# GHANA: ROADMAP FOR RESILIENT INFRASTRUCTURE IN A CHANGING CLIMATE

GLOBAL CENTER ON ADAPTATION

UNOPS

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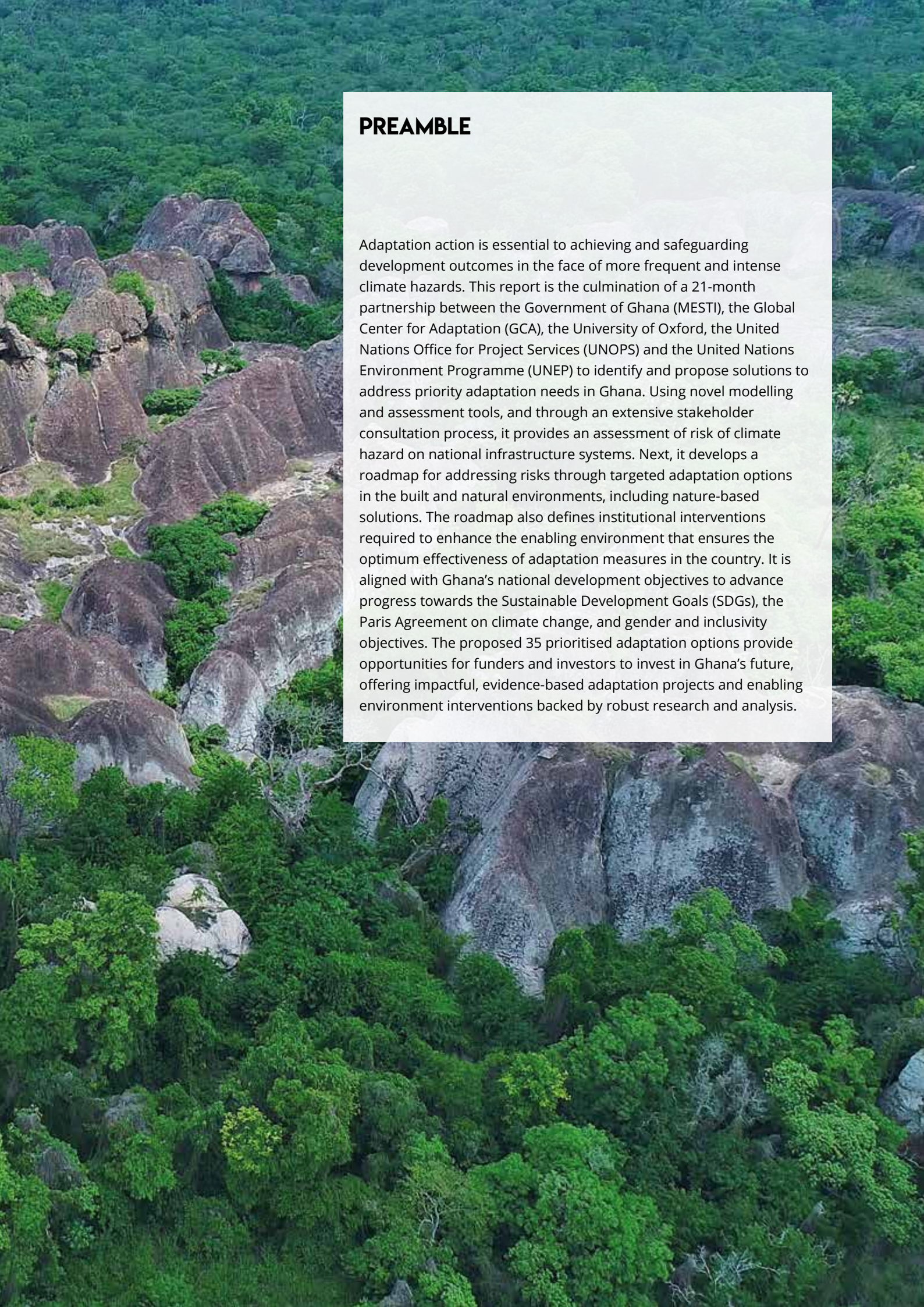


# PREAMBLE

Adaptation action is essential to achieving and safeguarding development outcomes in the face of more frequent and intense climate hazards. This report is the culmination of a 21-month partnership between the Government of Ghana (MESTI), the Global Center for Adaptation (GCA), the University of Oxford, the United Nations Office for Project Services (UNOPS) and the United Nations Environment Programme (UNEP) to identify and propose solutions to address priority adaptation needs in Ghana. Using novel modelling and assessment tools, and through an extensive stakeholder consultation process, it provides an assessment of risk of climate hazard on national infrastructure systems. Next, it develops a roadmap for addressing risks through targeted adaptation options in the built and natural environments, including nature-based solutions. The roadmap also defines institutional interventions required to enhance the enabling environment that ensures the optimum effectiveness of adaptation measures in the country. It is aligned with Ghana's national development objectives to advance progress towards the Sustainable Development Goals (SDGs), the Paris Agreement on climate change, and gender and inclusivity objectives. The proposed 35 prioritised adaptation options provide opportunities for funders and investors to invest in Ghana's future, offering impactful, evidence-based adaptation projects and enabling environment interventions backed by robust research and analysis.

# FOREWORD

**Hon. (Dr.) Kwaku Afriyie**

**Minister of Environment, Science, Technology and Innovation (MESTI)**

Climate Change has now become a development issue, which is increasingly taking a toll on the development fortunes of many developing countries including Ghana. There is already strong evidence of the direct manifestations of climate change in Ghana, i.e., increasing temperatures; rainfall variability, including unpredictable extreme events; and sea-level rise. These affect various facets of Ghana's socio-economic structure.

Specifically, physical infrastructure across the energy, water and transport sectors are sensitive to climate change. These infrastructures are the bedrock of the country's economic growth and development. The effect of current and future climate change impacts have the potential to put years of progress toward growth and development targets at risk, impacting the poor and the most vulnerable in society.

Ghana is focused on building a more sustainable and resilient society by putting in place measures that ensure we adapt to climate change impacts on infrastructures such as roads, dams, power distribution lines, homes, drains, and all structures that life revolves around. Thus climate-resilient infrastructure has the potential to improve the reliability of service provision, increase asset life and protect asset returns. Flexible, adaptive approaches to infrastructure development can be used to reduce the costs of building climate resilience given uncertainty about the future.

Safeguarding the physical and institutional components of Ghana's infrastructure system will enable the country to successfully progress along a trajectory of sustained growth. In line with this, the Government's Coordinated Programme of Economic and Social Development Policies indicates the importance of infrastructural planning and development for economic growth and poverty reduction. It recognizes the need to increase the country's "climate-proof" infrastructure, to effectively adapt to the impacts of current climate change variability and withstand any future impacts.

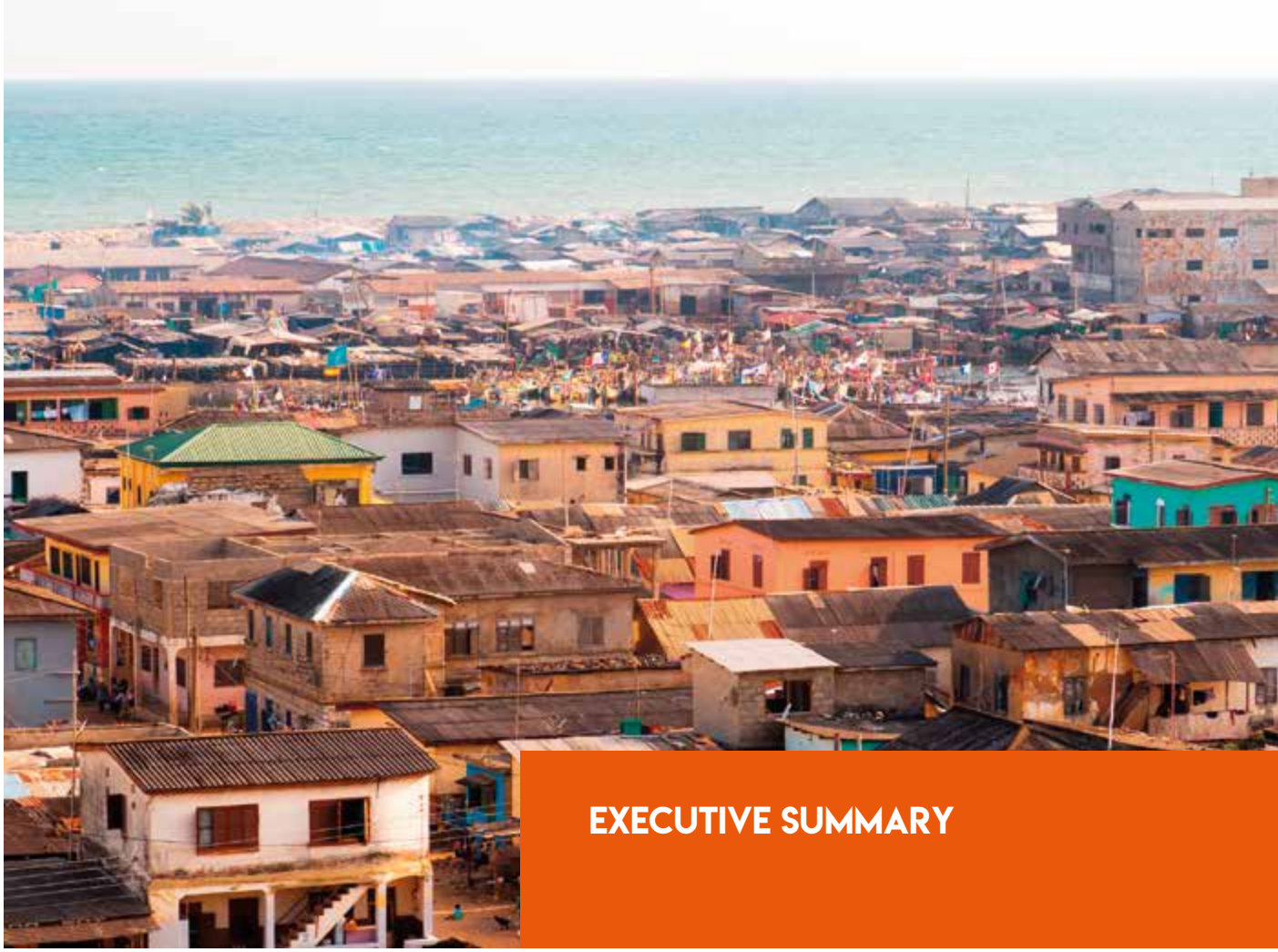
This resilient infrastructure roadmap has been developed through extensive multi-sectoral consultations and workings and presents 35 project concepts in the built, natural, or enabling environment to provide prioritized adaptation options for building a resilient infrastructure system for Ghana. The interconnected dimensions of the infrastructure system will enable and deliver development benefits linked to the achievement of the Sustainable Development Goals, the Paris Agreement, and gender and inclusivity outcomes.

The roadmap also defines actions for implementation, a key one being financing, by highlighting a total of 82 funds (worth approximately US$274 billion) with the potential to finance infrastructure in Ghana. Of the 82 funds identified, the government has an existing relationship (over the last 10 years) with 44% of the funds. This means 46 new funding opportunities exist that can increase the range of options for infrastructure financing available to the Government of Ghana.

The Government of Ghana therefore invites Investors/Financiers to partner with us to implement the identified prioritised climate resilience and adaptation projects.

We are grateful to our partners the Global Center on Adaptation (GCA), the United Nations Office for Project Services (UNOPS), the University of Oxford Environmental Change Institute (ECI) and the United Nations Environment Programme (UNEP) for the support provided in developing this road map.

Photo: Virgyl Sowah on Unsplash



# EXECUTIVE SUMMARY

**As a result of climate change, Ghana is expected to experience more acute climate hazards such as flooding, as well as more frequent and intense droughts. This has the potential to threaten the socio-economic development that has helped strongly position Ghana as a middle-income country. Climate-related extreme events have the potential to put years of progress toward growth and development targets at risk.**

This has specific implications for advancing toward the development objectives integrated in Ghana's national policies and frameworks, including its commitments under the Paris Agreement, and to making progress on the Sustainable Development Goals. In addition, social and economic outcomes on themes such as gender equality – a government priority and focus area within Ghana's Nationally Determined Contributions (NDCs) – may be hampered by climate impacts.

Adapting to the expected harmful impacts of climate change will be an essential part of Ghana's progress towards the SDGs, Paris Agreement, and other national sustainable development objectives. This includes adaptation of key infrastructure sectors, which form the backbone of Ghana's economy and society and play a central role in underpinning its future development. This study, developed under the leadership of Ghana's Ministry of Environment, Science, Technology and Innovation (MESTI), in collaboration with the Global Centre for Adaptation (GCA), the University of Oxford, the United Nations Office for Project Services (UNOPS) and the United Nations Environment Programme (UNEP), has quantified, for the first time, Ghana's climate adaptation needs across the energy, water and transport sectors. Based on these needs, government stakeholders have identified a prioritised 'roadmap' of investments and policies and accompanying financing options to meet adaptation needs.

The study has been developed using state-of-the-art methodology and tools made available by the project partners. This allowed for a novel geospatial assessment of 156 nationally significant built and natural infrastructure assets, 4 different hazard types, and 11 areas of the enabling environment, across the infrastructure lifecycle. Central to these methods and tools is a 'systems' approach to detailed infrastructure adaptation planning that builds on previous work undertaken by the government and various development partners, and addresses some of the limitations inherent within traditional approaches. The methodology adopted in this study includes: (i) quantifying infrastructure adaptation needs geospatially and at the asset scale; (ii) evaluating adaptation investment and policy options exhaustively within the built, natural and enabling environments; (iii) developing a roadmap of prioritised adaptation investment and policy options for meeting the quantified needs and contributing to national development priorities (the SDGs, NDCs and Gender impacts); and (iv) identifying potential sources of financing for the adaptation options identified.

Central to the study was a participatory stakeholder engagement process led by MESTI that included over 119 individuals, across 20 Ministries, agencies, and organisations. Participants in this process contributed to the evaluation of adaptation needs and prioritisation of adaptation options in the roadmap. This approach was chosen as a means of creating the necessarily broad "ownership" of climate adaptation solutions across the different parts of government responsible for infrastructure development and operation, which will help to ensure effective implementation of the various adaptation options.

Within Ghana's energy sector, geospatial risk analysis reveals that the main climate risks to service delivery are exposure to drought and flooding that threatens major components of the generation and transmission system: the top five exposed power plants provide electricity to 16.3 million people (Akosombo, Sunon-Asogli, Bui, Kpong, Cenpower), while the top five exposed substations (Ga West, Hohoe, Ga South, Greater Accra, Sefwi Bibiani-Anhwiaso Bekwai) provide electricity transmission to 3.9 million people.

Many mostly rural parts of the country rely on the natural environment for household energy generation through wood fuel. However, increased droughts in these parts threaten future energy availability to over 242 thousand people in the top five exposed districts alone (Wa East, Banda, Sissala West, Lawra, Wa West), with disproportionately large impacts on women and girls who are often responsible for fuel collection. Key institutional gaps in the sector, identified through detailed analysis, include: a lack of integration of climate adaptation in national policy and planning instruments; a lack of climate risk assessment in sector planning, locking in climate risks due to long asset life; unsuitable design standards that are not relevant to the national context; and insufficient maintenance funding for retrofitting, rehabilitation, and expansion of existing power generation.

Within the water sector, the priority climate risks include drought and flooding exposure that affects major water assets such as dams, the five most exposed of which have a total capacity of approximately 4.8 billion cubic metres (Akosombo, Bui, Tono, Vea, Weija). In addition, parts of Ghana rely on the natural environment (rivers and other water resources) for water abstraction for household use, often in smaller, rural districts. However, an increase in droughts will reduce river runoff, affecting up to 1.3 million people across the country, with large impacts on women and girls who are often responsible for water collection.

Flooding also threatens dam infrastructure and communities downstream. Key institutional gaps that were identified in the sector include: a lack of coordinated integrated water resource management (IWRM), resulting in a reactive approach to hazard response; limited guidance on incorporating nature-based solutions (NbS) into the design process; and a lack of proactive asset management that leads to faster deterioration of assets.

Within the transport sector, the analysis revealed pronounced climate risks due to flooding and landslide exposure that affects roads, including major highways, with the potential to cause up to 3.9 billion USD in damages on a national scale in a likely 2050 flooding scenario – triple the estimated 1.3 billion USD Ghana invested in transport infrastructure in 2019. As a result of expected flood damage, many districts in the Eastern, Central and Western regions may see over 80 percent of their population effectively cut off from healthcare services, which especially affects women, who access healthcare more often than men. Key transport hubs such as airports and ports, which contribute to economic development and local and international mobility, are also at high risk from floods – over half a million passenger trips in the top three exposed airports (Tamale, Ho, Takoradi) and 1.7 million in the top five exposed inland river ports (Makange, Yeji, Dambai, Dodolkope, and Kete Krachi). Key institutional gaps that emerge from detailed assessment of the sector include: a lack of integrated planning that accounts for the impacts of climate change on road and rail construction; inadequate integration of climate risk into feasibility studies and designs; limited maintenance funding for roads and emergency repairs; and uncoordinated asset management that is not climate risk-informed.

In response to these climate risks, 35 adaptation options have been identified and prioritised based on their suitability for addressing the identified risks, the government's prioritised needs, their ability to provide co-benefits that contribute to broader sustainable development objectives—including SDG targets, the NDCs and gender equality-related outcomes—and their economic, technical, political, and social feasibility.

The identification and prioritisation of adaptation options was accomplished through:

1. Desk-based research to define a comprehensive list of potential infrastructure adaptation options in the built, natural, and enabling environments;
2. Participatory stakeholder workshops with wide representation from across the Government of Ghana and its Ministries, agencies, utilities, and other organisations.

Based on the consultations with stakeholders, a final list of adaptation options was assembled, and project concept notes were developed for each one, which together form a resilient infrastructure roadmap to specifically address identified adaptation needs and build wider systemic resilience in Ghana. This includes 16 adaptation options that involve investment in the natural environment, 15 that involve investment in built infrastructure, and 13 that involve enabling environment components, with 9 solutions transcending these areas. Furthermore, 11 solutions are cross-sectoral or have application to more than one sector. The project concepts provide wide geographical representation across Ghana and include interventions in urban, rural, coastal, forest, and other environments.

In some instances, these options aim to capture Ghana's natural resource potential and harness NbS to provide wider adaptation benefits, such as flood absorption and slope stability. A number of catchment-level solutions provide a means of protecting all assets in a region exposed to a certain hazard, with some solutions focused on adaptation in urban settings. The development of cross-sectoral technical and institutional capacity can help to create the enabling environment for strong and proactive adaptation action in the future.

Proposed options respond to specific gaps and vulnerabilities identified in the needs assessment part of this study, including:

- Protecting critical energy or water supply facilities and natural resources;
- Safeguarding critical transportation infrastructure that underpins the economy and provides access to essential services;
- Supporting districts particularly vulnerable to climate impacts; and
- Building institutional capacity that aligns with and complements existing government policies, plans, and initiatives.

The project concept notes developed for this roadmap communicate key information that is essential for engaging potential sources of finance. Roadmap financing options are defined, including where public and private sector resources can be mobilised, alongside finance from traditional sources. An assessment of Ghana's financing landscape reveals that the Government of Ghana has access to 82 infrastructure-related funds, of which it has had existing relationships with 36 (44 percent) within the past 10 years. In total, 78 funds (95 percent) provide funding for projects in the built and natural environments, whereas 58 (71 percent) provide funding for enabling environment activities.

Lastly, 51 funds (62 percent) were identified as being able to provide project preparation financing – an important area to develop full bankable project proposals – necessary to engage private sector finance into climate adaptation in the country.

This study forms part of the Government of Ghana's integrated approach to building systemic climate resilience, and ultimately aims to support and accelerate the mobilisation of finance for climate resilience in Ghana through engagement with financing partners after conclusion of the study. The project partners will continue to work together to identify means of implementation for the adaptation options identified in the roadmap.

# INTRODUCTION

## Infrastructure that integrates climate adaptation underpins sustainable, resilient, and inclusive development in Ghana

> **Infrastructure systems comprise interconnected networks of assets, including natural assets, or green infrastructure, that provide essential services for people and the economy.**

These systems deliver inputs such as electricity and water to households and businesses; dispose of solid waste and wastewater; and connect people and the economy through access to transport and digital communications. Infrastructure in the form of social assets such as hospitals and schools also rely on these networks to provide health, education, and other social and economic services to communities and societies.

In addition to physical assets, infrastructure systems also include operational organisations and regulatory authorities that govern infrastructure service provision in the country. Together, this extended infrastructure "system of systems" underpins development in Ghana, and is central to achieving the Sustainable Development Goals, influencing 92 percent of the 169 targets.[1]

Yet, many of these infrastructure systems and their component assets have not been planned and built to withstand the impacts of climate change. Rising sea levels, overflowing rivers, landslides, wildfires, droughts, and other extreme events damage physical and natural infrastructure assets and disrupt social and economic services provided through these assets, exerting a significant human toll. Repeated cycles of acute and chronic climate change create a vicious trap that risks halting economic growth and disrupting or even reversing progress towards achieving the SDGs. These impacts place a heavy burden on public finances, particularly as the repercussions of Covid-19 reverberate through the economy.

Adapting infrastructure and increasing resilience to climate change is therefore directly linked to broader national sustainable development objectives. Women, girls, and vulnerable groups are usually disproportionately affected by the loss of services when infrastructure systems fail due to the impacts of climate change and environmental shocks. Often, it is these groups that bear the brunt of damages caused by natural disasters, who may lack the resources to rebuild their homes, communities, and livelihoods, and who may be disproportionately affected by health and other impacts caused by disruptions to basic services.

