacts on health; it is responsible for 123 annual deaths per 100,000 people in Cambodia. According to a World Bank study, replacing firewood with clean cooking fuels would lead to a 25 percent reduction in deaths (World Bank, 2023b), and therefore would save the lives of 4,600 people annually, reduce the morbidity of all household members involved, and save women's time in collecting and preparing firewood and cooking. Richer households are three times as likely to have a clean fuel stove as the poorest households (Dave et al., 2018). This suggests that those with lower purchasing power may need support, information, or subsidies to access clean fuel stoves. This is particularly vital as it would save poor households' medical costs related to respiratory problems associated with traditional stoves and would allow them to redirect the time spent on fuel collection to other productive activities. Clean cookstoves also represent an opportunity for gender equality as it would improve women's health and potentially their discretionary time (Setyowati et al., 2023).

Improving energy efficiency and lowering the GHG intensity of cooling systems will also be critical for curbing emissions growth, raising productivity, and adapting to climate change. Cooling systems in Cambodia account for a large portion of all electricity demand, according to the recent National Cooling Action Plan (NCAP). Under climate change, rising temperatures are projected to double the demand for space cooling over the next two decades (NCAP, 2023). Action to reduce the need for mechanical cooling is critical to avoid emissions and the negative impacts on the energy grid from the growing use of cooling appliances. CCDR modeling also shows that implementing the cooling targets in the recent NCAP could fully offset the labor productivity losses from the heat in industry, offset three-quarters of those in services, and one-third of those in agriculture. Integrating passive cooling solutions in national building laws and urban strategies will optimize building performance and maximize mitigation and adaptation benefits from efficient, climate-friendly cooling.

What we recommend

1. **Increase ambition on VRE targets this decade and establish policy incentives for investment in VRE and energy storage.** Key actions include: (i) increasing the ambition of VRE targets this decade and conducting an in-depth review of the options and energy system implications of a more rapid scale-up of solar and wind energy in Cambodia than is currently planned; (ii) establishing policy incentives for private investment in VRE and energy storage; and (iii) expanding competition, such as through the use of auctions, to lower VRE costs.
2. **Prioritize urgent grid enhancements to meet the fast-growing demand.** Key actions include: (i) enhancing and expanding the existing 230 kV and 115 kV transmission grid and distribution networks; (ii) building a 500 kV backbone to support system adequacy and resilience as it continues to grow rapidly; (iii) investing in storage capacity to increase power system flexibility; and (iv) optimizing dispatch to prioritize VRE generation
3. **Conduct a review of the existing PPAs** for the committed new coal power plants to ensure that they can facilitate the shift in the use of coal capacity from supplying baseload to peaking and do not become economically inefficient investments. For example, instead of take-or-pay, PPAs could be priced in a two-part tariff with separate capacity and energy charges.
4. **Increase energy efficiency and lower GHG intensity of cooling with effective enforcement of the NEEP (2022–2030) and the NCAP.** Key actions include: (i) promoting sustainable energy practices in industry by introducing a sub-decree on energy performance standards for major energy-sector operation and equipment; (ii) developing and implementing building energy codes, green building guidelines, and minimum energy performance standards; (iii) creating energy management programs for the industrial and commercial sectors; (iv) developing a standards and labeling program for appliances and equipment; (v) integrating passive cooling systems in national building laws and urban strategies; and (vi) developing innovative financial mechanisms to implement energy efficiency projects. For example, prioritizing energy service companies (ESCOs) to promote, improve, and de-risk financing for energy efficiency at the firm level is important. Better suited financial instruments, particularly concessional finance, are critical to unlock the financing required under ESCO contractual models to help facilitate the upfront capital investment. Spurring energy efficiency in the garments industry will be particularly important as garment firms typically lack experience in

these areas and lack access to capital. A robust ESCO framework would be well suited to crowd in the required investments.

5. **Set ambitious targets for clean cooking, apply incentives and standards, and raise awareness.** Set ambitious national targets for clean cooking, encouraging collaboration and synergies among government agencies to implement the clean cooking program; apply standards and labels to cookstoves and fuels under the NEEP to ensure quality, safety, efficiencies, and minimum energy performance standards; and tailor awareness raising and behavioral change activities to consumers.

6. **Mobilize private sector participation in the energy transition.** Better implementation of the PPP law and inclusion of climate considerations in the development, evaluation, and approval of PPP projects would further mobilize private sector investments. Focusing public funds on grid investment could help catalyze private investment in the integration of renewable energy, buildings, and e-mobility.

4.2.3. Tackle inefficient agricultural practices

Inefficient agricultural practices both increase emissions and lower productivity in the agriculture sector, while having negative consequences for climate adaptation. Methane emissions from rice production account for 65 percent of all GHG emissions from agriculture. Livestock emissions account for about 24 percent of agriculture-related emissions, with enteric fermentation consisting of 19.5 percent and manure management about 4.5 percent. The remaining GHG emissions in the sector come from nitrous oxide from soils (N_2O) and biomass burning. Agriculture sector emissions of methane (CH_4) and nitrous oxide (N_2O) accounted for 78 percent and 77 percent of the national CH_4 and N_2O emissions, respectively. The drivers of high methane in Cambodia's rice production include: (a) inefficient water use for irrigation; (b) very high seeding density and inefficient and high fertilizer application rates; (c) improper management of rice residues such as rice straw and husks; and (d) inefficient energy use in agriculture. Rice is grown in flooded conditions, creating ideal conditions for bacteria to thrive on decomposing organic matter, mainly rice straw residue, and release methane. Poor absorption by the rice plants of nitrogen-based fertilizers, which are often overused by farmers, further leads to nitrous oxide emissions. Livestock productivity is still low due to poor feed and breed quality since most livestock is raised under a subsistence system.

What we recommend

1. **Incentivize the shift toward low-carbon rice production practices.** A shift from continuously flooded irrigation to irrigation with just one single drainage (AWD) can reduce the emission intensity of rice by 40 percent, bring about beneficial water savings of up to 30 percent, and reduce fertilizer use and methane emissions. Instead of burning rice straw, farmers should practice the incorporation of rice straw as an organic amendment to improve soil health and boost yields, while reducing GHG emissions from rice production.

2. **Promote sustainable livestock production through production intensification and waste management.** There is room to achieve greater carbon efficiency in livestock production through higher per unit livestock productivity by breeding, improving animal health, and providing access to quality feed. There is a need for reproduction management in breeder herds and breeding for greater heat stress resistance and lower methane production. Farmers in Cambodia are already using waste from livestock farms as input to biodigesters, which provides biogas for clean cooking and organic fertilizer for better crops and healthier soil while reducing GHG emissions. This practice should be encouraged and supported to scale.

3. **Promote the practice of integrated agriculture.** Integrated agriculture will not only help to enhance productivity and diet diversity and increase profitability, but can also fight against deforestation and agriculture emissions. Multi-level agroforestry and intercropping can build the potential for soil

carbon sequestration, restore degraded land and associated ecosystem functions, and increase farmer resilience. However, integrated agriculture has high initial costs, which remain significant constraints to increasing pro-poor adoption and diffusion. The government should take advantage of opportunities for carbon finance and other forms of green finance to incentivize farmers to adopt integrated agriculture practices.

4. **Repurpose environmentally harmful subsidies.** By providing the right incentives (for example, through targeted subsidies, taxes, or price supports), technical tools, and credible enforcement mechanisms, farmers' actions can be effectively influenced to reverse inefficient/overuse of inputs, such as irrigation water, fertilizer, pesticides, and antibiotics, and promote more effective use of improved water management practices, seed and breeding materials, and land resources. There is also a need to urgently review the policy framework to assess the feasibility of phasing out the most distorting and environmentally and socially harmful fertilizer subsidies. Redirecting subsidies toward providing training and goods and services to enable farmers to adopt more productive and profitable production practices that also produce adaptation/mitigation benefits is necessary.

4.2.4. Plan and develop compact, low-carbon, and resilient cities

Cambodia's cities are growing outward, not upward, and the resulting low-density sprawl is locking in energy-intensive development patterns that are prohibitively costly to service and difficult to reverse. Between 1985 and 2020 Phnom Penh's urban footprint quadrupled. A sampling of seven medium-sized cities also showed similar rapid and sprawling expansion, growing an average of 961 percent between 1985 and 2020. At the same time, urban densities are declining despite the increased population. These factors will drive up the unit costs of infrastructure service provision—adding to the backlog of unmet demand.

Modeling for the CCDR shows that a vision scenario for compact low-carbon urban development could both lower infrastructure costs, land requirements, emissions, and flood and heat exposure at the same time. A climate and urban growth scenario model conducted for this CCDR for Phenom Penh demonstrates the positive impacts of a lower-carbon development path. It first models Phenom Penh's current energy-intensive development pattern and depicts how the city would perform in 2050 without significant changes in urban policy. It also models the potential city performance in 2050 following existing national and local plans and goals in a "plan" scenario. This scenario includes actions mentioned in the Phnom Penh Sustainable City Plan 2018–2030 and urban area growth in accordance with the 2035 Land Use Plan. Finally, it models a "vision" scenario, which shows the potential city performance in 2050 with ambitious low-carbon, compact, energy-efficient urban policies and investments. The vision scenario would have 50 percent higher population density than the current plan scenario, resulting in far lower infrastructure costs and capital investment needs that are only a quarter of those in the current plan, which involves substantial urban expansion and high associated infrastructure costs. The vision scenario would also result in 40 percent lower emissions, lower flood risk, and a lower share of the population exposed to urban heat (Table 4).

The actions needed to mitigate the projected jump in urban emissions in the coming decades must start now. Urban areas contributed four million tons of CO_2 emissions in 2015, 10 percent of total emissions nationally. But this source is the fastest growing, essentially doubling from 1990 to 2005, and again from 2005 to 2015. With Cambodia at its early stages of spatial transformation and in the absence of robust policy measures, future urban emissions will continue to increase rapidly. Urban source emissions in China, Indonesia, and Vietnam range from 32 to 44 percent—these countries signal the potential increase in the national share for Cambodia as it soon nears urbanization rates similar to its neighbors.

Figure 25. A compact, higher-density and low-carbon "vision" development scenario for Phnom Penh would result in lower infrastructure costs, emissions, climate risks, and land-use requirements
Spatial plan modeling for Phnom Penh by 2050

Source: World Bank modeling.

