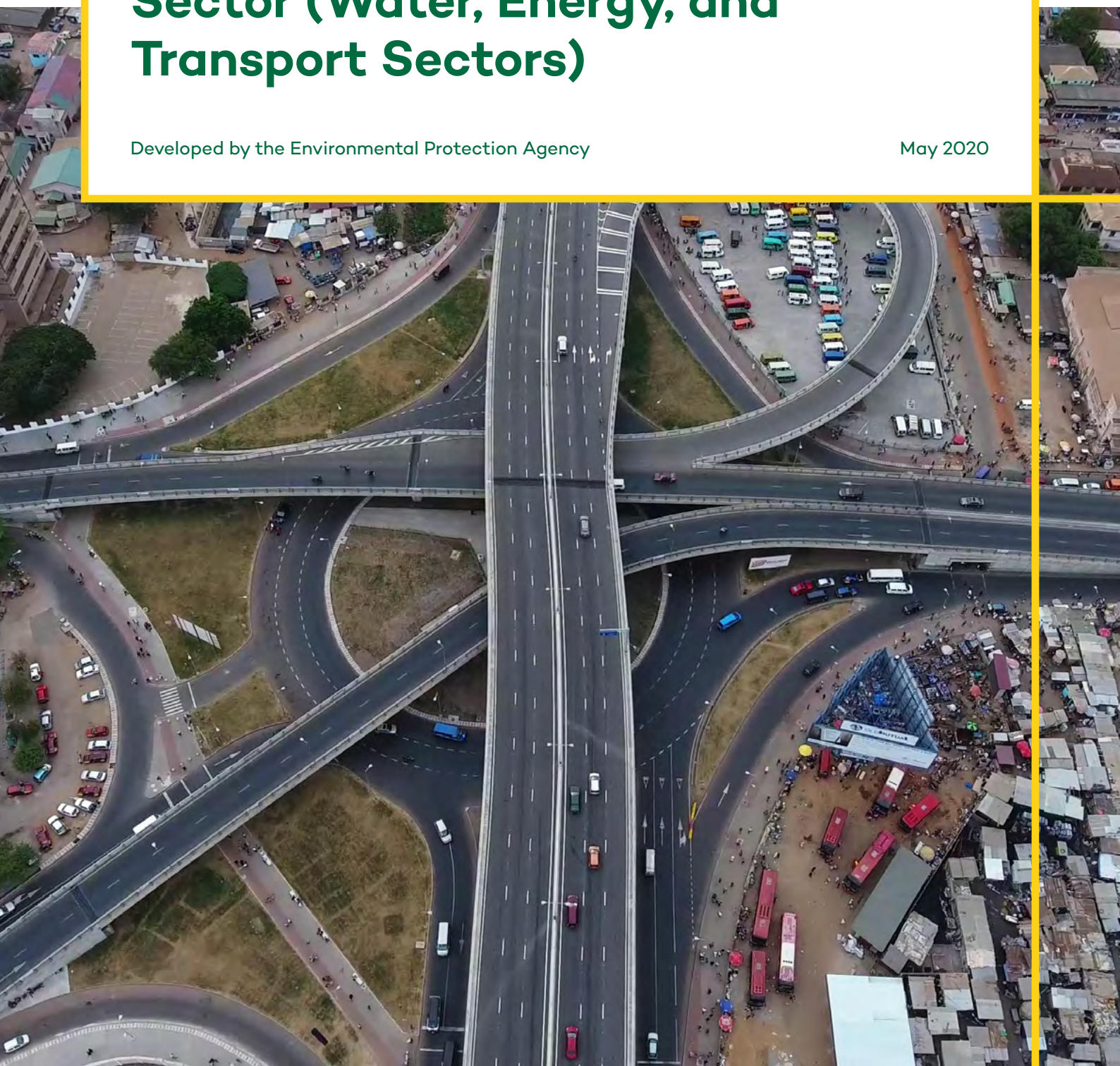
Ghana's Adaptation Strategy and Action Plan for the Infrastructure Sector (Water, Energy, and Transport Sectors)

Developed by the Environmental Protection Agency

May 2020



Original text: English

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Ghana's Adaptation Strategy and Action Plan for the Infrastructure Sector (Water, Energy, and Transport Sectors) was produced by the Government of Ghana, Environmental Protection Agency (EPA), with financial and technical support from the NAP Global Network.

The NAP Global Network was created in 2014 to support developing countries in advancing their NAP processes, and help accelerate adaptation efforts around the world. To achieve this, the Network facilitates sustained South–South peer learning and exchange, supports national-level action on NAP development and implementation, and enhances bilateral support for adaptation and climate-sensitive sectors through donor coordination. The Network's members include participants from more than 135 countries involved in developing and implementing National Adaptation Plans, as well as 11 donor members. Financial support for the Network has been provided by Austria, Canada, Germany and the United States. The Secretariat is hosted by the International Institute for Sustainable Development (IISD). For more information, visit www.napglobalnetwork.org

United States In-Country National Adaptation Plan (NAP) Support Program

Gift of the United States Government

In collaboration with:

Implemented by:

Initial funding for the Network also provided by:

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Acknowledgements

The Environmental Protection Agency (EPA), on behalf of the Ministry of Environment, Science, Technology and Innovation (MESTI), Ghana, would like to acknowledge the financial and technical support received to develop the infrastructure sector adaptation plan from the United States (U.S.) In-country Support Program, which is managed by the International Institute for Sustainable Development (IISD), host to the NAP Global Network Secretariat.

We are very grateful to the following ministries, departments, and agencies that collaborated with the EPA directly in developing this strategy. They include the Energy Commission, the Ministry of Transport, the Ministry of Roads and Highways, the Ministry of Sanitation and Water Resources, the Water Resources Commission, the Water Research Institute (WRI) of the Council for Scientific and Industrial Research, the Ministry of Finance, the National Development Planning Commission, and the National Disaster Management Organization. Special acknowledgement goes to the diverse civil society organizations and the private sector for their immense contributions and participation during the consultations and the validation workshop.

The EPA is also indebted to the following individuals for their inputs and contributions that gave the document a strategic focus: Mr. Ebenezer Appah-Sampong (Deputy Executive Director in charge of Technical Services, EPA), Dr. Banabas Amissigo (Researcher, WRI), Mr. Peter Derry (Acting Director for Environment, MESTI), Mr. Alec Crawford (IISD, Canada), Mr. Robert Mensah (Ministry of Finance), Mr. Winfred Nelson (NDPC), Dr. Daniel Tutu Benefoh (Climate Change Department, EPA), Ms. Joyce Oncansey (Energy Commission), Ms. Doris Edem Agbevivi (Energy Commission). Special appreciation goes to Dr. Antwi-Boasiako Amoah and his team (Ms. Stella Okoh, Ms. Rosemary Boateng, and Mr. Isaac Kwabena Danso) for coordinating the development of the infrastructure sector adaptation strategy.

Finally, the EPA would like to express its profound gratitude to the consultant, Dr. Philip Antwi-Agyei of the Kwame Nkrumah University of Science and Technology, Kumasi, for leading the development of Ghana's Infrastructure Sector Climate Change Adaptation Plan.

Foreword

The climate in Ghana is changing, with wide-ranging implications for cities, local communities, Indigenous businesses, industry, and government at different levels. Infrastructure, particularly relating to energy, water, and transport, has been identified as a priority sector in both Ghana's Nationally Determined Contributions under the Paris Climate Agreement and its National Adaptation Plan (NAP) Framework. The vulnerability and resilience of Ghana's infrastructure to the impacts of climate change will be crucially important to a number of different economic sectors. Placing priority on investments in increasing the resilience of Ghana's infrastructure in the face of a changing climate means taking conscious measures aimed at reducing the vulnerability of socio-ecological systems against existing and future climate change effects.

Ghana's infrastructure has already begun to experience the adverse impacts of climate change. These impacts include transmission lines and roads being washed out in flooding events, hydropower services being compromised by the increased frequency and severity of drought, energy distribution systems overheating with temperature increases, and coastal roads and ports being lost to increased storm surges and sea erosion. The infrastructure sector in Ghana is varied; as such, this strategy focuses on water, energy, and transport infrastructure.

I am very optimistic that the lead sectors for this strategy (i.e., energy, water, and transport) will own the content of this document and work closely with the Environmental Protection Agency to ensure the effective implementation of the strategy.

JOHN A. PWAMANG
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Executive Summary

Infrastructure, particularly that relating to energy, water, and transport, has been identified as a priority sector in both Ghana's Nationally Determined Contributions under the Paris Climate Agreement and its National Adaptation Plan (NAP) Framework. The vulnerability and resilience of Ghana's infrastructure to the impacts of climate change will be crucially important to a number of different economic sectors.

Recognizing this, the overarching goal of this plan is to develop an effective adaptation strategy and action plan for Ghana's water, energy, and transport infrastructure, covering all levels of decision making, in order to increase the sector's resilience to climate change. It is anticipated that the adaptation strategy and action plan will further enhance the implementation of Ghana's NAP process and set out a plan for ensuring that the country's infrastructure is more resilient to climate change impacts. Additionally, the development of the adaptation strategy and action plan will help the country maintain the momentum of its NAP process and help position Ghana to raise further funds to support adaptation, including from the Green Climate Fund.

The formulation of the adaptation strategy and action plan followed an all-inclusive, interactive and participatory approach involving an extensive desk-based review of key documents and policies on climate change to establish context, coupled with stakeholder consultations. Following the stakeholder consultations, a national validation workshop was held, where a multi-criteria analysis was used to evaluate and prioritize the adaptation actions needed to increase the resilience of the country's water, energy, and transport infrastructure.

The adaptation strategy and action plan highlights the historical, current, and projected climate trends in Ghana. It demonstrates that temperatures will increase across all agro-ecological zones, while rainfall will become more variable. Both will have implications for Ghana's infrastructure sector.

There is a broad legal and policy framework already in place to support the successful implementation of adaptation actions for Ghana's water, energy, and transport infrastructure. This strategy will therefore be anchored by and linked with these existing policy frameworks, including the National Climate Change Policy (2013), the National Climate Change Adaptation Strategy (2012), the Nationally Determined Contributions (2015), the NAP Framework (2018) and the National Climate Change Master Plan Action Programmes for Implementation (2015–2020).

Specific adaptation actions for the water, energy, and transport sectors have been identified and evaluated in this strategy. Implementation of the strategy will be the responsibility of the specific ministries responsible for the water, energy, and transport sectors: the Ministry of Sanitation and Water Resources, the Ministry of Energy, and the Ministry of Roads and Highways, respectively. The Environmental Protection Agency and the Ministry of Environment, Science, Technology and Innovation, as coordinating institutions for Ghana's NAP process,

will be providing oversight responsibility and the necessary technical support to ensure the effective implementation of the outlined adaptation strategies.

It should be noted that the impacts of climate change and extreme weather events are experienced differently along gender lines, and it is widely acknowledged that women, the elderly, and the disabled are more vulnerable to the threats of climate change, largely due to their frequent lack of control over productive assets that could otherwise help them to address the threats posed by climate change. This strategy advocates for a gender-responsive adaptation strategy for infrastructure that addresses the threats of climate change on the livelihoods of these socioeconomic groups. It is crucial that women, the elderly, and the disabled are actively involved in the design, planning, and implementation of climate change adaptation programs and interventions in the infrastructure sector. The views of such vulnerable groups should be reflected in the decision-making process on climate change adaptation to ensure their ownership of adaptation actions.

Funding will be critical to ensuring the effective and timely implementation of the various adaptation activities highlighted in this strategy. Therefore, the plan advocates for a coherent financial strategy to ensure adequate and sustainable financing—domestic and international, public and private—of the adaptation options highlighted in the strategy. In addition to funding, continuous capacity building and education would be essential within the respective sectors for effective implementation of the actions outlined in this strategy.

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Acronyms

CSO	civil society organization
CWSA	Community Water and Sanitation Agency
EPA	Environmental Protection Agency (Ghana)
GhIE	Ghana Institution of Engineers
GhIS	Ghana Institution of Surveyors
GMet	Ghana Meteorological Agency
HSD	Hydrological Services Department
IPCC	Intergovernmental Panel on Climate Change
IWRM	integrated water resources management
M&E	monitoring and evaluation
MCA	multi-criteria analysis
MESTI	Ministry of Environment, Science, Technology and Innovation
MMDA	Metropolitan, Municipal and District Assemblies
MoFA	Ministry of Food And Agriculture
NADMO	National Disaster Management Organization
NAP	National Adaptation Plan
NCCC	National Climate Change Committee
NCCAS	National Climate Change Adaptation Strategy
NCCMP	National Climate Change Master Plan
NCCP	National Climate Change Policy
NDC	Nationally Determined Contribution
NDPC	National Development Planning Commission
SDG	Sustainable Development Goal
UNFCCC	United Nations Framework Convention on Climate Change
WRC	Water Resources Commission
WRI	Water Resource Institute

1.0 Introduction

Located in West Africa on the Guinea Coast with a total land area of 239,460 km^2, Ghana lies close to the equator between latitude 11.50N and 4.50S and longitude 3.50W and 1.30E. It shares borders with Côte d'Ivoire to the west, Togo to the east, and Burkina Faso to the north. In recent years, Ghana has experienced significant economic growth, much of it driven by natural resources, and was classified as a middle-income country by the United Nations in November 2010. These economic gains are, however, threatened by climate change, which presents a major development challenge to the country due to its attendant effects on the climate-sensitive sectors—including infrastructure, agriculture, and natural resources—which underpin the livelihoods of a majority of households across the country.

Ghana signed the United Nations Framework Convention on Climate Change (UNFCCC) at the Rio de Janeiro Earth Summit in June 1992, after the convention was adopted on May 9, 1992. The UNFCCC required the Government of Ghana to take climate change issues into consideration in national development planning. As a signatory to the convention, the Government of Ghana has already begun to take definitive steps toward building its resilience and enhancing national capacities to adapt to climate change impacts, through its National Adaptation Planning (NAP) process and related supporting policies, including the National Climate Change Policy (2013), the National Climate Change Adaptation Strategy (2012) and the country's Nationally Determined Contributions (NDCs) (2015). In November 2018, the Environmental Protection Agency (EPA) released its National Adaptation Plan (NAP) Framework, which outlines, among other things, the country's vision, guiding principles, approaches, policy alignment, and next steps for the NAP process.

Adaptation is one of the two key approaches to addressing the threats of climate change (with the other being mitigation[1]). The Intergovernmental Panel on Climate Change (IPCC) defines adaptation as a "process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate harm or exploit beneficial opportunities" (IPCC, 2014, p. 118). It involves adjustments in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects (IPCC, 2014). Adapting Ghana's infrastructure to the impacts of climate change will help to ensure that it can withstand increasing temperatures, extreme weather events, changing precipitation rates, and coastal erosion, and continue to underpin a thriving Ghanaian economy into the future.

[1] Mitigation involves any activity aimed at reducing greenhouse gas emissions and includes any human intervention to reduce the sources or enhance the sinks of greenhouse gases.

2.0 The Purpose of the Sectoral Adaptation Strategy and Action Plan for Infrastructure

Enhancing the capacity of priority sectors in the Ghanaian economy to address climate threats will require the development and implementation of sector-specific adaptation plans; these need to be developed for all areas deemed to be particularly vulnerable to climate impacts, including water, health, infrastructure, agriculture, energy, and fisheries.

Infrastructure, particularly that relating to energy, water, and transport, has been identified as a priority sector in Ghana's NDCs under the Paris Climate Agreement (Government of Ghana, 2015a) as well as its Third National Communication to the UNFCCC (2015). The vulnerability and resilience of Ghana's infrastructure to the impacts of climate change will be crucially important to a number of different economic sectors, including agriculture and mining. Ghana's infrastructure has already begun to experience the adverse impacts of climate change. These impacts include transmission lines and roads being washed out in flooding events,[2] hydropower services being compromised by the increased frequency and severity of drought (Bekoe & Logah, 2013), energy distribution systems overheating with temperature increases, and coastal roads and ports being lost to increased storm surges and sea erosion (Boateng et al., 2017). Increased wildfires during periods of decreased precipitation and increased consecutive dry days associated with climate change can directly damage transmission and distribution lines. This can also lead to soot accumulation on insulators that can cause leakage (Hellmuth, Bruguera, & Ankoh, 2018). Climate change will also affect the availability and quality of water resources, while sea-level rise may cause saltwater to seep into coastal aquifers, affecting crops and increasing the cost of water treatment.