The Intergovernmental Panel on Climate Change (IPCC) has defined climate adaptation as the process of adjustment to actual or expected climate change and its effects. It is an essential element of the Paris Agreement on climate change, which aims to strengthen the global climate change response, in part by requiring countries to engage in adaptation planning and implementation. Resilience refers to the ability of a system and its parts to anticipate, absorb, accommodate, and recover from a hazardous event's impact in a timely and efficient manner. Infrastructure adaptation, therefore, involves measures to improve the resilience of infrastructure systems to the effects of climate change. Resilient infrastructure in turn improves the resilience of our societies and economies to various future shocks, while at the same time contributing to sustainable development and safeguarding progress. Some infrastructure adaptation investments, such as those in the natural environment, can also generate significant economic, social, and environmental co-benefits.

## Ghana's commitment to climate resilient infrastructure

Through the development of this study, the Government of Ghana is demonstrating its commitment to enhancing the resilience of its society.

Led by the Ministry of Environment, Science, Technology and Innovation, this study brings together the collective expertise across government with the support of the Global Center on Adaptation and partner organisations specialised in the research and practice of climate adaptation and resilience: the United Nations Environment Programme; the United Nations Office for Project Services; and the University of Oxford.

This study is designed to be aligned with, and to inform, Ghana's national strategic development plans and policies, including the National Adaptation Plan (NAP) and the revised Nationally Determined Contributions. To achieve this, the study has taken a whole-of-government approach: engaging 119 individuals across more than 20 government ministries and organisations and utilising nearly 100 data sources – including geospatial datasets and policy documents.

The participatory nature of the stakeholder engagement process has relied on the best available data and expert knowledge from partners and stakeholders in the country, including national and local government ministries and agencies, utilities, and the academic community, who form the project's Technical Working Group (TWG). Over the course of 18 months, the TWG not only provided inputs to and verification of the analysis, but through three targeted workshops coordinated the prioritisation of national adaptation needs and final selection of adaptation options for the roadmap, to ensure that they are grounded in evidence and are aligned with government objectives and implementation capacity (Figure 1).

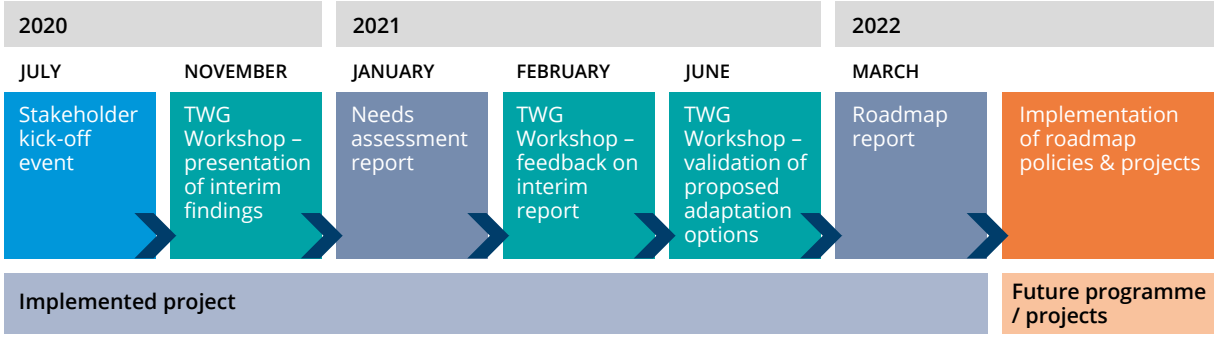
| | |
|---|---|
| 24 | Ministries, agencies, and organisations represented in the Technical Working Group |
| 119 | Individual stakeholders consulted |
| 36 | Datasets used |
| 90+ | Policy documents reviewed |

## A systems-based approach to infrastructure adaptation in Ghana

Through the collaboration of project partners and the TWG, this study has three main objectives:

1. To systematically assess the need for climate adaptation in the energy, water and transport sectors, in high-resolution, across the whole of Ghana;
2. To collaboratively plan a prioritised roadmap of appropriate, government-led investments and policies to respond to key needs, and to present these adaptation options as a series of project concept notes;
3. To strategically identify potential sources of financing for the project concepts in the roadmap to help advance them from concept phase to feasibility studies and, ultimately, implementation.

**Figure 1:**
*Timeline of the Ghana resilient infrastructure roadmap study.*



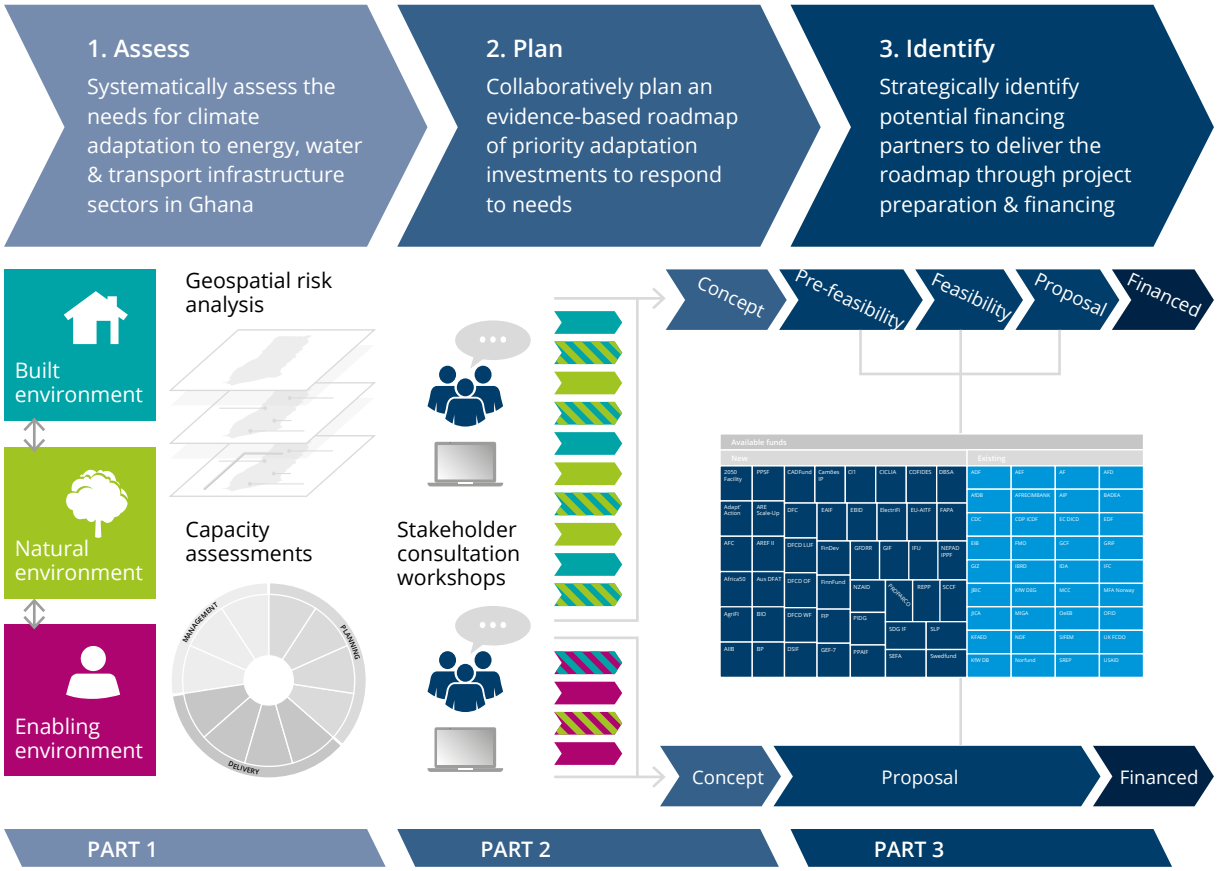



**Figure 2:**
*Methodological process for the study.*

To achieve these three objectives, the study has developed a three step methodological process (Figure 2). Transcending all three steps of the methodology is the concept of infrastructure as a "system of systems" that delivers the essential services that underpin Ghana's national development. Infrastructure is conceptualised not simply as traditional built infrastructure, but as the combined function of the built, natural and enabling environments (see Appendix A.1 for more explanation). In practical terms, this not only includes physical assets built with steel, concrete and wood, but also natural infrastructure such as wetlands and forests, as well as the rich tapestry of policies, regulations, laws and capacity that make up the enabling environment.

The study covers nine sub sectors across the energy, water and transport sectors, selected based their critical role in underpinning the Government of Ghana's national development priorities: 1) sustainable development, through the SDGs; 2) climate action, through the Paris Agreement on climate change; and 3) inclusive development, through action to enhance the lives of women, girls, and vulnerable groups.

Part 1 of the process involved the systematic assessment of climate risks to infrastructure systems in the energy, water and transport sectors, in high-resolution, across the whole of Ghana. Using state-of-the-art geospatial analysis developed at the University of Oxford (detailed in Appendix A.2), national adaptation needs within the built and natural environment were quantified by integrating location data for 156 nationally significant assets, with information on asset usage and adaptive capacity of their user base intersected with several scenarios involving four types of climate hazards. Using a unique tool developed by UNOPS (see Appendix A.3), adaptation needs were quantified for the enabling environment, across eleven stages of the infrastructure lifecycle with their ability to impact national development objectives highlighted. This study is the first time that such an assessment has been carried out in Ghana and the region.

Part 2 of the process involved collaborative development of a roadmap of prioritised appropriate and government-led investments and policies to respond to key needs, and to present these adaptation options as a series of project concept notes. This step in the process started by identifying critical assets and areas that should be candidates for adaptation interventions. This selection was informed by the detailed quantification of climate risks and adaptation needs (Part 1) and was led by stakeholders within the country, including sectoral experts who are focal points for adaptation within their Ministries and have the expert knowledge to determine where needs are greatest.

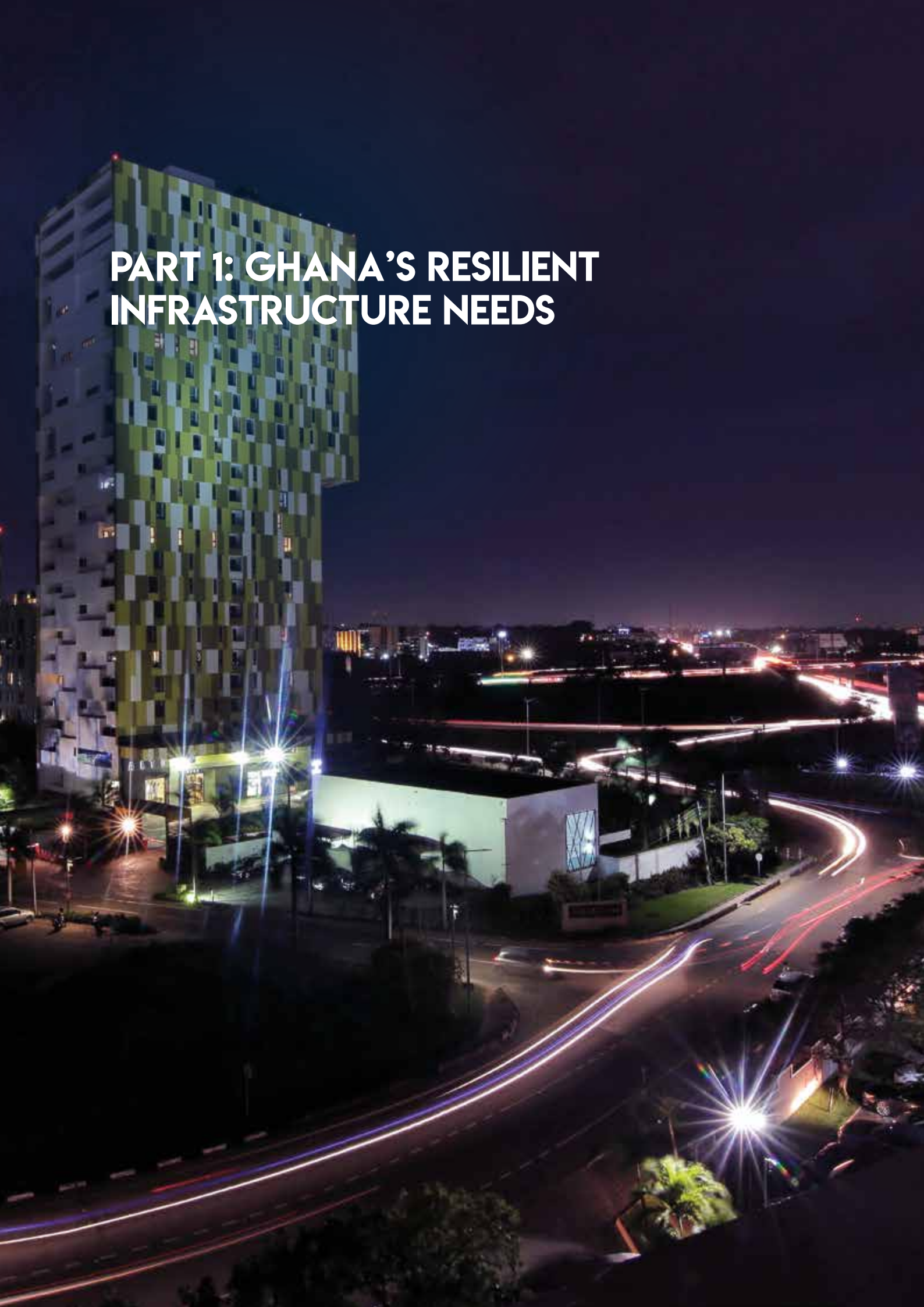
Following extensive consultation, 35 areas of critical need were selected for the roadmap. This number was determined by stakeholders to represent a manageable number of assets and areas that are candidates for adaptation through investment and policy development.

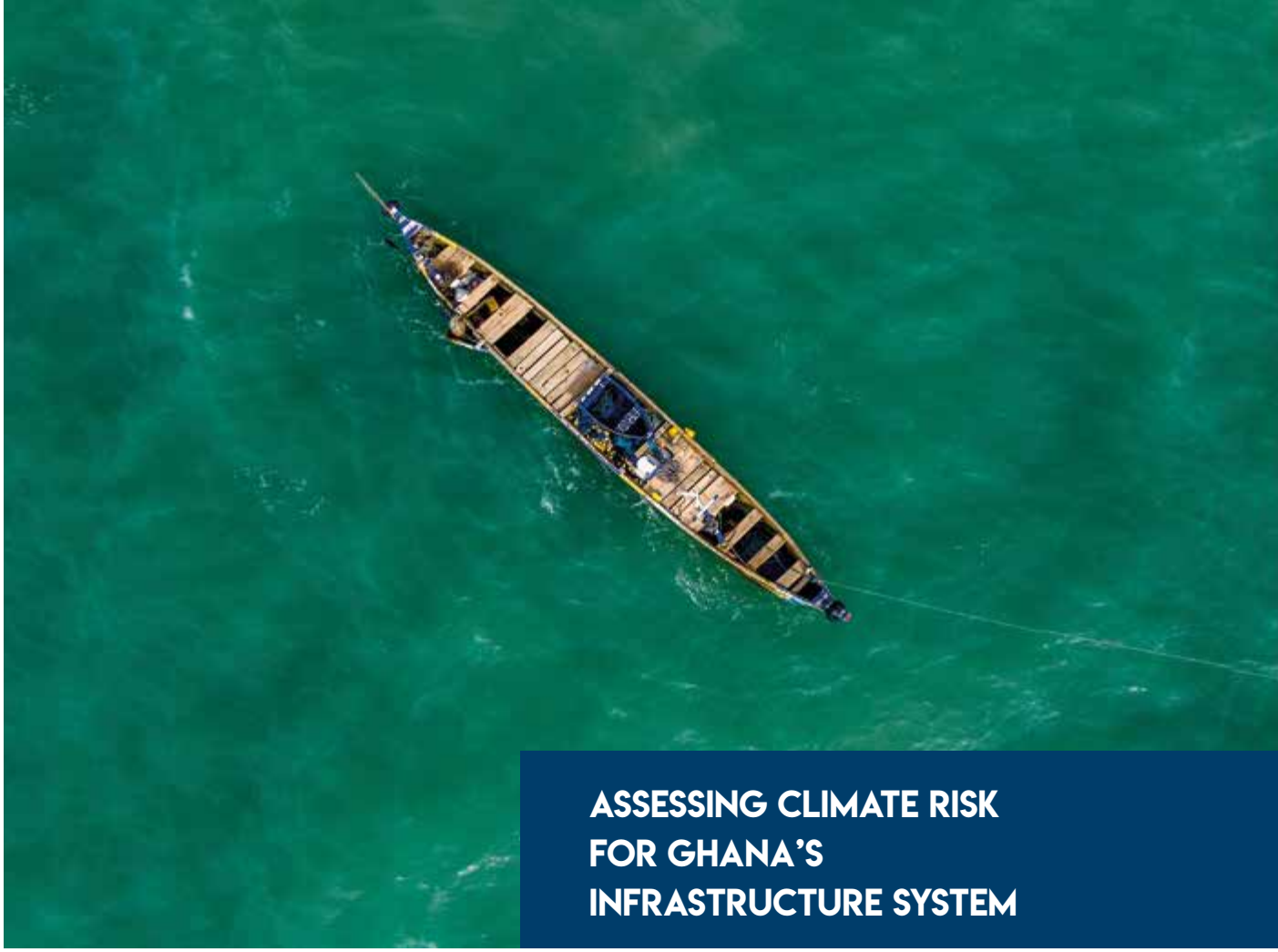
For each of these key needs, stakeholders selected appropriate adaptation solutions from a number of options, with preference given to solutions that could be led by the government. The selection of adaptation solutions was also informed by rich data on the broad range of costs and benefits of different solutions, including: their ability to meet adaptation needs; their relative cost and timescale for implementation; and their expected national sustainable development co-benefits. The roadmap projects are presented as a series of project concept notes that communicate key information that is typically requested by the infrastructure adaptation financing community.

Part 3 of the process involved strategic identification of potential sources of financing for the projects in the roadmap to help advance the projects from project concepts, through feasibility studies, into implementation. A variety of financing options were discussed, including public expenditure, donors, international financial institutions and the private sector. Financing options were disaggregated for the built, natural, and enabling environment projects, which require different types of proposal development to be able to receive project financing. Part 3 of the report concludes with broader discussion on how infrastructure adaptation can be scaled-up in Ghana.

The remainder of this report is structured around the three stages of the methodological process utilised within the study: Part 1 – Ghana's resilient infrastructure needs; Part 2 – Ghana's resilient infrastructure roadmap; and Part 3 – Scaling-up climate adaptation in Ghana.

# PART 1: GHANA'S RESILIENT INFRASTRUCTURE NEEDS





# ASSESSING CLIMATE RISK FOR GHANA'S INFRASTRUCTURE SYSTEM

**The resilient infrastructure roadmap presented in Parts 2 and 3 of this report is based on a robust and exhaustive assessment of climate risks and adaptation needs for Ghana's infrastructure system.**

The assessment analysed how climate change in Ghana is expected to affect infrastructure assets and the services provided through these assets, including services delivered by nature. The analysis focused on climate adaptation needs in the energy, water, and transport sectors, identifying specific vulnerabilities to climate hazards in Ghana.

## Assessing Ghana's adaptation needs in the built and natural environments

### Climate and environmental conditions in Ghana

Ghana belongs to the tropical savanna climate zone, and is split into two precipitation regimes and six agro-ecological zones which cause different levels of climate risk and exposure to a range of climate hazards across the country. The northern region has a single rainy season while the south has two. Average annual precipitation ranges widely, from 900 mm in the north, to 1500 mm in the south, to over 1800 mm in the south-west.

### Acute and chronic climate hazards in Ghana

The elevated risk of extreme events occurring due to climate change poses a threat to the resilience of infrastructure systems and the livelihoods they support. These impacts can be either acute or chronic, with each having specific implications for resilient infrastructure planning.

**Acute climate impacts** cause a sudden shock to the system, often from an extreme event such as a flood. The event may have widespread impacts, such as coastal flooding, or may be very localised, such as a landslide. Acute hazards have the potential to cause cascading impacts across other infrastructure sectors and services. Destruction of a key section of road, for instance, might cut off communities from essential services and divert resources from other outcomes such as education, restricting growth and development. Depending on the capacity of a community or region to recover from the shock the acute event may impact on the affected area for years or decades to come.

**Chronic climate impacts** result in gradual changes to climate-related variables such as precipitation or temperature, which can also cause erratic or unpredictable weather patterns. This can affect the infrastructure system's ability to supply services such as water or energy through impacts such as reduced hydropower potential in a given area. It may also shift demand for certain types of infrastructure, such as requirements for cooling. Infrastructure such as buildings will therefore need to be built to withstand these climate impacts by adapting to new hotter, dryer, or wetter normal conditions.