As Cambodia urbanizes rapidly, the private sector can help with investment in green buildings and construction. The building sector is one of the largest final energy consumers in Cambodia due to a large-scale and unregulated construction boom. The Cambodian government can do more to promote private sector investment in the development of green buildings. For example, as of March 2023 Cambodia only has 30 buildings certified under the US Green Building Council, a globally used green building certification program, compared with 336 buildings in Vietnam and 384 building in Thailand. Under the IFC's green building program (Excellence in Design for Greater Efficiencies), Cambodia lags behind Vietnam, with just 3 certified buildings compared with 52 buildings in Vietnam. Carefully designed and operated green buildings can reduce electricity and/or water consumption, resulting in lower utility costs and other co-benefits, such as health and environment.

Table 4. The "vision" scenario would lower infrastructure costs, emissions, and physical climate risks
Modeling estimates for different urban growth policies in Phnom Penh by 2050

	SSP5 **Business-as-usual**	***Plan*** **Per current national & city development plans**	***Vision*** **Compact low-carbon approach**
Population density (person sq/km)	8,913	7,023	11,381
Carbon emissions (KG CO_2 per capita)	597	786	466
Capital investment needs ($US, million)	12.8	31.4	7.4
Population at risk of flooding (%)	57.7	59.4	56.5
Population at risk of urban heat (%)	38.1	42.2	35.2

Source: World Bank analysis 2023, carried out by CAPSUS.

What we recommend

1. **Promote integrated and energy-efficient compact urban development in current and future urban plans:** Existing and future urban plans could build on this vision scenario, applying planning approaches that consider the interlinkages between key urban sectors, especially land-use and transport planning. An important focus will be developing more compact urban forms that are easier and less costly to service and more energy-efficient and that help reduce exposure to climate

risks by reducing expansion into valuable wetlands and hazard areas. This will require geo-spatial data for planning, strengthening the capacity and policy environment for urban management, and creating incentives to better guide private sector development.

2. **Introduce new green building standards and emissions-based performance ratings for cities.** Introduce new green building standards and improve key regulations to increase demand for green buildings and a more sustainable construction sector. Decarbonization of cities can be promoted or rewarded with emissions-based performance ratings. However, effective performance measures cannot ignore the effects of differing demographic, economic, and geographic conditions on actual CO_2 levels in cities.
3. **Incentivize private sector investment in green construction with targeted incentives.** This can be achieved by issuing better and targeted financial products, such as construction finance, mortgages, and home improvement loans, and through better financial terms, such as lower interest rates and longer tenors for green buildings.

4.3. Reorient the economy to seize new opportunities from trade, investment, and technological progress

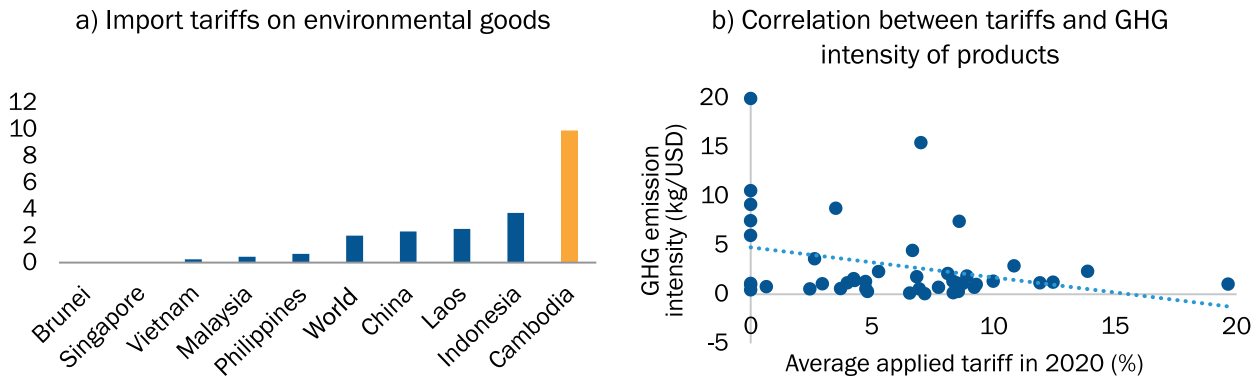
This section provides detailed analysis and recommendations for how Cambodia can seize new opportunities and minimize risks from the global net-zero transition. Chapter 2 outlined several ways in which the net-zero transition globally could offer opportunities for Cambodia's development, but also some risks. Cambodia is a highly trade- and FDI-dependent economy and will be impacted, directly and indirectly, by the net-zero transition in the world's major economies through trade, investment, and technology availability. Globally, the net-zero transition is creating rapidly growing demand for goods and services that feed into the low-carbon economy, while the net-zero commitments of firms and countries are altering patterns of comparative advantage. This section focuses first on how Cambodia can seize these new opportunities for trade while minimizing risks to competitiveness. The net-zero transition globally also offers opportunities for higher-skilled job creation in green industries. This section explores Cambodia's green jobs landscape and how Cambodia can seize opportunities for job creation.

4.3.1. Adjust trade and FDI policy to integrate low-carbon goods and services into value chains

A key development challenge will be for Cambodia to diversify with more complex, higher value-added products and value chain segments; rapid demand growth for low-carbon goods and services offer potential opportunities to do so. To maintain Cambodia's high export base, the country will need to both maintain competitiveness in apparel manufacturing and concurrently move into more complex and higher value-added tasks, goods, and services. The rapid growth in demand for goods and services that feed into the low-carbon economy offers one potential avenue to do so. Cambodia has already seen rapid growth in exports of solar panels, modules, and accessories, and the RGC has identified manufacturing opportunities in products such as EVs and battery storage. Several countries have already started developing strategies to take advantage of new manufacturing opportunities from the net-zero transition. In India, for example, the Production Linked Incentive scheme encourages solar PV and battery manufacturing.

However, Cambodia's trade policies, including high tariffs on intermediate inputs, currently undermine competitiveness and participation in value chains for low-carbon goods. Cambodia's tariffs on environmental goods are higher than the world average and regional peers in ASEAN (Figure 26). Renewable energy products face on average a 10 percent tariff in Cambodia, which is five times higher than the global average tariff applied to these products. A similar picture emerges for the other categories of environmental goods where tariffs in Cambodia are considerably higher than those levied elsewhere in the world. In addition to a relatively high tariff on final environmental goods, Cambodia levies high duties on parts and components, which undermines participation in value chains. For example, the tariff on solar panels is 7 percent, but tariffs on critical intermediate inputs for solar PV installations like batteries, cables, fuses, breakers, and surge protection devices face much higher tariffs—as high as 35 percent. The tariffs levied in Cambodia are typically much higher than those imposed by other countries, raising costs for the firms manufacturing these products, hindering their competitiveness, and raising the cost of decarbonization.

Figure 26. Cambodia levies considerably higher tariffs on environmental goods than other ASEAN countries (left) and places higher tariffs on less GHG-intensive goods (right)



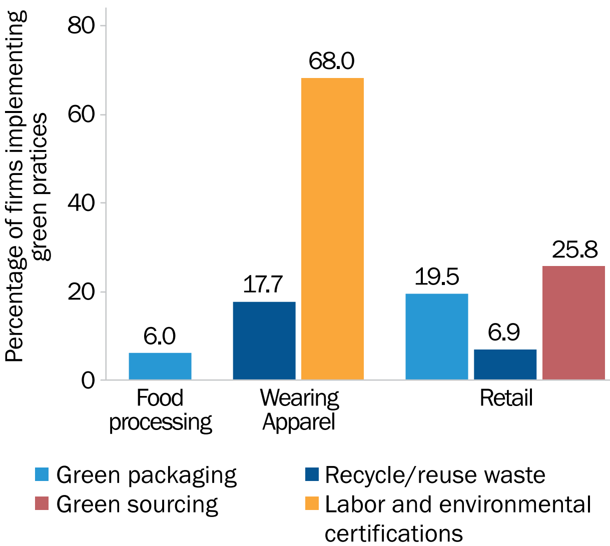
Source: World Integrated Trade Solution and World Bank analysis.

The new update to the investment law seeks to prioritize certain low-carbon industries but will need to be supported by improvements in the business environment to effectively attract and support these industries. The list of eligible business sectors in the investment law update includes environmental management and protection and green energy technologies. It provides additional tax incentives for green energy producers by registering as Qualified Investment Projects. The law offers different options of basic incentives, but the most used ones are an income tax exemption from three to nine years as from the time when income was first earned and, subsequently, a sliding scale of tax breaks on income tax. In addition, there are a host of other incentives: including exemptions for prepayment tax, minimum tax, and export tax, and a deduction of 150 percent from the tax base for activities such as research and development, human resource development, and the construction of facilities for employees such as accommodation, canteens, and nurseries. This law could provide an important impetus for investment into clean energy sectors in Cambodia. However, it will be essential that the law be implemented in a transparent way that minimizes the use of discretion to avoid unnecessary fiscal costs. The law will also need to be supported by improvements in the investment climate. Investors will need transparent and clear regulations so they can be certain of their investment returns. Lowering regulatory burdens to obtaining permits to acquire land, build, and operate and to improving the clarity of guidance on procedures will also be essential.

Cambodian firms are currently lagging on the adoption of green technologies—technology upgrading could both tackle low productivity and low capital intensity in manufacturing and lower emissions. In 2022, the World Bank conducted a Firm-Level Adoption of Technology survey in Cambodia in 768 manufacturing and services firms (Cirera et al., 2023). It found that firms in Cambodia show very low adoption of green technologies across all types (Figure 27). In addition, good practices such as water management in high intensity usage food processing or apparel are scarce. The exception is apparel firms, which report a high share of firms implementing labor and environmental certificates, reflecting the high international demand for standards in apparel manufacturing. This low adoption of green practices reflects the relatively low

Figure 27. Cambodia currently lags behind peers in green technology adoption

Share of firms implementing green technologies (%)



Source and notes: Panel a) Ministry of Commerce. Panel b) Cirera et al. (2023), Firm-Level Adoption of Technology Adoption survey in Cambodia.

technological sophistication of firms in general in Cambodia. In addition, they also found that the use of generators is relatively high compared to other countries, which they estimate is likely to double the amount of carbon emissions in the source of energy compared to using electricity from the grid.

Currently, policy barriers are deterring the private sector from investing in low-carbon technologies, impeding the ability of firms to meet corporate emissions targets and, in turn, their competitiveness. One key technology is rooftop solar, where regulations: (i) only allow a solar PV installation capacity of a maximum 50 percent of the consumer's contracted capacity with the utility company; (ii) require rooftop solar owners to pay a relatively high additional fixed monthly fee (capacity charge); (iii) do not allow time-of-use tariffs, feeding of excess solar power back to the grid, or peer-to-peer energy trading; and (iv) do not allow virtual or physical corporate PPAs. In addition, securing approvals and contracting with Électricité du Cambodge to install the solar PV system is lengthy because there is no standardized documentation for this process. According to the garment industry energy audits by the Global Green Growth Institute in 2021–2022, there is significant low-carbon related investment opportunity of US$2.1 million for 50 garment factories and an estimated US$27.3 million for 650 factories, which could be missed due to such barriers.