Given this threat, infrastructure—particularly that relating to the water, energy, and transport sectors—was identified as a good starting point for the development of a sectoral adaptation strategy and action plan under Ghana's NAP process. The strategy presented here focuses on increasing the resilience of Ghana's water, energy, and transport infrastructure to climate change and covers all levels of decision making. It includes concept notes on adaptations to drive climate-resilient investment in the sector.

It is anticipated that this adaptation strategy and action plan will further enhance the implementation of the NAP process in Ghana and set out a plan for infrastructure that is more resilient to climate change impacts. Additionally, the development of the adaptation strategy and action plan for infrastructure will help the country maintain the momentum with its NAP process and help position Ghana to secure future adaptation funding, including from the Green Climate Fund.

[2] According to Hellmuth et al. (2018), Ghana's transmission and distribution system is vulnerable to a number of stressors, particularly extreme rainfall and flooding, sea-level rise and coastal erosion, temperature and drought.

Effective, reliable infrastructure—roads, ports, power stations, waterworks, and the like—underpins economic activity. For Ghana, the impacts of recent flooding and severe weather events (including excessive heat conditions) on the country's infrastructure emphasize the risks that climate change could pose to the Ghanaian economy and the livelihoods of its population in the coming decades. The impacts could be widespread. In addition to the direct impact of storms on the integrity of Ghana's infrastructure, high temperatures could increase energy demand as people increase their use of air conditioning, straining electricity grids. Higher temperatures could also increase the rate at which tarred roads deteriorate. Increased severe weather, both in Ghana and internationally, could disrupt supply chains and resources that infrastructure companies rely on for construction materials; it could also have implications for day-to-day operations by delaying the arrival of supplies coming into the country's ports and airports. These climatic events underscore the need for urgent and appropriate adaptation actions within the infrastructure sector.

Understanding the extent to which Ghana's existing and new infrastructure is resilient to the changing climate will be crucial for the government as it determines whether current levels and types of investments in existing and new infrastructure are adequate in the face of the climate crisis. This demonstrates a strong case that climate change will have significant impacts on the country's infrastructure and why an adaptation strategy is urgently needed.

For the purpose of the strategy, infrastructure is taken to include "basic equipment, utilities, productive enterprises, installations, institutions and services essential for the development, operation and growth of an organization, city or nation" (New York State, n.d.). This strategy will focus on three kinds of infrastructure: energy (energy-related systems and infrastructure, including small-scale and large-scale energy generation through hydroelectric power), water (all water resources and infrastructure), and transportation (including roads, bridges, railway lines, shipping corridors, and ports) (Dazé & Echeverria, 2016, p. 33).

3.0 Ghana's NAP Framework

Ghana's NAP process seeks to provide the enabling framework for the planning and implementation of the adaptation actions enshrined in the National Climate Change Policy (2013), the National Climate Change Adaptation Strategy (2012) and the NDCs (2015), all done within the context of Ghana's medium- and long-term development agenda and its commitment to achieving the Sustainable Development Goals (SDGs). Improving adaptation planning through the NAP process will help build local adaptive capacity to address climate change. This will not only support Ghana's commitment to SDG 13 on climate action, but it will also support action on reducing poverty and enhancing livelihood opportunities (SDG 1) and improving gender equality (SDG 5), among other SDGs.

Ghana's NAP Framework[3] seeks to provide an overall structure to guide the country in developing, coordinating, implementing, and monitoring its NAP process by clarifying the overarching vision and structure for the process and its added value (EPA, 2018). Specifically, the objectives of the NAP Framework are to:

- Clarify Ghana's approach to its NAP process. This includes an articulation of the country's vision of climate change adaptation, its adaptation objectives and principles, the roles played by stakeholders within the national government, and priority adaptation actions to be undertaken. It also provides a reference point for bringing together various adaptation planning efforts from different sectors, subnational structures, and scales of decision making.
- Align the NAP process with existing policies, strategies, and adaptation research.
- Identify specific themes that are particularly relevant and/or unique to the country context.
- Serve as a basis for stakeholder engagement.

[3] The NAP Framework proposes a more sectoral-based approach to climate change adaptation planning in Ghana, "with the EPA coordinating the development of an overarching NAP and with adaptation priorities identified for key sectors such as agriculture, forestry, water, energy, gender and health" (Ghana Business News, 2019; EPA, 2018).

4.0 Current and Projected Climate Trends in Ghana

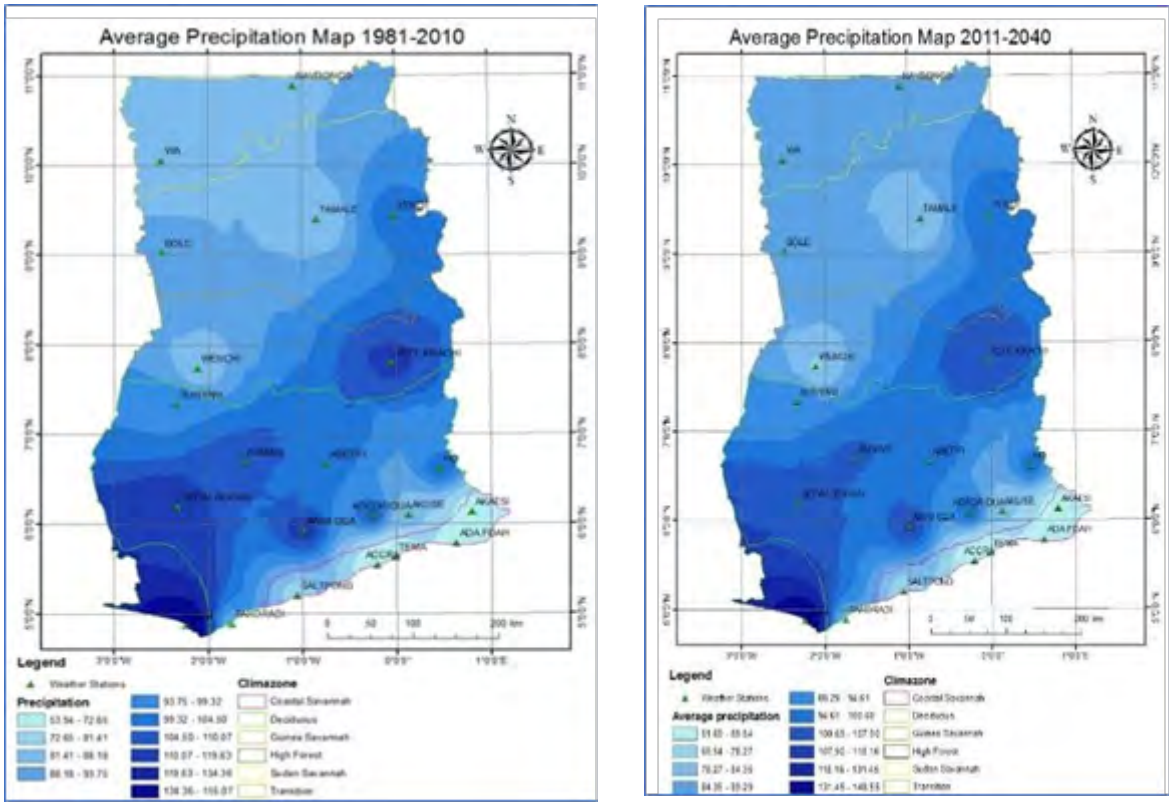
4.1 Overview

The climate in Ghana is tropical and influenced by the West Africa monsoon winds (Government of Ghana, 2015b). Rainfall and temperature have been generally variable in Ghana. Seasonal patterns in Ghana are heavily influenced by the position of the Inter-Tropical Conversion Zone as it oscillates between the south and the north. Seasonal variations in temperature in Ghana are greatest in the north, which is also the hottest part of the country, with temperatures reaching an average of 27°C–30°C during the hot, dry season (April, May, June) (Asante & Amuakwa-Mensah, 2015). Closer to the coast in the south, temperatures are cooler, with averages of 22°C–25°C from June to August. However, there are instances where the southern and northern parts of Ghana have recorded average temperatures of 18°C and 40°C, respectively (Asante & Amuakwa-Mensah, 2015). The northern part of Ghana has one rainy season, with an average annual rainfall of 750–1,050 mm (30–40 inches) between the wet season of May to October; this is followed by a long dry season from November to April (Government of Ghana, 2015b). This dramatic range makes households in the north of Ghana particularly vulnerable to the adverse impacts of climate change: flooding in the wet season and drought in the dry season (Antwi-Agyei et al., 2012). Southern Ghana, by contrast, is wetter and has two rainy seasons, running from April to July and from September to November (Asante & Amuakwa-Mensah, 2015).

4.2 Historical Rainfall Patterns

Rainfall in Ghana was particularly high in the 1960s and decreased to particularly low levels in the late 1970s and early 1980s. This resulted in an overall decreasing trend in precipitation for the period 1960–2006, with an average decrease in precipitation of 2.3 mm per month (2.4%) per decade (McSweeney et al., 2010; Stanturf et al., 2011). Rainfall in Ghana generally increases as you move south toward the coast. The wettest area in Ghana is the extreme southwest, where annual rainfall is about 2,000 mm; by contrast, annual rainfall in the extreme north is less than 1,100 mm (Ministry of Food and Agriculture [MoFA], 2016). Using daily rainfall data for 40–45 years, Yorke and Omotosho (2010) observed that the early onset and late cessation dates that characterized the rainy season during the 1960s and early 1970s, which resulted in long rainy seasons almost everywhere in Ghana, have now changed significantly. Since the 1980s, the rainy season increasingly arrives later and ends sooner. McSweeney et al. (2010) also observed considerable variability in rainfall patterns, both internally and between decades, that may be attributed partly to variations in the Inter-Tropical Conversion Zone, the West African monsoon and the El Niño Southern Oscillation. Figure 1 shows the observed (1980–2010) and the projected average rainfall (2011–2040) in Ghana.

Figure 1. Maps of observed and projected average rainfall 1980–2010 (left) and 2011–2040 (right)



Source: Government of Ghana, 2015b.

4.3 Future Projections for Rainfall and Sea-Level Rise

Downward trends in precipitation were observed for most agro-ecological zones in Ghana between 1951 and 2000. This is expected to continue, leading to a decrease in water flows in Ghana by 15–20% and 30–40% from 2000 to the years 2020 and 2050, respectively (Owusu & Waylen, 2009; Water Research Institute [WRI], 2000). The EPA (2010) has projected that, from a 2010 baseline, rainfall is expected to decrease across all agro-ecological zones by an average of 2.8%, 10.9%, and 18.6% by 2020, 2050, and 2080, respectively. Using 2000 as a baseline year, the WRI (2000) has projected a reduction in groundwater recharge rates of 30%–40% by 2050. High temporal and spatial variability in the distribution of precipitation in the Volta basin has often led to a high degree of seasonal, inter-annual, and spatial variability in runoff (Amissigo et al., 2015).

Based on global climate models, the World Bank Group (2019) projects that Ghana will experience:

- A decline in total annual rainfall of 1.1% by 2020 and 20.5% by 2080.
- A decrease in mean annual precipitation of 2.3 mm by 2050.
- An increase in the proportion of total annual rainfall that falls in heavy rainfall events, a decrease in dry season rainfall (January to June), and increases in wet season rainfall (July to August).
- An increase in one- and five-day rainfall maximum rates.

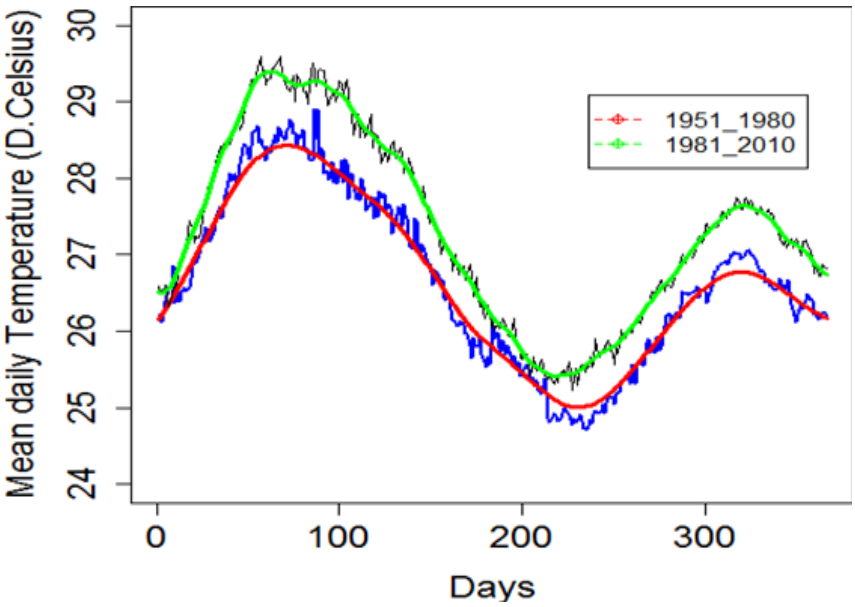
Based on historical rainfall patterns (1981–2010), it has been projected that overall rainfall will decrease by 2.9% in the near future (2040), followed by a slight increase in the mid-future (2060) by 1.1% and later decrease in the future (2080) by 1.7% (Government of Ghana, 2015b).

Sea levels will continue to rise in already vulnerable coastal areas. Scenarios of sea-level changes, with respect to the 1999 mean, predict an average rise of 5.8 cm, 16.5 cm, and 34.5 cm by 2020, 2050, and 2080, respectively. It is projected that this increase will affect the 30-metre contour of the nation's coastal zone, where more than 25% of the population lives (Ministry of Environment, Science, Technology and Innovation [MESTI], 2015). These trends are particularly pertinent for Ghana's NAP and its infrastructure, given that the country's coast is among the most densely populated parts of the country. Sea-level rise will lead to flooding and shoreline recession, putting coastal communities, ecosystems, and critical infrastructure at risk (Government of Ghana, 2017). Areas particularly vulnerable to future coastal hazards are likely to be especially problematic due to the low-lying nature of Ghana's coast.

4.4 Historical Temperature Patterns

Mean annual temperatures in Ghana have increased by 1.0°C since 1960, at an average rate of 0.21°C per decade (McSweeney et al., 2010; MESTI, 2012). The rate of increase has been higher in the northern regions of the country than in the south. The average number of "hot" days per year increased by 48 between 1960 and 2003 (McSweeney et al., 2010). The average number of "cold" days per year decreased by 12 (3.3% of days) between 1960 and 2003. In the north, temperatures now range from 27°C to 30°C during the hot season from April to June and from 25°C to 27°C during the coolest part of the year, from July to September (McSweeney et al., 2010). In the south, temperatures range from 25°C to 27°C during the warm season and from 22°C to 25°C during the cool season (Government of Ghana, 2015b) (see Figure 2). The temperature increase for Ghana is consistent with other regional temperature observations for West Africa (Daron, 2014).