### Box 1: Description of climate hazard datasets that were selected for the study, to align with current planning processes within Ghana

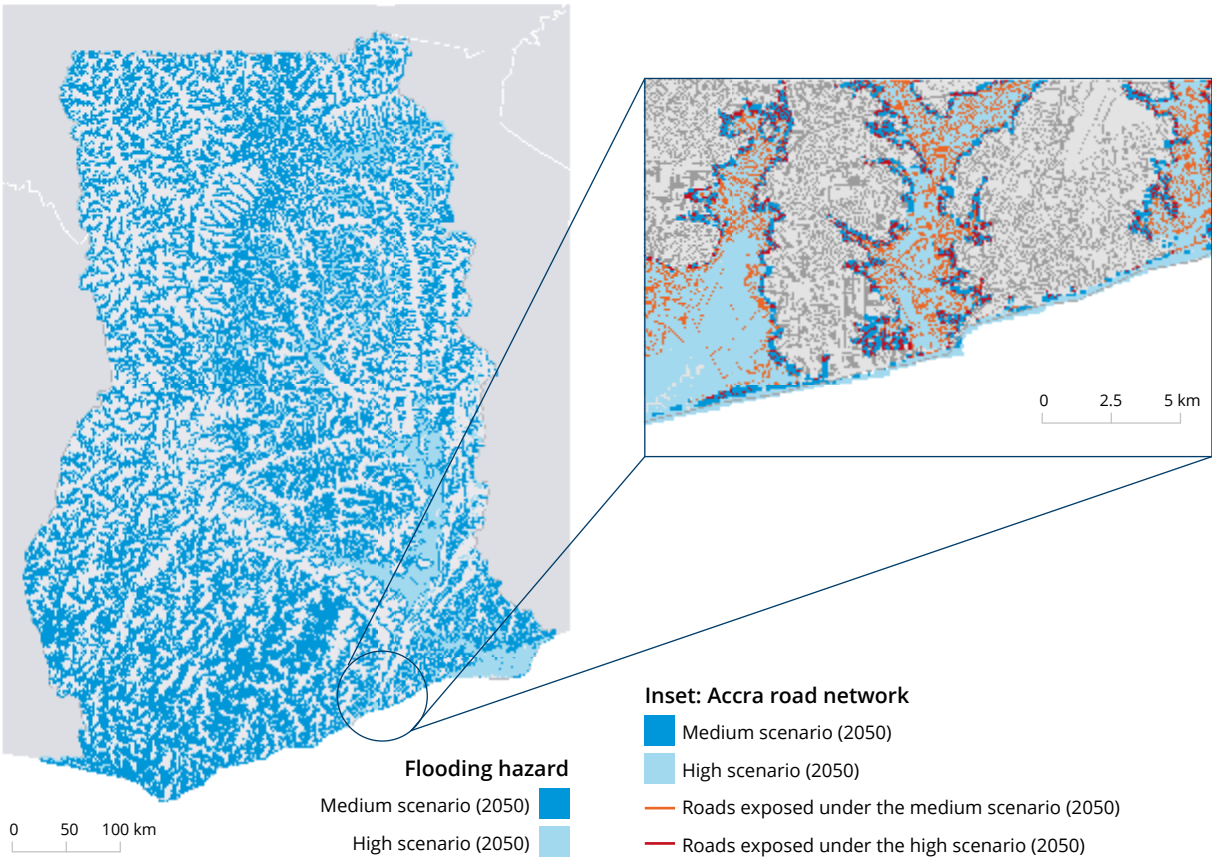
**Flooding** scenarios indicate areas with a medium or high likelihood of flooding for a future timeline up to 2050. Based on data from the National Disaster Management Organization Ghana (NADMO), the technical parameters of the **medium** and **high** scenarios are defined by the *Height Above Nearest Drainage (HAND)* methodology. NADMO has identified IPCC AB1 as the most appropriate climate prediction for Ghana, which represents a future world of very rapid economic growth, low population increase and rapid introduction of new and more efficient technology, using a mix of fossil and non-fossil energy sources. The hazard data on flooding scenarios are non-probabilistic, meaning that no quantified value is given for depth, time, or duration of the hazard. This allows for an estimation of exposure, rather than risk – in other words, *whether or not the asset is in a hazard-prone area*.

**Landslide** scenarios indicate **medium** and **high** levels of susceptibility for a current timeline, using hazard data layers provided by NADMO from a recent assessment. No further information on the details of this hazard dataset has been provided.

**Drought** scenarios are based on predictions for meteorological drought using evapotranspiration and rainfall data, and do not account for the impact of other hydrological states like groundwater levels or soil composition. This method places emphasis on cumulative rainfall deficit, consistent with the NADMO approach. Two scenarios for drought hazards by 2050 indicate the number of days per year that *cumulative rainfall deficit exceeds a threshold of 600mm*: **medium** (20–70 days), or **high** (>70days). These scenarios are also based on the NADMO A1B scenario and are non-probabilistic.

**Reduced river runoff** is represented by a *probabilistic* scenario which refers to the *change in future mean annual discharge in percentage* (2046–2065 vs. 1998–2014) for the p50 simulation using 30 climate model runs of the CORDEX-Africa ensemble (RCP4.5 and RCP8.5).

While an exposure analysis was performed across all scenarios and sectors, the presentation of results in this report focuses on the **high hazard scenario** for floods and landslides which has been identified by NADMO as the *highest likelihood scenario*. Drought exposure is also based on the **high hazard scenario** indicating the *highest drought intensity*. River runoff is assessed according to the **median reduction scenario** for 2055.




## Climate hazard: Flooding

Flooding poses a threat for Ghana's infrastructure systems primarily in the form of inundation or destruction of energy, transport, and water infrastructure assets, or a reduction in the efficiency of dams and reservoirs through increased sediment transport. In addition, flooding can impact other sectors such as agriculture, causing destruction to crops and irrigation infrastructure.

Flooding is projected to increase in Ghana due to changes in the frequency and intensity of heavy rainfall events and changes in soil saturation. While IPCC RCP climate models estimate there will be little change in the total annual precipitation until 2080, the number of days with heavy precipitation events, as well as the intensity of such events, are expected to increase in response to growing temperatures. Rainfall is projected to become more extreme. At the same time, rising sea levels will pose a growing challenge.

**Figure 3:**
*Flooding scenarios for Ghana with medium and high hazards. Inset on flood hazards in Accra, with road assets in flood-prone areas highlighted in red.*

From 2000 to 2050, different IPCC climate models, including IPCC RCP6.0, project very similar levels of around 20 cm of sea level rise in Ghana, which constitutes a threat for coastal communities and assets, and increases the risk of saline intrusion.

Figure 3 presents a spatial analysis on the potential extent of acute flooding hazards under different hazard likelihood scenarios in Ghana. The risk of flooding is determined in large part by topographical characteristics of the area, with low, flat surfaces close to water bodies most prone to flood events. Light shading indicates areas projected to be exposed to a *high likelihood* of flooding by 2050, while dark shading indicates *medium likelihood* of flooding.

The national-level flood assessment report classifies 65 percent of Ghana's total land surface area as 'no hazard' (a total of 155,000 km$^2$); 12 percent as high hazard (29,000 km$^2$); and 13 percent of the country as medium hazard regions (31,000km$^2$). By aggregating this data to Ghana's 216 districts, 35 percent of districts are expected to experience high flood hazards and 32 percent of districts medium flood hazards by 2050. Districts located in the floodplains of the White Volta and the area downstream from the Akosombo Dam are particularly relevant given their high exposure to flood risk. Other factors such as development planning and population growth may exacerbate the impacts of flooding into the future.

## Climate hazard: Landslides

Heavy rainfall and flooding linked to climate change can increase landslide risk through heightened ground saturation, erosion, and the undercutting of slopes. Figure 4 shows the potential extent of acute landslide hazards in Ghana, which are concentrated in mountainous parts of the country. Light shading indicates regions where existing landslide susceptibility is currently presumed to be *medium*, whereas dark shading indicates high susceptibility to these hazards. Taken together, the high landslide hazard covers 8,400 km$^2$ of Ghana's total area of 238,000 km$^2$. The northern part of the Volta Region, the Bono, and the Ashanti regions are particularly affected by the landslide hazards due to their specific terrain, slope, geology, soil, and/or rainfall patterns. Sections of key national highways are located along landslide hazard zones, including the N2, N6, and N10. Downstream interventions to adapt development projects such as roads and housing (including informal settlements) to landslide hazards will need to account for local slope geology and soil dynamics.

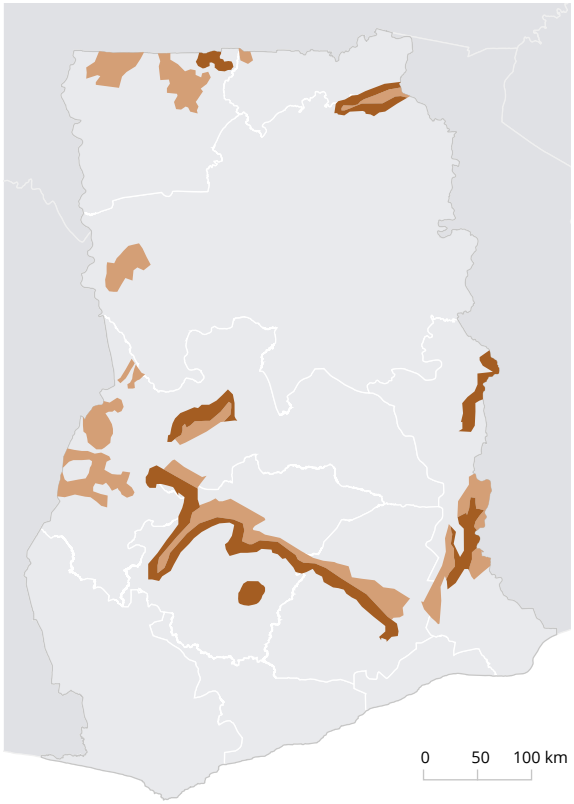



**Figure 4:**
*Landslide scenarios for Ghana with medium and high hazards.*

## Chronic climate hazards: Drought and reduced river runoff

Droughts are predominantly caused by meteorological trends and conditions, in particular changes in precipitation patterns and rates of evapotranspiration. Reduced precipitation and river runoff are projected to decrease the availability of both surface water and groundwater, which in turn can impact hydropower potential, agricultural production, and potable water availability.

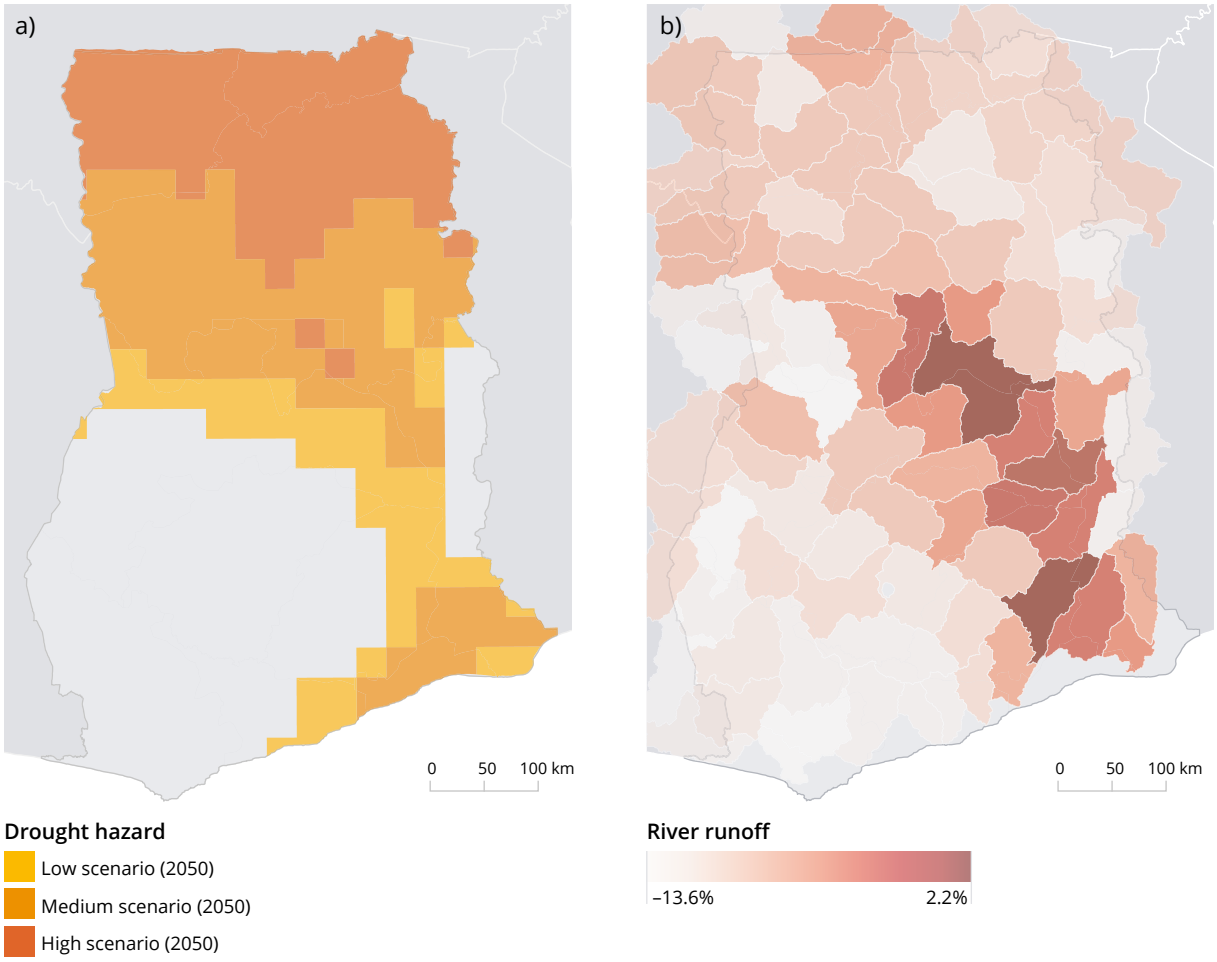



**Figure 5:**
*(a) Drought and (b) river runoff scenarios for Ghana.*

As warmer air can hold more water vapour, rising temperatures are furthermore expected to cause a higher rate of potential evapotranspiration and reduced soil moisture, with associated impacts in crop reduction, soil erosion and desertification. Figure 5 shows the potential extent of chronic drought trends by 2050, measured in terms of cumulative rainfall deficit, by areas with *low*, *medium*, and *high* exposure. This is estimated using changes in potential evapotranspiration and rainfall.

The northern part of the country exhibits the highest rainfall deficit – measured in terms of the number of cumulative dry days – while the eastern and south-eastern parts exhibit a medium rainfall deficit drought hazard. The future climate change scenario shows a spatially-distributed increase in the rainfall deficit drought hazard, mainly in the central and central-southern parts of Ghana.

In addition, probabilistic river runoff changes were estimated for Ghana's main water catchment areas, using calculations of long-term mean flow conditions gauged at key sites along river networks and simulated for future years using climate runs modelled for the West African region.

Reduced river runoff, especially in the dry season, will affect water supply and hydropower generation infrastructure, with severe implications for those communities largely reliant on river-derived water to cover their drinking and general water needs. In addition, river runoff changes also alter the viability of hydropower plants, which feature prominently in Ghana's energy infrastructure planning. The large reductions in river runoff can be seen in catchments centred along the Volta. Nationally, 45 of Ghana's 216 districts are exposed to a reduced river runoff of more than a five percent reduction as a yearly average by 2055, which is generally worse during the dry season.

### Physical assets and infrastructure systems

Exposure of built (assessed by asset exposure) and natural (assessed by administrative district exposure) infrastructure assets to climate hazards in Ghana is identified by overlaying asset data in each assessed sector with each of these four different climate hazards (Figure 6a). Exposure is defined as assets or services located in a hazard-prone area, according to the Intergovernmental Panel on Climate Change.[2] Through stakeholder consultation, asset data was obtained on the following built infrastructure: 29 power plants, 76 substations, 24 dams, 137,047 km of roads including 4,544 km of highways, 9 airports, and 18 ports (including 14 Volta river ports). In addition, for natural infrastructure, 25 land use classes were identified, along with 86 sub-catchment areas and 297 forest areas (Figure 6b). By assigning socio-economic data to the service provided by each built or natural asset, it is possible to estimate potential service disruption following hazard exposure.

Limitations in the availability and verification of geospatial data restrict the analysis within this study. As a result, the scope of the *quantitative analysis* excludes:

- Electricity transmission lines (only incomplete data could be obtained);
- Water transmission networks (geospatial information on urban and peri-urban supply points was not available, nor the capacities and people served by existing water supply assets), groundwater and boreholes;
- Railways (data on 668 km of existing and 2,475 km of planned railways was obtained, allowing some exposed sections to be identified. However, key information on passenger numbers and station locations required to perform a prioritisation assessment was not available);
- Domestic airports (passenger numbers not available);
- Major seaports (freight and passenger numbers not available).

Furthermore, data on the spatial distribution of any future infrastructure projects was not available; therefore, this analysis uses the assumption that *current assets will continue to serve the existing population into the future*. However, the geospatial tools and training provided alongside this report provide an opportunity to extend the assessment if and when additional datasets become available.

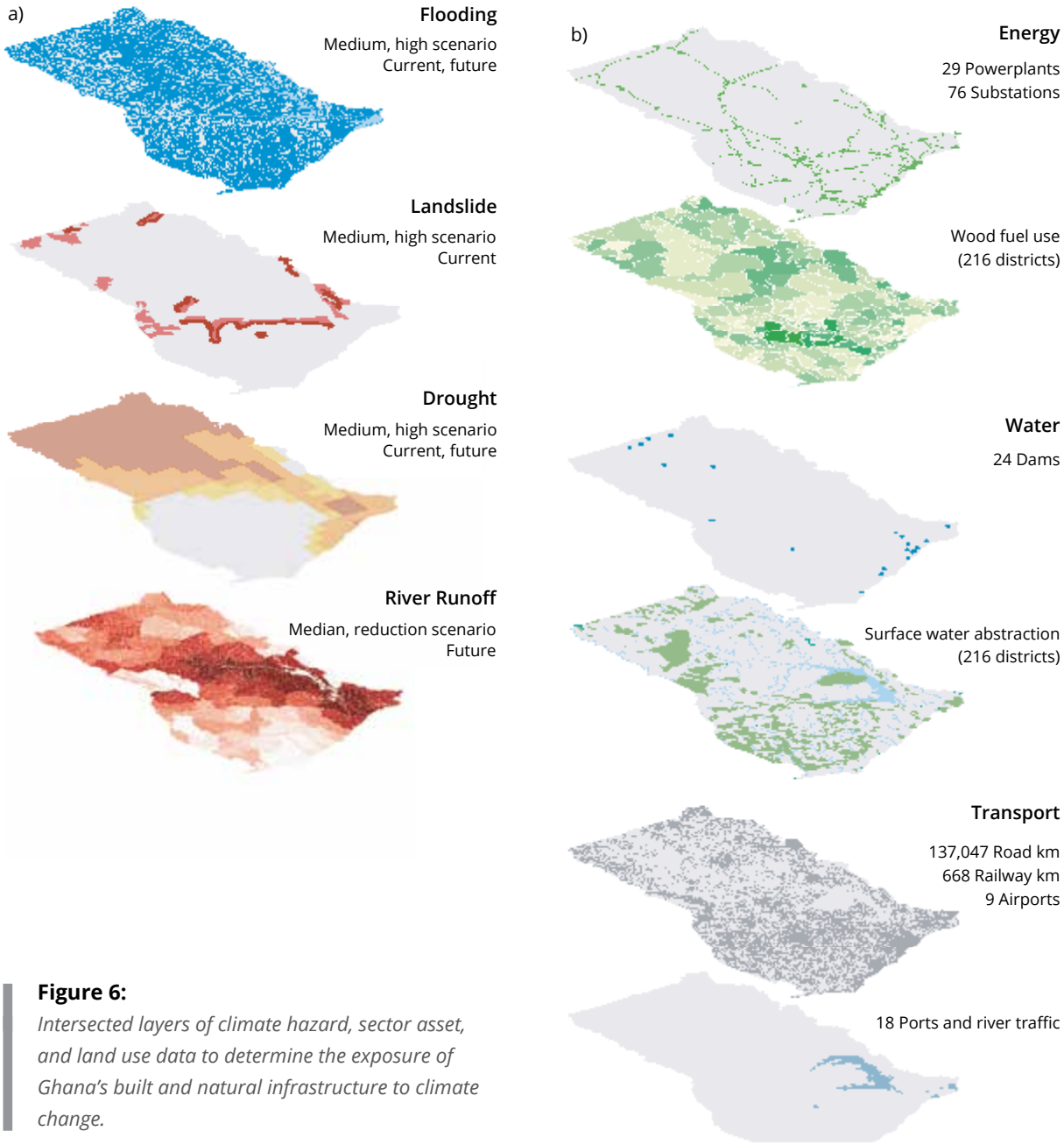



**Figure 6:**
*Intersected layers of climate hazard, sector asset, and land use data to determine the exposure of Ghana's built and natural infrastructure to climate change.*

## Social and economic services provided through infrastructure

Prioritising adaptation investments requires analysing and quantifying the impact of climate hazards on services provided through infrastructure systems.

| Subsector | **Flood** highest intensity | **Drought** highest intensity | **Landslide** highest likelihood | **Reduced river runoff** median reduction scenario | Exposure prioritised by: | Incorporate district vulnerability |
|---|---|---|---|---|---|---|
| Power plants | ✓ | ✓ | | | Population served | |
| Substations | ✓ | | ✓ | | Population served | ✓ |
| Wood fuel | | ✓ | | | Prevalence of firewood used (district) | ✓ |
| Roads | ✓ | | ✓ | | Population losing access to healthcare | ✓ |
| Airports & Ports | ✓ | | | | Passenger trips | |
| Dams | ✓ | ✓ | | | Dam capacity ($m^3$) | |
| Surface water abstraction | | | | ✓ | Population using natural drinking water supply | ✓ |

**Figure 7:**
*Summary of hazard assessment and exposure prioritisation criteria for types of built and natural assets considered in this study.*

Spatial data on services in Ghana is limited but depending on the nature of the asset and available data, exposure was prioritised by people-focused indicators such as population served (power plants and substations), passenger trips (ports and airports), potential loss of access to healthcare (roads), or reliance on a natural resource for household use (wood fuel and surface water abstraction) (Figure 7), which are characterised in the individual sector results.

Focusing on the economic value of infrastructure services runs the risk of excluding vulnerable populations from adaptation investment decisions. The analysis addresses this concern by integrating a vulnerability measure based on adaptive capacity of populations at the district level. Due to non-climate factors such as poverty, low educational attainment, or inadequate health infrastructure, Ghana's districts have different abilities to recover from climate hazards. In Ghana's National Climate Change Report (known as the *Fourth National Communication*) this is calculated as each district's adaptive capacity.