As well as opportunities for new exports, climate-related trade and investment policies in other countries also pose risks to Cambodia's current export base, particularly later in the decade. Declining demand for carbon-intensive goods and policies that penalize high-carbon production also pose risks to existing export industries and practices. One potentially important policy is the EU's CBAM. The EU is a key destination for Cambodian exports, accounting for over 70 percent of the aggregate exports as of 2021 (WTO, 2023). The CBAM is mainly aimed at protecting EU domestic industries, creating incentives for other countries to adopt carbon pricing and avoiding carbon leakage as well as limiting the reallocation of EU-based industries to countries with less stringent climate regulations. At present Cambodia is not highly exposed to the EU's CBAM, with exports of the five products currently covered (cement, fertilizers, iron and steel, aluminum, and electricity) accounting for only 0.02 percent of Cambodia's total exports in 2021. However, this could change later in the decade given the EU's plans to expand CBAM to include all goods covered by the EU Emissions Trading System by 2030. Planning to avoid over-reliance on an export base that is exposed to declining demand and future climate-related trade policies could ensure Cambodia's vision of further structural transformation is achieved.

What we recommend

1. **Lower tariffs on environmental goods and particularly on inputs into key clean energy exports.** Tariffs should be lowered on environmental goods, particularly renewable energy product imports and key intermediate inputs, including those for solar PV installation like batteries, cables, fuses, breakers, and surge protection devices.

2. **Lower barriers to adoption of rooftop solar PV by private companies.** This can be achieved by: (i) lowering the capacity charge on solar rooftops; (ii) removing the solar PV installation capacity limits of 50 percent of contracted capacity with Électricité du Cambodge; (iii) introducing net billing to allow solar PV owners to sell back excess solar power to the grid; (iv) allowing time-of-use tariff for solar PV owners; and (v) streamlining the process of securing approvals and contracting with Électricité du Cambodge. Cambodia can also explore the potential of peer-to-peer trading and virtual and physical PPAs. Cambodia's neighbors, such as Thailand, Malaysia, and Vietnam, are piloting peer-to-peer trading to increase solar deployment and grid flexibility.
3. **Ensure the investment law is implemented in a transparent way that minimizes the use of discretion and is supported by improvements in the investment climate.** Ensure that the investment law provides cost-effective support for low-carbon industries by implementing it in a transparent way that avoids the use of discretion and minimizes lost revenues. To increase the cost effectiveness of incentives, the RGC could also consider a heightened use of cost-based instruments (for example, credits/allowances) instead of profit-based instruments (such as tax holidays and reduced rates). To facilitate more investments in low-carbon industries, the private sector will also need a more certain and transparent operating environment with lower regulatory barriers. The RGC can introduce automation in business registration, customs clearance, tax administration, and sectoral licensing. In addition, the RGC can implement the Insolvency Law, SME insolvency procedures, and out-of-court workouts to facilitate dispute resolution and creditor protection.
4. **Consider a comprehensive review and strategy to identify opportunities to increase competitiveness in new low-carbon industries and incentivize apparel manufacturing firms to upgrade technology.** Cambodia could consider implementing a full review to identify opportunities in manufacturing and services to serve growing demand for low-carbon products in major markets. This could also include ways to assist existing apparel manufacturing firms to upgrade technology and lower their emissions.

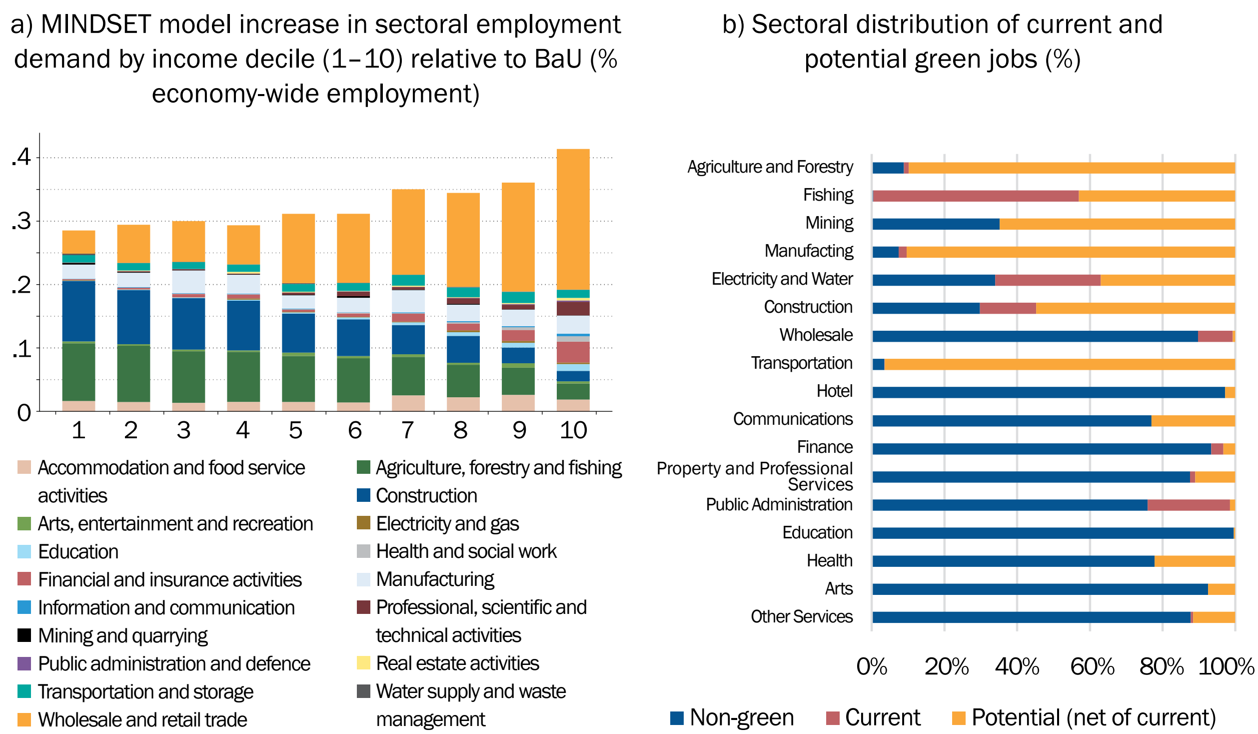
4.3.2. Ensure that workers have the skills to seize green job opportunities

The low-carbon transition provides an opportunity to create better jobs with higher productivity and higher skill requirements. Cambodia has identified "green technology" under "industries serving regional production lines and those of future strategic importance", one of the five priority sectors in the 2015–2025 Industrial Development Plan. The National Strategic Plan on Green Growth 2013–2030 also sets forth the need to create green jobs, including by attracting green investors. As mentioned in the previous section, the global net-zero transition is likely to increase demand for jobs in low-carbon industries and the clean energy sector. Moreover, projections of the sectoral impacts of decarbonization measures conducted for the CCDR using the MINDSET model, as discussed in Section 2.3, show that demand for jobs in services and trade, construction, skilled agriculture, forestry, fisheries, and manufacturing will expand relative to the BaU scenario (Figure 28a). These results show that the jobs created by the low-carbon transition are more likely to be higher paid and that the low-carbon transition could result in an increase in demand for a wide range of high-skilled jobs, including those in clean technology manufacturing, professional roles, scientific and technical roles, finance, and insurance. Cambodia will need an educated workforce that is able to nimbly develop the necessary skills to transition into these emerging roles.

Cambodia's workforce will also need to be able to adapt quickly to conduct more tasks involving green technologies and practices. In addition to resulting in expanding sectors and occupations, the low-carbon transition will also change the tasks being conducted in existing jobs. Analysis for this CCDR hence also applies a task content approach to analyze jobs and worker profiles in Cambodia. It defines green jobs as "jobs involving tasks related to developing or applying technologies and practices that lessen the footprint on the environment." Two types of green jobs are identified: current and potential green jobs. Current green jobs are jobs involving existing green tasks exclusively, while potential green jobs are defined as "jobs involving green tasks and jobs involving tasks that could be greened" (Granata and Posadas, 2022).

A narrow subset of the current workforce in Cambodia is employed in an occupation involving environmentally friendly tasks. The analysis undertaken for the CCDR find that, in Cambodia, 16 out of 154 occupations are classified as jobs involving current green tasks. Current green jobs employ 5 percent of the total workforce, with the fishing industry and the electricity and water sectors having the highest concentration of workers performing (current) green jobs (Figure 28b). When considering jobs involving potential green tasks, 62 of 154 occupations in Cambodia have the potential to involve environmentally friendly tasks in the future. The occupations with the highest green potential are spread across sectors and are most represented in the agriculture and forestry, manufacturing, and transport sectors, totaling 64 percent of the workforce (Figure 28b). This suggests that Cambodia has substantial scope for current occupations to adopt more environmentally friendly practices.

Figure 28. The low-carbon transition will create more high-skilled jobs (left) and will need more workers to use green practices in existing roles (right)



Source: Panel a) MINDSET model impacts for a single year of a non-LULUCF low-carbon development policy scenario to meet LTS4CN emissions targets, in the scenario with financing. Numbers on the x-axis refer to income deciles (1 to 10). These scenarios assume a low-emissions scenario in the baseline and do not explicitly include the losses from climate change or any adaptation measures. The MINDSET model is further discussed in Section 2.3. Panel b) McKenna and Safir (2023). This analysis combines the 2019/20 socioeconomic survey data for Cambodia with Granata and Posadas (2022)'s dictionaries of green jobs.

While green jobs pay better in Cambodia, they are predominantly low-skilled and there is significant scope to expand the share of medium-skilled jobs. Among current wage employees, current green jobs pay an average of 25 percent more than other jobs. Studies in the US (Vona et al., 2019) and Indonesia (Posadas et al., 2022) show that the greener the job, the higher the wage. When examining current green tasks, low-skilled jobs make up the lion's share of green jobs in Cambodia. This is in line with what is seen in Indonesia, where most of the employment in green jobs is low-skilled (Posadas et al., 2022). However, the role of medium-skilled workers increases when looking at potential green jobs, particularly those that involve a larger share of green tasks. The share of high-skilled jobs is limited among current green jobs, which reduces further when applying the potential green job definition.