Figure 2. Mean annual temperature cycle



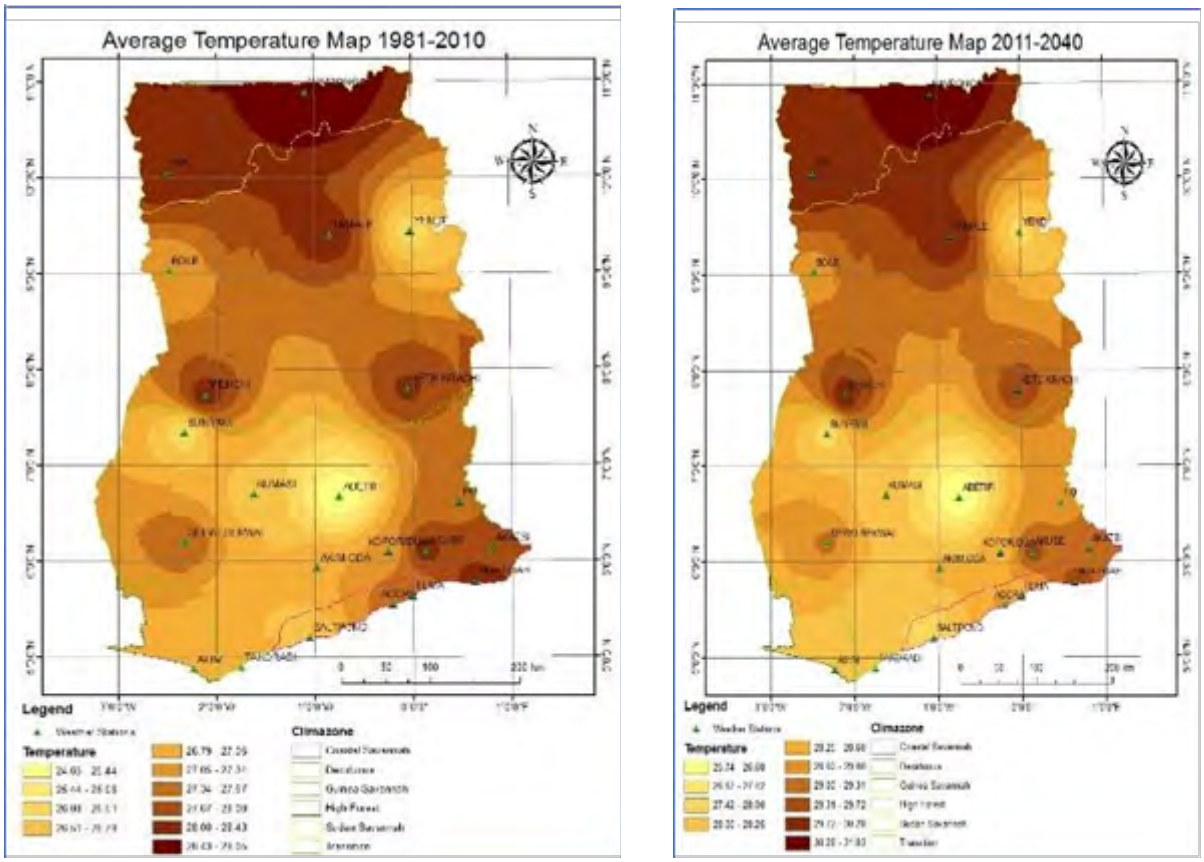
Source: Government of Ghana, 2015b.

4.5 Future Projections for Temperature

In Ghana, general circulation models indicate that Ghana will experience increased temperatures over the next 50 years across all ecological regions (De Pinto et al., 2012). Nonetheless, these projections will vary. Stanturf et al. (2011) project that mean temperatures will increase by between 1.5°C and 3.0°C by 2080 across most ecological zones. MESTI (2012) projects an increase in average annual temperatures of up to 5.4°C by 2080 across all ecological zones. Ghana will continue to get warmer, with the mean temperature projected to increase by 1.0°C–3.0°C by 2060 and 1.5°C–5.2°C by 2090 (EPA, 2010). The EPA (2010) forecasts that temperatures will increase on average by 0.6°C, 2.0°C, and 3.9°C by 2020, 2050, and 2080, respectively, across all agro-ecological zones in Ghana.

Based on global circulation models, such as the ensemble model, the World Bank Group (2019) projects that the trend for temperatures in Ghana over the period 2010 to 2050 indicates warming in all regions, with the highest temperatures found in the Northern, Upper East, and Upper West regions (World Bank Group, 2019). According to the World Bank (2011), the northern regions of Ghana will experience increased rates of warming. Temperatures in the three northern regions will rise by 2.1°C–2.4°C by 2050. Warming will occur in other regions, though not at the same rate: the predicted increase in the Ashanti, Western, Eastern, Central, and Volta regions is expected to be 1.7°C–2.0°C by 2050, and the temperature increase in the Brong-Ahafo Region could be 1.3°C–1.6°C (McSweeney et al., 2010). All projections suggest that the frequency of hot days and nights will increase substantially (World Bank Group, 2019). Occurrences of extreme weather events, including droughts and storms, have also been projected to increase across all ecological zones of the country (Government of Ghana, 2015b). Figure 3 shows the observed (1980–2010) and the projected average temperatures (2011–2040) (Government of Ghana, 2015b). A full list of projected changes in rainfall and temperatures is provided in Table 1.

Figure 3. Maps of observed and projected average temperatures 1980–2010 (left) and 2011–2040 (right)



Source: Government of Ghana, 2015b.

Table 1. Observed and projected changes in temperature and rainfall in Ghana

	Temperature	Precipitation
Observed	• Increase in annual temperatures over the period 1960–2011 (Kabo-Bah et al., 2016). • Variability in temperature, where there were "instances of decreasing annual minimum and maximum temperatures between 1970 and 1980 in some of the stations, such as Axim, Accra, Wa, Saltpond and Ho" (Kabo-Bah et al., 2016, p. 9). • Ghana has recorded a mean annual temperature increase of 1°C since the 1960 at an average rate of 0.21°C per decade (World Bank, 2011). • The average number of hot days per year increased by 48 between 1960 and 2003. Also, the average number of hot nights per year in the same period increased by 73. Furthermore, the average number of cold days per year decreased by 12 (3.3% of days) between 1960 and 2003.	• General decline in mean annual rainfall over the period 1981–2010 (Logah et al., 2013). • Primary decreasing trends from 1961 to 1985 as well as decreasing trends from 1986 to 2010 (Manzanas et al., 2014). • Downward trend in annual rainfall over the period 1951–2000 (Owusu & Waylen, 2009). • 20% drop in mean annual rainfall in the forest region of the country to the southwest, twice the proportion experienced in the savannah zones (Owusu & Waylen, 2009). • Ghana recorded high rainfall in the 1960s, but this decreased to considerably low levels in the late 1970s and early 1980s. This produced overall decreasing rainfall patterns between 1960 and 2006. Average rainfall was 2.3 mm per month (2.4%) per decade (World Bank, 2011). • Negative departures of rainfall implied a consistent downward trend over the period 1990–2008 (Nkrumah et al., 2014).
Projected	• An increase of 1.0 to 3.0°C by the 2060s, and 1.5 to 5.2°C by the 2090s has been projected in the mean annual temperature (World Bank, 2011). • "Substantial increases in the frequency of days and nights that are considered 'hot' in the current climate, but the range of projections between different models is large" (McSweeney et al., 2011, p. 3). • Mean annual temperatures are expected to rise by 1.9°C in 2050 (World Bank Group, 2019). • Total annual hot days of temperature above 35°C will rise by 70.5 days in 2050 (World Bank Group, 2019).	• By 2020 and 2080, total annual rainfall is projected to decline by 1.1% and 20.5%, respectively (World Bank, 2011). • In the transitional zone, seasonality will change, with early termination of rainfall which is likely to convert the current bi-modal regime to a uni-modal one (World Bank, 2011). • Rainfall patterns are expected to be cyclical over the period 2010–2050 for all regions within the country, with rainfall levels expected to be followed by a drought every decade or so (World Bank, 2011). • Mean annual precipitation will fall by 2.3 mm in 2050 (World Bank Group, 2010). • Based on historical rainfall patterns (1980–2010), rainfall across the country is projected to decrease by 2.9% (Government of Ghana, 2015b).

	Temperature	Precipitation
Examples of Impacts on Infrastructure	• Higher evaporation of water bodies (Kabo-Bah et al., 2016). • Energy distribution systems overheating with temperature increases. • Temperature extremes can also increase the expansion stress and movement experienced by steel bridges and rail tracks (Meyers, 2010). • Increased temperature causes the adverse expansion of concrete joints, protective cladding, coatings, and sealants on bridges (Meyers, 2010).	• Destruction of transmission lines and roads being washed out in flooding events, as well as coastal roads and ports being lost to storm surges and sea erosion. • Sea-level rise may also cause saltwater to seep into coastal aquifers, increasing the cost of water treatment. • Anticipated droughts that could lead to shortages of drinking water. • Destruction of infrastructure on roads, railways, pipelines, seaports, and airports.

5.0 Climate Change Vulnerabilities in Ghana

Climate change presents considerable threats to the socioeconomic development of Ghana (Asante & Amuakwah-Mensah, 2015). Climatic projections suggest that Ghana will experience higher temperatures and suffer more intense droughts, increased storms, and variable rainfall patterns (Christensen et al., 2007). Ghana's vulnerability to the adverse impacts of climate change is reflected in its economy, which is heavily dependent on climate-sensitive sectors (including agriculture). The country has low levels of infrastructure development and has stakeholders who are limited in their adaptive capacities (see Antwi-Agyei et al., 2012; Stanturf et al., 2011). The Notre Dame Global Adaptation Initiative (2017) ranks Ghana 114th of 181 countries on its 2017 list of countries most vulnerable to climate change. From a regional perspective, Ghana ranks higher than many of its West African neighbours in terms of its readiness to adapt to climate impacts (see Table 2).

Table 2. Comparison of Global Adaptation Index Scores for Ghana and neighbouring countries

	Vulnerability*		Readiness**		Overall
Country	World rank	Score	World rank	Score	World rank
Ghana	114	0.468	110	0.370	107
Côte d'Ivoire	134	0.514	159	0.271	145
Nigeria	127	0.489	169	0.242	148
Burkina Faso	162	0.572	157	0.276	161
Togo	141	0.539	142	0.298	145

** Lower score indicates lower vulnerability. The vulnerability score is determined based on indicators of exposure, sensitivity, and adaptive capacity, taking into consideration indicators related to six life-supporting sectors: food, water, health, ecosystem services, human habitat, and infrastructure.*

*** Higher score indicates a higher degree of preparedness. The readiness score takes into account a measurement of economic readiness, governance readiness, and social readiness to pursue adaptation actions.*

Source: Notre Dame Global Adaptation Initiative, 2017.

5.1 Relevance of Adapting Infrastructure in Ghana to Climate Change

Reliable infrastructure, including roads, ports, power stations, waterworks, and the like, underpins economic activity. The risks faced by different actors in the infrastructure sector are interlinked. For instance, infrastructure operators risk economic losses from poorly adapted assets, including loss of revenue or damaged or inefficient assets. Users, including businesses, households and individuals, are exposed to risks of service failure, disruptions to supply chains, and safety. Within the private sector, investors bear investment risks from the economic losses of infrastructure operators and from other investments reliant on infrastructure, while insurers and re-insurers bear increased risks as climate-related losses are offset through insurance claims. Finally, the government may ultimately act as a risk bearer of last resort, stepping in to assist with those private losses suffered in extreme circumstances.

It should also be noted that the transition to a low-carbon economy, a central component of both the Paris Agreement and the SDGs (MESTI, 2016), could have a significant impact on Ghana's economy and infrastructure investment. A global transition toward renewable energy generation and away from fossil fuels could cut demand and price for Ghanaian oil and gas products, consequently affecting the government revenues generated from this sector and limiting public budgets for the development and maintenance of new and existing infrastructure.

Based on national stakeholder consultations and a review of the literature, the key types of infrastructure exposed to climate risks in the energy, water, and transport sectors are listed in Table 3.

Table 3. Key climate-vulnerable infrastructure for the energy, water, and transport sectors

Energy	Water	Transport
• Fossil fuel and hydropower generation • Renewable energy generation • Energy distribution • Fuel processing and storage	• Water supply and treatment infrastructure • Wastewater collection, treatment and disposal infrastructure	• Paved and unpaved roads • Railways and stations • Seaports and airports • Bridges • Trunk roads • Drainage systems • Tunnels and culverts

This section provides a brief overview of the adverse impacts of climate change on Ghana's infrastructure sector, with a focus on infrastructure for the water, energy, and transport sectors.

5.2 The Water Sector

Water lies at the heart of the government's strategy for Ghana's socioeconomic development. For instance, the country's Shared Growth Development Agenda (2014–2017) highlighted the importance of improving service delivery in water and protecting water bodies and ecosystems

(Government of Ghana, 2014). Access to safe drinking water is improving; however, water scarcity remains a major concern, threatening the attainment of SDG 6, which seeks to provide universal access to clean water and sanitation by 2030 (United Nations Development Programme, 2015). Integrated water resources management (IWRM) has been identified as one of the key adaptation options outlined in Ghana's NDC, and the country's IWRM plan seeks to strengthen equitable distribution and access to water for 20% of the population living in communities at risk of climate change impacts (Government of Ghana, 2015a; Water Resources Commission, 2012).

Climate change will affect the availability and quality of water resources and compound water insecurity, particularly in developing countries. In Africa, for example, where the majority of livelihoods depend on rain-fed agriculture, an estimated 75 million–250 million people will be exposed to water stress by the 2020s due to climate change (Arnell, 2004). Despite its relatively high levels of income per capita, Ghana is not immune to this stress. It is projected that, by 2020, all river basins in Ghana will be vulnerable to climate change and the whole country will face an acute water shortage (Kankam-Yeboah et al., 2011).

In the face of expected increases in the frequency and severity of extreme weather events, it is likely that climate change will worsen future water scarcity in many parts of the country; floods, for example, are expected to occur more rigorously and frequently in Ghana as a result of climate change (Appeaning, 2014). If unprotected, such events could wreak havoc on the country's critical water infrastructures, affecting both domestic water supply and hydropower generation (Kankam-Yeboah et al., 2011). Increased frequency in flooding linked with climate change could also adversely affect the quality of water in the country's rivers and lakes, as flooding events carry pollutants into water bodies. This will, in turn, restrict "their use and put further constraint on water availability to meet growing demand" (Kankam-Yeboah et al., 2011, p. 67).

Ghanaians experienced significant floods in 1999, 2001, 2007, 2008, 2009, 2010, and 2011. However, the 2007 floods, which affected the Northern region, were among the most serious, claiming the lives of 61 people with 25,923 houses damaged, collapsed, or washed away; 70 feeder roads destroyed; and over 97,000 hectares of farmland destroyed (MESTI, 2015).

Substantial increases in the risk to critical transportation infrastructure from marine inundation have also been reported (Monioudi et al., 2018). Additionally, sea-level rise may also cause saltwater to seep into coastal aquifers, affecting crops and increasing the cost of water treatment. Increased riverbank erosion and sea-level rise could affect agriculture, food security, and aquaculture in coastal areas. This will compromise the capacity of coastal communities, especially poor farmers and fishers, to provide for their families (MESTI, 2015).

In Ghana, Act of Parliament 522 (1996) mandated the Water Resources Commission (WRC) with the responsibility of regulating and managing water resources and coordinating water-related government policies in relation to water resources (Water Resources Commission, 2015). Additionally, the WRC represents the country on all transboundary water issues with Ghana's riparian counterparts, with support from basin management boards. The WRC followed on from the National Community Water and Sanitation Program, which was launched in 1994 to ensure that Ghana's water resources were protected (Water Resources Commission, 2015).

The Water Sector Strategic Development Plan (2014) and the National Environmental Sanitation Strategy and Action Plan (2010) are two key national documents that have since shaped the development and management of the water and environmental sanitation sectors in Ghana. Although both plans, alongside other related water sector strategies and plans, mention climate change briefly as an environmental problem, explicit links of actions to climate change adaptation are not well articulated in these policy documents (MESTI, 2015).

The WRC's work is underpinned by the National Water Policy (2007), which provides the framework for the sustainable development, management, and use of Ghana's water resources to improve health and livelihoods (Ministry of Water Resources, Works and Housing, 2007). The National Water Policy seeks to "achieve sustainable development, management and use of Ghana's water resources to improve health and livelihoods and reduce vulnerability while assuring good governance for present and future generations" (Ministry of Water Resources, Works and Housing, 2007, p. 19). The policy therefore acknowledges the need to address the threat of climate change to water resources in Ghana.

5.3 The Energy Sector

Access to cheap and reliable energy is crucial for sustainable livelihoods and economic growth in Ghana; per capita energy use is considered a key indicator of economic development (Asante & Amuakwa-Mensah, 2015). According to the government, electricity demand is growing between 6% and 7% annually, while consumption of petroleum products is expected to increase by about 5% per annum (Ministry of Energy, 2010).

Currently, Ghana's power supply comes from a variety of sources: hydroelectricity, thermal energy (fuelled by crude oil, natural gas, and diesel), and solar. Despite planned diversification to include other energy sources, hydropower is expected to remain a major energy source over the coming decades; Ghana currently relies heavily on hydropower, with three plants (Akosombo Dam, Bui Dam, and Kpong Dam) composing 41% of Ghana's available electric capacity[4] (see Table 4).