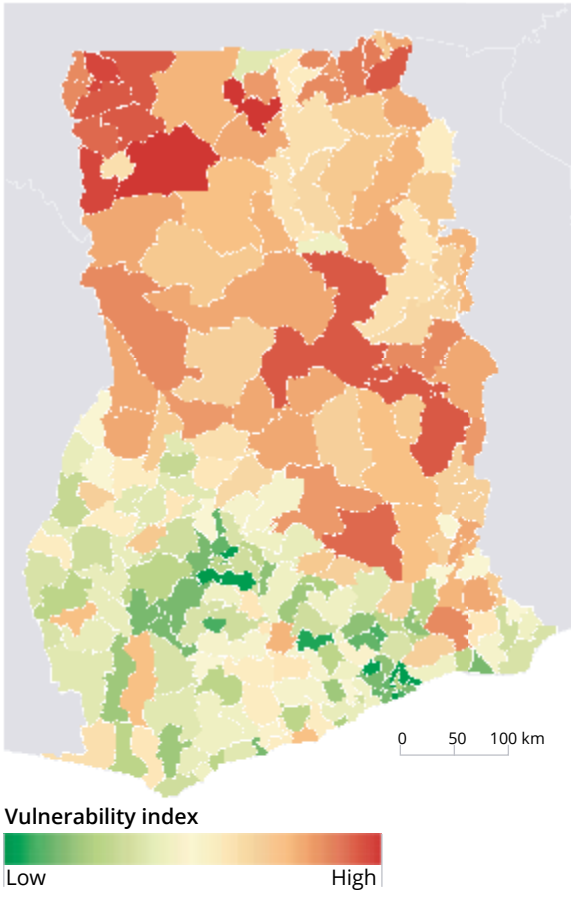



**Figure 8:**
*Ghana district vulnerability index: calculated as the inverse of adaptive capacity from the Fourth National Communication.*

Here, the *inverse* of this measure provides a district vulnerability score which is included in the calculation of exposed assets or districts where exposure of the asset largely affects the local district population (Figure 8). In this study, this measure was used as one factor in determining prioritisation of exposed substations, roads, and local wood fuel use and surface water abstraction.

Hazard, asset, and socioeconomic data were collected and validated by the Technical Working Group, aligning with existing practice and use in MESTI and across sector-focused ministries and agencies of the Government of Ghana such as the Ministry of Energy, the Ministry of Roads and Highways, and the Ghana Water Company.

## Adaptation in the enabling environment

Climate adaptation is prioritised in Ghana's development agenda through a strong policy and legal framework that aims to facilitate the successful implementation of the infrastructure adaptation strategy and action plan. However, across the infrastructure lifecycle, various challenges have been identified related to institutional coordination and political commitment, regulations and enforcement, technical and human resource capacity, funding and financing of adaptation activities and climate hazard and infrastructure-related data management and sharing. These have consequences for the successful mainstreaming of climate adaptation measures into Ghana's infrastructure sectors.

The assessment of Ghana's enabling environment for climate adaptation identified and prioritised areas that can be strengthened to better support the planning, delivery, and management of sustainable, resilient, and inclusive infrastructure, and to help guide resources where they are most needed.


**Figure 9:**
*Institutional areas assessed in this study on Ghana's infrastructure development. Eleven sub-indicators are considered within the planning, delivery, and management stages of the infrastructure lifecycle.*

Needs are assessed in terms of 11 indicators that map to key stages of the infrastructure lifecycle within the broader categories of *planning*, *delivery*, and *management* (Figure 9), and are prioritised for each sector, based on the indicator potential to support sustainable, resilient and inclusive development. To align with high-level sustainable development priorities in Ghana, this impact assessment was carried out using the targets of the SDGs (sustainability) and key policy areas of the NDCs (resilience), including key gender dimensions of both (inclusivity).

The following subsections present data and insights on the climate risks and adaptation needs in the energy, transport, and water sectors. The geospatial risk analysis is presented for the built and natural environment, while an institutional capacity assessment presents climate related gaps in the enabling environment.

# CLIMATE ADAPTATION NEEDS: ENERGY

**The energy sector analysis focused on Ghana's electricity grid system, which includes 29 power plants and 76 sub-stations, as well as the use of wood fuel as an energy source. Power plants include large-scale hydropower (defined as over 100 MW), renewable energy (solar, wind, and micro-hydro), and non-renewable energy.**

Data on national transmission networks were not available for this analysis. In addition, a number of communities currently meet their household energy needs by generating non-grid energy from the natural environment through wood fuel. In addition to contributing to the depletion of forests, this exposes communities to climate risks such as drought. Finally, the analysis focused on gaps in the enabling environment related to energy sector planning, project pipeline development and prioritisation, project preparation, design, and operation and maintenance, as well as on the gender and inclusivity impacts of these gaps.

### Gender impacts in the energy sector

Providing clean and reliable energy to households may have specific benefits to women and girls linked to improved health, well-being, safety, and increased agency to pursue economic and educational endeavours. This may be most pronounced in Ghana's northern districts where there is still a large reliance on wood fuel for household energy. While Ghana's policies and plans include gender considerations, they do not account for gender-differentiated vulnerabilities to climate change impacts or provide measures to manage these risks. Although the Ministry of Energy's medium-term expenditure framework allocates a budget for activities focused on mainstreaming gender,[3] the implementation of these planned activities is hampered due to inadequate and delayed funding. As a result, addressing the specific energy needs of women and children during implementation of sector programmes and projects remains a challenge.

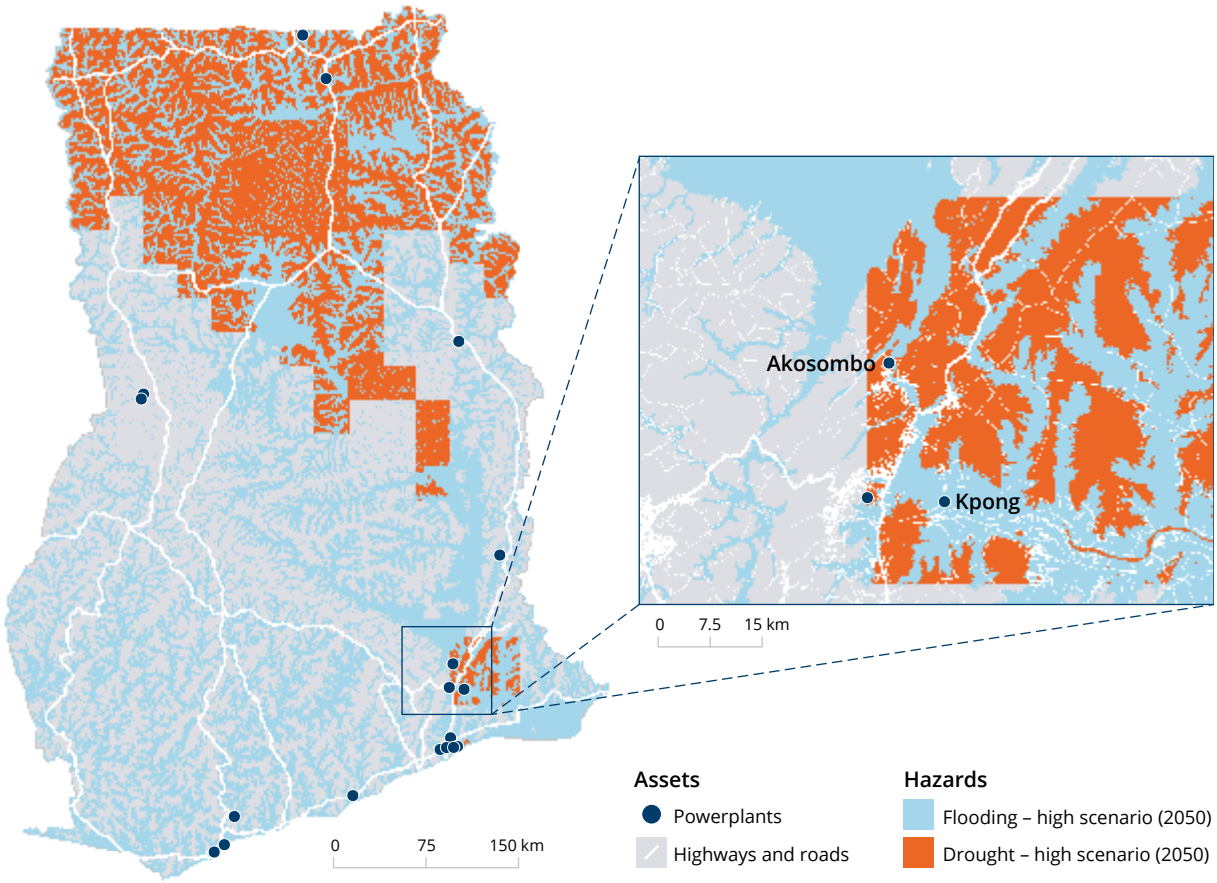
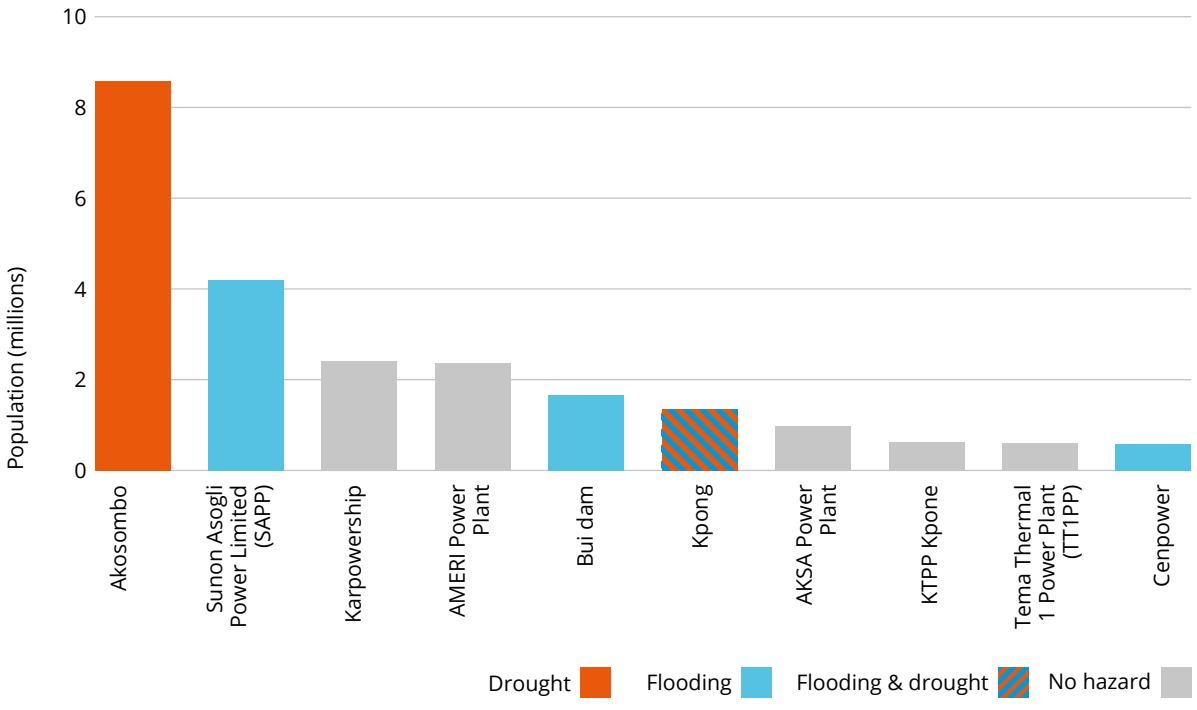



**Figure 10 (above):**
*Inset shows the intersection of selected energy assets and their hazard exposure: Akosombo (drought high intensity in red) and Kpong (flood high likelihood in blue and drought high intensity in red).*

**Figure 11 (below):**
*Power plants exposed to flood and drought hazards under a high 2050 scenario: ranked by population served.*



## Built environment

Figure 11 provides a summary of Ghana's power plant assets that were identified as most at-risk to potential *flood* and *drought* hazards. This risk profile was developed using a high hazard scenario for 2050, which is used to identify assets potentially impacted by the highest likelihood *flood* events and the *highest hazard drought intensity*, according to NADMO. Power plants were ranked and prioritised based on the estimated residential population served.

Notably, the Akosombo hydroelectric power plant in the Asuogyaman District, Eastern Region, with 1020 MW generation capacity and serving over 8.6 million people, is affected by exposure to high drought intensity. This includes the location of the power plant as well as a part of the Lake Volta reservoir which supplies the plant. This poses an increased risk of reduced river flow and a reduction in reservoir capacity, which reduces generation capacity.

Several periods of severe electricity rationing have occurred in recent decades (1983–4, 1997–98, 2003, 2006–2007), attributed to low water levels in the reservoir, which reduced generation capacity to about one third of its potential. This left factories idle, reduced state revenues, and threatened Ghana's image as an attractive destination for foreign investment.[4]

The Kpong dam, further downstream, is affected by this same level of drought hazard in addition to flooding, which can impact its 160 MW generation potential and 1.3 million people served by this dam. The Sunon-Asogli thermal power plant at Tema, which has a generation capacity of 560 MW and serves over 4 million people, is exposed to river flooding hazards – and is also likely to be vulnerable to coastal flooding from sea level rise and increased storm surge owing to its location near the sea coast (though this has not been quantified in this analysis).

Other prioritised power plants exposed to river flooding include the 400 MW Bui dam (1.7 million residents served) and the 360 MW Cenpower CCGT plant (576 thousand residents served) in the Tema industrial zone. A full list of Ghana's power plants, and their climate hazard exposure, is found in Appendix B.3.1.

Figure 12 provides a summary of Ghana's power substation assets that were identified as most at-risk to potential flood and landslide hazards. This risk profile was developed using a high hazard scenario for 2050, which is used to identify assets potentially impacted by the highest likelihood flood and landslide events, according to NADMO.

Substations were ranked and prioritised as a function of the population served by the substation and the vulnerability of the population in each district. This is based on each district's adaptive capacity, measured in terms of a combination of several socioeconomic factors including education, sanitation, health, security, governance, economic activity, poverty, and inequality.[5]

Twenty-one (21) substations face some degree of flooding exposure under a high hazard scenario. Substations in Ga West (district vulnerability 0.23), Ga South (0.43), Greater Accra (0.16), and Sefwi Bibiani-Anhwiaso Bekwai (0.37) are most exposed, which collectively threaten power disruptions to 2.7 million residents.

Meanwhile, two (2) substations are exposed to landslide hazards. Notably, the substation at Hohoe in the Volta region, which serves nearly one million residents living in a district with high vulnerability (0.72), is very susceptible to landslides. A full list of Ghana's substations, and their climate hazard exposure, are found in Appendix B.3.1.

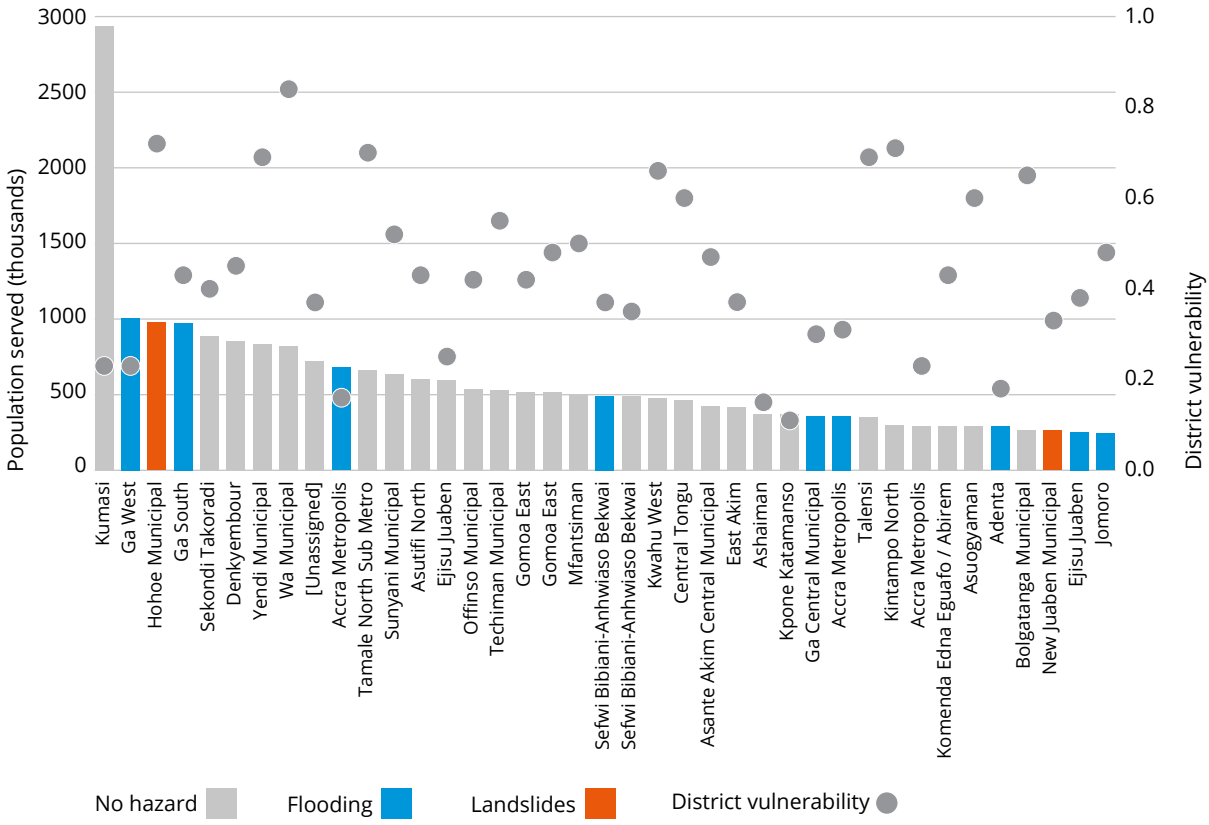



**Figure 12:**
*Power substations exposed to flood and landslides hazards under a high 2050 scenario: ranked by population served (left y-axis) with district vulnerability to hazard impacts shown (right y-axis).*

## Natural environment

Higher incidence of drought will also impact the regeneration capacity of forests that many communities rely upon for extraction of wood fuel and will particularly impact women and girls who are often tasked with firewood collection in these areas. Figure 13 provides a summary of Ghana's districts that are identified as most at-risk to potential drought impacts on energy supply. This risk profile was developed using a **high hazard scenario for 2050**, indicating the *highest hazard drought intensity*, according to NADMO.

Districts were ranked and prioritised as a function of three features: the *anticipated drought hazard*, the annual amount of *per capita wood use as a primary fuel source* in the district, and the *population vulnerability* in the district.

Several districts in the Upper West, Savannah, and Bono regions are particularly vulnerable, including:

- **Wa East**: High hazard, 1.4 tonnes/person, vulnerability 0.93;
- **Banda**: Medium hazard, 1.1 tonnes/person, vulnerability 0.75;
- **Sissala West**: High hazard, 0.5 tonnes/person, vulnerability 0.87;
- **Lawra**: High hazard, 0.5 tonnes/person, vulnerability 0.8;
- **Wa West**: High hazard, 0.4 tonnes/person, vulnerability 0.89.