What we recommend

1. **Provide incentives for firms and individuals to invest in upskilling in green sectors.** There is a need to provide incentives, such as specific training programs, to facilitate the movement of workers into green jobs and to help firms build the skillsets to use more green technologies and practices. RGC should also consider developing cross-cutting skills training on issues that are relevant across a wide range of sectors, such as energy-saving practices or solar panel installation. Furthermore, improving labor market information is necessary to closely monitor changes in the demand for and skill requirements of emerging green jobs.
2. **Update curricular standards to place more focus on the skills demanded by the low-carbon economy, including digital and STEM skills.** With the higher skill requirements of green jobs, seizing the opportunities from the low-carbon transition will require having a sufficiently educated workforce, underscoring the importance of improving Cambodia's education outcomes across the board. In addition, it will require having curricula at secondary and tertiary level that are tailored to provide students with the necessary skill sets to respond to the needs of the green economy. Along with having higher skill requirements, jobs for the low-carbon economy have also been shown to have higher digital and STEM skill requirements. Promoting skills development in these areas, as well as skills relating to clean energy technologies, could improve the competitiveness of firms in these industries.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Financing, institutions, and incentives

5. Financing, institutions, and incentives

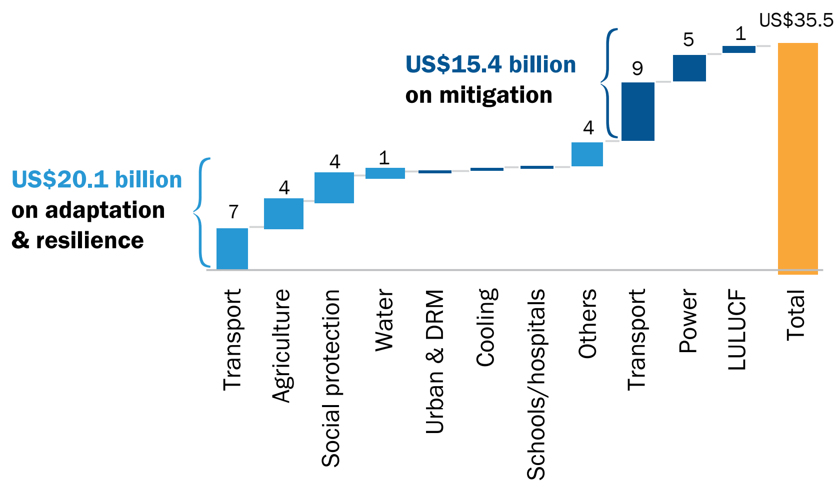
5.1. The transition to resilient, low-carbon development requires significant investment

The measures outlined in this report will require the mobilization of significant yet manageable financing from the private and public sectors. Measuring the additional investment needs for climate change is fraught with challenges given the inherent uncertainty surrounding the future costs of investments, which largely depend on how costs of low-carbon and resilient options evolve in comparison with their alternatives. For example, if incomes grow rapidly, farmers may invest in irrigation and climate-smart agricultural practices as the default choices that maximize profits, irrespective of any adaptation policies. In some cases, adaptation measures would even save—rather than cost—money, as is the case for the improved urban land-use planning described above. Likewise, if EVs continue to fall in price, they could become cheaper than non-EV alternatives and could be adopted by households as the default choice without incentives provided or much incremental investment required. However, it is important to emphasize the importance of more available information in managing risks associated with these transitions. There is thus a role for the public sector in helping private actors overcome some of the barriers. Nevertheless, this CCDR provides estimates of the potential incremental investment needs for the climate adaptation and mitigation measures outlined in this report, relative to the current BaU scenario of existing policies and investments already in place. Estimates for adaptation measures are calculated based on the sectoral analysis in Chapter 4.1 with estimates provided for the key recommendations. Estimates for mitigation measures are calculated using the macroeconomic modeling presented in Chapter 2, while estimates for the LULUCF sector are taken from the REDD+ investment plan. Estimates are discounted by a 6 percent discount rate to generate an NPV estimate. The Technical Appendix provides more information on these calculations, along with undiscounted estimates and aggregate totals, including the investments under the BaU.

This CCDR estimates that the package of measures to respond to climate change outlined in this report could require an additional US$36 billion (NPV) from the private and public sectors over the next three decades. This is the additional investment that will need to take place by the private or public sector to meet the key recommendations outlined in this report. This encompasses additional investments, above and beyond existing investments that are planned or policies in place to achieve climate goals. For example, for mitigation in the power sector this includes only the additional investment required for a more rapid VRE scale-up than is currently planned in the PDP. This total investment is equivalent to 1.7 percent of cumulative GDP from 2023 to 2050. Adaptation would account for just under two-thirds of the total, while mitigation measures would account for one-third of the total (see Figure 29). The Technical Appendix also provides estimates of existing investments, showing that including these existing planned investments brings the total to US$70 billion in NPV terms.

Figure 29. Achieving climate goals could require US$36 billion (NPV) in incremental investment between from 2023–2050 (1.7% of GDP)

Cumulative incremental investment needs 2023–2050 (US$, billion)



Source and notes: World Bank analysis. Estimates are in NPV terms, with a 6 percent discount rate used for future investments. Investments are incremental, relative to a BaU scenario of current policies or investments already in place. Estimates for adaptation measures are described in Chapter 4.1. Estimates for mitigation measures are from the macroeconomic modeling in Chapter 2, with the exception of LULUCF, where estimates follow the REDD+ and LTS4CN investment needs.

There are several ways in which Cambodia can finance the climate transformation outlined in this report. The private sector already plays as important role in investing in climate adaptation and mitigation in Cambodia, as was outlined in Chapter 4. For example, the private sector is already playing a role in financing EV charging stations, in financing solar energy projects, in adopting energy efficiency measures, and in investing in climate-smart agricultural technologies. It will be crucial to further catalyze private investments by removing distortions that deter private sector investments, thereby improving the enabling environment and providing the right incentives. Expanding the role of green finance and attracting FDI could also play important roles, while there are several sources of external financing that could also support Cambodia's climate transition. Public financing can be mobilized relatively quickly through supportive and progressive policy reforms, while deeper reforms to improve the efficiency of public spending could further free up fiscal space. Removing fossil fuel subsidies and introducing carbon pricing could also play a role in financing the necessary investments, but such policies would need to ensure that they do not affect lower-income households.

5.2. Catalyzing private investment will be critical

Green finance could play an important role in channeling capital to climate-related investments, but Cambodia's capital markets are at a nascent stage and underdeveloped and hence the growth of green finance to date has been limited. Currently, only nine publicly traded companies are listed, and as of March 2022, nine corporate bonds with a combined value of US$160 million had been issued. Despite significant growth, the overall bond market in Cambodia remains weak, creating major drawbacks in accessing alternative funding sources, particularly debt financing. The first corporate bond in Cambodia was only issued in 2018. The government has made some progress in developing the market by establishing tax incentives and legislation to ensure that the regulatory framework governing the issuance of bonds is effective. However, several barriers remain. On the demand side, Cambodia lacks a robust and diversified domestic institutional investor base. Besides commercial banks, most pension funds and insurance companies keep cash in bank accounts, as interest rates on bank deposits are generally highly competitive. On the supply side, there are not many incentives for bond issuers besides the recently legislated tax incentives. At the same time, other challenges also exist, such as the lack of a proper benchmark for interest rates, difficulty in obtaining a credit rating for a Cambodian bond, and the recent directive by the RGC that bond issues should be denominated in Cambodian riels as opposed to US dollars.

The overall readiness for green finance in the financial sector remains low and to date there are few green loans and just one green bond issued in Cambodia. In August 2020, the Association of Banks in Cambodia (ABC) surveyed its members—representing almost half of all commercial banks—on their readiness for sustainable financing. While progress was being made with 87 percent of respondents reporting adoption of the Cambodian Sustainable Finance Principles (CSFPs), only 30 percent had an environmental and social risk management system in place. Less than half reported any procedures or guidelines for managing and monitoring environmental and social risks. There are several barriers to green finance. First, there is a lack of understanding and guidance on what qualifies as green finance. Cambodia lacks its own green taxonomy or process for classifying financial flows by their relationship to and impact on different types of sustainable development. Second, there is little awareness of the pipeline of green projects. Third, there is limited green loan data reporting from financial institutions. Without such data reporting, it is hard for policymakers to identify gaps and calibrate incentives. Fourth, local financial institutions have limited capacity, green policies, and practices to verify, monitor, and assess green projects. The ABC published the CSFPs in 2016, followed by guidelines on implementation. However, the principles are voluntary, and it is up to individual banks' discretion to decide how and when to implement them. Fifth, the cost of bond issuance in Cambodia remains high. The underwriting fee of 2.5 percent for domestic bonds is significantly higher than comparable US$-denominated Asian high-yield bonds. Moreover, the cost of external review in the case of issuing green bonds further escalates the overall issuance cost of green bonds. Last, as green policies are not embedded in the financial ecosystem, the lack of industry regulatory and policy support for the development of green assets is also a major challenge to promoting green finance in Cambodia.

International development assistance and FDI could also be important catalysts for green and sustainable finance. Foreign investment generally requires local financial partners to demonstrate proper enterprise security risk management systems to disburse capital. However, without the necessary environmental, social, and governance (ESG) policies and practices, Cambodia will find it increasingly difficult to access necessary foreign capital. The National Bank of Cambodia can accelerate changes toward green finance and ESG adoption through timely, targeted regulatory interventions. Cambodia remains a competitive destination for FDI, with inflows between 2000 and 2020 jumping from US$145 million to US$3.6 billion. With a sufficient landscape of FDI attraction, FDI could thus play a heightened role in financing climate adaptation and mitigation in Cambodia. The RGC already has plans to encourage investments in EV-assembling plants in Cambodia, which could be expanded to other opportunities. However, despite high levels of FDI, the quality of these investments remains weak, as foreign firms are not providing the much-required backward integration and knowledge and technology transfer. This is primarily due to business environment and trade-related regulatory barriers as discussed, with solutions proposed, in Chapter 4.3.

Blended concessional financing can be an important tool to crowd in private sector investments. Green projects can leverage finance from donors or third parties alongside commercial financing or financing from development finance institutions to mitigate investment risks. For example, potential sources of concessional financing may include the Global Environment Facility, Green Climate Fund, Special Climate Change Fund, Least Developed Countries Fund, and Climate Investment Funds. Cambodia can explore these dedicated funding resources to leverage both public and private investments in renewable energy development, grid enhancement for renewable energy, building and e-mobility integration, energy efficiency improvement, and clean cooking to accelerate its energy transition.