[4] Other sources estimate 38% national energy coming from hydro (Arndt et al., 2015).

Table 4. Existing hydropower plants in Ghana

Region	Plant name	Available capacity [Mw]	Share of Ghana's total capacity [%]
North	Bui	330	10%
Southeast	Akosombo	900	27%
Southeast	Kpong	140	4%
TOTAL		**1,370**	**41%**

Source: Hellmuth et al., 2018.

This raises concerns about the effect of climate change on river flows, the generation capacity of the Akosombo Dam, the country's main dam for hydropower generation, and its ability to power national economic development. Ghana's Climate Change Adaptation Strategy (2012) highlights the vulnerability of hydropower generation to decreased water availability. Hydropower generation[5] in Ghana is highly dependent on available water resources, which are likely to be adversely affected by climate change through increased temperatures and erratic rainfall patterns (Kabo-Bah et al., 2016). In fact, the water levels of the Akosombo Dam have already fallen below the required levels on multiple occasions, leading to power blackouts. Climate change is expected to add a "significant amount of uncertainty to the already uncertain operation of hydropower systems" (Schaeffer et al., 2012, p. 4).

The transboundary management of the Akosombo Dam raises additional concerns on the future generation of electricity from the dam (Asante & Amuakwa-Mensah, 2015). While Ghana aims to keep Lake Volta at optimal levels for power production, Burkina Faso is focusing on increasing the retention of water for agriculture within the Volta basin. Rainfall variability will greatly affect river flow and runoff with repercussions for energy supply from hydropower sources.

In addition to hydropower, a significant portion of Ghana's energy for domestic consumption is obtained from biomass in the form of firewood and charcoal. It is estimated that 90% of wood fuel is obtained directly from the country's natural forests, which suffer from an annual deforestation rate of 3% (Tilburg et al., 2011). Rising temperatures and an increase in the frequency and intensity of extreme weather events will affect these forest resources—heat and drought leading to increased wildfires, for example—further constraining national energy supply. Table 5 shows the projected change in climate and potential impacts on hydropower in Ghana.

[5] "Hydropower is an essential energy source harnessed from water moving from higher to lower elevation levels, primarily to turn turbines and generate electricity" (Owusu & Asumadu-Sarkodie, 2016, p. 5).

Table 5. Projected change in climate and potential climate impacts to hydropower in Ghana

	Temperature increases and extremes	Extreme precipitation events	Sea-level rise
Change in condition	• Average, minimum, and maximum temperatures are projected to increase in all zones. • Increasing water temperature and potential evaporation and transpiration rates. • All models project increases in average annual temperature.	• There is strong model agreement of projected increases in the proportion of precipitation that falls during extreme rainfall events. • Increasing high flows and the frequency and intensity of flooding.	• Sea level is expected to continue to rise, reaching 0.4 to 0.7 m by 2090 relative to the 1986–2005 historical period. • The frequency and intensity of tide-related waves and storm surges are expected to increase, exacerbating shoreline erosion, recession, and inundation. • By 2040, land loss due to submergence is expected to reach 2.59 to 3.09 km^2 per year and erosion is projected to reach 0.15 to 0.68 km^2 per year.
Impacts on hydropower	• Increased temperatures can lead to increased demand by competing water users (e.g., irrigators), reducing water available for generation. • Increased potential evaporation and transpiration reduces water available for generation. • Higher water temperatures can reduce dissolved oxygen levels and affect biological processes for aquatic species. • Increased water temperatures lead to increased temperatures in the rivers where water is diverted.	• Increased temperatures can lead to increased demand by competing water users (e.g., irrigators), reducing water available for generation. • Increased potential evaporation and transpiration reduces water available for generation. • Higher water temperatures can reduce dissolved oxygen levels and affect biological processes for aquatic species. • Increased water temperatures lead to increased temperatures in the rivers where water is diverted.	• These coastal hazards may lead to inundation of and direct damage to low-lying infrastructure and access roads. • Impacts on conventional storage. • The combination of reduced downstream flow and sedimentation from upstream impoundment can result in increased salinity and land subsidence.

	Temperature increases and extremes	Extreme precipitation events	Sea-level rise
Implications for Ghana	• Since hydropower is concentrated in the Volta River basin, the risks to hydropower are highest there. • Agricultural water consumption is projected to increase as a result of higher temperatures. • The southwest region does not contain any hydropower resources, though there is potential for smaller-scale hydropower development.	• Increases in extreme rainfall events pose risks to existing hydropower infrastructure in the Volta River basin. • The risk is localized (e.g., direct erosion and damages), but also could increase as runoff moves downstream from the north to the southeast.	• Ghana's hydropower plants may not experience significant impacts from sea-level rise and other coastal hazards, as all existing and planned plants are inland, not along the coast. • The impact of upstream impoundment affects coastal erosion and water quality in the Volta Estuary due in part to changes in the river flows. • Increased sea-level rise, and removal of mangroves for wood.

Source: Hellmuth et al., 2018

Electricity production in Ghana will be further hampered by climate change due to projected increased incidence of flooding that is closely linked to climate change, as severe floods have recently caused power outages in many parts across Ghana.[6] With electricity consumption projected to increase by 2030[7] due to population growth and economic development, increased flooding could hamper the attainment of the SDGs, given energy's central role in the socioeconomic development of Ghana. The Ghana Integrated Resource and Resilience Planning Program indicates that climate change could indirectly affect power generation in Ghana via "increased reservoir sedimentation due to soil erosion associated with intense precipitation on degraded watersheds" (Hellmuth et al., 2018, p. 20). Direct climate impacts on mini-grids include disruption to the supply of electricity, damage to infrastructure from extreme weather, and temperature increases that reduce solar, wind, and distribution efficiency. Indirect impacts of climate change are those "facilitated" by climate stressors, including loss of distribution towers due to erosion caused by extreme rainfall (Hellmuth et al., 2018).

The Energy Commission, established by Act 541 (1997), regulates and manages the use of energy resources in Ghana. It also advises the energy minister on national policies for the efficient, economical, and safe supply of electricity, natural gas, and petroleum products. The Energy Commission's guiding policy, the National Energy Policy (2015), aims to guide the development and management of Ghana's energy sector in light of the emerging oil and gas

[6] Wind gusts and storms associated with climate change affect energy transportation infrastructure. Climate change will also impose a new set of conditions on the design, operation, and maintenance of existing and planned infrastructure (World Bank, 2011).

[7] Using an Autoregressive Integrated Moving Average (ARIMA) model with a time series spanning from 1980 to 2013, Asumadu-Sarkodie (2017) forecasted that Ghana's electricity consumption will grow from 8.52 billion kWh in 2012 to 9.56 billion kWh in 2030.

sectors. The Energy Policy has two main objectives: "(i) secure long-term fuel supplies for the thermal power plants, and (ii) reduce technical and commercial losses in power supply; minimize the environmental impacts of energy supply and consumption through increased production and use of renewable energy; and make energy delivery efficient" (Ministry of Energy, 2010).[8]

Although the Energy Policy recognizes the energy sector's vulnerability to climate change and environmental impacts, adaptation issues have not been given much attention so far compared to mitigation. In recent years, however, adaptation issues, especially within the context of energy and gender, are gaining ground in energy sector actions. Recently, NDC actions in the energy and agriculture sectors, for instance, have been assessed and are being refined to make them gender-responsive. The Energy Policy acknowledges the need to build capacity to adapt to and mitigate the effects of climate change. The Ghana Strategic National Energy Plan also promotes the development and use of renewable energy and energy-efficiency technologies in Ghana (Ghana Energy Commission, 2006).

5.4 The Transport Sector

Transportation is an integral part of the daily life of Ghanaians, and climate change will affect the design, construction, safety, and maintenance of the country's transportation infrastructure and systems. More frequent and intense rainfall events, including flooding and windstorms, could disrupt transportation networks and services with washout and visibility problems, disrupting existing road networks across the country. The IPCC's Special Report, *Global Warming of 1.5°C* (Hoegh-Guldberg et al., 2018), indicated that, globally, road, rail, shipping, and pipeline transportation could be affected directly or indirectly by weather and climate. The adverse impacts could result from a host of factors, including increases in precipitation and temperature, extreme weather events (flooding and storms), and sea-level rise.

The price tag for new transportation infrastructure is also expected to increase with higher climate adaptation design standards (Gelete & Gokcekus, 2019). The two key climatic variables—temperature and precipitation—represent weather stress parameters that contribute to the deterioration of road pavements (Nemry & Demirel, 2012). Heat stress is particularly relevant for asphalt road pavement, for which binder needs to be adapted accordingly. High temperatures will also cause roads to deform and asphalt to melt. Temperature extremes can increase the expansion stress and movement experienced by steel bridges and rail tracks and cause the adverse expansion of concrete joints, protective cladding, coatings, and sealants on bridges (Meyers, 2010). Increases in precipitation, temperature, and flooding closely linked with climate change will also increase the rate of surface deterioration and require larger allocations of the budget going toward road maintenance (Arndt et al., 2015). This will have implications for the construction of new road infrastructure, with higher maintenance costs potentially limiting the availability of funds for new construction. All told, it has been estimated that Ghana will spend USD 473 million per annum to maintain and repair damages caused to its road infrastructure due to climate change for the period 2020 to 2100 (Twerefou et al., 2014).

[8] National stakeholders' consultations revealed that the energy sector is mainstreaming climate change considerations in Ghana. At the policy level, this is being done by ensuring that energy is produced and used in an environmentally friendly manner, addressing the environmental challenges of energy production, transportation, and use.

Additionally, transport infrastructure in coastal areas could be adversely affected by sea-level rise and the increased potential for storm surges linked to climate change (Taylor & Philp, 2010). Incidences of increased tide-related waves, storm surges, extreme rainfall, and coastal erosion and recession that are closely linked to climate change-induced flooding have been reported (Boateng, 2012; Boateng et al., 2017). Sea-level rise associated with climate change will also pose risks for road and rail infrastructure located along the coasts, as well as port infrastructure. Road infrastructure in the coastal areas is also quite vulnerable to the adverse impacts of climate change as a result of sea erosion.[9]

The delivery of fuel to markets by tankers will also likely be affected by road networks deteriorating due to climate change. If these impacts are not mitigated and addressed, this will likely affect the movement of people, goods, and services, which will eventually have significant adverse impacts on national development. Key gaps in addressing the threats of climate change to Ghana's infrastructure include inadequate funding, low levels of research and development, a lack of capacity among personnel and institutions, inadequate data, inadequate emergency preparedness and response measures, and limited climate risk assessments, auditing, and reporting.

To reduce the risks that water, energy, and transportation infrastructure faces from climate change, planned but flexible adaptation responses are required. It is not about eliminating all risks to infrastructure from climate change or extreme weather events. It is about putting in place measures that enable the cost-effective management of climate impacts to reduce the risk that climate change presents to infrastructure and owners, investors, users, insurers, and government. These measures include integrating the impacts of climate change into decision making and design for new infrastructure and into the maintenance of existing infrastructure. Table 6 shows some of the major infrastructure sites in Ghana and how climate change could affect them.

[9] National consultations reveal that the energy sector is introducing energy-efficient electrical appliances and cook stoves to reduce energy and wood fuel consumption and is working to ensure a more sustainable supply of wood fuels.

Table 6. Selected infrastructure and possible climate change impacts in Ghana

	Infrastructure	Possible climate change impacts
1.	Akosombo and Bui dams	• Decreased dam gate performance due to increased sediment content • Blockage of gate due to suspended materials • Risk of dam collapse due to heavy rainfall events
2.	Aboadze thermal energy plant	• Decreased efficiency of cooling systems leading to decreased plant efficiency • Thunderstorms could cause damage to power distribution • Floods could cause rupture of pipes and cable connections • Damage to pumps and safety systems
3.	Coastal highways	• Coastal storm flooding and erosion of road base • Asphalt degradation due to extreme heat • Debris on roads from storms interrupting traffic • Decrease in the expected lifetime of roads and highways
4.	Ports	• Risk of damage from storms and sea-level rise • Changes in navigability of channels • Damage to cranes and other dock and terminal facilities
5.	Power distribution	• Increased maintenance costs • Disrupted power transmission • Possible rupturing of cable connections

5.5 The Water–Energy–Transport Nexus

The nexus approach has emerged as a key concept for integrated resource management involving water, energy, and transport (Nhamo et al., 2018). The nexus approach provides an important framework and decision support tool for understanding the complex interrelations, synergies, and trade-offs between the demands on water, energy, and transport infrastructure (Scott, Kurian, & Wescoat, 2015). Conscious efforts are therefore required to ensure that adaptation measures in one sector do not exacerbate the vulnerability of another sector by compromising the ability of that sector to address the threats posed by climate change effectively. In all cases, it is anticipated that adaptation programs and plans will seek to enhance synergies among these sectors while minimizing the trade-offs associated with them.

6.0 Methodological Approach for the Development of the Sectoral Adaptation Plan

The formulation of Ghana's infrastructural adaptation strategy and action plan followed an all-inclusive, interactive, participatory approach involving two interlinked phases: a desk-based review and stakeholder consultations. In Phase I, an extensive desk-based review of key documents on climate change in Ghana was conducted, including the National Climate Change Policy (NCCP) (2013), NAP Framework (2018), the National Climate Change Adaptation Strategy (NCCAS) (2012), National Climate Change Master Plan (NCCMP) (MESTI, 2015), Ghana's NDCs (2015), and Ghana's First, Second, and Third National Communications to the UNFCCC[10] (2001, 2011, and 2015, respectively). Relevant academic studies and project reports were also reviewed. Additionally, the National Energy Policy (2010), National Water Policy (2007), and National Transport Policy (2008) were reviewed. The review was conducted to understand Ghana's climate context and its policy and legislative environment, with a particular focus on the infrastructure sector.

Phase II involved consultations with key stakeholders drawn from Ghana's Ministry of Sanitation and Water Resources, Ministry of Energy, and Ministry of Transport, as well as other relevant ministries, sectors, and departments. Interviews were held with key contact persons from these ministries from April to June 2019. Formal meetings were also held with the national climate change focal point for climate change adaptation at Ghana's EPA within the MESTI. Following the development of a draft adaptation strategy for the infrastructure sector, a validation workshop was held in August 2019 to convene stakeholders to review the draft and to evaluate adaptation measures using multi-criteria analysis (MCA). The criteria were informed by the UNFCCC criteria for analyzing adaptation options. MCA provides a structured way of making complex decisions that allows for the incorporation of qualitative and quantitative information. It provides a mechanism to evaluate and prioritize adaptation options at multiple geographic scales and sectors (Fontana et al., 2013).

Participants were split into groups according to the three focus sectors (water, energy, and transport), and each group was asked to evaluate the identified adaptation measures, reflecting the level of implementation urgency assigned to each adaptation measure.[11] This exercise was based on the UNFCCC criteria for analyzing adaptation options: (1) alignment with national and sectoral policies and plans; (2) the upfront cost of any required technologies; (3) the measure's expected effectiveness and impact; (4) the practicability of the option; (5) institutional capacities to support design and implementation; (6) urgency (how soon does the option need to be implemented?); (7) the size of expected beneficiary group(s) and equity issues pertaining to the option (whether the option will benefit vulnerable groups and communities); and (8) synergies with other initiatives.

[10] Find all three documents here: https://unfccc.int/national_reports/non-annex_i_natcom/items/2979.php.

[11] This approach is similar to the one used in Saint Lucia in the development of its Sectoral Adaptation Strategy for the Water Sector (see: https://www4.unfccc.int/sites/NAPC/Documents/Parties/Saint%20Lucia%20Sectoral%20Adaptation%20Plan%20for%20Water.pdf)

7.0 Enabling Policy Framework for Water, Energy, and Transport Sectors in Ghana

There is a broad legal and policy framework in place to support the successful implementation of the infrastructural adaptation strategy and action plan. The government's resolve to mainstream climate change into the country's development agenda has been demonstrated over the years, including through the country's medium-term development agendas, the Ghana Shared Growth and Development Agenda I & II (2010–2017). The Ghana Shared Growth and Development Agendas integrate climate change across all thematic areas, with both acknowledging that climate change is a major challenge for the country, one that could not only erode the country's development gains but also hamper further growth (MESTI, 2013). Supporting this, the vision outlined in the NCCP is to "ensure a climate-resilient and climate-compatible economy while achieving sustainable development through equitable low-carbon economic growth for Ghana" (MESTI, 2013, p. ix). The three objectives of the NCCP are effective adaptation, social development, and mitigation. Further, the NCCAS (2012) seeks to facilitate the mainstreaming of climate change and disaster risk reduction into national development.