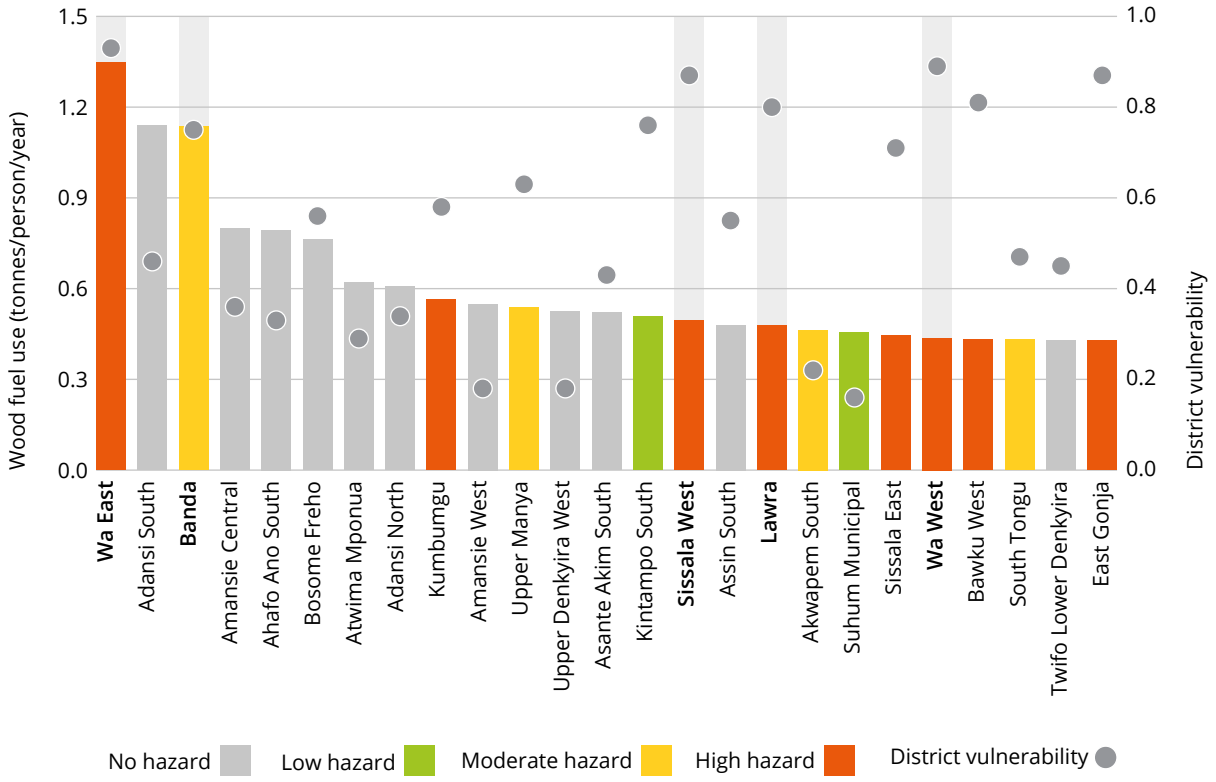
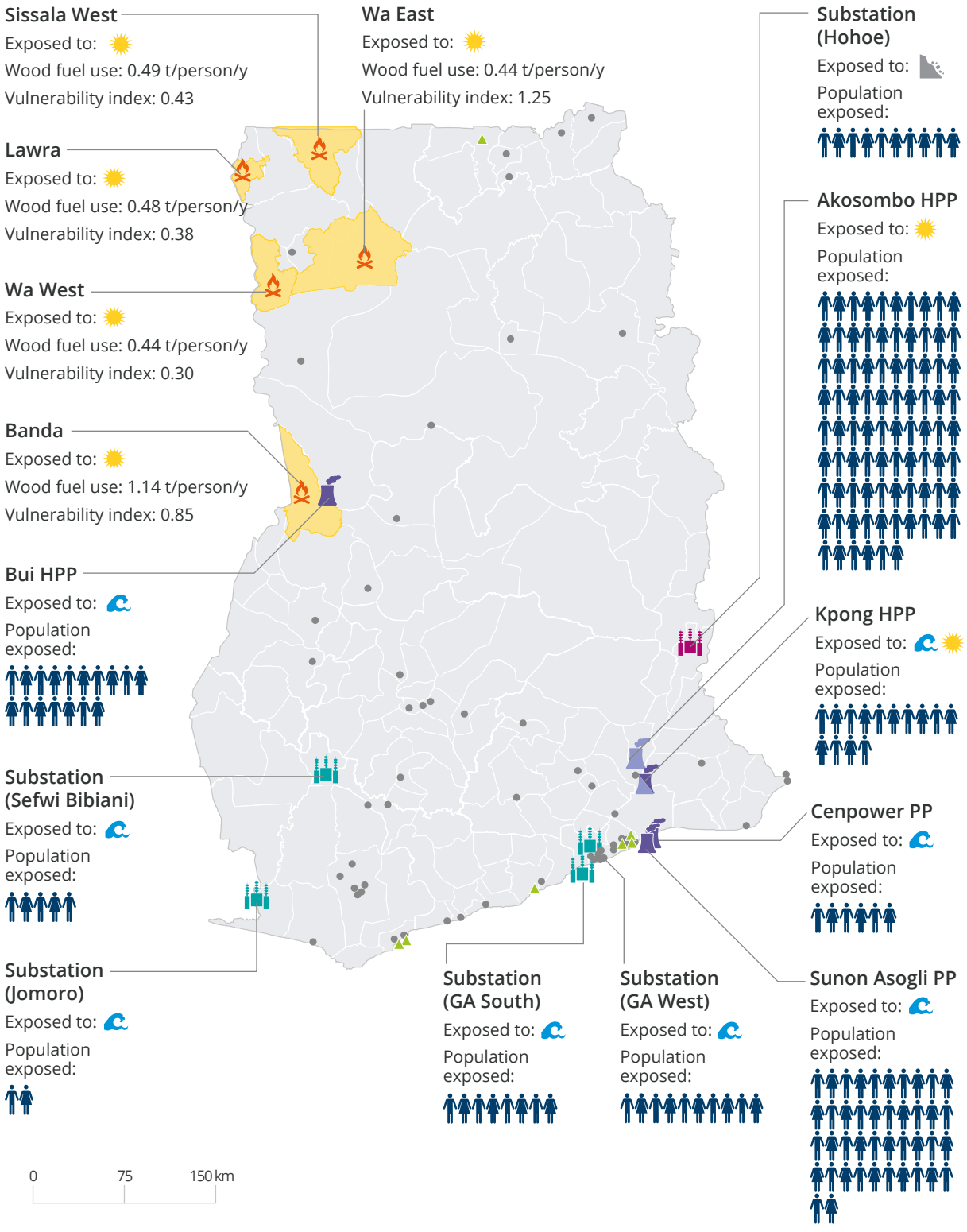



**Figure 13:**
*Districts exposed to drought hazards under a high 2050 scenario: wood fuel use (left y-axis), with district vulnerability to hazard impacts shown (right y-axis). Note: the top five exposed districts, accounting for the highest combination of all three of these factors, are highlighted in bold.*

**Figure 14 (page 31):**
*Built and natural asset data analysed for Ghana's energy sector. The locations of all analysed assets are shown, with more information provided on the top five prioritised natural and built assets, including the hazard and population exposed.*

Nationally, over 10 million people live in districts vulnerable to some form of drought, where annual per capita wood fuel use is also over 0.1 tonnes (100 kg). An extended list of Ghana's districts vulnerable to drought impacts on wood fuel are found in Appendix B.3.1.

Figure 14 summarises the built and natural asset data analysed in the energy sector in terms of their spatial distribution across the country, highlighting the highest-exposed assets and districts which are addressed through adaptation options proposed in Part 2 of this report.




**Power plants**

- Prioritised power plants exposed to flooding
- Prioritised power plants exposed to droughts
- Prioritised power plants exposed to flooding & droughts
- Other power plants
- HPP Hydropower plant
- PP Power plant (fossil fuel)

**Substations**

- Prioritised substations exposed to flooding
- Prioritised substations exposed to landslides
- Other substations

**Districts with high wood fuel demand**

- Prioritised districts exposed to droughts

**Exposure**

- Population affected (representing 100,000 people)
- Exposed to flooding
- Exposed to droughts
- Exposed to landslides

## Enabling environment

Key sectoral needs are identified across five indicators representing different stages of the infrastructure lifecycle, which have potential implications for Ghana's development goals and objectives.

### Infrastructure sector planning

The national policy and planning instruments in Ghana's energy sector and sub-sectors recognise climate change as an issue, and explicitly promote renewable energy as a central driver of climate mitigation action. However, they do not address the role of the energy sector in driving climate adaptation or identify goals, targets and actions required to manage climate risks for energy infrastructure and its users. Further, the Integrated Power System Master Plan for Ghana (IPSMP 2018–2030) includes adaptation strategies for the power sector informed by modelling of climate risks and future uncertainties but is not supported by implementation or investment plans. Interviews with sector stakeholders revealed that decision makers and technical staff in the relevant institutions often lack the resources to determine and quantify the economic benefits of implementing adaptation measures.

### Project pipeline and prioritisation

The energy sector is the leading recipient of climate finance inflows with allocation for energy sector projects amounting to 58 percent of the total climate funds committed over the next eight years. While these funds are earmarked for projects that are mitigation- rather than adaptation-focused, many co-benefits and interlinkages exist between these two sets of outcomes, enhancing the value for money of climate funding.

As per the energy sector's Medium-Term Development Plan (2018–2020), approximately 3 billion (USD) is allocated for projects that are primarily aimed at emission reduction but can also help achieve around half of the adaptation outputs identified in Ghana's Adaptation Strategy and Action Plan for the Infrastructure Sector. Renewable energy diversification, for example, remains the largest contributor to both mitigation and adaptation outcomes. However, informed investment decisions are hindered by the absence of a detailed investment plan that includes prioritised options linked to adaptation objectives. Further, despite the private sector's key role in resilient energy investment, the process and incentives for mobilising private sector finance are not in place. This is especially true in areas such as the implementation of mini-grids that can ensure the alleviation of energy poverty for remote and rural communities.

### Project preparation

During project preparation, climate risk assessments are not required for new energy sector projects. For large scale, donor-funded energy sector projects, such as power plants and dams, Environmental and Social Impact Assessments (ESIAs) are completed by consultants to comply with Environmental Assessment Regulations (1999) and donor requirements, but do not always incorporate future risks and uncertainties. For example, the ESIAs for the recently planned Bui and Pwalugu dam projects utilised historic data on rainfall, hydrology and temperature, but not projections of future climate conditions and hazards to inform the design. This can increase the flood risk to downstream communities, potentially impacting their future energy supply, agricultural productivity and public safety if dam construction does not account for potential high levels of rainfall.

For small-scale government-funded projects, such as the electrification of rural communities, ESIAs and climate risk assessments are not completed due to limited funds for external consultants and lack of access to climate risk data and technical capacity to complete in-house assessments. This exacerbates the vulnerability of project beneficiaries in rural communities.[6] When climate risk assessments and risk mitigation plans are not completed prior to the commencement of construction, climate risks are locked-in for decades due to the long life of assets.

### Design

While various international standards are used to design new, large-scale energy infrastructure, such as dams, these are not enforceable in the country and are often not relevant to Ghana's local context. The Ghana Standards Authority (GSA) led the development and adoption of national standards for the energy sector, such as those on street lights, solar modules, batteries, inverters, solar lanterns and liquid biofuel. There is a need to strengthen their capacity to develop and/or adopt climate-resilient and locally relevant national standards.[7] Ghana's Adaptation Strategy and Action Plan for the Infrastructure Sector (2020) promotes off-grid alternate sources as a key adaptation measure that can benefit disconnected and rural communities. However, their actualisation remains a challenge as the standards for mini-grid development in Ghana are yet to be adopted.[7]

### Operation and maintenance

Finance for scheduled maintenance of existing plants is recovered from customer tariffs through a common fund system. The challenge lies in ensuring the collection of tariffs is sufficient to meet costs for retrofitting, rehabilitation and expansion of existing power generation and transmission assets.

Due to limited funds and no requirement to do so, the impacts of extreme events related to flooding and precipitation are not incorporated in planned retrofits of energy assets. For example, while the Volta River Authority (VRA) commissioned a study to develop a retrofitting plan for the Tapco thermal plant in order to extend its design life, there is no funding allocated in the VRA's budget for implementing the plan. As increased precipitation and flooding are expected to affect the Takoradi area in which the power plant is located, not integrating risk reduction strategies in the retrofitting plan can affect the overall generation capacity.

In Ghana, communities that are sparsely populated or have populations below 500 are served with Solar Home Systems (SHSs) under a national scheme to ensure electricity access to remote areas that are not connected to the national grid. While Ghana's Adaptation Strategy and Action Plan for the Infrastructure Sector (2020) promotes the use of roof-top solar systems as a key adaptation measure, the lack of technical know-how about basic maintenance of solar technology and unavailability of components at the village level for replacement of dysfunctional components results in poor maintenance and breakdown of the installed SHSs.

The Ghana energy sector enabling environment needs are summarised in Figure 15.

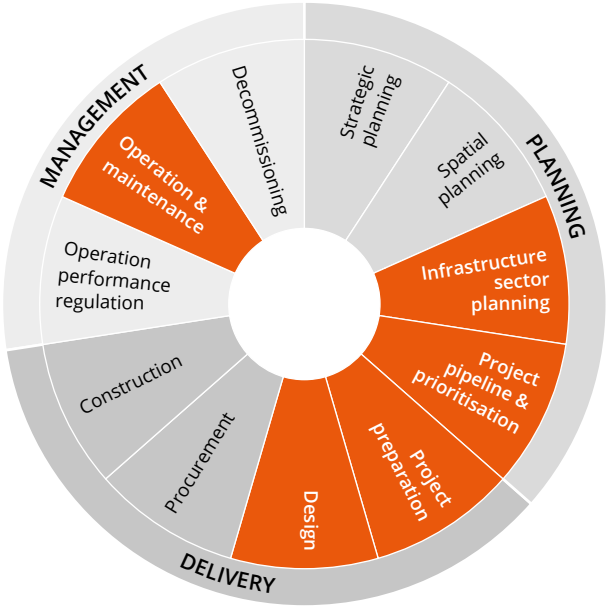



**Figure 15:**
*Energy sector needs in the enabling environment.*

| Adaptation needs – energy sector | Gender-related needs | NDC thematic area addressed | Potential SDG impacts |
|---|---|---|---|
| **Infrastructure sector planning**<br>• Adaptation targets, implementation plan & investment plan<br>• Capacity development for decision makers | • Gender-differentiated vulnerability not represented | #4 Resilience for gender & vulnerable<br>#5 Mobilising investment<br>#7 Monitoring, report & verification | 1 NO POVERTY<br>5 GENDER EQUALITY<br>7 AFFORDABLE AND CLEAN ENERGY<br>9 INDUSTRY, INNOVATION AND INFRASTRUCTURE<br>10 REDUCED INEQUALITIES<br>11 SUSTAINABLE CITIES AND COMMUNITIES<br>13 CLIMATE ACTION<br>16 PEACE, JUSTICE AND STRONG INSTITUTIONS<br>SUSTAINABLE DEVELOPMENT GOALS |
| **Project pipeline & prioritisation**<br>• Mainstreaming adaptation in project pipeline<br>• Incentives for private sector investment | • Gender-blind budgeting<br>• Delayed release of funds | #4 Resilience for gender & vulnerable<br>#5 Mobilising investment | |
| **Project preparation**<br>• Integrating climate risk assessment in ESIAs for projects of all scales<br>• Enforcement of ESIAs | | #4 Resilience for gender & vulnerable<br>#6 Technology & capacity development | |
| **Design**<br>• Climate-resilient national standards for large-scale infrastructure & renewables | • Under-representation of women engineers | #1 Climate-resilient infrastructure<br>#4 Resilience for gender & vulnerable | |
| **Operations & maintenance**<br>• Finance earmarked for retrofitting with climate risk assessment<br>• Maintenance procedures for renewable systems | | #4 Resilience for gender & vulnerable<br>#6 Technology & capacity development | |

# CLIMATE ADAPTATION NEEDS: WATER

**Water supply is expected to be affected both by acute climate-related hazards (causing damage to water supply assets and networks due to short term shocks) and chronic climate change impacts (reducing future abstraction capacity from rivers and other water sources due to gradual reduced river runoff).**

Furthermore, the lack of reliably piped water in many areas leaves many communities vulnerable to shocks. Both floods and droughts have a detrimental impact on the ability of Ghana's dams to supply water. In addition to its destructive power, floods increase siltation, which reduces storage and discharge capacity as well as the dam's ability to attenuate future flood waters. Droughts reduce water levels, leading to underutilisation of treatment plants.

Water supply infrastructure consists, both, of the larger scale dams and distribution networks, but also individual bore wells at local level, especially in rural settings. This analysis focused on data provided by the TWG regarding the country's *34 major dams*. However, around 12 percent of the population also abstract water from rivers for drinking water supply: in rural savannah areas, up to 26 percent of the population is estimated to obtain water in this way. This analysis therefore also addressed the exposure of *natural surface water abstraction* to the impacts of climate hazards. These hazards may also impact groundwater resources, irrigation potential, and water quality, although these impacts could not be quantified in this analysis. Furthermore, gaps in the enabling environment related to water *sector planning, project pipeline and prioritisation, design, and operation and maintenance* were addressed, as well as the gender and inclusivity impacts of these gaps.

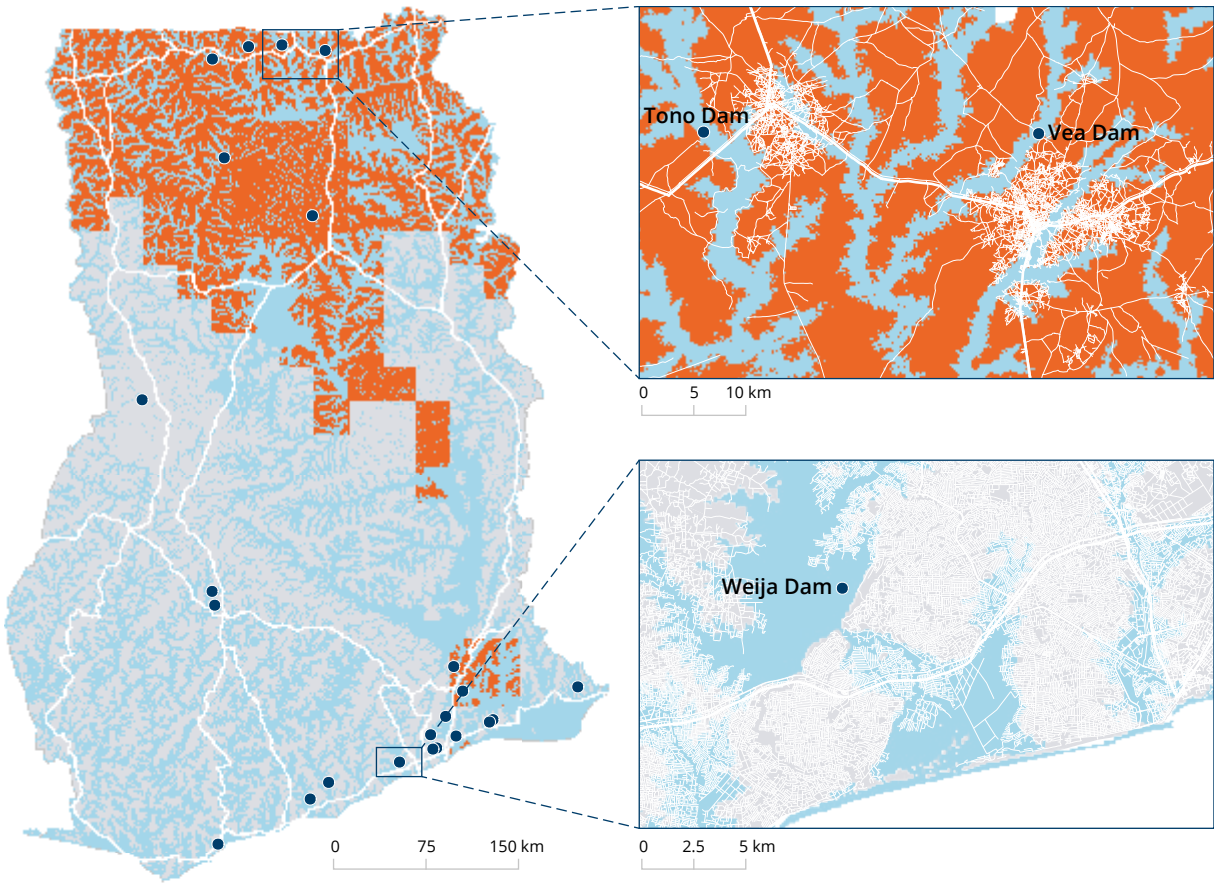



**Figure 16:**
*Inset shows the intersection of selected water supply assets and their hazard exposure: Tono and Vea dams (top); Weija dam (bottom).*

### Gender and inclusivity considerations in the water sector

Disruptions to water infrastructure have a significant impact on women, children, the disabled, people in remote or indigenous communities, and other vulnerable groups. For example, reductions in water supply create an unequal burden borne largely by women as they fulfil duties related to farming or household care.

In Ghana, gender mainstreaming projects in the water sector are planned and implemented with donor funding, limiting their long-term sustainability, with priority placed on other long-term needs within the water sector. While there is a WASH sector guideline and toolkit for gender mainstreaming, resource constraints and lack of prioritisation of gender-related activities hinder its implementation. Water sector budgeting is found not to account for different roles, responsibilities, capabilities, and needs faced by women and girls. The IWRM Action Plan does not identify expected gender outputs to be delivered and their respective budgetary allocations place women at a higher risk of vulnerability in sourcing water due to fewer financial resources targeting household water provision.

## Built environment

Figure 17 provides a summary of Ghana's **dam** assets that were identified as most at-risk to potential *flood* and *drought* hazards. This risk profile was developed using a **high hazard scenario for 2050**, which is used to identify assets potentially impacted by the *highest likelihood flood* events and the *highest hazard drought intensity*, according to NADMO. Given that the impacts of water supply disruptions to major dams are not always specific to surrounding districts, hazard impacts are not localised. Exposed dams were thus ranked and prioritised based on the total dam capacity.

The Akosombo dam (148 billion $m^3$ capacity) is once again the most exposed asset to drought hazards according to the selected prioritisation criteria, although it focuses on electricity generation rather than water supply. The Bui dam, also on the Volta with a capacity of 12.6 billion $m^3$, is the country's most exposed to flood hazards. In the Upper East region, the Tono (3.8 billion $m^3$) and the Vea (816 million $m^3$) dams are both drought- and flood-exposed, with large implications for agricultural irrigation in addition to local water supply. Along the Densu river, the Weija dam, serving the capital Accra, faces flood exposure affecting its 115 million $m^3$ capacity. The Barekese dam (90 million $m^3$), while not exposed to flooding under a high hazard scenario, is exposed under a medium scenario; given this and its key role in serving Ghana's second-largest city of Kumasi, concern has been raised about the deterioration of its reservoir. A full list of Ghana's dams, and their climate hazard exposure, are found in Appendix B.3.2.

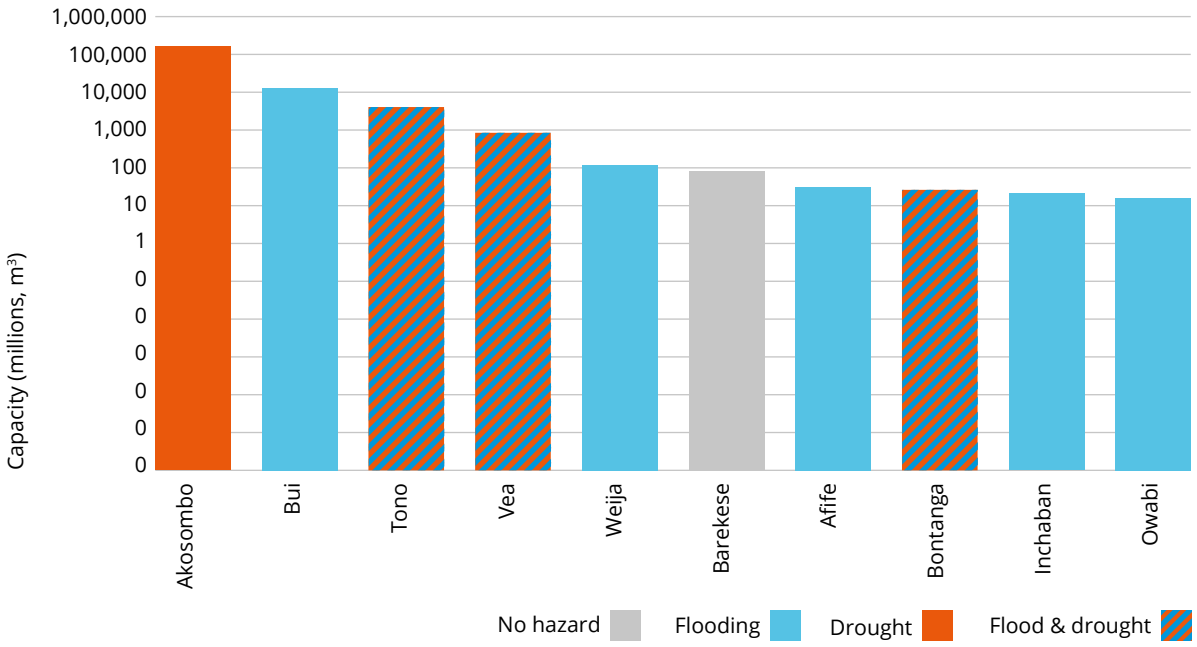



**Figure 17:**
*Dams exposed to flood and drought hazards under a high 2050 scenario, ranked by dam capacity (y-axis). Note: capacity shown in log scale.*

## Natural environment

Catchment systems provide important water-related services in Ghana, by directly providing freshwater resources to communities (e.g. rivers, streams, ponds), and indirectly through the regulation of water quality and flows for piped water supplies. For both drinking and non-drinking uses, rural areas are much more reliant upon this direct water extraction from natural resources than urban areas, with particular impacts on women who are often tasked with household water collection in these areas.