What we recommend

1. **Develop a green finance taxonomy**, including a clear definition of what activities qualify as "green." A taxonomy will establish a common green investment language and provide the necessary foundations for a green financial ecosystem, which is essential for the other recommendations here. A single taxonomy for Cambodia is preferable, and its focus should be relatively narrow—on environmental issues—making implementation easier and faster. The National Bank of Cambodia can consider mandatory standards, which can be a phased in based on the capacity and readiness of the financial sector.
2. **Mandate monitoring and reporting of green loan data.** Regulators, lenders, and investors require data to make informed decisions. Such reporting should be made mandatory as part of regular reporting to the National Bank of Cambodia and made publicly available through the annual National Bank of Cambodia Supervision Report. Such a mandate will allow financial institutions to justify investments in new systems and processes. It should be based on a set of guidelines that consider local practices and the state of economic and financial development in Cambodia and aligned with the green finance taxonomy.
3. **Adopt international best practices to identify green projects.** The lack of internal procedures for and expertise on green finance assessment is a key challenge for many banks. The National Bank of Cambodia can help the banks track their green credit growth consistently and transparently against their targets and to apply eligibility criteria to a relatively broad range of sectors or projects. The government can further incentivize green credit supply by providing long-term seed funding to supplement banks' finances for green projects. Borrowers for climate change projects should be supported through grants, tax rebates, subsidized interest rates, and comprehensive knowledge.
4. **Establish a taskforce for green finance readiness** to effectively coordinate a range of stakeholders and guide the overall green finance reform process. Key stakeholders include Cambodian ministries responsible for implementing Cambodia's commitments to climate change (such as NDCs), financial sector stakeholders, and the international community. This taskforce can coordinate and oversee sub-working groups tasked with developing key components of the green finance ecosystem, such as the green taxonomy, disclosure and reporting standards, and technical assistance for capacity building.
5. **Support the development of a national climate finance facility** that can be funded by donor financing to de-risk local green projects by providing direct long-tenor financing and concessional funding to local banks, accompanied by project preparation and capacity-building support, as outlined below. Such a facility can enable and crowd in the local financial sector by incentivizing local banks to increase their credit risk appetite and their experience with green projects, thereby scaling up climate finance in Cambodia.
6. **Mandate financial institutions' adoption of enterprise security risk management systems** to improve risk analysis in lending decisions. This mandate will replace the voluntary CSFPs and has been adopted by authorities in the region, such as by the directive by the State Bank of Vietnam in 2015.
7. **Deepen capital markets and further develop the green bond market to address climate change and finance growth more generally.** With the international emergence of new sustainable finance products and the increasing focus on the transition of heavy industries to lower-carbon footprints, market participants are often looking for strong transaction benchmarks to build confidence and unlock potential businesses. Cambodia can benefit from this trend, attracting green capital to develop an effective, resilient, and credible transition pathway. Potential policy actions to grow the green bond market could include incentives such as tax exemptions for the coupon of green bonds

and capacity building for green bond verifiers to decrease issuance costs.

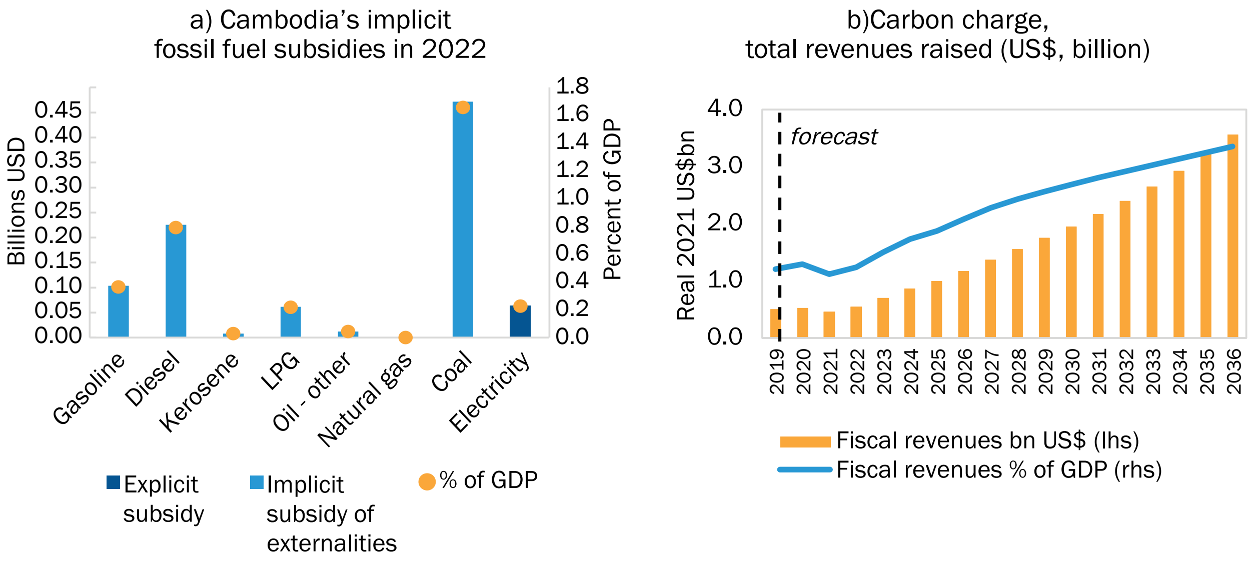
8. **Develop a capacity-building program on green finance for stakeholders including financial institutions and regulators.** Additional incentives for bond issuers can be introduced, including offsetting added cost of issuing thematic bonds, such as reimbursement of listing fees, credit rating costs, second-party options, and legal support. At the same time, grant-funded technical assistance can also be utilized to motivate and fund bond issuance design and structuring, cover the early-stage costs of projects funded by issue proceeds, or strengthen the same projects' commercial viability and developmental impact.

5.3. Fiscal policies could play a role in mobilizing resources

Repurposing fossil fuel subsidies or applying carbon pricing both offer opportunities to increase revenues and lower emissions at the same time. The government currently subsidizes residential electricity by up to 0.2 percent of GDP. In addition, the social cost of fossil fuels, related to their externalities on global warming, air pollution, and vehicles, is not factored into market prices. The IMF (2023) shows that Cambodia's "implicit subsidies," defined as the difference between the socially optimal price, including the cost of externalities, and the retail price, currently amount to US$870 million (-3.2 percent of GDP). Figure 30a) presents the decomposition across fossil fuels and shows that the implicit subsidy on coal is the largest due to its high negative externalities on global warming and air pollution (IMF, 2022; Parry et al., 2021).

Simulations suggest that a potential carbon price rising to US$75/t$CO_2$e by 2030 could raise revenues equivalent to 4 percent of GDP by 2030 (Figure 30b). This is a relatively high carbon price, but this CCDR provides estimates to illustrate the potential revenue-generating value. The adverse effects of carbon pricing on growth and equity could be addressed by recycling revenues to compensate the most affected households. In practice, perfect compensation of household income may not be feasible or progressive, as it likely implies disproportionate transfers to wealthier households. Instead, revenues could be used to strengthen existing social protection systems and target households that are likely to be vulnerable to carbon price increases. Targeted cash transfers could be used for that purpose. Revenues could also be invested in forest protection to curb emissions further.

Figure 30. Cambodia directly subsidizes residential electricity by 0.2% of GDP (left) while a carbon charge rising to US$75/t$CO_2$ by 2030 could raise additional revenues of 4% of GDP (right)



Source: Panel a) (IMF, 2022; Parry et al., 2021) Panel b) Simulations using World Bank Carbon Pricing Assessment Tool. Non-energy emissions (agriculture, LULUCF) are assumed to be flat.

What we recommend

1. **Conduct a review of fossil fuel subsidies and consider introducing carbon pricing with appropriate revenue recycling.** Phasing out fossil fuel subsidies could both increase fiscal revenues and also remove distortionary incentives which disincentivize energy efficiency investments. However, initiatives should ensure protection of the poorest households, by providing transfers to those of the lowest income groups, for example. Introducing carbon pricing, with appropriate revenue recycling to both protect poorer households and invest in climate-related projects, could incentivize reduced emissions, while also potentially benefiting the economy, since green investments tend to have high fiscal multipliers.

5.4. Cambodia's disaster risk financing gap requires urgent attention

Even with investments in adaptation, the RGC may have to incur significant disaster-related contingent liabilities from floods. The government's contingent liabilities, be they explicit or implicit, come from the need to finance response and recovery following climate and disaster events, in particular emergency operations, restoration of critical public services, reconstruction of lifeline public infrastructure, residential assets of the poor and vulnerable population, and cost-sharing with provincial governments. The flood modeling for Cambodia shows that a flood with a five-year return period can cause damage of US$700 million to residential and industrial assets that are not covered by insurance, taking into account Cambodia's low insurance market penetration rate of less than 1 percent. The government may have to bear a significant share of contingent liabilities in the event of disasters, particularly for the poor, vulnerable, and at-risk households, as shown in Table 5.

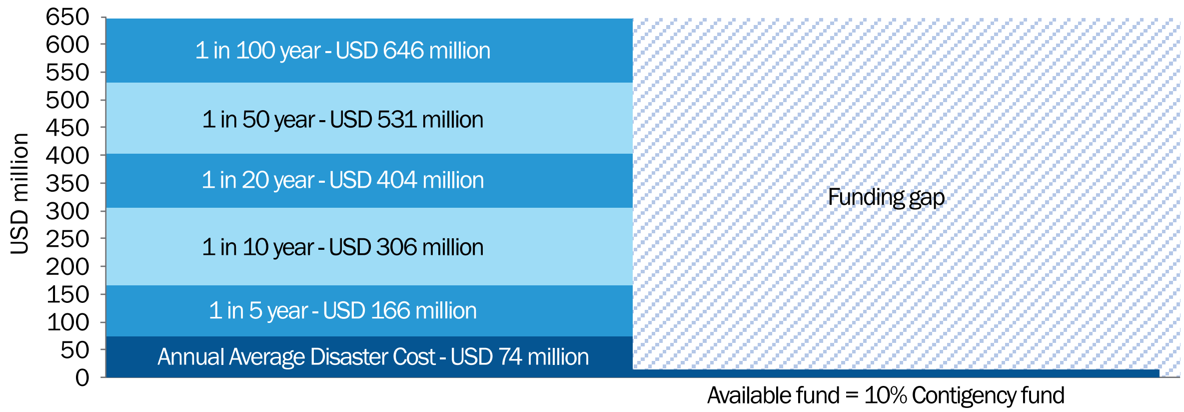
Table 5. The RGC faces annual average contingent liabilities of US$74 million from floods
Annual expected losses from floods at different return periods by type of asset (US$, million)

Return Period	Annual Average	1 in 5 year	1 in 10 year	1 in 20 year	1 in 50 year	1 in 100 year	1 in 200 year
Residential	301	680	1,250	1,650	12,170	2,640	3,220
Residential: Govt's Contingent Liability	74	166	306	404	531	646	788
Commercial	71	30	90	140	190	230	280
Industrial	28	20	40	50	60	70	90

Source: The World Bank's Disaster Risk Finance and Insurance Program Analysis using JBA's Flood Risk Profile for Cambodia.