Finally, as a signatory to the UNFCCC, the Government of Ghana, through its EPA, submitted its Intended Nationally Determined Contribution (ratified as the NDC) in 2017 as part of its commitment under the Paris Agreement (Government of Ghana, 2015a). Ghana's NDC highlighted several mitigation and adaptation actions that are required across sectors, including energy, water, agriculture, and forestry; these are considered priority sectors for building climate change resilience in Ghana.

The adaptation strategy and action plan for infrastructure in Ghana will be anchored by and linked with these existing policy frameworks. Key policies are listed in Table 7.

Table 7. Enabling policy and legislation framework for the infrastructural sectoral strategy and action adaptation

Name of the policy, strategy, plan	Responsible ministry	References to climate change (yes/no)	References to water infrastructure (yes/no)	References to energy infrastructure (yes/no)	References to transport infrastructure (yes/no)
NATIONAL DEVELOPMENT					
40-Year Socio-Economic Transformational Plan (2015/18)	NDPC	Yes	Yes	Yes	Yes
National Climate Change Policy (2012)	MESTI	Yes	Yes	Yes	Yes
National Climate Change Master Plan (2015)	MESTI	Yes	Yes	Yes	yes
Nationally Determined Contributions (2015)	MESTI	Yes	Yes	Yes	Yes
National Climate Adaptation Strategy (2010)	EPA	Yes	Yes	Yes	No
National Climate Adaptation Plan (NAP) Framework (2018)	EPA	Yes	Yes	Yes	Yes
Agenda For Jobs: Creating Prosperity And Equal Opportunity For All (2018)	NDPC	Yes	Yes	Yes	Yes
Local Governance Act (2016)	MLGRD	Yes	Yes	Yes	Yes
National Climate Change and Green Economy Learning Strategy (2016)	MESTI	Yes	Yes	Yes	Yes
Ghana Meteorological Agency Act 2004 (Act 682)	MoC	Yes	No	No	No
SECTORAL DEVELOPMENT					
National Ghana Forest and Wildlife Policy (2012)	MLNR	Yes	Yes	Yes*	No
National Environment Policy (2014)	MESTI	Yes	Yes	Yes	No
National Water Policy (2007)	MWRWH	Yes	Yes	Yes	Yes

Name of the policy, strategy, plan	Responsible ministry	References to climate change (yes/no)	References to water infrastructure (yes/no)	References to energy infrastructure (yes/no)	References to transport infrastructure (yes/no)
National Transport Policy (2008)	MoT	Yes	No	No	Yes
National Energy Policy (2010)	MoE	Yes	No	No	No
CROSS-CUTTING THEMES					
National Gender Policy (2015)	MoGCSP	Yes	Yes	Yes	Yes
Ghana Plan of Action For Disaster Risk Reduction and Climate Change Adaptation (2011-2015)	NADMO	Yes	Yes	Yes	No

MGCSP – Ministry of Gender, Children and Social Protection; MWRWH – Ministry of Water Resources, Works and Housing; MLNR – Ministry of Land and Natural Resources; NADMO – National Disaster Management Organization; NDPC – National Development Planning Commission; WRC – Water Resources Commission; MoC – Ministry of Communications; MoE – Ministry of Energy.

** It makes reference only to Ghana's Energy Policy and not actual infrastructure.*

8.0 Gender Considerations

Different socioeconomic groups (including women, men, children, the elderly, and the disabled) experience varying degrees of climate change vulnerability. It is widely acknowledged that women are more vulnerable to the threats of climate change (Van Aelst & Holvoet, 2016) due largely to their oftentimes limited control over the productive assets that could help them to address the threats posed by climate change (Antwi-Agyei, Dougill, & Stringer, 2015). United Nations WomenWatch (2011) notes that, in many contexts, women are especially vulnerable when they are highly dependent on local natural resources for their livelihoods. Dankelman (2010, p. 59) argues that "women have less access to resources that are essential to disaster preparedness, mitigation and rehabilitation." It is therefore crucial that women, the elderly, and the disabled are actively involved in the design, planning, and implementation of climate change adaptation programs and interventions in the infrastructure sector. Their views should be strongly reflected in the decision-making process on climate change adaptation to help ensure the ownership and acceptance of such adaptation actions (Dankelman, 2010).

The active participation of the different socioeconomic groups will also ensure that the design and implementation of any adaptation actions do not compromise the capacity of the most vulnerable in society to address the threats posed by climate change. Adopting a gender lens for the adaptation strategy will also provide a better understanding of the different experiences of the threats posed by climate change between men and women but also between individuals within those groups based on age, educational levels, ethnic origins, and marital status (Arora-Jonsson, 2011). Additionally, women hold critical local knowledge that can be used for the development of new technologies aimed at addressing the challenges related to the infrastructure sector.

Ghana's NAP Framework stipulates that the NAP process should adopt a gender-responsive approach to addressing the threat of climate change. Issues pertaining to women, the elderly, the disabled, children, and the youth should all be given consideration in any adaptation program or actions in the infrastructure sector. As such, the strategy and associated adaptation actions should work to promote gender equality: recognizing gender differences in adaptation needs, opportunities, and capacities; ensuring equitable participation and influence by women and men in adaptation decision-making processes; and working toward equitable access to financial resources and other benefits resulting from investments in adaptation between women and men (EPA, 2018).

9.0 Inter-Ministerial Collaboration for the Implementation of the Adaptation Strategy

An inter-ministerial working group is required for the effective implementation of the adaptation strategy.[12] The MESTI, the EPA, and the NDPC are the primary institutions responsible for coordinating the implementation of policies and programs on climate change and the general environment in Ghana. The EPA is mandated to advise the MESTI on the formulation of policies of all aspects of the environment and, in particular, to make recommendations for the protection of the environment. The NDPC, based on Act 87 of the 1992 constitution, is expected to make proposals for the protection of the natural and physical environments; furthermore, by virtue of its monitoring and evaluation (M&E) functions, the NDPC also advises the president of the Republic of Ghana on progress made in protecting the natural and physical environments.

The implementation of the infrastructure adaptation strategy and action plan will be the responsibility of the specific ministries responsible for the water, energy, and transport sectors: the Ministry of Sanitation and Water Resources, the Ministry of Energy, and the Ministry of Transport, respectively. The lead ministries will submit, on a yearly basis, a report to the National Climate Change Committee (NCCC) on the progress made in the implementation of the adaptation strategy. In addition, reports will be given to the NDPC as feedback into the national development policy framework through the national annual progress reports.

These will then be fed back into the overall NAP M&E. The EPA, the MESTI, and the NDPC will be providing oversight responsibility and the necessary technical support to ensure the effective implementation of the adaptation actions that have been outlined in this strategy in particular and the national development policy framework in general. Key indicators on climate and environmental issues in the resulting national M&E framework will be incorporated into the NAP M&E mechanism. These institutions should undertake periodic spot checks to verify and ascertain the validity of the information provided in the annual reports.

Water and energy are key drivers of socioeconomic development in Ghana and are foundational to the livelihoods of many households across the country. These sectors, together with the transport sector, are critical to the broader economy and have cross-

[12] The NAP proposes the establishment of four technical working groups, or cross-sectoral planning groups, focusing on health, water, infrastructure, and the land–energy–agriculture nexus, each comprising a dozen representatives from government and academia.

sectoral impacts. Hence, for greater success, it is expected that these leading ministries will collaborate with other ministries on the implementation of adaptation actions as appropriate, including the MoFA; the Ministry of Gender, Children and Social Protection; the Ministry of Health; the Ministry of Finance; the Ministry of Planning; and the Ministry of Monitoring and Evaluation. Others, including the Ministry of Roads and Highways and the Ministry of Local Government and Rural Development, will also be crucial in the implementation of the strategy. Additionally, sector agencies—including the urban roads, community water, and sanitation agencies—and development partners will all be important stakeholders. The Metropolitan, Municipal and District Assemblies (MMDAs) are also key in the actual implementation. Finally, there is also the need to closely work with private sector and civil society organizations (CSOs) in the infrastructure sector to ensure broad participation in the design, implementation, and M&E of the adaptation actions identified in this strategy.

10.0 Funding Mechanisms for this Adaptation Strategy and Action Plan

Funding is critical to ensuring the effective and timely implementation of the various adaptation activities highlighted in this strategy.[13] A coherent strategy is needed to ensure adequate and sustainable funding mechanisms for the strategy. High-level political buy-in and commitment will be critical for the successful implementation of the sectoral adaptation strategy and action plan. Integrating climate resilience into the budgets of the relevant ministries, as well as into the national development policy frameworks, will be crucial to ensuring that future infrastructure is climate-proofed and that existing infrastructure is maintained and rehabilitated in a way that ensures its resilience to climate change.

To date, the majority of funding for climate change adaptation actions in Ghana has been donor driven (see Ghana's NAP Framework, EPA, 2018). To help address this, the Government of Ghana should increase its budgetary allocations on climate change initiatives and projects in order to build the resilience of vulnerable communities. About 2–5% of the total budget secured for funding the adaptation strategy and action plan should be allocated to its M&E. The strategy should have a comprehensive M&E framework to ensure continuous monitoring and periodic evaluation. It should also be noted that the EPA is in the process of developing a private sector engagement strategy for the NAP, which will, among other things, identify those private sector actors[14]—both enterprises and financiers—who can support the design, implementation, and M&E of adaptation actions, either as direct implementers or as sources of financing. In this regard, business networks, including the Sustainable Banking Principles Committee[15] and the Club 100,[16] will be crucial. The private sector should also be supported to write bankable proposals to secure funding for climate change adaptation. Some of the adaptation actions could be funded through public–private partnerships.

[13] A report by the UNEP suggests that the cost of adapting to climate change in developing countries could hit USD 500 billion per year by 2050 (United Nations, 2016).

[14] A successful NAP process will require leveraging the private sector for climate change adaptation. Hence, Ghana's NAP framework includes a strategy for influencing private sector investment in climate-resilient technologies and production methods (EPA, 2018).

[15] This committee aims to develop sustainable banking principles to ensure that banks and its clients are aligned with the SDGs, particularly SDG 13 (EPA, 2018).

[16] This is an annual compilation of the top 100 companies in Ghana.

11.0 Training for Budget Officers and Infrastructure Providers in Ghana

It is also important to organize training programs for budget officers within the lead ministries and the MMDAs and equip infrastructure providers with the skills they need to design climate-resilient infrastructure. Climate change will place buildings, roads, and transport infrastructure under considerable stress. Contractors, architects, and urban planners must therefore be supported to consider climate issues in the design and development of road, rail, water, and other types of infrastructure. Implementing infrastructure without climate change considerations could result in extensive damage and loss to these types of infrastructure. It is important that the NDPC, as a central government agency responsible for policy guidance and in partnership with the EPA, liaise with professional bodies and other stakeholders in the infrastructure industry, including the Ghana Institution of Engineers (GhIE), the Ghana Institution of Surveyors (GhIS) and academia, to provide appropriate training on how to design climate-resilient infrastructure in Ghana.

12.0 Adaptation Actions for the Infrastructure Sector: Water, energy, and transport

Table 8 summarizes the adaptation priorities identified for the infrastructure sectors in Ghana's NCCP, NCCAS, and NDC. These adaptation actions were either identified from the literature or through national sectoral consultations with stakeholders in the water, energy, and transport sectors. Ghana's long-term adaptation goal, as outlined in its NDC, is to increase climate resilience and decrease vulnerability for enhanced sustainable development (Government of Ghana, 2015a). This will be based around (i) good governance and intersectoral coordination; (ii) capacity building and an increased role for science, technology, and innovation; (iii) adequate adaptation financing from both domestic and international sources; and (iv) increased outreach based on informing, communicating with, and educating the citizenry.

Table 8. Key adaptation options by sector (Note: A list of abbreviations is found at the end of the list)

	Adaptation Measures	Expected Outputs	Responsibilities	Alignment with Existing Policy Framework
TECHNICAL ADAPTATIONS IN THE WATER SECTOR				
1	Develop IWRM Strategy for Ghana that includes changing climate adaptation.	IWRM Strategy for the Water Sector in Ghana developed and implemented.	Ministry of Sanitation and Water Resources, Water Commission, Ghana Water Company, WRI of CSIR, EPA, Ghana Irrigation Authority, MoFA	National Water Policy (2007), NCCMP (20115), NDCs, NCCAS (2012), 3rd UNFCCC (2015), National IWRM Plan (2012)
2	Develop and improve small-scale and community irrigation systems.	Small-scale irrigation infrastructure for communities developed.	Ministry of Sanitation and Water Resources, WRC, Ghana Water Company, Ghana Irrigation Authority, MoFA	Ghana National Irrigation Policy, National Water Policy (2007), FASDEP II, NCCMP (2015), 3rd UNFCCC, 1D1F

	Adaptation Measures	Expected Outputs	Responsibilities	Alignment with Existing Policy Framework
3	Promote wastewater reuse programs, including efficient use of grey water in educational and commercial institutions in Ghana.	Training session on wastewater and reuse treatments promoted. Regulations for the use of grey water and grey water products developed.	Ghana Water Company, Community Water and Sanitation Agency, Ministry of Sanitation and Water Resources	National Water Policy (2007), WRC Act
4	Maintain, rehabilitate, and re-engineer existing water systems (for example, dams, irrigation systems, canals, pumps, rivers).	Priority infrastructural interventions and capacity-building activities for maintenance and rehabilitation undertaken.	Ministry of Sanitation and Water Resources, Ghana Water Company	NCCMP (2015), National Water Policy (2007), 3rd UNFCCC (2015)
5	Design and implement structural adaptation measures such as retarding basins, road elevation and culverts, and sediment discharge control.	Structural adaptation measures including retarding basins, road elevation, and culverts and sediment discharge undertaken.	Ministry of Sanitation and Water Resources, Ministry of Roads and Highways	NCCMP (2015), National Water Policy (2007)
6	Improve institutional coordination and planning for efficient water resource use. Institutionally, the sector is fragmented, with overlapping areas of responsibility.	Institutional coordination and planning for efficient water resources use improved. Frameworks for integrated planning in the water sector formulated and implemented.	Ministry of Sanitation and Water Resources, WRC, WRI	National Water Policy (2007), WRC Act, 3rd UNFCCC (2015), NCCMP (2015), National IWRM Plan (2012)
7	Develop multipurpose water harvesting and storage facilities.	Multipurpose water harvesting and storage facilities developed.	Ministry of Sanitation and Water Resources, WRC	Water Resources Act, National Water Policy (2007)

	Adaptation Measures	Expected Outputs	Responsibilities	Alignment with Existing Policy Framework
8	Promote local research into water–climate linkages for effective water management.	Public campaigns and training sessions to raise awareness of water–climate linkages for effective water management instituted.	Research institutions and universities, WRC, Council for Scientific and Industrial Research	NCCP (2013), NCCMP (2015), 3rd UNFCCC (2015)
9	Build barrier islands and coastal wetlands to prevent inland movement of seawater.	Barrier islands and coastal wetlands constructed.	Ministry of Sanitation and Water Resources, Water Resources Commission, Coastal Development Authority	NCCMP (2015), National Water Policy (2007)
10	Introduce efficient technologies such as desalination, drip irrigation, water recycling, and water quality testing systems.	A program for introducing efficient technologies like desalination, drip irrigation, water recycling, and water quality testing is designed, tested, and operational.	Ministry of Sanitation and Water Resources, WRC, WRI	National Water Policy (2007), universities, research institutions, WRC, 3rd UNFCCC (2015)
POLICY ADAPTATIONS IN THE WATER SECTOR				
11	Develop and implement a communication strategy for creating awareness and increasing public sensitization for the judicious management and protection of water resources in a changing climate.	Communications and awareness-raising strategy to raise public awareness on IWRM, water efficiency, etc. developed and implemented.	Ministry of Sanitation and Water Resources, WRC, EPA	National Water Policy (2007), research institutions and universities, WRC, 3rd UNFCCC (2015), Ghana's NAP Framework (2018)