Figure 18 provides a summary of Ghana's districts where populations utilise and rely on surface water supplies that are most susceptible to future river runoff changes. The analysis classified districts seeing runoff reductions of 3 percent or greater as a potential risk. Districts are ranked and prioritised as a function of three features: the *population utilising surface water* in the district, *population vulnerability* in the district, and the *anticipated river runoff change*. Several districts in the Savannah, Northern, Eastern, and Volta regions are particularly vulnerable, including:

- **Kpandai**: Large reduction, population impacted 115,283, vulnerability 0.79;
- **Ho Municipal**: Large reduction, population impacted 56,946, vulnerability 0.48;
- **Krachi East**: Large reduction, population impacted 39,102, vulnerability 0.86;
- **Kwahu Affram Plains North**: Large reduction, population impacted 29,245, vulnerability 0.69;
- **East Gonja**: Large reduction, population impacted 27,722, vulnerability 0.87.

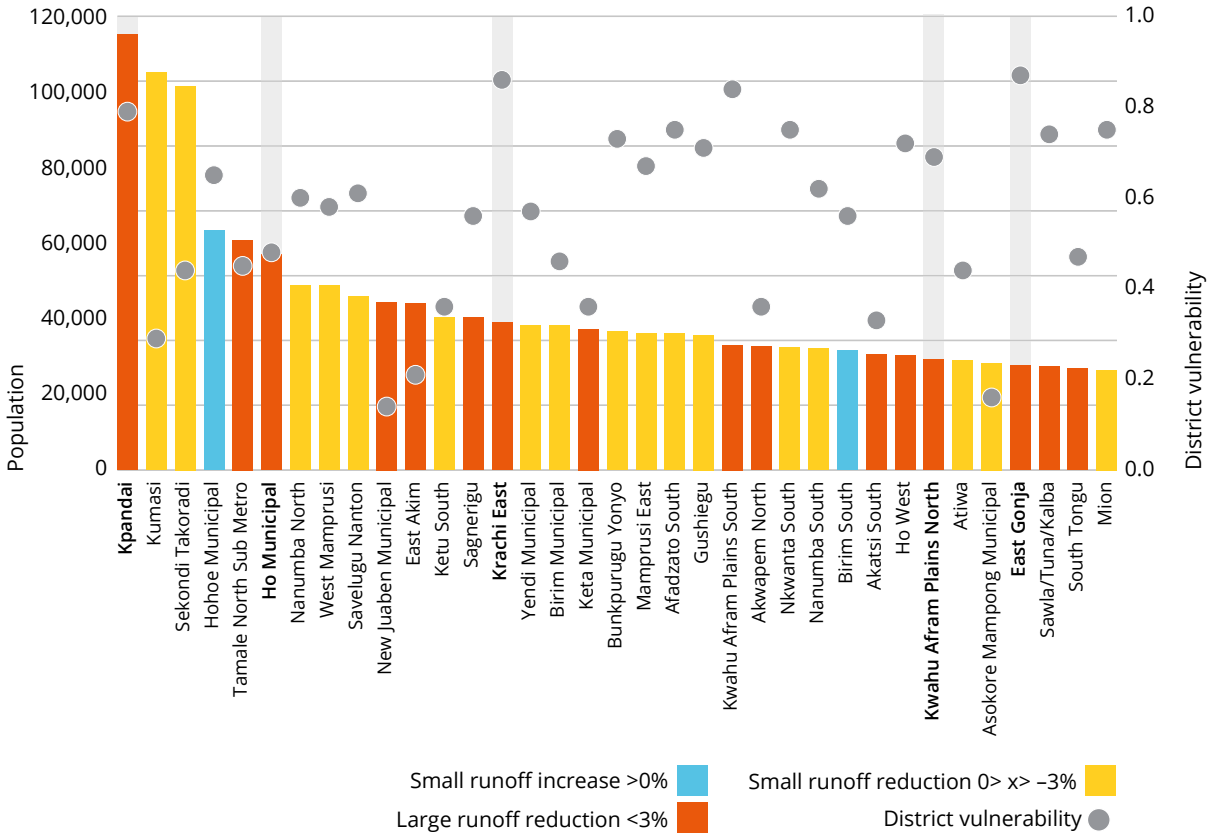



**Figure 18:**
*Districts most exposed to river runoff reductions, population impacted (left y-axis), and community susceptibility to hazard impacts (right y-axis). Note: the top five exposed districts, accounting for all three of these factors, are highlighted in bold.*

Nationally, reduced river runoff may affect districts with a combined population of 1.3 million reliant on river abstraction as a primary water source. A full list of Ghana's districts vulnerable to drought impacts on surface water abstraction are found in Appendix B.3.2, along with a more detailed derivation of the prioritisation measure.

Figure 19 summarises the built and natural asset data analysed in the water supply sector in terms of their spatial distribution across the country, highlighting the highest-exposed assets and districts which are addressed through adaptation options proposed in Part 2 of this report.

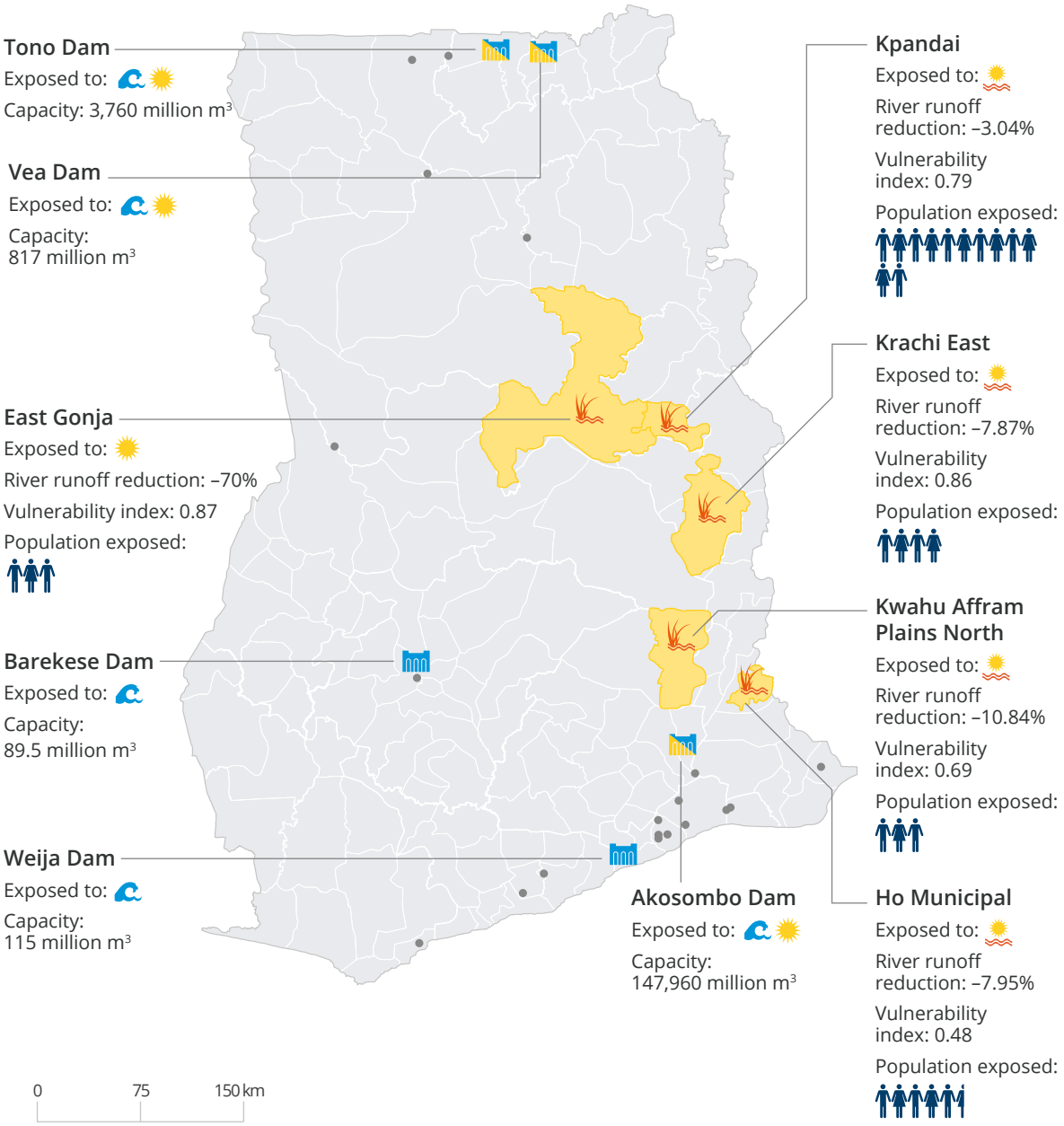



**Figure 19:**
*Built and natural asset data analysed for Ghana's water sector. The locations of all analysed assets are shown, with more information provided on the top five prioritised natural and built assets, including the hazard and population exposed.*

## Enabling environment

Key sectoral needs were identified across four indicators representing different stages of the infrastructure lifecycle, which have potential implications for Ghana's development goals and objectives.

### Infrastructure sector planning

Water sector projects are often planned in isolation instead of adopting a **holistic integrated water resource management (IWRM) approach** and are not informed by climate adaptation measures. This leads to a reactive approach wherein temporary measures are adopted to respond to hazards, with little consideration of linkages between flood control and water resource management mechanisms in managing long-term risks. The interlinkages between flood control and water resource management mechanisms in the reduction of risks from extreme weather events are not leveraged during the planning process. Flood and drought early warning systems are also not well-developed to ensure timely response. Further, the role of natural infrastructure and nature-based solutions (NbS) are not considered and incorporated in the planning process.

### Project pipeline and prioritisation

Flood protection activities have the highest funding allocation within the Ghana Infrastructure Plan with an earmarked budget of approximately 42.7 billion USD for implementing drainage, flood control and coastal protection measures. However, medium-term priorities are focused on the implementation of water resource management measures with only 76.25 million USD allocated in planned programmes until 2025. Failures in flood protection infrastructure can have compounding effects on water resource security. Excessive flooding, for example, results in contamination of existing water resources and places pressure on the structural integrity of dams to control these floods. The absence of a detailed investment plan that promotes an integrated water resource management approach and includes prioritised options across flood and water resource management, as well as nature-based solutions, limits the ability of decision-makers to make climate risk-informed investment decisions.

### Design

Inadequate technical capacity and **guidance for incorporating nature-based solutions or climate change considerations into the design process** limit their use in the implementation of flood risk management measures. Flooding events are occurring more frequently in Ghana due in part to existing ageing drainage infrastructure which is not suited to current needs or recognises the impact of a changing climate, inadequate structural design and challenges around governance roles and coordination. There is a focus on grey infrastructure for flood risk management, and the role of NbS is not well understood and therefore not well-leveraged.

There is a lack of institutional capacity, particularly with regard to formalised processes, standards, guidance, technical expertise, and understanding of NbS. This was highlighted by stakeholders from various water sector institutions during the interviews (Ghana Meteorological Agency, Ghana Water Company, Hydrological Services, Ghana Water Company Limited). Currently, staff across the sector agencies approach the design of water control infrastructure from a traditional perspective focusing on grey infrastructure solutions and use standards that do not reflect changing climate considerations or incorporate nature-based solutions.

### Operation and maintenance

More proactive asset management measures are needed to improve the efficacy of the water and drainage system. Competing priorities between new builds and retrofitting or maintaining infrastructure are exacerbated by an already strained fiscus. Although the Water Sector Medium Term Development Plan (SMTDP): 2018–2021 outlines the immediate climatic risks to water infrastructure, budgetary constraints have hindered the incorporation of resilience or much needed maintenance measures for existing water and flood protection infrastructure. Although the immediate climatic risks to water infrastructure are known,[8] maintenance is mostly reactionary with upgrades to restore structural integrity or the collection of debris and waste which is creating blockages and exacerbating flooding.

Within the Greater Accra region, limited routine maintenance leads to siltation and clogging of drainage pipes and culverts, which exacerbate flooding during rainfall events.[9] The structural integrity of dams is compromised under sustained pressure from extreme weather events. The Weija dam is one such example where this dual effect of ineffective asset management and climate change impacts is apparent. Cracks in the dam combined with heavy rains result in the risk of structural failure. The Weija dam supplies water to about 80 percent of Accra's population, thus failure of the dam would have devastating effects to the development gains accrued in water provision in the Greater Accra Region.

The Ghana water sector enabling environment needs are summarised in Figure 20.

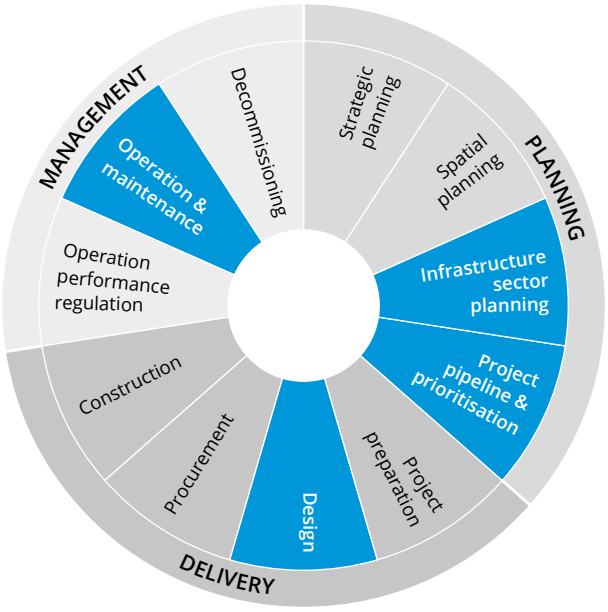



**Figure 20:**
*Water sector needs in the enabling environment*

| Adaptation needs – water sector | Gender-related needs | NDC thematic area addressed | Potential SDG impacts |
|---|---|---|---|
| **Infrastructure sector planning**<br>• Adaptation targets, prioritisation of long-term goals into sector plans<br>• Uniform climate data and models to inform plans | | #1 & #2 Climate resilient infrastructure<br>#3 Water resources | |
| **Project pipeline & prioritisation**<br>• Aligning adaptation activities in project pipeline | • Gender-blind budgeting<br>• Delayed release of funds | #1 & #2 Climate resilient infrastructure<br>#3 Water resources<br>#4 Resilience for gender & vulnerable | |
| **Design**<br>• Climate-resilient national standards for grey and green infrastructure systems<br>• Technical capacity in implementing nature-based solutions | | #1 & #2 Climate resilient infrastructure<br>#3 Water resources<br>#6 Technology & capacity development | |
| **Operations & maintenance**<br>• Finance earmarked for maintenance with climate risk assessment<br>• Assessment management systems integrated with early warning systems for flood prevention and a water management | | #1 & #2 Climate resilient infrastructure<br>#3 Water resources | |

# CLIMATE ADAPTATION NEEDS: TRANSPORT

**Ghana's transport sector connects the country's cities, communities, and infrastructure users, providing physical access to basic services (such as health care) and economic opportunities, as well as international links for passengers and cargo.**

The analysis of this sector included asset data provided by the TWG in relation to roads (137,000 kilometres), airports (7), and ports (18, with focus on 16 inland river ports), which can be seriously impacted by flood, drought, and landslide events. It also includes natural infrastructure assets such as inland waterways. The analysis also focuses on gaps in the enabling environment related to transport sector strategy, design, and operation and maintenance, including gender and inclusivity impacts.

### Gender impacts in the transport sector

The transport sector is male-dominated with only 22 percent of the workforce in the Ministry of Transport and its agencies being female. This gender imbalance perpetuates inconsistencies in the use of gender-disaggregated data in the planning and development of transport systems.

Further, the deterioration of paths due to climate change has a greater impact on vulnerable groups such as women and the disabled in terms of their access to economic, social, or political empowerment. In rural areas, 82.4 percent of women commuted to work on foot everyday in 2013, compared to only 66.1 percent of men. In addition, over 500 thousand women in Ghana live too remotely to access health services via the road network or must travel more than 100 kilometres to access health services. Therefore, women are disproportionately affected by increased precipitation, coastal winds and variability of extreme events that hinder pedestrian mobility. The Medium-Term Expenditure Framework (MTEF, 2016–2018) for the sector does not allocate a budget line for gender mainstreaming activities, and therefore, transport sector budgeting is found to be gender-blind. It is important for transport sector and sub-sector plans and budgets to address gender-differentiated travel patterns and vulnerabilities to ensure continuity of service and access to health, educational and economic opportunities for women and children.

## Built environment

Damage to roads caused by climate hazards threatens access to basic social services within the country, such as access to health service centres. Accessibility can be measured in terms of the distance and time it takes for a population concentrated at a location to travel to the nearest health service centre – such as a hospital, clinic, or community-based health planning service – based on the least time of travel along the road network.

Figure 21 provides a summary of the exposure of Ghana's **roads** to flooding using a **high hazard scenario for 2050**, which represents the *highest likelihood of flood events*, according to NADMO. Districts exposed to road flooding were ranked and prioritised as a function of three features: the *population that may lose access to healthcare services* in a future flood event, *population vulnerability* in the district, and the *anticipated flood hazard*. Most-exposed districts include:

- **Accra**: population impacted 588,527, vulnerability 0.19;
- **Kumasi**: population impacted 545,259, vulnerability 0.29;
- **Sekondi-Takorad**i: population impacted 432,837, vulnerability 0.44;
- **Ga South**: population impacted 220,318, vulnerability 0.43;
- **Krachi East**: population impacted 98,208, vulnerability 0.86.

A full list of Ghana's districts vulnerable to flood impacts on access to health care are found in Appendix B.3.3, along with a more detailed derivation of the prioritisation measure.

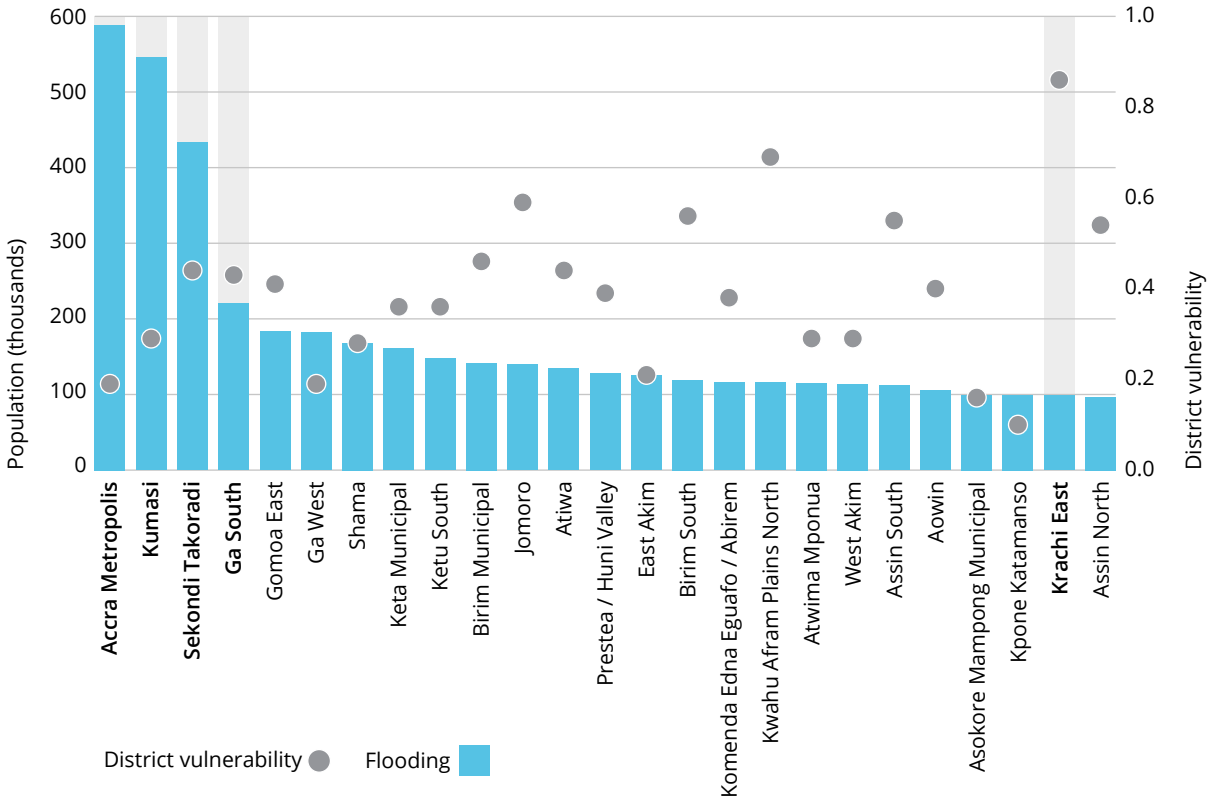



**Figure 21:**
*Districts exposed to flood hazards on roads under a high 2050 scenario, ranked as a function of potential population loss of access to healthcare services (left y-axis) and district vulnerability (right y-axis). Note: the top five exposed districts, accounting for all three of these factors (exposure, population at risk, vulnerability), are highlighted in bold.*

Road flooding in Ghana can cause large damages, and resulting economic costs. Under the **high hazard scenario for 2050**, several districts in the Northern and Western parts of Ghana, as well as Greater Accra, are expected to have hundreds of kilometres of flooded roads (Figure 22a). Using assumptions on rehabilitation costs linked to road types, pavement conditions, and lanes, estimated damages can be calculated, amounting to up to 3.9 billion USD in damages on a national scale in a likely future flooding scenario. Figure 22b shows these estimated damages for roads within Ghana's districts. The largest were seen in the Accra Metropolis district within the Greater Accra region, where the estimated damage losses exceeded US 130 million USD. Losses are also high in the Northern and Western parts of the country. Adaptation needs are therefore high in these regions. More detailed derivation of these results can be found in Appendix B.2.3.