There is therefore a significant funding gap between the funds available for disaster-related costs and projected disaster-related contingent liabilities that may be incurred by the government. Figure 31 shows the funding gaps for various disaster events in different return periods. When the estimates of financing available through DRF instruments are compared with the estimated damage costs of up to US$0.5 billion for disasters in 2011 and 2013, a significant fiscal resources gap for financing the costs of disasters is apparent (in 2010, the contingency budget is US$115 million, and the total international donors' commitment is US$26 million, much smaller than the estimated damage costs of US$0.5 billion).

Figure 31. Cambodia faces a fiscal resource funding gap of US$400 million for a 1-in-20 year flood
Government contingent liabilities for poor, vulnerable, and at-risk households compared to available contingency funding



Source: Cambodia Disaster Risk Financing Strategy 2022–2023.

Widening its range of risk management instruments will help the government better manage fiscal and debt impacts of disasters. Given the country's high vulnerability to natural disasters, there is a need to consider different risk retention instruments, such as resources from budget allocations, contingency reserves, a fiscal stabilization fund, and exclusive contingent credit lines, based on a comprehensive assessment of the physical risks to the country's fiscal sustainability and public finances. Extending the National Disaster Risk Strategy to include more instruments could better ensure public assets and ensure natural disasters and climate change impacts are included in fiscal planning and debt management.

What we recommend

1. **Adopt a strategic approach toward DRF and develop an enabling policy, legal, and institutional framework.** Update current legislations on disaster-related fiscal risk management to allow for: (i) better quantification, recognition, and disclosure of disaster-related contingent liabilities; (ii) improvement in public financial management systems and practices for better post-disaster budget execution; (iii) clear definition of roles and responsibilities of various parts of the government and any cost-sharing arrangements between the national and provincial governments in DRF; (iv) use of new or alternative risk financing instruments through PPPs to crowd in private risk capital and lessen the burden on the government; and (v) improvement in the regulatory framework and practices for effective market development, regulation, and supervision of disaster- and climate-related financial and insurance products.

2. **Develop and implement priority sovereign DRF programs and solutions.** Development of the following DRF programs will assist the government in managing the fiscal and financial impacts of disasters efficiently.

    a. **Sovereign budget protection.** The government can consider the implementation of the following instruments to protect the budget.

    - **Reserve fund.** The government may want to explore and set up a dedicated multi-year reserve fund for climate and disaster shock response and recovery to ensure timely funding for frequent events.
    - **Contingent financing.** The government may seek to establish a contingent financing facility with support from multilateral and bilateral development partners and regional platforms to

secure affordable and adequate access to finance for post-disaster response and recovery.

- **Sovereign risk transfer.** The government can also consider and implement sovereign risk transfer programs through partnership with the local insurance industry, regional risk pooling mechanisms, and international reinsurance and capital markets.

b. **DRF for adaptive social protection, agriculture, and public assets.**

- Implement a DRF instrument, such as a sovereign risk transfer program or contingent finance facility, to support disaster-related cash transfer programs as part of the adaptive social protection system.
- Design and implement a DRF program for the agriculture sector for key crops and agricultural assets, including options for agriculture DRF such as contingent credit and insurance.
- Combine different financing instruments for public assets, including through the government's self-retention and use of contingent financing and insurance to complement the state budget.

3. **Improve access to finance through credit and insurance services for the impacts of disasters** to contribute to reducing fiscal impacts of a disaster, as individuals and businesses would be less reliant on the RGC for relief following a disaster and the tax base would be less adversely affected.

5.5. Aligning institutions and incentives

There is a lack of integration between climate policy and development policy frameworks along with fragmented climate change accountability mechanisms. Chapter 3 provided an overview of Cambodia's climate change related institutions, strategies, policies, and legal instruments, highlighting several ways in which these could be augmented to support the integration of climate and development goals. One critical limitation of the current institutional setup is that climate adaptation and mitigation targets are not yet fully integrated into Cambodia's development plans, particularly for each ministry. This results in a lack of clear ownership and responsibility. In addition, ministries are not required to identify climate change-related expenditures in their yearly budgets, making them reluctant to spend on climate efforts. Incorporating climate spending in Budget Strategic Plans for individual ministries could improve incentives and monitoring.

Monitoring of climate-related risks is fragmented across ministries, with different approaches taken and limited information sharing. Chapter 3 also outlined the various efforts to measure and monitor climate exposure and vulnerability, highlighting the fragmented efforts and different methodologies and approaches used, such as the Vulnerability Index and Vulnerability Reduction Assessment. In addition, public investment management does not sufficiently consider physical climate risks. Currently, project appraisal and selection for externally or domestically financed capital projects or PPPs do not include requirements for considering climate-related issues, while adding such requirements could lower public investment exposure to climate risks.

What we recommend

- **From separate climate and development plans to one integrated approach.** Currently, new climate targets on adaptation and mitigation are laid out their own separate plans, while targets are not yet integrated into development plans, particularly for each ministry, resulting in a lack of clear ownership and responsibility. One harmonized and integrated framework with ownership for each ministry could improve progress monitoring and accountability.
- **From concentrated to distributed climate financing and harmonized budget tagging.** The recent SOP for public financial management to integrate climate change public finance could be expanded

to incorporate climate change spending for individual ministry budgets. In addition, climate spending could be required in Budget Strategic Plans for all ministries, while funding could be dispersed more widely in line with climate spending priorities.

- **From minimal to more comprehensive climate public expenditure management.** Physical climate risks could be included in project appraisal and selection regulations. Lessons could be drawn from pilots conducted currently at the MPWT for green urban infrastructure projects. This could also include creation of a public asset registry and inclusion of disaster risks in the fiscal risk statements.
- **From fragmented to harmonized and enhanced monitoring of climate and disaster risk.** The Vulnerability Index and Vulnerability Reduction Assessment could be harmonized, with a consistent methodology for determining vulnerability. Greater harmonization between the two systems could lead to a richer understanding of the risks and needs of climate development planning, especially at the commune or district level. This could also involve disaggregating data by sex, age, and disability, and estimating economic and infrastructure loss. A publicly available national information system could also be established to improve the quality and quantity of disaster-related data. This should also involve increasing data collection and monitoring to better understand and address water deficit challenges.

6

From analysis to action

6. From analysis to action

6.1. Prioritizing policy recommendations

The CCDR highlights the urgency for certain interventions, because of the irreversibility of some decisions (such as lock-ins to coal-fired power generation). It also emphasizes many synergies and low-hanging fruits that would accelerate development and increase resilience or reduce emissions and do not need to be delayed for more analysis. Informed of its unique vulnerabilities and building on its unique resources, Cambodia can build on these synergies to implement strong climate action and accelerate its journey toward high-income status while achieving its commitment to achieve carbon neutrality by 2050 while protecting its people from the impacts of climate change.

This section summarizes the key recommendations from the report, scored in terms of cost, urgency and impact, as regards climate adaptation, mitigation, and development. It organizes the highest priority actions for each policy package based on urgency and impact. Urgency is broken down into two levels: actions that are urgent, and other interventions that can be delayed due to lack of financing or the possibility that they may become more affordable in the future. While many measures are important, some are relatively more urgent because inaction will lock in carbon-intensive development patterns or vulnerabilities that increase subsequent costs and financial risks. Regarding impact, some measures are expected to contribute to both climate and development goals. Recommendations are hence ranked as high, medium, or low in terms of their impact on climate adaptation, climate mitigation, and Cambodia's development vision. This development ranking considers whether policies will have positive development impacts even if climate risks do not materialize. Costs are broken down into those that are high, medium, or low, based on the investment needs identified above. The shading highlights the top ten policies identified from this ranking in terms of their overall score across these five categories.

An analysis of the recommendation shows the multisectoral and macroeconomic dimension of resilient and low-carbon development. Table 6 shows that the CCDR recommendations span all sectors, with cross-cutting economy-wide recommendations making up the biggest category in terms of number of recommendations. This high number of economy-wide recommendations confirms the need to mainstream climate adaptation and mitigation into development and economic policies, including on fiscal and financial issues. In the forestry, transport, and agriculture sectors, there is a balance between adaptation and mitigation recommendations, while others are more focused on one or the other.

Table 6. CCDR policy recommendations

Key: +++ =high, ++ =medium, + =low,
A=adaptation, M=mitigation, D=development, top ten policy actions

Objective	Priority policy actions	Cost	Urgency	Impact		
				A	M	D
Reduce exposure and vulnerability to climate change						
Lower climate exposure through resilience of critical infrastructure, DRM, and risk-informed planning	Align road design standards with climate risk levels, increase resilience standards for future infrastructure, and increase allocation for road maintenance, prioritizing critical rural roads	High	+++	+++	+	+++
	Increase budgetary allocation for repairs and maintenance of water storage infrastructure, repurpose existing reservoirs by adding additional functions such as flood control, and increase the resilience of water storage systems to hydroclimatic conditions	High	++	+++	+	++

Objective	Priority policy actions	Cost	Urgency	Impact		
				A	M	D
Lower climate exposure through resilience of critical infrastructure, DRM, and risk-informed planning (cont.)	Formulate and enforce building codes and standards to decrease the exposure and vulnerability of health and education facilities	Low	++	+++	+	++
	Develop a comprehensive flood management strategy that combines risk-informed planning, physical infrastructure improvements, and nature-based solutions	Medium	++	+++	++	++
	Establish a National Emergency Center and enhance early warning system coverage by improving access and reliability	Low	+++	+++	+	+
Lower climate vulnerability through climate-smart agriculture, enhanced health system resilience, and adaptive social protection	Develop programs and introduce incentives to modernize existing irrigation infrastructure and promote water use efficiency and AWD production systems	High	+++	+++	++	+++
	Introduce incentives and expand extension services to promote diversification from high-risk crops toward climate-resilient and high-value marketable crops	Low	+++	++	+	+++
	Fund community-level investments that improve the capacity of poor and smallholder farmers to cope with natural disasters	Medium	+++	+++	+	+++
	Institute a monitoring system to better understand and respond to climate-related health risks	Medium	++	++	+	+
	Legislate and fund a permanent adaptive social protection program	High	+++	+++	++	+++
Reverse deforestation and loss of wetlands and deploy nature-based solutions	Prioritize urgent reforms to implement monitoring and evaluation of progress against LTS4CN targets and to enhance protected area management and law enforcement to eliminate illegal logging	Low	+++	+++	+++	+++
	Finalize and implement the Environment and Natural Resource Code to prevent further loss of natural wetlands	Low	+++	+++	+++	++
	Launch a program to expand public greenspaces in urban areas to reduce flooding and urban heat island effects	Medium	++	++	++	++
Realign the emissions trajectory to achieve climate mitigation goals in ways that benefit development						
Accelerate the clean energy transition, increase city density, and catalyze investments in energy-efficient technologies	Increase the ambition of renewable energy targets and conduct a review of PPA terms, while expanding the use of auctions	Medium	+++	++	+++	+++
	Revise urban plans to promote compact urban development	Low	+++	+++	+++	+++
	Enhance the capacity and flexibility of transmission and distribution networks to enable renewable energy connection and integration	Medium	+++	++	+++	+++
	Incentivize investments in energy-efficient technologies and efficient cooling systems through implementation of the NEEP and NCAP	Medium	++	+++	+++	++
	Provide incentives in the form of subsidies/credits for switching to efficient and clean cookstoves for the residential sector	Medium	+++	++	++	++
Reorient the economy to seize new opportunities from trade, investment, and technological progress						
Lower trade, investment, and skills barriers in low-carbon industries	Lower tariffs on environmental goods and particularly on inputs into key clean energy export products	Low	+++	+	+++	+++
	Lower the capacity charge on rooftop solar, remove the solar PV installation capacity limits of 50 percent, and introduce net billing, allowing time-of-use tariffs and streamlining the approval process	Low	+++	++	+++	+++