	Adaptation Measures	Expected Outputs	Responsibilities	Alignment with Existing Policy Framework
12	Establish and strengthen local institutions to facilitate adaptive management and self-determination, including establishing and enforcing more sustainable behavioural norms for uses of natural resources like water.	Comprehensive capacity-building program designed for local institutions. Regulations on sustainable behavioural use of natural resources such as water designed and implemented.	Ministry of Sanitation and Water Resources, WRC, EPA	Water Resources Act, EPA Act 490, NCCP (2013), NCCMP (2015), National IWRM Plan (2012)
13	Facilitate basin-scale multistakeholder institutions to establish partnerships, develop common visions, lead adaptive management, and connect the local to regional measures for more effective adaptation and sustainability.	Partnerships between basin-scale and multistakeholder institutions established. Common goals on adaptive management developed and implemented.	Ministry of Snatiation and Water Resources, WRC, EPA, MoFA, ECOWAS	NCCP (2013), Integrated Watershed Plans, National IWRM Plan (2012)
14	Strengthen human and institutional capacity to carry out key IWRM mandates, including transboundary cooperation in the management of shared river basins.	Comprehensive capacity-building program on key IWRM mandates designed for technical officers and institutions.	Ministry of Sanitation and Water Resources, WRC, WRI, ECOWAS	Water Resources Act, IWRM Policy ECOWAS Treaty, NCCMP (2015)
15	Revise current Water Policy to coherently integrate climate change adaptation considerations.	Integrated water policy and climate change adaptations revised and submitted.	Ministry of Sanitation and Water Resources, Water Resources Commission	National Water Policy (2007), National IWRM Plan (2012), NCCP (2013)

	Adaptation Measures	Expected Outputs	Responsibilities	Alignment with Existing Policy Framework
TECHNICAL ADAPTATIONS IN THE ENERGY SECTOR				
16	Adopt an energy generation mix that reduces the vulnerability of current energy infrastructure to climate change while building resilience to future climate change.	Reduced vulnerability of energy infrastructure to climate change. Resilience of energy infrastructure to climate change strengthened.	Ministry of Energy, Energy Commission	NDCs, Renewable Energy Act, Sustainable Energy for All Action Plan, Draft National Energy Master Plan
17	Use ICT in monitoring and evaluating climate events and providing an early warning system.	Capacity-building programs designed for information technology officers of relevant institutions. M&E of climate events and early warning systems improved.	Ghana Meteorological Agency (GMet), NADMO, Ghana Health Service, MoFA, Ministry of Communication	NCCMP (2015), Ghana's NAP Framework (2018), Ghana Meteorological Agency Act 682
18	Ensure climate-resilient design and construction of energy facilities, including good site selection for energy infrastructure, effective permitting, licensing, standards/ regulation regimes, and effective monitoring and enforcement.	Budget for the construction of energy facilities submitted and funded. Permits and other useful licences granted. Standards and regulation regimes monitored and enforced.	Ministry of Energy, Energy Commission, GhIE, Ghana Institution of Surveyors	NCCMP (20115), Draft Energy Master Plan

	Adaptation Measures	Expected Outputs	Responsibilities	Alignment with Existing Policy Framework
19	Integrate climate risk into energy planning and decision-making processes, improve climate data collection and management, strengthen the capacity for modelling climate change impacts on energy systems, strengthen capacity for forecasting and climate risk analysis.	Integrated framework of climate risk and energy planning and decision-making processes formulated and implemented. Modelling climate change impacts on energy systems strengthened. Forecasting techniques and climate risk analysis improved.	Energy Commission, GMet, EPA, university and energy research institutions, Ghana Atomic Energy Commission	NCCMP (20115), Draft Energy Master Plan, Ghana Meteorological Agency Act 682
20	Establish off-grid solar systems and roof-top solar systems in institutions and homes.	Budget for off-grid solar systems and roof-top solar systems submitted and funded. Off-grid solar systems and roof-top solar systems constructed.	Ministry of Energy, Energy Commission Ministry of Works and Housing	Renewable Energy Act, Draft National Energy Master Plan, Sustainable Energy for All Action Plan, National Building Code
24	Effectively enforce energy-efficiency standards and regulations for electrical appliances/ cookstoves, licensing, permitting, monitoring, and regulation of energy projects.	Energy-efficiency standards and regulations for electrical appliances developed and enforced.	Energy Commission, ECG/PDS, Architects and Planners	NDC, Draft National Energy Master Plan, Sustainable Energy for All Action Plan
25	Ensure effective dissemination of climate data and information.	Communication and dissemination of climate data and information improved.	Ministry of Communications, Ministry of Interior, Ghana Meteorological Agency, NADMO, EPA, all ministries, departments and agencies	NCCP (2013), Ghana's NAP Framework (2018)

	Adaptation Measures	Expected Outputs	Responsibilities	Alignment with Existing Policy Framework
26	Ensure effective dissemination of climate data and information.	Communication and dissemination of climate data and information improved.	Ministry of Communications, Ministry of Interior, Ghana Meteorological Agency, NADMO, EPA, all ministries, departments and agencies	NCCP (2013), Ghana's NAP Framework (2018)
27	Increase the use of off-grid alternative energy resources.	The use of off-grid alternative energy resources encouraged.	Ministry of Energy, Energy Commission, VRA	Renewable Energy Act, Sustainable Energy for ALL, Draft National Energy Master Plan, 3rd UNFCCC (2015)
28	Expand the use of efficient domestic appliances. Investment in energy-efficiency programs (such as the ended refrigerator program).	The use of efficient domestic appliances encouraged. Public awareness-raising campaigns in energy-efficiency programs (such as the ended refrigerator program) conducted.	Ministry of Energy, Energy Commission, NDC, EPA	Draft National Energy Master Plan (2015), Montreal Protocol, 3rd UNFCCC (2015)
29	Use seasonal and annual weather forecasts to improve hydropower reservoir management.[17]	Improved weather prediction for hydropower management developed.	Energy Commission, Ministry of Energy, VRA, GMet	NCCMP (2015), Ghana Meteorological Agency Act 682
30	Develop low-head, run-of-river hydroelectricity schemes.	Low-head run-of-river hydroelectricity schemes developed and implemented.	Ministry of Energy, Energy Commission, VRA	Renewable Energy Act, Sustainable Energy for ALL, 3rd UNFCCC (2015), Draft National Energy Master Plan
31	Protect watershed to secure adequate water supply to reduce silt loading and attenuate peak flow.	Improved watershed management.	Ministry of Energy, Energy Commission, VRA	NCCMP (2015), Ghana's NAP Framework (2018)

[17] Hellmuth et al., 2018

	Adaptation Measures	Expected Outputs	Responsibilities	Alignment with Existing Policy Framework
32	Create "green" buffers around transmission and distribution infrastructure to reduce tree contacts with sagging lines due to extreme temperatures.[18]	Green buffers developed for transmission and distribution infrastructure.	Ministry of Energy, Energy Commission	NCCMP (2015)
33	Construct levees, berms, flood walls and storm surge barriers to protect exposed T&D infrastructure. [19]	Levees and berms constructed for improved infrastructure management.	Ministry of Energy, Energy Commission	NCCMP (2015)
POLICY ADAPTATIONS IN THE ENERGY SECTOR				
34	Deepen climate vulnerability and impact studies on energy infrastructure across the country to understand climate change impacts in the energy sector.	Climate vulnerability and impact studies on energy infrastructure designed.	Ministry of Energy, Energy Commission, Gridco, VRA, EPA, universities and research institutions	NAP Framework (2018), Nationally Determined Contributions (2015)
35	Design policy intervention to promote retrofitting high-risk energy infrastructure against extreme weather events (where economically feasible).	Policy intervention to promote retrofitting high-risk energy infrastructure against extreme events formulated and implemented.	Ministry of Energy, Energy Commission	Draft National Energy Master Plan

[18] Hellmuth et al., 2018

[19] Hellmuth et al., 2018

	Adaptation Measures	Expected Outputs	Responsibilities	Alignment with Existing Policy Framework
36	Integrate climate change adaptation and gender issues into national energy policy planning and decision making.	Framework integrating climate change adaptation and gender issues into national energy policy planning and decision making formulated and promoted.	Ministry of Energy, Energy Commission, Ministry of Gender, Children and Social Protection, Department of Gender	Draft National Energy Master Plan, 3rd UNFCCC (2015)
37	Design and promote policy to encourage energy conservation.	Creation of awareness programs on energy conservation. Policies to encourage energy conservation formulated and promoted.	Energy Commission, EPA, VRA, Gridco, ECG/PDS, PURC	Draft National Energy Master Plan, NCCP (2015), 3rd UNFCCC (2015)
38	Build continuous awareness of climate change and its impacts on the energy sector, particularly on energy infrastructure.	Public awareness creation on the impacts of change on the energy sector undertaken.	Ministry of Energy, Energy Commission, VRA, Gridco, ECG/ PDS, EPA	Ghana's NAP Framework (2018)
39	Expand energy infrastructure to reduce pressure on the existing grid in the face of climate change.	Strategic locations for the construction of more energy infrastructure identified. Construction of energy infrastructure initiated.	Ministry of Energy, Energy Commission, Gridco, VRA	Draft National Energy Master Plan, 3rd UNFCCC (2015)
40	Integrate climate change issues into energy planning and decision-making processes.	Development of framework integrating climate change issues into energy planning and decision-making processes formulated and implemented.	Ministry of Energy, Energy Commission, NDPC, VRA, Gridco, Ghana Gas Company	Draft National Energy Master Plan, Sustainable Energy for ALL, NCCP (2015)

	Adaptation Measures	Expected Outputs	Responsibilities	Alignment with Existing Policy Framework
41	Improve data collection and management and strengthen capacities for energy modelling.	Capacity building for technical officers on energy modelling. Capacities for energy modelling strengthened. Data collection and management improved.	Energy Commission, Ministry of Energy, universities and research institutions, VRA, Gridco, PURC	NCCMP (2015), 3rd UNFCCC (2015)
42	Diversify energy supply sources, moving toward renewables.	Public awareness on renewable sources of energy created and encouraged. Reduced non-carbon emission factors for consumption and production of biomass fuels.	Ministry of Energy, Energy Commission, VRA	Draft National Energy Master Plan, Sustainable Energy for ALL, 3rd UNFCCC (2015), Renewable Energy Act, NCCP (2015), NCCMP (2015)
43	Build capacities in the areas of adaptation of climate change, standards/ regulations.	Public awareness and capacity building on adaptation	Energy Commission, EPA, VRA, ECG/PDS, Gridco	Draft National Energy Master Plan, NCCP (2015)
44	Ensure compliance of procurement and installation of climate-resilient energy equipment.	Installation of climate-resilient energy equipment initiated. Compliance of procurement enforced.	Energy Commission, VRA, Gridco, ECG/ PDS	Ghana Procurement Act (2016)
45	Establish or expand demand-response programs that encourage consumers to voluntarily reduce power consumption during peak demand events.[20]	Demand-response programs to encourage voluntary consumer power reduction during peak hours established and expanded.	ECG/PDS, Energy Commission, VRA, PURC	Draft National Energy Master Plan

[20] Hellmuth et al., 2018

	Adaptation Measures	Expected Outputs	Responsibilities	Alignment with Existing Policy Framework
46	Establish public education programs to promote lifestyles that are less energy-dependent[21]	Public education programs on less energy-dependent lifestyles established.	Energy Commission, EPA, PURC, ECG/ PDS	Draft National Energy Master Plan, 3rd UNFCCC (2015), Climate change Master Plan (2015)
47	Adopt mandatory minimum energy performance standards for appliances (including air conditioners).[22]	Mandatory energy performance standards developed and implemented.	Energy Commission, ECG, EPA	Draft National Energy Master Plan
TECHNICAL ADAPTATIONS IN THE TRANSPORT SECTOR				
48	Deepen climate vulnerability and impact studies on transport infrastructure across the country.	Climate vulnerability and impact studies on transport infrastructure designed. Public awareness creation on climate change impacts in the transport sector.	Ministry of Transport, Ministry of Roads and Highways, Department of Urban Roads	NCCMP (20115), NAP Framework (2018)
49	Promote greater engagement of the transport sector in issues relating to adaptation to climate change, through capacity building and dissemination of information.	Plan for strengthening greater engagement of the transport sector in climate change adaptation issues formulated. Capacity-building activities to strengthen the engagement of the transport sector in climate change adaptation issues delivered.	Ministry of Roads and Highways, Ministry of Transport, EPA	NCCMP (2015), Ghana's Adaptation Plan Framework (2018)

[21] Hellmuth et al., 2018

[22] Hellmuth et al., 2018

	Adaptation Measures	Expected Outputs	Responsibilities	Alignment with Existing Policy Framework
50	Plant and manage vegetation along roads to decrease direct exposure to heat. Improve urban drainage designs.	Planting and management of vegetation along roads undertaken. Urban drainages designed and improved.	Ministry of Roads and Highways, Department of Urban Roads	NCCP (2013)
51	Integrate climate adaptation considerations into the design of transportation infrastructure (e.g., the use of materials on road surfaces that reflect solar radiation and consequently reduce the temperature of the pavement).	Framework integrating climate change adaptations into the transportation infrastructure designed and implemented. Sealing of unpaved roads initiated.	Ministry of Transportation, Ministry of Roads and Highways, Engineers and Planners Council, GhIE, Ghana Institution of Surveyors	NCCMP (2015), Ghana's Adaptation Plan Framework (2018)
52	Increase cooperation between climatologists and road authorities.	Cooperation between climatologist and road authorities increased.	Ministry of Roads and Highways, Ministry of Transport, GMet	Ghana Meteorological Agency Act 682
53	Integrate climate-resilient building practices into the construction and maintenance of key ports and airports.	Framework integrating climate-resilient building practices into construction and maintenance of key ports and airports developed and implemented.	Ministry of Aviation, Ghana Airport Company, Ghana Ports and Harbour Authority, Ministry of Transportation, Ministry of Roads and Highways	NCCP (2013), Ghana Meteorological Agency Act 682
POLICY ADAPTATIONS IN THE TRANSPORT SECTOR				
54	Develop and implement plans, action protocols, and preventive measures to increase the capacity of the transport sector to respond to extreme climate events.	Plans, action protocols, and preventive measures to increase the capacity of the transport sector to respond to extreme climate events developed and implemented.	Ministry of Transport, Ministry of Roads and Highways	NCCMP (2015), Ghana's NAP Framework (2018)

	Adaptation Measures	Expected Outputs	Responsibilities	Alignment with Existing Policy Framework
55	Integrate climate change adaptation issues into national transport policy.	Framework integrating climate change adaptation issues into national transport policy developed and implemented.	Ministry of Transport, Ministry of Roads and Highways.	NCCP, National Climate Change Adaptation Strategy
56	Develop disaster risk management policy for national ports.	Risk management policy for national ports developed.	Ghana Ports and Harbour Authority, NADMO	Ghana Plan of Action for Disaster Risk Reduction and Climate Change Adaptation (2011–2015), NCCP (2013)
57	Provide an enabling policy environment to include and enforce climate resilience in land-use planning and construction of transport and road infrastructure.	Building and enforcement of climate resilience in land-use planning and construction of transport and road infrastructure delivered.	Land Use and Spatial Planning Authority, Ministry of Transport, Ministry of Roads and Highways	NCCMP (2015), Ghana's National Adaptation Plan Framework (2018)

ECG – Electricity Company of Ghana; ECOWAS – Economic Community of West Africa States; EPA – Environmental Protection Agency; GMet – Ghana Meteorological Agency; ICT – information and communications technology; NADMO – National Disaster Management Organization; PURC – Public Utilities Regulatory Commission; 3rd UNFCCC – Third National Communication to the United Nations Framework Convention on Climate Change; VRA – Volta River Authority; 1D1F – One District One Factory Programme

13.0 Concept Notes for Climate Change Adaptation for the Infrastructure Sector in Ghana

This section describes several key concept notes for adaptation in the infrastructure sector. These concept notes are based on the vulnerabilities of the various sectors (as described in Section 5) and reflect the prioritized measures contained in Ghana's NDC and National Climate Change Master Plan Action Programme for Implementation: 2015-2020 (MESTI, 2015). The concept notes on adaptation actions included here are not presented in order of priority but are meant to guide the Government of Ghana and implementing agencies on the appropriate adaptation actions to take to address sector-specific climate change threats. The indicative costs of the various concept notes have been derived from different sources, including the NCCMP (2015) and the NCCP (2013). Given that our knowledge in climate change keeps evolving, it is envisaged that additional project concept notes on adaptation will be added over time to respond to the emerging challenges.