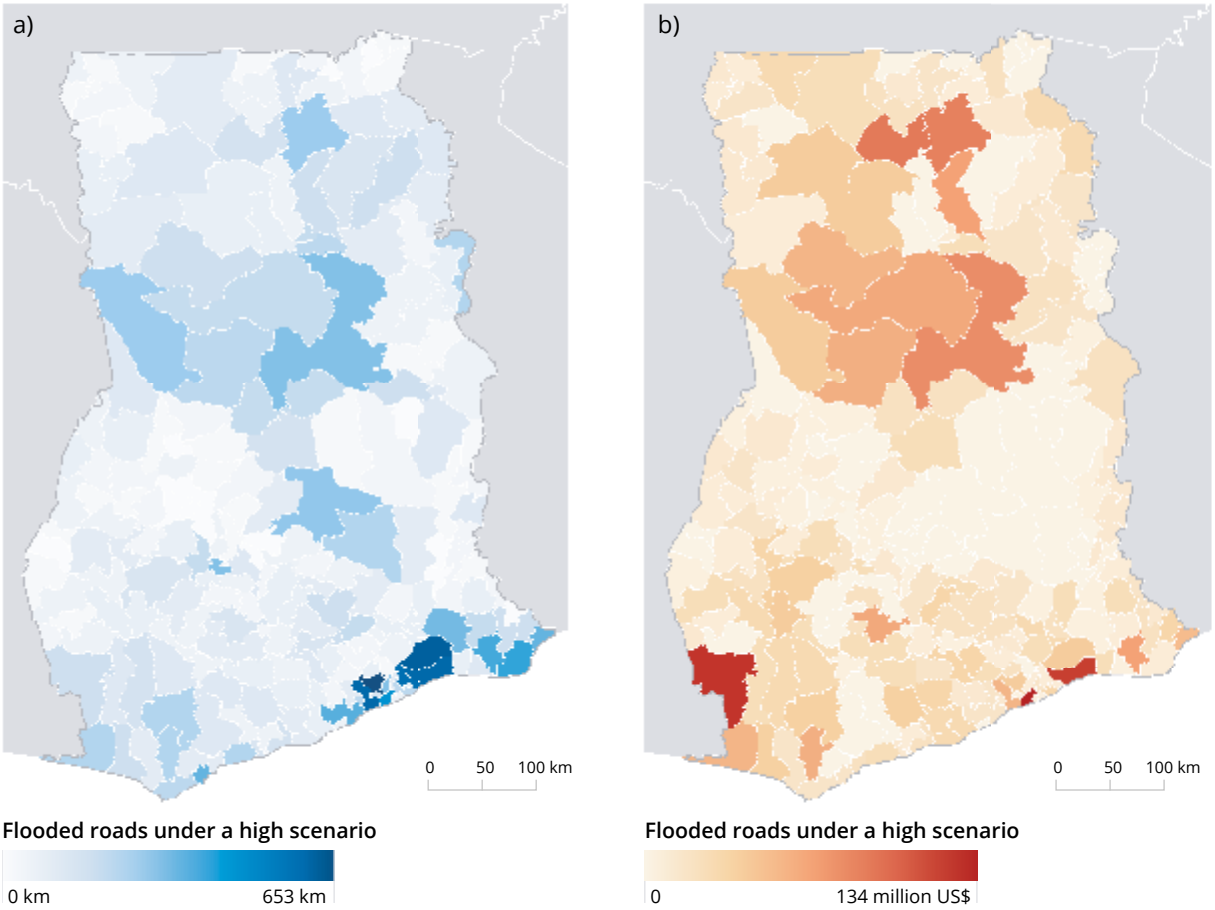



**Figure 22:**
*(a) Estimated kilometres of roads flooded within districts of Ghana when exposed to a high flood hazard scenario for 2050; (b) Estimated damage losses in USD (millions) at the district level in Ghana for roads exposed to a high flood hazard scenario for 2050.*

In addition to its impact on economic outcomes, flood damage to roads is likely to have differentiated consequences by gender – for example, in restricting the mobility of women and their ability to access health services related to pregnancy and family planning, or additional care responsibilities. Accounting for varying modes of transport (women travel more often using footpaths), changes in women's accessibility of health care within a flood scenario can be analysed. Figure 23 illustrates the potential impact by district: in several districts in the Eastern, Central and Western parts of the country, the percent of women cut off from health care access due to road flooding in a most-likely high flood hazard for 2050 may be over 80 percent. More detailed derivation of these results can be found in Appendix B.2.3.

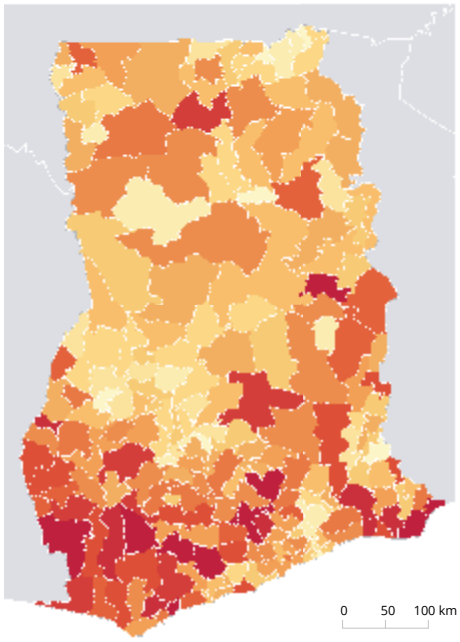



**Figure 23:**
*District-level estimation of the percentage of women with no access to health services following road damages and disruptions due to a most likely flood hazard scenario.*

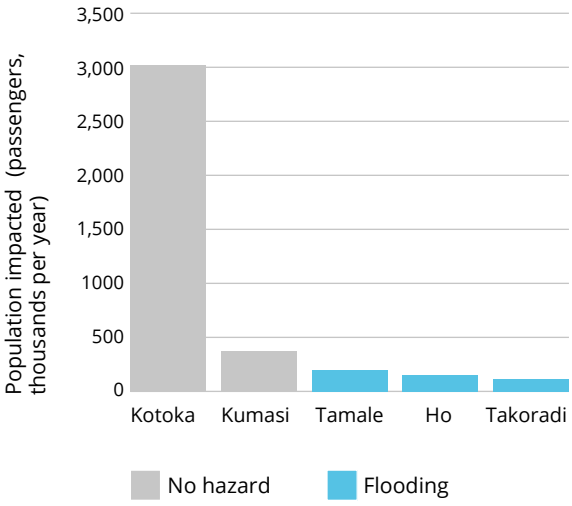



**Figure 24:**
*Airports exposed to flood hazards under a high 2050 scenario, ranked by passenger trips (y-axis).*

Figure 24 summarises **airport** assets identified as most at-risk to potential *flooding* in Ghana. This risk profile used a **high hazard scenario for 2050**, developed to identify assets potentially impacted by the *highest likelihood flood* events, according to NADMO. Airports were ranked and prioritised based on **passenger trips**. Airports with greatest exposure were those in Tamale, Ho, and Takoradi, with a combined 460 thousand annual passenger trips. A full list of Ghana's airports, and their climate hazard exposure, are found in Appendix B.3.3. Due to data limitations, this analysis was largely constrained to airports with international connections.

## Natural environment

Inland water transport systems provide passenger and cargo transportation services to local communities. The main means of inland water transport is the Volta Lake, which has a total surface area of 8,502 km$^2$ and stretches 450 kilometres from north to south. Communities within the Volta basin are engaged mainly in fishing and farming. Given that many of these communities are isolated due to inadequate road linkages, the lake serves as a primary means of transportation for these communities, including transferring their farm produce. Resilience of the Volta Lake is therefore critical to safeguard and the socio-economic development of the area.

Both floods and reduced river runoff can significantly impact the transportation services in the Volta Lake. Flooding can expose all major inland ports in the lake as well as the nine associated ferry connections, significantly hampering the transportation of up to 500 thousand tonnes of cargo and over 4 million passengers each year due to overtopped ports and strong currents that make transportation more difficult. In addition to flooding, reduced river runoff, especially in combination with periodic drops in the level of the lake, exposes navigation hazards like tree stumps and sand banks that greatly reduce the ability to navigate along the lake. To continue to ensure socio-economic development in these regions, it is thus imperative to adapt inland water transport systems to hazards of flooding, low water levels, and reduced river runoff.

Figure 25 summarises Ghana's **port** assets identified as most at-risk to potential flood and drought hazards. This risk profile was developed using a **high hazard scenario for 2050**, which was used to identify assets potentially impacted by the *highest likelihood flood* events and the *highest hazard drought intensity*, according to NADMO. Ports are ranked and prioritised based on **passenger trips**.

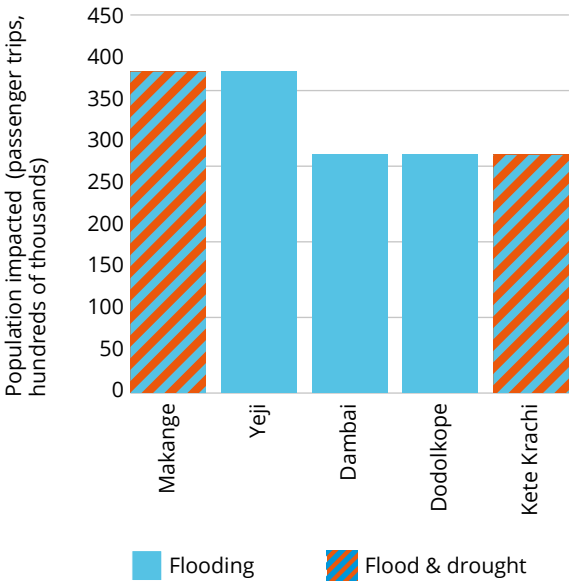
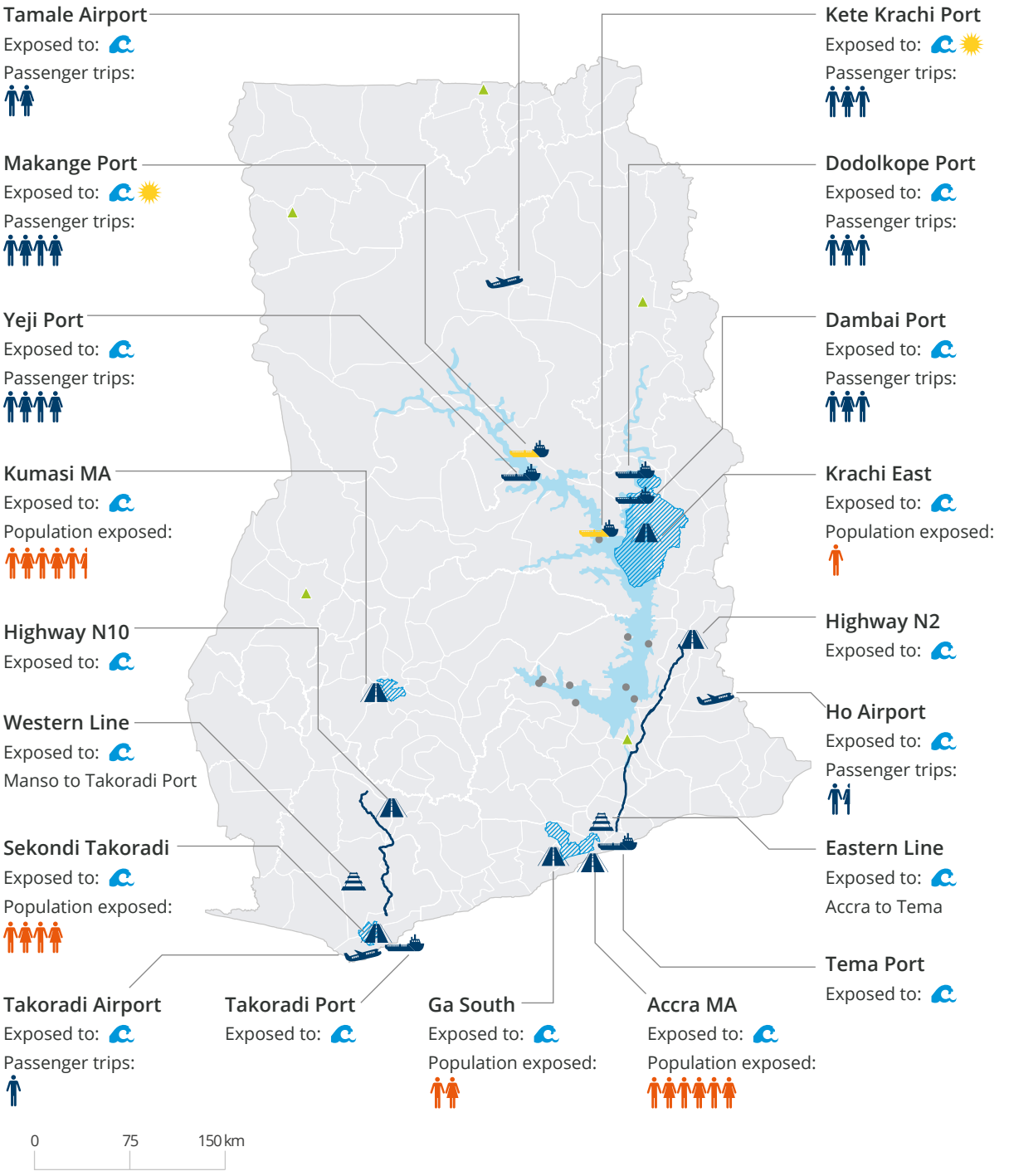



**Figure 25:**
*Ports exposed to flood and drought hazards under a high 2050 scenario, ranked by passenger trips (y-axis).*

Inland ports with greatest exposure were those at Makange, Yeji, Dambai, Dodolkope, and Kete Krachi, with a combined 1.8 million annual passenger trips. A full list of Ghana's ports, and their climate hazard exposure, are found in Appendix B.3.3.

Figure 26 summarises the built and natural asset data analysed in the transport sector in terms of their spatial distribution across the country, highlighting the highest-exposed assets and districts which are addressed through adaptation options proposed in Part 2 of this report. Proposed railway lines, though not prioritised in this study, are highlighted where flood risks are high.




**Railway lines**
- Prioritised railways exposed to flooding

**Ports**
- Prioritised ports exposed to flooding
- Prioritised ports exposed to flooding and droughts
- Other ports

**Airports**
- Prioritised airports exposed to flooding
- Other airports

**Districts with high exposure of the road network**
- Prioritised districts exposed to flooding

**Highways**
- Prioritised highways exposed to flooding

**Exposure**
- Exposed to flooding
- Exposed to droughts
- Population that could lose access to healthcare services (representing 100,000 people)
- Passenger trips (representing 100,000 trips)

**Figure 26 (page 50):**
*Built and natural asset data analysed for Ghana's transport sector. The locations of all analysed assets are shown (with non-prioritised roads removed), with more information provided on the top five prioritised natural and built assets, including the hazard and population exposed.*

## Enabling environment

Key sectoral needs are identified across three indicators representing different stages of the infrastructure lifecycle, which have potential implications for Ghana's development goals and objectives.

### Infrastructure sector planning

Ghana lacks a strong **integrated planning framework** for mainstreaming adaptation and resilience in the transport sector. While the National Transport Policy (2021)[10] provides goals and direction for mainstreaming climate mitigation measures in the sector, it does not contain adaptation measures. The sector's long- and medium-term plans do not account for the impacts of climate change on roads and rail construction, including maintenance procedures and costs. They promote strategies, targets and budget for mitigation measures, but not for enhancing resilience.

### Design

Inadequate **procedures, guidance and training for integrating climate risk** into feasibility studies and designs inhibits the mainstreaming of climate adaptation in the design and review process of transport infrastructure. Technical capacity of engineers, technical staff and environmental safeguard officers in transport agencies needs to be strengthened to better incorporate climate risk data into the design process. The Road Design Guide (1991) is outdated and needs to be updated to include aspects of climate resilience to ensure long asset lifespan. The Ghana Infrastructure Conference in 2020 convened practitioners from Ghana and abroad to deliberate the revision of road design standards. If the revision does not take into account the management of future climate risks and uncertainties, this could impede transport of exports, food distribution to rural areas, access to livelihoods, and overall economic growth and development.

### Operation and maintenance

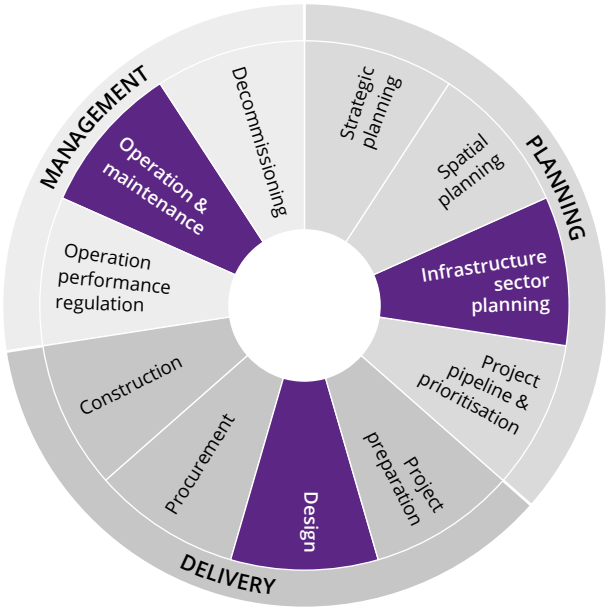
A key challenge for the roads sector in Ghana is inadequate **funds for road maintenance and emergency repairs**. Consequently, in 2018, annual targets for routine and periodic maintenance were met for trunk roads, but not for urban (28 percent) and feeder (55 percent) roads.[11] Increases in precipitation, flooding and temperature can increase the rate of surface deterioration, which adds to the cost of road maintenance. High intensity rainfall and flooding lead to roads being washed away, and emergency funds available for repairs remain limited.

For example, following the devastating floods in 2015, in the absence of contingency funds, the Government of Ghana had to secure funding of USD 6.4 million for emergency repairs of drainage systems, buildings, and roads in Accra from an ongoing World Bank-funded project, causing that project to be negatively affected. If no adaptation measures are implemented, it has been estimated that Ghana will need to spend USD 473 million to maintain and repair the cumulative damages caused to its road infrastructure due to climate change from 2020 to 2100.[12] The delays in obtaining financing for repairs results in further deterioration of assets and greater operational and management costs in the long run, in addition to costs associated with increased disruptions to transport services, economic activities, transportation of goods and access to livelihoods.

The procedures for carrying out **asset management and periodic asset condition assessments** to identify deteriorating assets are not climate risk-informed or coordinated across Ghana's districts and road transport agencies (GHA, DUR and DFR).[12] For example, the GIS-based system used by DFR for road asset management does not use information on the vulnerability of assets to climate change impacts to identify or prioritise assets for maintenance, retrofitting or upgrade.[13] With almost 70 percent of roads unpaved,[14] the majority of the existing network remains vulnerable to the effects of extreme climate conditions. This results in frequent flooding and greater rates of deterioration which require high levels of maintenance and associated costs.

The Ghana transport sector enabling environment needs are summarised in Figure 27.

**Figure 27:**
*Transport sector needs in the enabling environment.*




| Adaptation needs – transport sector | Gender-related needs | NDC thematic area addressed | Potential SDG impacts |
|---|---|---|---|
| **Infrastructure sector planning**<br>• Institutional framework for coordinating adaptation across sub-sectors<br>• Framework for mainstreaming adaptation measures & targets in sector & sub-sector plans | • Under-representation of women in public institutions<br>• Gender-blind plans and expenditure framework | #4 Resilience for gender & vulnerable<br>#5 Mobilising investment<br>#7 Monitoring, report & verification | |
| **Project pipeline & prioritisation**<br>• Climate-resilient national standards for roads<br>• Technical capacity to integrate climate risk considerations | | #1 Climate resilient infrastructure<br>#4 Resilience for gender & vulnerable<br>#6 Technology & capacity development | |
| **Design**<br>• Climate-risk informed asset management<br>• Financing for maintenance & emergency repairs | | #1 & #2 Climate resilient infrastructure | |

# ENABLING ENVIRONMENT CROSS-SECTORAL INFRASTRUCTURE NEEDS

## Strategic planning

> Across sectors, technical experts and engineers **lack access to the climate risk data** needed for long-term, evidence-based, risk-informed planning, delivery and management of infrastructure, which has implications for policymakers and investors.

The dissemination of climate risk and vulnerability data and information is not carried out effectively to sub-national government institutions in order to inform risk-informed implementation and management. This includes socially- (including gender) disaggregated data that can enhance the understanding of climate change impacts and vulnerabilities on different groups, along with data on natural infrastructure. Inadequate collection, management and sharing of climate-risk data limits the ability of sector institutions to achieve evidence-based, risk-informed infrastructure planning, delivery and management.

## Spatial planning

The Ghana National Spatial Development Framework makes provision for the protection of natural infrastructure such as green areas, water systems, ecological networks and wildlife corridors. However, inadequate resources and procedures for the **enforcement of land use plans and regulations** lead to widespread encroachment on protected land, non-compliance and loss of protected and environmentally sensitive areas, which leads to greater risks of flooding and asset damage across sectors. The land falling under protected areas is sometimes sold without approval from planning institutions, leading to illegal encroachment. While there are processes in place through which developers get Development and Building Permits, compliance remains a challenge due to a lack of resources.