Objective	Priority policy actions	Cost	Urgency	Impact		
				A	M	D
	Initiate a green competitiveness review to identify opportunities to increase competitiveness in low-carbon industries and support the private sector	Low	++	+	++	+++
	Encourage private sector participation in low-carbon industries through a transparent implementation of investment law and improvements in the investment climate	Low	+++	+	++	+++
	Develop targeted skills training programs and update curricular standards to place more focus on the skills demanded by the low-carbon economy, including digital and STEM skills	Low	++	+	++	+++
Cross-cutting priorities						
Align institutions and incentives	Mandate physical climate risk assessments in public investment project appraisal and selection	Low	+++	+++	+	+
	Expand the mandate of the Climate Change Technical Working Group to serve in a role that initiates larger-scale programs.	Low	+++	++	+++	++
	Integrate climate targets for adaptation and mitigation into development plans for each ministry	Low	++	+++	+++	++
	Incorporate climate change spending in individual ministry budgets and require climate spending to be included in Budget Strategic Plans	Low	+++	+++	+++	++
	Establish a more comprehensive, advanced, and standardized approach for measuring and monitoring climate change risks and exposure	Low	+++	+++	+	++
Finance the transformation	Develop a green finance taxonomy and green capacity building, aligned with international standards and supported by verification and validation systems	Low	+++	++	+++	+
	Update current legislation on disaster-related fiscal risk management to quantify, recognize, and disclose disaster-related contingent liabilities	Low	++	+++	+	+
	Initiate fiscal reforms and explore options for carbon pricing instruments that incorporate revenue recycling	Medium	+++	+++	+++	++
	Provide incentives to the insurance sector to develop and expand micro-insurance and contingent finance solutions	Medium	+++	+++	+	++

6.2. Timeline for action – ten immediate priorities for the next five years

This section takes the top ten priorities identified from the prioritization above and further orders them in terms of potential sequencing over the next five years. Those actions that would result in irreversible impacts if delayed are ordered as first priority, followed by those that could be delayed by a few years without irreversible impacts or those that will not be feasible immediately due to financing or coordination constraints. This hence lays out a roadmap of the most crucial and impactful actions for the next five years in Cambodia.

2023–2024: Requiring immediate action and otherwise irreversible

1. Prioritize urgent reforms to implement rigorous monitoring and evaluation of progress against LTS4CN targets and to enhance protected area management and law enforcement to lower illegal logging.

2. Finalize and implement the Environment and Natural Resource Code to prevent further loss of natural wetlands.
3. Increase the ambition of renewable energy targets and conduct a review of PPA terms, while expanding the use of auctions.
4. Revise urban plans to promote compact urban development.
5. Develop a comprehensive flood management strategy that combines risk-informed planning, physical infrastructure improvements, and nature-based solutions.

2025–2027: Less immediately urgent or requiring greater funding or coordination

6. Develop programs and introduce incentives to modernize existing irrigation infrastructure and promote water use efficiency and AWD production systems.
7. Enhance the capacity and flexibility of transmission and distribution networks to enable renewable energy connection and integration.
8. Lower the capacity charge on rooftop solar, remove the solar PV installation capacity limits of 50 percent, and introduce net billing, allowing time-of-use tariffs and streamlining the approval process.
9. Legislate and fund a permanent adaptive social protection program.
10. Incorporate climate change spending in individual ministry budgets and require climate spending to be included in Budget Strategic Plans.

Although this CCDR has attempted to be comprehensive, given the breadth of the topics of climate change and development, it has not been able to address all related issues in depth. Further work will be required on certain topics to understand the consequences of climate change and the low-carbon transition more comprehensively. For example, one key understudied area has been the negative effects of sea level rise and the resources needed to adapt. Further work is also needed to better understand the costs of the energy transition using an energy planning modeling exercise. It is also important to understand how the domestic labor market may adjust to expected technology shifts in high-emitting sectors (energy, transport, and agriculture), as well as the new opportunities that may arise from higher demand for low-carbon products by industries and consumers. Likewise, more attention should be paid to how climate change is affecting water security (how much and how good), water management, and in particular the compounding effects of climate change and poor planning on coastal ecosystems, and coastal infrastructure. These are just a few examples that highlight the need for a continued examination of climate issues in Cambodia beyond the CCDR.

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Technical appendix

Macroeconomic modelling addtional details

Measurement of climate change impacts on GDP

The estimates of the impacts of climate change on GDP presented in Chapter 2.3 combine four different damage channels: the impacts of floods on assets, the impacts of climate change on labor productivity, the impacts of climate change on agricultural crop yields, and the impacts of climate change on tourism revenues. These channels are in no way exhaustive and climate change will have a variety of complex impacts that this CCDR is not able to model explicitly. Each of these microeconomic impact channels is modelled as outlined in Chapter 2.3.1 and described in more detail below.

Labor productivity impacts

Temperature directly affects the productivity of labor, where the effect intensifies for labor types that are outdoors and are conducting more intense physical work. Labor productivity impacts follow the methodology applied by the International Labor Organization (ILO 2019), which has been applied globally and used in other similar studies, such as in Kjellstrom et al. (2018). The approach is based on workday wet bulb globe temperatures as an indicator of heat stress, which refers to the exposure of individuals to extreme heat or hot environments that lead to the body's inability to regulate internal temperature (CDC 2020). A measure of heat stress is used to quantify the percentage of a typical working hour that a person can work. The analysis is conducted at a 0.5 x 0.5 degree spatial resolution for the relevant sectors of the economy, resulting in annual shocks to labor productivity for every scenario being evaluated.

Labor productivity effects are then estimated based on the percentage of hours that an acclimatized worker can be engaged in work based on their level of heat stress. Occupations with lower physical activity can tolerate higher levels of heat stress. Labor productivity loss curves from wet bulb globe temperatures for three levels of physical activity (measured in watts), are derived from the ISO 7243:1989 standard (ISO 1989) and Kjellstrom et al. (2018) and validated through additional epidemiological studies, as presented in ILO (2019b). Generally, 200 watts represent clerical or light physical work, 300 watts moderate physical work in industry, and 400 watts heavy physical work in agriculture or construction. Work intensities are then matched to labor hours by sector and occupation using available reported data. We apply available assumptions on outdoor exposure by occupation to data on employment by sector in order to split the share of hours worked indoors versus outdoors. We then estimate the impacts of heat stress on labor productivity for each category of workers (by sector and occupation) and for both indoor and outdoor workers.

For indoor workers, we exclude the share of those who worked in spaces with air conditioning and assume they do not experience any heat stress. Adoption of air conditioning within a country (by 0.5 degree grids) is estimated using regional percent coverage of curves from Davis et al. (2021), based on mean household income levels and cooling degree days by grid cell. Generally, regions with higher mean household incomes and/or cooling-degree days have a higher air conditioning adoption rate. Mean household incomes by country are obtained from United Nations and World Bank data (World Bank, n.d.; United Nations 2022). When available, data on mean percent adoption of air conditioning at a national scale is used to calibrate the estimates obtained from Davis et al.

For the final step, monthly labor productivity impacts by 0.5 degree grid cell are aggregated nationally by macroeconomic sectors (agriculture, industry, and services) and on an annual scale for all the completed time series. For agriculture, grid cell level impacts are aggregated using the share of cropland as a proxy of the spatial distribution of agricultural workers, using data from the Copernicus Fractional Land Cover dataset (Buchhorn et al. 2020). For industry, we assume a distribution of workers using gridded gross domestic product data from Wang and Sun (2022). For services, we aggregate using gridded population data from WorldPop of the University of Southampton (Bondarenko et al. 2020b; 2020a).

Available climate scenarios were first obtained from the World Bank's Climate Change Knowledge Portal for 29 General Circulation Models (GCMs) from the Coupled Model Intercomparison Project 6 (CMIP6) suite of model outputs. Each GCM has up to five combinations of Shared Socioeconomic Pathway (SSP) and Representative Concentration Pathway (RCP) emissions scenario runs available. For each GCM-SSP combination, a modeled history from 1995 to 2014 and projections from 2015 to 2100 were available for monthly mean temperature and precipitation at a 1x1 degree grid resolution. Given that GCM output is biased relative to observed climate conditions, bias correction and spatial disaggregation was conducted, before then interpolating monthly variables to a daily timestep.

Probabilistic flood modelling

The flood modelling used in this CCDR is outlined in the Disaster Risk Profile for Cambodia, conducted by CIMA (2023) and described more in the companion piece to this CCDR. It uses a probabilistic risk assessment approach based on a modelling approach to best predict possible present and future scenarios, taking into consideration the spatial and temporal uncertainties involved in the analyzed process. Probabilistic disaster risk profiles consider all possible risk scenarios in a certain geographical area. A realistic set of all possible hazardous events (scenarios) that may occur in a given region, including very rare, catastrophic events, is simulated. This means that both low frequency, high loss impact events, as well as high frequency, lower loss impact events are calculated, such that their probability of occurrence is included in the assessment. Events which have never been historically recorded but might occur in projected climate conditions are also considered in the risk analysis. This feature is particularly useful in the context of climate change, which is dramatically increasing uncertainty about future hazard patterns.