CONCEPT NOTE 1

Project Title:

Design and implement a communication strategy for creating awareness and increasing public sensitization for the judicious management and protection of water resources in a changing climate.

Objectives:

To generate and increase public awareness and participation in efficient water resources management and demonstrate the role played by each individual in causing and solving water resource management problems in Ghana.

Rationale:

Climate change will greatly affect water resources across the country, and it is expected to put water supply and quality at risk. This will inadvertently pose a threat to users of water resources, including households, farmers, industries, and commercial and educational institutions. These impacts may be reflected in floods, droughts, and saline intrusion. Adaptation to climate change in the water sector is clearly going to be urgently needed in order to reduce the vulnerability of various water users to the threats posed by climate change. Adaptation actions in the water sector may also build the resilience of water users to future changes in the climate. Nonetheless, effective adaptation requires action by multiple stakeholder groups and at different scales because of the cross-sectoral nature of water issues. It is appropriate that individuals, communities, and organizations are made aware of their specific roles and responsibilities to address climate change threats. Therefore, the public clearly needs to understand the issues concerning climate change and the need for adaptation. These can be achieved through awareness campaigns targeted at groups, including government officials, politicians, professional bodies, and security services. Environmental education and awareness creation on climate change can play a major role in informing people of how to improve local management of water resources. Therefore, there is the need to develop and implement a communication strategy aimed at creating awareness and increasing public sensitization for the judicious management, conservation, and protection of water resources in a changing climate in Ghana.

Activities and tasks:

- Promote awareness of climate change impacts in the water sector, including increasing public awareness on water conservation and efficient water use.
- Organize an annual exhibition during the week of World Water Day.
- Design and organize water-themed inter-school competitions across the country.
- Implement conservation activities, including but not limited to tree planting, river/wetland clean up exercises.
- Strengthen the education and training of stakeholders in water and environment facilities at all levels.

Indicative costs:

USD 213,070,400 (based on the NCCMP, MESTI, 2015)

Responsible agencies/partners:

Ministry of Local Government and Rural Development, Community Water and Sanitation Agency (CWSA), Ministry of Water Resources and Sanitation, Ministry of Information and Media Relations/ Information Services Department; CSOs, development partners, universities

Additional information:

The project is aligned with and contributes to the implementation of the NCCMP (2015) and the NCCP (2013).

CONCEPT NOTE 2

Project Title:

Building resilience in the water sector by mainstreaming climate change adaptation.

Objectives:

To mainstream climate change considerations in the water sector in Ghana.

Rationale:

Climate change will affect the availability and quality of water resources and compound water insecurity in Ghana. In the face of expected increases in the frequency and severity of extreme weather events, it is likely that climate change will worsen future water scarcity in many parts of the country; floods, for example, are expected to occur more rigorously and frequently in Ghana as a result of climate change. High temperatures associated with climate change will also cause reduced groundwater recharge and lower lake and reservoir levels. National government and local government structures need to mainstream climate change adaptation into the water sector in order to build the resilience of the water sector to the adverse impacts of climate change. It is important to identify current and future vulnerabilities in the water sector and use these baseline data to develop strategies and plans in managing and protecting Ghana's water sources, basins, and wastewater. Additionally, climate change considerations should be brought to bear in the design and implementation of the large-scale irrigation projects in order to maximize synergies with the health and agricultural sectors while minimizing the trade-offs associated with such large-scale irrigation projects as adaptation mechanisms.

Activities and tasks:

- Improve collaborative management of transboundary water resources.
- Enhance the capacity of water resource institutions to monitor water resources for early warning and planning.
- Design and implement locally relevant technologies that enhance water resource efficiency.
- Develop and mainstream appropriate disaster risk reduction strategies in water sector planning and service delivery.
- Integrate climate change consideration into the design and implementation of efficient irrigation systems.

Indicative costs:

USD 5,075,489,183 (based on estimates from other countries)

Responsible agencies/partners:

Ministry of Sanitation and Water Resources, Ghana Water Company, CWSA, NDPC, MMDAs, the private sector, CSOs

Additional information:

The project is aligned with the National Water Policy (2007).

CONCEPT NOTE 3

Project Title:

Develop multipurpose water harvesting and storage facilities

Objectives:

Promote the harvest, storage, and conservation of rainwater for future use and reduce the potential risk of flooding.

Rationale:

Torrential and unpredicted rainfall closely linked to climate change has often led to flooding in many cities across the country, resulting in loss of human life, damage to infrastructure, displacement of households, and the disruption of socioeconomic activities. With temperature and the variability of rainfall patterns both projected to increase, floods are expected to occur more rigorously and frequently in the future as a result of climate change, change in land-use patterns, unplanned rapid urbanization, and poor watershed management. Increased incidence of floods is expected to interact with non-climate stressors to aggravate the vulnerability of socioeconomic systems. This threatens the livelihoods of millions of households and perpetuates existing poverty and climate vulnerability. Mechanisms should be put in place to harvest, store, and conserve rainwater for future use. This will help reduce the incidences of flooding and put the harvested rainwater to use for agriculture.

Activities and tasks:

- Undertake climate change vulnerability mapping exercises to identify potential locations for water harvesting and storage infrastructure.
- Appraise locally relevant technologies for the design of water harvesting and storage infrastructure for various purposes.
- Water harvesting and storage infrastructure should be incorporated into the medium-term development plans of MMDAs.
- Promote river runoff harvesting and enhance the use of dams for water conservation in underserved areas.
- Revise the water policy to include water harvesting in the building code.

Indicative costs:

N/A

Responsible agencies/partners:

Ministry of Sanitation and Water Resources, Ghana Water Company, CWSA, MMDAs, the private sector, CSOs

Additional information:

The project is aligned with the NCCP (2013), Ghana's Third National Communication to the UNFCCC (2015), and the National Water Policy (2007).

CONCEPT NOTE 4

Project Title:

Promote local research into water–climate linkages for effective water resource management

Objectives:

To generate and improve the knowledge base through research in the management and protection of water resources in Ghana.

Rationale:

The role of scientific research in generating new evidence on climate change and its impacts on water resources cannot be over-emphasized. Currently, there are serious gaps in information and knowledge, including how water resources will be affected by climate change under various climate conditions, the impacts of climate change on aquatic ecosystems, and how to build climate resilience in the water sector. Uncertainty also exists on the potential impacts of climate change on groundwater recharge and availability. Urgent research is therefore required to generate the necessary data and build a database of information to support the planning of water resources infrastructure as well as the operation and maintenance of existing facilities. Research is also needed to test new water technologies that may be more resilient to the threats posed by climate change.

Activities and tasks:

- Design and implement climate and weather observation and monitoring systems.
- Establish a database on water schemes, drawing on traditional knowledge and modern information technology to support forecasting and evidence-based decision making.
- Investigate appropriate models for alternatives to wastewater treatment, processing and uses.
- Conduct scientific investigations in water resource assessment, water supplies, management and development.

Indicative costs:

USD 18,720,000 (based on the NCCMP, MESTI, 2015)

Responsible agencies/partners:

Ministry of Sanitation and Water Resources, WRI, WRC, EPA, universities and research institutions, CWSA, GMet, Hydrological Services Department (HSD), NADMO, CSOs and non-governmental organizations, traditional authorities

Additional information:

The project is aligned with and contributes to the implementation of the NCCMP (2015) and the NCCP (2013).

CONCEPT NOTE 5

Project Title:

Improve human and institutional capacity to implement IWRM, including transboundary cooperation in the management of shared river basins.

Objectives:

To improve the capacity of humans and institutions for IWRM across all levels of water governance.

Rationale:

Water is a key driver of socioeconomic growth, a basic necessity for the effective execution of primary health care, and a prerequisite for successfully combating child mortality, poverty, hunger, and environmental damage. Abundant, global freshwater resources face exhaustion due to increasing demands by different sectors, pollution, and uncoordinated development and management of the resource. In Ghana, a lack of coordinated action for water management and development has been identified as one of the key bottlenecks in the water sector. Therefore, a holistic and sustainable way of managing water resources is by adopting IWRM. IWRM deals with the sustainable and coordinated development, allocation, management and monitoring of water, land, and related resources to maximize economic and social welfare in an equitable manner. IWRM is highlighted as a priority area for managing water resources under Ghana's NDCs. However, the implementation of IWRM faces a lot of challenges—a key one being capacity building. Improving the human and institutional capacity to implement IWRM will not only help address shortfalls in water management but also will provide improved management of water resources to cope with extreme weather conditions.

Beneficiaries:

Public and private sectors, rural and urban communities, water users and planners, researchers

Activities and Tasks:

- Provide logistics to promote efficient river basin institutions and the enforcement of regulations.
- Coordinate the development of a detailed basin-level data and information management system.
- Provide educational materials and support to train individuals/institutions in IWRM using a multi-level approach.
- Enhance the coordination of different sectors by establishing multi-sectoral forums to strengthen information sharing.
- Strengthen arrangements for transboundary water management in shared river basins.

Indicative costs:

USD 18,720,000 (Based on the NCCMP, MESTI, 2015).

Responsible agencies/partners:

Ministry of Sanitation and Water Resources, WRI, WRC, EPA, universities and research institutions, CWSA, GMet, HSD, NADMO, CSOs, and non-governmental organizations, traditional authorities

Additional information:

The project is aligned with and contributes to the implementation of Ghana's NDCs (2015), the NCCMP (2015) and the NCCP (2013).

CONCEPT NOTE 6

Project Title:

Adopting an energy generation mix that reduces the vulnerability of current energy infrastructure to climate change while building resilience to future climate change

Objectives:

To reduce dependency on climate-sensitive energy sources and supplies.

Rationale:

Per capita energy use is considered a key indicator of economic development, as efficient and reliable energy supply is critical for the development of the national economy. Hence, access to cheap and reliable energy is crucial for sustainable livelihoods and economic growth in Ghana. Currently, Ghana's energy production relies heavily on hydropower plants (i.e., the Akosombo) with a small percentage from thermal fuelled by crude oil, natural gas and diesel, and solar. Over the years, these sources of energy production, particularly hydropower, have demonstrated vulnerability to extreme events such as droughts and floods. With projected increases in temperature coupled with increasing rainfall variability, the reliability of the hydropower to generate enough power for economic development in Ghana should be critically examined. Therefore, it is important to incorporate climate change considerations into current and future programs and actions in the energy sector in order to build a resilient energy system that will promote economic development.

Activities and tasks:

- Conduct risk and vulnerability assessments of energy infrastructure.
- Promote energy efficiency programs.

Indicative costs:

N/A

Responsible agencies/partners:

Ministry of Energy, MMDAs, the private sector, CSOs

Additional information:

The project is aligned with and contributes to the implementation of the National Energy Policy (2010), NCCMP (2015) and the NCCP (2013).

CONCEPT NOTE 7

Project Title:

Build capacity to design climate-resilient road infrastructure

Objectives:

To build the capacity of engineers and other professionals in designing and constructing climate-resilient road infrastructure.

Rationale:

Projected increases in temperature coupled with increased rainfall variability will place road and transportation infrastructure under considerable stress. This will compromise the ability of such infrastructure to deliver essential services and exacerbate the current and future climate vulnerabilities. Destruction to road and rail networks due to increased incidences of flood events closely linked to climate change will greatly impact the transportation of goods, services, and agricultural products from the hinterlands to the urban centres. This is likely to affect the livelihoods of many of the population and further jeopardize the country's efforts to achieve food security and economic development. To address these challenges, it is important that the design and development of road and rail infrastructure should take into consideration climate change issues and the occurrence of climate-related disasters. Good design and planning of road, rail, and other transport infrastructure will ensure effective use of utilities and make infrastructure resilient to natural disasters, including flooding and rainstorms.

Activities and tasks:

- Ensure that design standards for road infrastructure and spatial planning include parameters related to climate change and variability, as well as future scenarios.
- Strengthen the capacity of engineers, architects, and planners to design and integrate climate change adaptation and disaster risk reduction into their development agendas.
- Support research into appropriate infrastructure design standards for climate-related events.

Indicative costs:

USD 10,500,000 (Based on NCCMP, 2015).

Responsible agencies/partners:

MESTI; NADMO; Ministry of Water Resources, Works and Housing; Ministry of Local Government and Rural Development; Building and Road Research Unit; EPA; GhIE, GhIS

Additional information:

The project is aligned with and contributes to the implementation of the NCCMP (2015) and the NCCP (2013)

CONCEPT NOTE 8

Project Title:

Deepen climate vulnerability and impact studies on transport infrastructure across the country to understand climate change trends in the transport sector

Objectives:

To understand the extent to which road and transport infrastructure are vulnerable to the adverse impacts of climate change.

Rationale:

Investments in transport infrastructure by the central government, as well as the private sector, require long planning horizons because of the high capital outlay associated with such projects. Yet there is a lack of understanding of the extent to which road and transport infrastructure will be vulnerable to the adverse impacts of climate change. This sometimes hampers the development of resilient road and transport infrastructure. An understanding of the differential impacts of climate change on various road and transport infrastructure in the country requires further investigation through more detailed climate change vulnerability assessment.

Activities and tasks:

- Conduct risk and vulnerability assessments of transport and road infrastructure.
- Conduct an audit of existing key road and transport infrastructure and prioritize their levels of vulnerability and risk to climate hazards.
- Formulate recommendations to adapt to climate change based on climate simulations and the analysis of possible impacts on road and transport infrastructure.

Indicative costs:

N/A

Responsible agencies/partners:

Ministry of Road and Transport, MESTI

Additional information:

The project is aligned with and contributes to the implementation of the NCCMP (2015) and the NCCP (2013).

14.0 Communication Strategy for the Adaptation Strategy and Action Plan

The successful and effective implementation of the adaptation strategy and action plan for the infrastructure sector requires a proactive communication strategy that would help to secure the active participation of sector ministries as well as CSOs, non-governmental organizations, private sector actors, and development partners. A communication strategy for adaptation in the infrastructure sector will require the identification of key messages tailored to target audiences that are then delivered through the most effective channels of communication. Communications should particularly target private enterprises and private financiers, including the Private Enterprise Federation and the Sustainable Banking Principles Committee, who are likely to be partners in the mobilization of funds for the implementation of this strategy.

15.0 Monitoring and Evaluation

The M&E procedure for the adaptation and action plan should be in sync with that of the NAP. The NAP Framework outlines that the NCCC shall be responsible for overall M&E of Ghana's NAP process. Therefore, it is expected that the lead agencies, including the Ministry of Sanitation and Water Resources, the Ministry of Energy, and the Ministry of Transport, will report on implementation progress annually to the NCCC. This will also allow appropriate revisions to be made to the sectoral adaptation strategy over time to ensure its successful implementation.

16.0 Conclusion

Ghana's infrastructure, particularly that relating to water, energy, and transport, is vulnerable to the adverse impacts of climate change. This adaptation strategy will support the continued planning and implementation of Ghana's NAP process and sets out a plan for critical infrastructure that is more resilient to climate change impacts. Implementation of the sectoral adaptation strategy for infrastructure will help the country continue to move its NAP process forward and will help spur conversations around financing needs for climate-resilient infrastructure, including funding coming from the national and ministerial budgets, the private sector, and international sources of adaptation funding, including the Green Climate Fund and the Adaptation Fund.

The successful implementation of this strategy requires the concerted efforts and commitment of key stakeholders from both the private and public sectors. High-level political buy-in and commitment will be critical for the successful implementation of the sectoral adaptation strategy and action plan, and there is a pressing need to ensure greater alignment with existing policy and legal frameworks in Ghana aimed at addressing the threats of climate change. To ensure effective coordination, a multistakeholder and multi-sectoral process should be adopted under the leadership of MESTI, with technical support provided by the Climate Change Unit of the EPA. Given that this strategy advocates for gender-responsive adaptation strategies to address the threats of climate change to the livelihoods of these socioeconomic groups, it is also crucial that women, the elderly, and the disabled are actively involved in the design, planning, and implementation of climate change adaptation programs and interventions in the infrastructure sector.

References

Amissigo, B. A., McCluskey, A., & Swanson, R. (2015). Modelling impact of climate change on water resources and agriculture demand in the Volta Basin and other basin systems in Ghana. *Sustainability, 7*(6), 6957–6975.

Antwi-Agyei, P., Dougill, A. J. & Stringer, L. C. (2015). Impacts of land tenure arrangements on the adaptive capacity of marginalized groups: The case of Ghana's Ejura Sekyedumase and Bongo Districts. *Land Use Policy, 49,* 203–212.

Antwi-Agyei, P., Fraser, E. D. G., Dougill, A. J., Stringer, L. C. & Simelton, E. (2012). Mapping the vulnerability of crop production to drought in Ghana using rainfall, yield and socioeconomic data. *Applied Geography, 32,* 324–334.

Appeaning, A. K. (2014). Coastal vulnerability index to sea level rise in Ghana. *Coastal and Marine Research, 2*(1), 1–7.

Arndt, C., Asante, F. & Thurlow, J. (2015). Implications of climate change for Ghana's economy. *Sustainability, 7,* 7214–7231.

Arnell, N. W. (2004). Climate change and global water resources: SRES emissions and socio-economic scenarios. *Global Environmental Change, 14*(1), 31–52.

Arora-Jonsson, S. (2011). Virtue and vulnerability: Discourses on women, gender and climate change. *Global Environmental Change, 21*(2), 744–751.

Asante, F. A. & Amuakwa-Mensah, F. (2015). Climate change and variability in Ghana: Stocktaking. *Climate, 3*(1), 78–101.

Asumadu-Sarkodie, S. (2017). Estimating Ghana's electricity consumption by 2030: An ARIMA forecast. *Energy Sources, Part B: Economics, Planning, and Policy, 12*(10), 936–944.

Bekoe, E. O. & Logah, F. Y. (2013). The impact of droughts and climate change on electricity generation in Ghana. *Environmental Sciences, 1*(1), 13–14.

Boateng, I., Wiafe, G. & Jayson-Quashigah, P. N. (2017). Mapping vulnerability and risk of Ghana's coastline to sea level rise. *Marine Geodesy, 40*(1), 23–39.

Boateng, I. (2012). An assessment of the physical impacts of sea-level rise and coastal adaptation: A case study of the eastern coast of Ghana. *Climatic Change, 114*(2), 273-293.

Christensen, J. H., Hewitson, B., Busuioc, A., Chen, A., Gao, X., Held, R., Jones, R., ... Laprise, R. (2007). Regional climate projections. In S. Solomon et al. (Eds.), *Climate change: The physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (pp. 847–940). Cambridge University Press.

Daron, J. D. (2014). *Regional climate messages: West Africa. Scientific report from the CARIIA Adaptation at Scale in Semi-Arid Regions (ASSAR) Project.* CARIAA and ASSAR.

Dazé, A. & Echeverria, D. (2016). *Review of current and planned adaptation action in Ghana* (CARIAA Working Paper No 9). https://idl-bnc.idrc.ca/dspace/bitstream/10625/55865/1/IDL-55865.pdf

De Pinto, A., Demirag, U., Haruna, A., Koo, J., & Asamoah, M. (2012). *Climate change, agriculture, and food crop production in Ghana* (Policy Note 3). http://www.ifpri.org/publication/climate-change-agriculture-and-foodcrop-production-ghana

Dankelman, I. (2010). Climate change, human security and gender. In I. Dankelman (Ed.), *Gender and climate change: An introduction*. Earthscan.

Environmental Protection Agency. (2018). *Ghana's National Adaptation Plan Framework*. https://www.researchgate.net/publication/334416010_Ghana's_National_Adaptation_Plan_Framework

Environmental Protection Agency. (2010). *Climate change impacts: Why must Ghana worry?* https://www.undp.org/content/dam/ghana/docs/Doc/Susdev/UNDP_GH_SUSDEV_AAP%20Climate%20Change%20Policy%20Briefs.pdf

Fontana, V., Radtke, A., Bossi Fedrigotti, V., Tappeinera, U., Tasserc, E., Zerbeb, S. & Buchholzd, T. (2013). Comparing land-use alternatives: Using the ecosystem services concept to define a multi-criteria decision analysis. *Ecological Economics, 93,* 128–136.

Gelete, G. & Gokcekus, H. G. (2019). The economic impact of climate change on transportation assets. *Journal of Environmental Pollution and Control, 1*(1),1–6.

Ghana Business News. (2019, June 7). EPA deepens media knowledge in Climate Change Adaptation plan framework. https://www.ghanabusinessnews.com/2019/06/07/epa-deepens-media-knowledge-on-climate-adaptation-plan-framework/

Ghana Energy Commission (2006). *Strategic National Energy Plan 2006-2020*. http://energycom.gov.gh/files/snep/MAIN%20REPORT%20final%20PD.pdf

Government of Ghana. (2014). *Ghana Shared Growth and Development Strategy*. National Development Planning Commission.

Government of Ghana (2015a). *Ghana's Intended Nationally Determined Contribution (INDC) and accompanying explanatory note*. https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Ghana%20First/GH_INDC_2392015.pdf

Government of Ghana (2015b). *Ghana's Third National Communication Report to the UNFCCC*. https://unfccc.int/resource/docs/natc/ghanc3.pdf

Government of Ghana (2017). *The coordinated programme of economic and social development policies (2017–2024). An agenda for jobs: Creating prosperity and equal opportunity for all*. https://s3-us-west-2.amazonaws.com/new-ndpc-static1/CACHES/PUBLICATIONS/2018/04/11/Coordinate+Programme-Final+(November+11,+2017)+cover.pdf

Hellmuth, M., Bruguera, M., & Ankoh, M. (2018). *Ghana Integrated Resource and Resilience Planning Program: Risks and Resiliency in Ghana's Electric Power Sector*. IRRP Project USAID. https://www.researchgate.net/publication/337154965_GHANA_INTEGRATED_RESOURCE_AND_RESILIENCE_PLANNING_PROGRAM_Risks_And_Resiliency_In_Ghana's_Electric_Power_Sector_GHANA_INTEGRATED_RESOURCE_AND_RESILIENCE_PLANNING_PROGRAM_Risks_And_Resiliency_In_Ghana'

Hoegh-Guldberg, O., Jacob, D., Taylor, M., Bindi, M., Brown, S., Camilloni, I., Diedhou, A., Djalante, R., Kristie, L. E., Engelbrecht, F., Guiot, J., Hijioka, Y., Mehrotra, S., Payne, A., Seneviratne, S. I., Thomas, A., Warren, R., & Zhou, G. (2018) Impacts of 1.5°C global warming on natural and human systems. In *Global warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty* [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)]. https://www.ipcc.ch/site/assets/uploads/sites/2/2019/02/SR15_Chapter3_Low_Res.pdf

Intergovernmental Panel on Climate Change. (2014). *Climate change: Impacts, adaptation and vulnerability: Contribution of working group II to the IPCC Fifth Assessment Report.* Cambridge University Press. https://www.ipcc.ch/site/assets/uploads/2018/02/ar5_wgII_spm_en.pdf

Kabo-Bah, A. T., Diji C. J., Nokoe, K., Mulugetta, Y., Obeng-Ofori D. & Akpoti, K. (2016). Multiyear rainfall and temperature trends in the Volta river basin and their potential impact on hydropower generation in Ghana. *Climate, 4,* 49.

Kankam-Yeboah, K., Amissigo, B. & Obuobi, E. (2011). Climate change impacts on water resources in Ghana. *Ghana and Unesco 2009/2010,* 65-69.

Logah, Y., Obuobie, E., Ofori, D. & Kankam-Yeboah, K. (2013). Analysis of rainfall variability in Ghana. *International Journal of Latest Research in Engineering and Computing, 1*(1), 1–8.

Manzanas, R., Amekudzi, L. K., Preko, K., Herrera, S. & Gutiérrez, J. M. (2014). Precipitation variability and trends in Ghana: An intercomparison of observational and reanalysis products. *Climatic Change, 124*(4), 805–819.

McSweeney, C., New, M. & Lizcano, G. (2010). *UNDP climate change country profiles: Ghana.* https://digital.library.unt.edu/ark:/67531/metadc226664/

Meyers, M. (2010). *Design standards for U.S. transportation infrastructure: The implications of climate change.* Transportation Research Board. http://onlinepubs.trb.org/onlinepubs/sr/sr290meyer.pdf

Ministry of Energy (2010). *Ghana's Energy Policy.* https://www.greengrowthknowledge.org/sites/default/files/downloads/policy-database/GHANA%29%20National%20Energy%20Policy.pdf

Ministry of Environment, Science and Technology. (2013). *Ghana National Climate Change Policy.* https://pef.org.gh/documents/climate-change/national-climate-change-policy.pdf

Ministry of Environment, Science, Technology and Innovation. (2015). *Ghana National Climate Change Master Plan Action Programme for Implementation: 2015-2020.* https://www.weadapt.org/sites/weadapt.org/files/2017/ghana_national_climate_change_master_plan_2015_2020.pdf

Ministry of Environment, Science, Technology and Innovation (MESTI). (2012). *National Climate Change Adaptation Strategy.* http://www.undp-alm.org/sites/default/files/downloads/ghana_national_climate_change_adaptation_strategy_nccas.pdf

Ministry of Environment, Science, Technology and Innovation (2016). *National Climate Change and Green Economy Learning Strategy: Strategy to Advance Climate Change and Green Economy Learning, Skills Development, and Public Awareness in Ghana.* https://www.un-page.org/file/4314/download?token=AYscm-gN

Ministry of Food and Agriculture. (2016). *Agriculture in Ghana: Facts and figures (2015).* http://agricinghana.com/wp-content/uploads/2017/07/AGRICULTURE-IN-GHANA-Facts-and-Figures-2015.pdf

Ministry of Water Resources, Works and Housing. (2007). *National Water Policy.* Government of Ghana. https://www.gwcl.com.gh/national_water_policy.pdf

Monioudi, I., Asariotis, R., Becker, A., Bhat, C., Dowding-Gooden D. et al. (2018). Climate change impacts on critical international transportation assets of Caribbean Small Island Developing States: The case of Jamaica and Saint Lucia. *Regional Environmental Change, 18*(8), 2211–2225. https://link.springer.com/article/10.1007/s10113-018-1360-4

Nemry, F. & Demirel, H. (2012). *Impacts of climate change on transport: A focus on road and rail transport infrastructures* (Joint Research Centre Scientific and Policy Reports). European Commission. https://publications.jrc.ec.europa.eu/repository/bitstream/111111111/26928/1/transport%20and%20climate%20change%20final%20report.pdf

New York State. (n.d.). *Glossary of weather and climate terms.* https://www.health.ny.gov/environmental/weather/glossary.htm

Nhamo, L., Ndlela, B., Nhemachena, C., Mabhaudhi, T., Mpandeli, S., & Matchaya, G. (2018). The water-energy-food nexus: Climate risks and opportunities in Southern Africa. *Water, 10,* 567.

Nkrumah, F., Klutse, N. A. B., Adukpo, D. C., Owusu, K., Quagraine, K. A., Owusu, A., & Gutowski, W. (2014). Rainfall variability over Ghana: Model versus rain gauge observation. *International Journal of Geosciences, 7*(7). https://doi.org/10.4236/ijg.2014.57060

Notre Dame Global Adaptation Initiative (ND-GAIN). (2017). *Ghana country profile.* http://index.gain.org/country/ghana

Owusu, K. & Waylen, P. (2009). Trends in spatio-temporal variability in annual rainfall in Ghana (1951–2000). *Weather, 64*(5),115–120.

Owusu, P. & Asumadu-Sarkodie, S. (2016). A review of renewable energy sources, sustainability issues and climate change mitigation. *Civil and Environmental Engineering, 3,* 1. https://www.cogentoa.com/article/10.1080/23311916.2016.1167990

Schaeffer, R., Szklo, A. S., deLucena, A. F. P., Borba, B., Moreira, B. S., Nogueira, L. P. P., Fleming, F. P., Troccoli, A., Harrison, M., & Boulahya, M. S. (2012). Energy sector vulnerability to climate change: A review. *Energy, 38,* 1–12.

Scott, C. A., Kurian, M. & Wescoat, J. L. (2015). The water-energy-food nexus: Enhancing adaptive capacity to complex global challenges. In *Governing the nexus: Water, soil and waste resources considering global change* (pp. 15–38). Springer International Publishing.

Stanturf, J. A., Melvin, L. W., Charnley, J. S., Polasky, S. C., Goodrick, S. L., Armah, F. & Nyako, Y. A. (2011). *Ghana climate change vulnerability and adaptation assessment.* https://www.climatelinks.org/sites/default/files/asset/document/Climate%20Change%20Assessment_Ghana_%20FINAL.pdf

Taylor, M. A. P. & Philp, M. (2010). Adapting to climate change: Implications for transport infrastructure, transport systems and travel behaviour. *Road and Transport Research: A Journal of Australian and New Zealand Research and Practice, 19*(4), 66–79.

Tilburg, X. V., Würtenberger, L., Rivera, R., & Atta-Owusu, F. (2011). *Policy brief: Low Carbon options for energy demand.* Energy Research Centre of the Netherlands. http://www.ecowrex.org/system/files/repository/2011_policy-brief-low-carbon-options-for-energy-demand_energy-research-centre-of-the-netherlands.pdf

Twerefou, D. K., Adjei-Mantey, K. & Strzepek, N. L. (2014). *The economic impact of climate change on road infrastructure in sub-Saharan Africa countries: Evidence from Ghana* (WIDER Working Paper 2014/032). United Nations University's World Institute for Development Economics Research. https://www.wider.unu.edu/sites/default/files/wp2014-032.pdf

UN WomenWatch. (2011). *Women, gender equality and climate change.* http://www.un.org/womenwatch/feature/climate_change/downloads/Women_and_Climate_Change_Factsheet.pdf

United Nations. (2016, May 10). *UN report: Cost of adapting to climate change could hit $500B per year by 2050.* https://www.un.org/sustainabledevelopment/blog/2016/05/unep-report-cost-of-adapting-to-climate-change-could-hit-500b-per-year-by-2050/

United Nations Development Programme. (2015). *Sustainable Development Goals.* http://www.undp.org/content/undp/en/home/sdgoverview/post-2015-development-agenda.html

Van Aelst, K. & Holvoet, N. (2016). Intersections of gender and marital status in accessing climate change adaptation: Evidence from rural Tanzania. *World Development, 79*, 40–50.

Water Research Institute. (2000). *Climate change vulnerability adaptation assessment on water resources of Ghana.* Council for Scientific and Industrial Research.

Water Resources Commission (WRC). (2015). *About us.* http://www.wrc-gh.org/about-us/

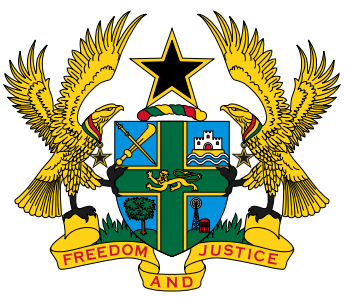
Water Resources Commission. (2012). *National Integrated Water Resources Management (IWRM) Plan.* http://doc.wrc-gh.org/pdf/National%20IWRM%20Plan.pdf

World Bank. (2011). *Ghana – Vulnerability, risk reduction and adaptation to climate change.* http://documents.worldbank.org/curated/en/2010/01/17486030/ghana-economicsadaptation-climate-change-eacc-vol-1-2-main-report

World Bank Group. (2010). *Economics of adaptation to climate change: Ghana country study.* World Bank.

World Bank Group. (2019). *Ghana - Climate change knowledge portal.* Retrieved from https://climateknowledgeportal.worldbank.org/country/ghana/climate-data-projections.

Yorke, C. & Omotosho, J. (2010). Rainfall variability in Ghana during 1961–2005. *Journal of Ghana Science Association, 12*(1), 125–134. http://10.4314/jgsa.v12i1.56813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