The Disaster Risk Profile for Cambodia provides a comprehensive view of hazard, risks, and uncertainties for floods in a changing climate, with projections for the period 2017–2100. The risk assessment considers a large number of possible scenarios, their likelihood, and associated impacts. In this risk profile, three different climate scenarios were considered:

- under current climate conditions: with disaster risk assessed using the observed climate conditions in the 1979–2016 period.
- under projected climate conditions, upper boundary: with disaster risk being assessed under projected climate conditions to 2100, considering the IPCC SSP5-RCP8.5 scenario, which foresees high radiative forcing by the end of the century, driven by the economic success of industrialized and emerging economies, coupled with the exploitation of abundant fossil fuel resources and the adoption of resource and energy intensive lifestyles around the world.
- under projected climate conditions, lower boundary: with disaster risk being assessed under projected climate conditions to 2100, considering the IPCC SSP1-RCP2.6 scenario, designed with the aim of simulating a development that is compatible with the 2°C target, assuming climate mitigation measures being taken.

The flood risk assessment aims at understanding the probability that different magnitudes of damaging flood characteristics will occur over an extended period of time. These estimates can be calculated both in current and projected climate conditions, resulting in detailed hazard maps, to be then combined with the reproduction of past event patterns and the modelling of projected future events. Information on the performance capacity of flood protection measures is finally added to the analysis. This workflow allows for the estimation of the "expected" water depth for a certain location and/or individual infrastructures, for a set of reference scenarios. From this step on, it is possible to explore the full frequency distribution of events and the consequent damage to exposed assets, taking into consideration their different levels of vulnerability (UNDRR 2019). Flood risk results are calculated in terms of annual average loss and probable maximum loss curves for several indicators at different spatial levels of aggregation: national and subnational (administrative level 1). Their spatial distribution has been computed in current and projected climate conditions using the SSP1-RCP2.6 and SSP5-RCP8.5 scenarios in Cambodia, with and without the implementation of adaptation measures.

Information on the built-up area refers to two main aspects: to the description of the physical exposure of buildings, in terms of their economic value, their spatial location inside or outside flood-prone areas, and the elements which might influence its vulnerability, such as its occupancy characteristics, the existence of basements, and the type of constructive materials. The built-up data prepared for the present risk profile were obtained from the exposure dataset used in the Global Assessment Report, updated by UNEP-GRID within a project financed by CDRI and managed by UNDP. They have been divided into three sector classes, according to the exposure categories reported in the Sendai Framework indicators: housing sector distribution, service sector distribution, and industrial sector distribution. The spatial resolution of such information has been improved through a proper downscaling procedure, guaranteeing coherence among the distributions of population and residential areas.

Critical infrastructures data refer to the description of the physical exposure in terms of spatial location of educational and health facilities, as well as the transport network combined with their economic values related to the rehabilitation cost. The main added values of this information rely on knowing the exact location of the infrastructure and the rehabilitation cost. Local datasets made available by national entities were combined with global datasets from OpenStreetMap to yield a uniform representation of the spatial location of critical infrastructures in the whole of Cambodia.

Impacts on tourism

Estimates of the impacts on tourism use data from the World Travel & Tourism Council Country Profiles (WTTC 2022) and the United Nations World Tourism Organization (UNWTO 2021) to estimate the size and breakdown of tourism revenues. We then distribute revenues from international leisure travelers to 0.5 x 0.5 degree grid cells in the country using the location of points of interest from the Humanitarian OpenStreetMap Team geospatial data (HOTOSM 2020), as well as available literature that accounts for high-revenue tourist sites that may be overlooked in the OpenStreetMap data (for example, the point location of a major attraction may represent a higher volume of revenues than a relatively smaller site).

Impacts on leisure revenues due to changes in average climatic conditions are estimated following the approach developed by Hamilton, Maddison, and Tol (2005), which was also applied by Roson and Sartori (2016). We consider the percent change in total arrivals as a proxy for the percent change in revenues from international leisure travelers. For changes in domestic leisure travelers, we consider the percent change in total departures, which results in a decrease in revenues from an increase in departures (that is, as a region gets hotter, residents will prefer more pleasant locations elsewhere). This approach assumes that the mean revenues generated per traveler remain constant as temperatures change. A final tourism shock is calculated by aggregating the effect on international and domestic leisure revenues, assuming the fraction of revenues from business travel does not change.

Impacts on crop yields

The analyses use the W5E5 bias-corrected reanalysis dataset for historical observation and dynamically downscaled models (part of the CORDEX-CORE initiative) for future projections. The CORDEX CORE framework simulate with two RCMs (REMO and RegCM) and three GCMs representing the range of low, medium, and high global equilibrium climate sensitivity (ECS): (NCC-NORESM (low ECS), MPI-ESM-LR/MPI-ESM-MR (medium ECS), and HadGEM-ES (high ECS)). Therefore, in total, there are six different climate simulations per domain. However, Cambodia is situated at the intersection of two domains, namely EAS-22 and SEA-22. Thus, for this analysis and to increase the robustness of the presented results, this document uses nine climate simulations (six from SEA-22 and three from EAS-22). As previously reported, the same GCM-RCM combination in different CORDEX domains can give rise to significantly different results.

The framework applied to assess climate change impacts on crops is the following:

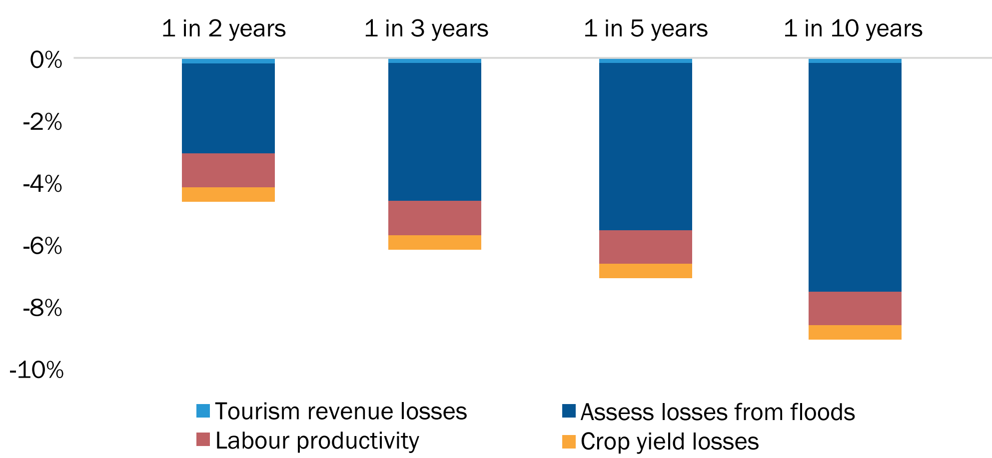
1. pyAEZ was run to simulate the maximum potential yield for several crops using three bias-corrected CORDEX-CORE simulations. The bias correction was performed with the W5E5 bias-corrected reanalysis dataset. The simulation period ran from 1976 until 2099.
2. The results were averaged by province as pyAEZ produces results at the same spatial resolution as the climate models used.
3. Results from different climate models were averaged (ensemble) and averaged based on the time frame (2031–2060 and 2061–2090).

Since most crops are not irrigated in Cambodia, the effect of irrigation on potential yield can be calculated based on the difference between simulated yields with and without irrigation. We define a high potential for irrigation when the differences between yields are higher than 20%.

Sensitivity analysis of flood impacts

The modelling results presented in Section 2.3.1 demonstrated that in the MINDSET model, the impacts of floods accounted for the largest component of the GDP impacts. This modelling included a ten-year flood. This Annex also repeats this modelling, replacing the flood type to understand the range of impacts under different flood scenarios. The total GDP impacts are highly sensitive to the type of flood that occurs in the year being studied, as is presented in Figure 32. In all of these estimates, however, floods have the greatest GDP impact.

Figure 32. MINDSET model sensitivity analysis altering the flood return period
MINDSET model impacts of climate change on GDP for floods of different return period



Source: MINDSET modelling.

Investment needs estimate details

Incremental investment needs were identified as additional investments that would need to be made by the private or public sector to achieve the objectives outlined in this report, in addition to existing investments already being undertaken or that will be imminently implemented from existing plans. For climate adaptation, these incremental investments were outlined in each section of Chapter 4.2. For climate mitigation, these investment needs are calculated as follows.

- Transport sector. The incremental investment estimate includes the cost of achieving the vehicle electrification targets outlined in the LTS4CN. The cost is calculated as the difference in cost between EVs and internal combustion vehicles as estimated in the modelling of EV costs in Cambodia outlined in Section 2.7. This modelling uses the FTT transport model for Cambodia and allows for declining EV costs over time. The cost differential is taken as the difference in price for the lower range of cars.
- Power sector. The incremental investment estimate includes the cost of an "accelerated decarbonization scenario" relative to the current PDP. This scenario is as shown in the low-carbon pathway scenario in the CGE modelling presented in Section 2.6. It involves a more rapid scale-up of solar energy and the introduction of some wind energy to achieve power sector emissions that are 70 percent lower in 2050 than under the current PDP. Unit cost estimates for energy sources are taken from the FTT energy model, as used in the MINDSET modelling presented in Section 2.6.
- LULUCF sector: investments follow the REDD+ investment plan.

This table presents additional estimates of investment needs without discounting and with investment needs represented in aggregate as well as incremental terms. For adaptation, projected existing or planned investments include investments already underway or projected to occur without further policy action for the purpose of the climate adaptation goals outlined in the report. For mitigation, the investment needs include not only the additional cost of lower-carbon options relative to the higher-carbon alternatives (for example, the cost difference between electric and non-electric vehicles) but the total investment.

Table 7. Investment needs extension without discounting and including aggregate totals
Cumulative investment needs from 2023–2050 (US$, billion)

	Undiscounted			Discounted by 6% (NPV)		
	Projected existing or planned investment	Required additional investment	Aggregate investment	Projected existing or planned investment	Required additional investment	Aggregate investment
	Climate adaptation					
Climate-resilient agriculture		7.53	7.53		3.96	3.96
Water storage and WASH	1.13	1.31	2.45	0.60	0.69	1.29
Resilient transport	2.57	13.12	15.69	1.35	6.91	8.26
Urban planning & DRM	0.05	0.32	0.37	0.03	0.17	0.20
Efficient cooling	1.74	0.87	2.61	0.91	0.46	1.37
Climate resilient schools and health facilities	0.00	0.22	0.22	0.00	0.12	0.12
Social protection		7.73	7.73	0.00	4.07	4.07
Others		7.54	7.54	0.00	3.97	3.97
	Climate mitigation					
Power	43.90	8.66	52.57	23.11	4.56	27.67
Transport	31.09	32.59	63.68	8.70	9.46	18.16
LULUCF		2.15	2.15		1.13	1.13
Total	**80.48**	**82.05**	**162.53**	**34.70**	**35.49**	**70.19**

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