Few developers and landowners lack adequate knowledge in the process of acquiring a development and building permit. In a case of non-compliance, building inspectors can issue warnings to land developers of the unlawfulness of their project and issue a stop work notice. However, the lack of logistics and resources hinders the LUSPA from monitoring and ensuring the efficiency of land use planning and management in all the Districts.

## Project preparation and prioritisation

In all sectors, **climate risk assessments at the project preparation stage** are not carried out to inform infrastructure decision making to improve adaptation. There is a need to establish a process for sector ministries to ensure that climate risk assessments are completed when making infrastructure investment decisions so that long-term environmental risks to assets are understood. Although some project prioritisation in the country is already informed by cost benefit analysis at the planning stage, these assessments are driven by short-term cost considerations and not by long-term adaptation benefits. Further, natural infrastructure and nature-based solutions are not prioritised in the project pipelines of the three sectors and therefore, investments in NbS are not made even though they can have long-term positive impacts.

# PART 2: GHANA'S RESILIENT INFRASTRUCTURE ROADMAP

*Photo: Accra Urban Transport Project - Pokuase Interchange) funded by AfDB, 28 June 2021*

# ADDRESSING PRIORITISED INFRASTRUCTURE ADAPTATION NEEDS THROUGH A RESILIENT INFRASTRUCTURE ROADMAP

**Part 1 of this study provided a detailed quantification of national adaptation needs in the energy, water and transport sectors. Using this information, as well as other contextual factors, adaptation experts from the TWG collaboratively prioritised 35 adaptation needs that are considered essential for Ghana's national development.**

Leveraging further data and tools from the project partners, the stakeholders then designed a selection of nationally appropriate investment and policy solutions to meet these needs – thereby creating the resilient infrastructure roadmap. The following subsections of this report provide: (i) a description of the priority needs; (ii) an overview of the chosen roadmap projects that respond to needs; and (iii) a presentation of 35 project concept notes that convey the salient points of each of the roadmap projects and act as a communication tool to discuss the projects with potential sources of financing.

## Identification of priority adaptation needs

Through a process of consultation with MESTI and the TWG, it was decided that the Government of Ghana would select 35 priority needs within the energy, water and transportation sectors, or a combination of them. This number was selected based on the need to choose a 'manageable' number of projects that together make up a national portfolio of adaptation options. In addition to coverage across multiple sectors and subsectors, the needs were also selected to ensure an appropriate distribution across: hazard types; geographic areas in Ghana; the rural/urban divide; service impact types; vulnerability distribution among service users; and for the enabling environment, different aspects of the infrastructure lifecycle.

To ensure that the roadmap is government-led, priority needs were identified by the TWG and additional experts from across various ministries within the Government of Ghana. The prioritisation was evidence-based: informed by the national adaptation needs assessment that is presented in Part 1 of this report. More specifically, through interactive workshops and a 5-month consultation process, the TWG explored and discussed the evidence provided, both sectorally and cross-sectorally, to identify priorities for intervention. The prioritisation was further informed by contextual opportunities and constraints, such as the political or social importance of different assets and locations, and the potential to feed into existing or planned policy revision processes. This helps to ensure that the adaptation options proposed to address the prioritised needs are contextually appropriate and synergistic to national development objectives.

Table 1 provides a description of the priority areas of need that were identified by the TWG. Key information is provided for each priority need, including: the sector and subsector to which it belongs; the the name of asset/s or areas where the specific need manifests; and a justification for the need. For the built and natural environment, the justification of need is expressed in terms of the hazard exposure, the impacts of that exposure on infrastructure services and the vulnerability of the communities who rely on that service. For the enabling environment, the justification of need is expressed in terms of its impacts on the SDGs, Paris Agreement and gender equality objectives.

**Table 1: Description of prioritised adaptation needs**

| Sector & sub-sector | Asset/s or areas | Justification for prioritised adaptation need |
|---|---|---|
| **Energy**<br>Power plant – hydroelectric | Akosombo dam | **Hazard: Drought**<br>Reduced river flow and reservoir capacity reduces generation capacity.<br>**Other considerations:**<br>• Ghana's largest hydroelectric electricity generation asset, providing energy supply for 8.6 million people<br>• Low water levels in the reservoir have reduced generation capacity and caused severe electricity rationing |
| **Energy**<br>Power plant – hydroelectric | Bui dam | **Hazard: Flooding**<br>Increases sedimentation and reduces reservoir capacity, causing physical damage to assets and increasing risk of downstream floods.<br>**Other considerations:**<br>• Ghana's second-largest hydroelectricity generation asset, providing energy supply for over 1.7 million people<br>• Flood hazard impacts on wildlife and biodiversity in Bui National park |

| Sector & sub-sector | Asset/s or areas | Justification for prioritised adaptation need |
|---|---|---|
| **Energy**<br>Power plants – thermal | Western region (Aboadze) | **Hazard: Flooding**<br>Five thermal power plants serving over 900 thousand people (including the Takoradi PPs) are at risk of coastal flooding.<br>**Other considerations:**<br>• Energy sector stakeholders identified this a as high priority for adaptation because of recent flooding of these facilities |
| **Energy**<br>Power plants – thermal | Sunon-Asogli power plant | **Hazard: Flooding**<br>Most significant thermal power plant vulnerable to river flooding, serving 4.2 million people.<br>**Other considerations:**<br>• In addition to river flooding, it is also at risk of coastal flooding due to sea level rise |
| **Energy**<br>Substations | Key substations in Ga South and West, Hoehoe, Bibiani/Anhwiaso/ Bekwal, and others | **Hazards: Flooding and landslides**<br>• Up to 6.9 million people in Ghana vulnerable to electricity disruptions caused by flood and landslide impacts on 23 substations under a high hazard scenario, including nearly two million people in the capital region (Ga South and West)<br>• Nearly a million people served by the Hohoe substation are exposed to multiple risks in the Volta region, which is also landslide-impacted and is located in a district with low adaptive capacity<br>• Substations in the Western and Western North regions are also highly exposed |
| **Energy**<br>Power plants – thermal and solar | All non-hydroelectric power plants, with priority to those in drought-affected regions | **Hazard: Drought**<br>Drought conditions causing depleted water resources can result in reduced plant efficiency and generation capacity.<br>**Other considerations:**<br>• Large water requirements for power plant cooling and removal of waste heat impact negatively on communities and ecosystems that rely on river runoff. |
| **Energy**<br>Wood fuel | Key districts in the Upper West, Savannah, and Bono regions | **Hazard: Drought**<br>The following districts: 1) face increased drought hazard; 2) rely heavily on wood fuel; and 3) are socio-economically vulnerable:<br>• Wa East: High hazard, 1.4 tonnes/person, vulnerability 0.93;<br>• Banda: Medium hazard, 1.1 tonnes/person, vulnerability 0.75;<br>• Sissala West: High hazard, 0.5 tonnes/person, vulnerability 0.87;<br>• Lawra: High hazard, 0.5 tonnes/person, vulnerability 0.8;<br>• Wa West: High hazard, 0.4 tonnes/person, vulnerability 0.89. |

| Sector & sub-sector | Asset/s or areas | Justification for prioritised adaptation need |
|---|---|---|
| **Energy**<br>Enabling environment | Capacity development and regulatory frameworks | • Lack of planning capacity and clear regulatory frameworks exacerbate the risks of flooding and droughts that can lead to energy insecurity that impact the resilience of remote and vulnerable communities.<br>• Implementation of climate adaptation options and achievement of climate resilient energy infrastructure systems is hindered by a centralised energy system with limited local capacity at the district level. |
| **Energy**<br>Enabling environment | Design standards | • Not incorporating climate risks into design standards exposes all assets to climate hazards.<br>• Use of international design standards in the absence of appropriate national and context-specific standards.<br>• May not be legally recognised and therefore, not enforceable in the country. |
| **Water**<br>Dam | Weija dam | **Hazard: Flooding**<br>Flood waters threaten the dam infrastructure and surrounding residential areas.<br>**Other considerations:**<br>• Supplies 80 percent of the potable water for the entire city of Accra and its surrounding areas, approximately one million urban residents of the capital city. |
| **Water**<br>Dam | Northern dams (Vea, Tono) | **Hazards: Flooding and drought**<br>Flooding threatens the integrity of dam components such as retaining walls, spillway, dam floor and embankments, causing damage to farmland and homes. Drought reduces potable water supply through reduced river flow and reservoir capacity.<br>**Other considerations:**<br>• Include the second- and third-most exposed dams to both flood and drought impacts in Ghana (Vea and Tono)<br>• Provide the main source of water for household use and agricultural irrigation in the Northern region, with up to 4.5 billion $m^3$ capacity |
| **Water**<br>Dam | Barekese dam | **Hazard: Flooding**<br>Increases fluvial sediment and reduces reservoir capacity, causing physical damage to assets and downstream floods.<br>**Other considerations:**<br>• Provides approximately 80 percent of the total public pipe-borne water to the Kumasi metropolis and its environs (Ghana's second largest city) |

| Sector & sub-sector | Asset/s or areas | Justification for prioritised adaptation need |
|---|---|---|
| **Water**<br>All urban assets | Accra plains | **Hazards: Flooding and drought**<br>Accra has high vulnerability to flooding due to topography, coastal erosion,torrential rainfall, as well as anthropogenic factors. Limited absorptive capacity reduces ability to retain water during the dry season.<br>**Other considerations:**<br>• Exposure of the capital city's infrastructure assets and nearly four million people to heavy traffic on roads, disruption to commercial activities, and loss of lives. |
| **Water**<br>Surface water, e.g. rivers | Key districts in the Savannah, Northern, Eastern, and Volta regions | **Hazards: Drought and reduced river runoff**<br>The following districts: 1) face large runoff reductions; 2) rely heavily on surface water abstraction for household use; and 3) are socio-economically vulnerable:<br>• Kpandai: Large reduction, population impacted 115,283, vulnerability 0.79;<br>• Ho Municipal: Large reduction, population impacted 56,946, vulnerability 0.48;<br>• Krachi East: Large reduction, population impacted 39,102, vulnerability 0.86;<br>• Kwahu Affram Plains North: High hazard, population impacted 29,245, vulnerability 0.69;<br>• East Gonja: High hazard, population impacted 27,722, vulnerability 0.87. |
| **Water**<br>Enabling environment | Planning alignment across ministries | • Lower effectiveness of adaptation measures to flooding and drought due to lack of alignment between institutional and planning alignment mechanisms, adaptation targets and criteria, and implementation and monitoring mechanisms. |
| **Water**<br>Enabling environment | Asset management | • Water infrastructure management that is reactionary, not proactive, increases both the risks to hazards as well as their impacts.<br>• There is no risk-informed asset management system for relevant government institutions. |
| **Transport**<br>Road, rail | Accra urban | **Hazard: Flood**<br>Inadequate urban drainage along roads and streets makes the city vulnerable to damage from pluvial and coastal flood hazards.<br>**Other considerations:**<br>• In Greater Accra, 22 percent of the road network is exposed to flood events with potential damage costs exceeding 130 million USD.<br>• Damage to roads can have other impacts on economic activity and access to livelihoods and services. |

| Sector & sub-sector | Asset/s or areas | Justification for prioritised adaptation need |
|---|---|---|
| **Transport**<br>Road, rail | Kumasi, Weija highways; Western and Eastern railway lines | **Hazard: Flooding**<br>Threatens damage to roads and interruption of transport services in Ghana.<br>**Other considerations:**<br>• Total damage to the road network due to floods may reach 3.9 billion USD by 2050.<br>• Disruption of vital commercial and economic activities which this infrastructure supports. |
| **Transport**<br>Port | Tema port | **Hazard: Flooding**<br>Coastal and river flooding affects the port facility and surrounding infrastructure.<br>**Other considerations:**<br>• The port is the largest in Ghana, averaging 1511 vessel calls per year. The port serves as a logistic point for inland clearance, container storage, freight forwarders, and related service centres. |
| **Transport**<br>Road | Major highways: N6 (all exposed to landslides ~15 km), N10 Mid-West (~ 60km), N2 South-East (~85km) | **Hazard: Landslides**<br>Landslide risks intensified by increased rain and flooding disrupt major transport routes, as well as causing destruction to buildings and communities.<br>**Other considerations:**<br>• Disruption of vital commercial and economic activities which these highway routes support. |
| **Transport**<br>Airport | Airports: Ho, Tamale, Takoradi | **Hazard: Flooding**<br>Many airports are located on areas of flat land, making them particularly vulnerable to flooding – in many cases, airports are located on reclaimed land such as marshlands, or near large bodies of water.<br>**Other considerations:**<br>• Disruption to commercial flights and economic activity across the country<br>• Loss of air transport sector revenue to government and private investors |
| **Transport**<br>Road, rail | Prioritised roads in Accra; planned railways; Adomi bridge | **Hazard: Flooding**<br>Cuts off key transport links, including in rural districts, which can limit local access to social and economic services (such as healthcare).<br>**Other considerations:**<br>• Disruption of vital commercial and economic activities which these transport links support. |

| Sector & sub-sector | Asset/s or areas | Justification for prioritised adaptation need |
|---|---|---|
| **Transport**<br>Airport, road | Takoradi airport and exposed roads | **Hazard: Flooding**<br>River flooding and coastal inundation which puts infrastructure assets at risk of damage.<br>**Other considerations:**<br>• Disruption of air and highway transport<br>• Loss of air and highway sector revenue to government and private investors. |
| **Transport**<br>Rail | Takoradi to Kojokrom section of the Western rail line; Accra to Tema section of the Eastern rail line; Freight railway operational lines are from Manso to Takoradi port | **Hazard: Flooding**<br>Construction of transport assets can be disrupted during the rainy season, when flooding is most likely.<br>**Other considerations:**<br>• Disruption in construction activities on transport assets could lead to extension of infrastructure project delivery timeline as well as the increase in the cost of project delivery, all of which impact on vital commercial and economic activities. |
| **Transport**<br>Enabling environment | Risk-informed, multi-modal transport master plan | • A lack of coordinated planning limits integration of climate adaptation into infrastructure design, construction, and operation, enhancing exposure to all hazards. |
| **Transport**<br>Enabling environment | Resilient design and construction | • Infrastructure design does not account for climate hazards, increasing the risks to assets from flooding, temperature rise, and others.<br>• Locally relevant design standards and materials including the use of NbS can help to maximise responsive to climate risks. |
| **Transport**<br>Enabling environment | Climate-risk informed asset management system and operations and maintenance practices for roads | • Increases in precipitation, flooding and temperature increase the rate of asset deterioration and, which should be factored into the maintenance system and its financing.<br>• Contingency plans will increase the adaptive capacity of the system by enabling more rapid and efficient response to climate change-induced events. |
| **Cross-sectoral**<br>Power plant – hydroelectric, dams, roads, river ports | Volta River reservoir | **Hazards: Flooding and drought**<br>Flooding increases fluvial sediment and reduces reservoir capacity; physical damage to assets including river ports; downstream floods.<br>Droughts affect river flow and reservoir capacity which reduce generation capacity.<br>**Other considerations:**<br>• Main river system in Ghana, providing a key water transport route through the country. It also includes a large reservoir and multiple dams generating hydroelectric power and water supply. |

| Sector & sub-sector | Asset/s or areas | Justification for prioritised adaptation need |
|---|---|---|
| **Cross-sectoral**<br>Roads, buildings, natural features | Accra/Takoradi urban areas | **Hazards: Flooding and drought**<br>Inadequate urban drainage along roads and streets increases vulnerability to damage from pluvial and coastal flood hazards. Drought causes decreased urban water supply. |
| **Cross-sectoral**<br>Enabling environment | Data management | • Lack of access to data, use of conflicting data, and uncoordinated and decentralised data storage and management results in climate risks not being factored into planning and design of infrastructure<br>• Sub-optimal data management practices increase the costs of storing and using data.<br>• Decentralised data management makes it hard to identify gaps that need filling or updating |
| **Cross-sectoral**<br>Enabling environment | Land management | • Difficulties in enforcing land use plans and regulation leads to non-compliance, and widespread encroachment and loss of protected land and deforestation, resulting in increased flood risk.<br>• Lack of climate-risk informed land-use planning can lead to future infrastructure site selection that exposes assets to high climate risks.<br>• Lack of enforcement of land use regulations and land tenure reform exposes environmentally sensitive areas to higher risks. |
| **Cross-sectoral**<br>Enabling environment | Climate risk assessment and EPA permitting process | • Climate risk assessments are not completed at the project preparation stage for all projects, increasing vulnerability to all hazards.<br>• EPA permits are not secured for all infrastructure projects, specifically small-scale projects, due to limited funds and resources, challenges with enforcement, lack of access to climate risk data and low technical capacity. |
| **Cross-sectoral**<br>Enabling environment | Gender mainstreaming | • Policy and planning instruments do not represent gender-differentiated vulnerabilities to climate change or provide measures to manage these risks. |
| **Cross-sectoral**<br>Enabling environment | Nature-based solutions | • Planning and design processes, standards, and guidance do not include climate adaptation considerations or promote NbS that can help Ghana combat risks to infrastructure assets and service delivery. |

## Development of a roadmap of projects

Following the identification of priority needs, the TWG and additional adaptation experts from the government identified contextually appropriate adaptation solutions to ensure that those needs can be addressed.

In addition to the exhaustive national adaptation needs assessment (Part 1), the government was provided with further key information relating to a large range of adaptation options that can be used in order to respond to prioritised needs (all options are detailed in Appendices C1 and C2).

This long-list of options was developed by the project partners through extensive review of the academic and grey literature. For each adaptation option, important information was provided, including their relative cost, implementation time, and benefits, expressed in terms of national development priorities related to the SDGs, the NDCs and gender outcomes.

Through a dedicated workshop and 5 month consultation process, the TWG reviewed all proposed adaptation options, to ensure that they were technically feasible and appropriate solutions for the national context in Ghana. Next, sectoral experts from the TWG, alongside adaptation experts from within the country and from the project partners then selected which type of adaptation solution should be assigned to address each of the priority needs.

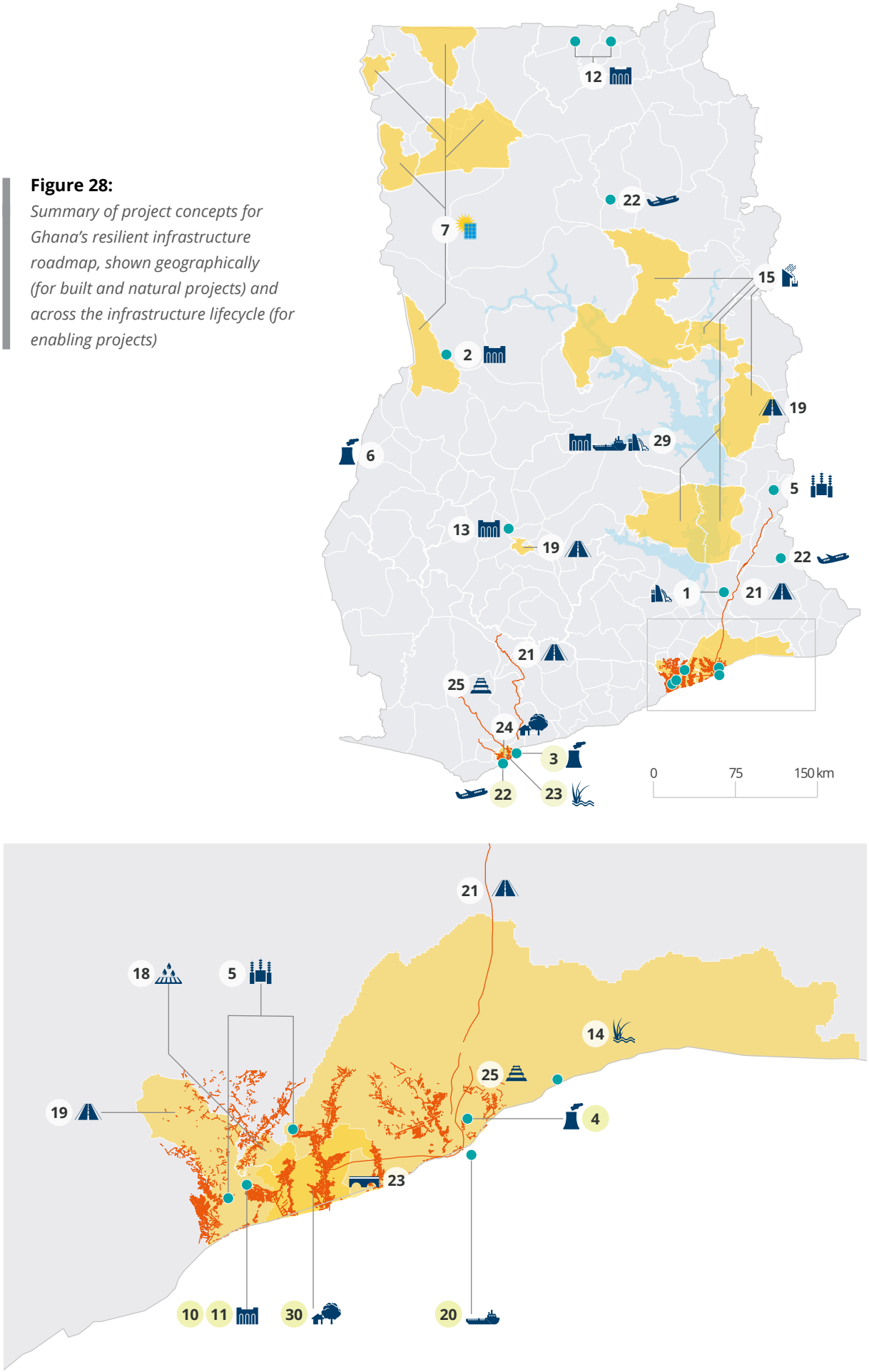
This process resulted in the selection of the 35 projects that make up the resilient infrastructure roadmap. Table 2 details the types of adaptation options selected for the roadmap, including novel adaptation approaches like NbS. For each type, a description is provided, alongside the number of them that are included in the roadmap.

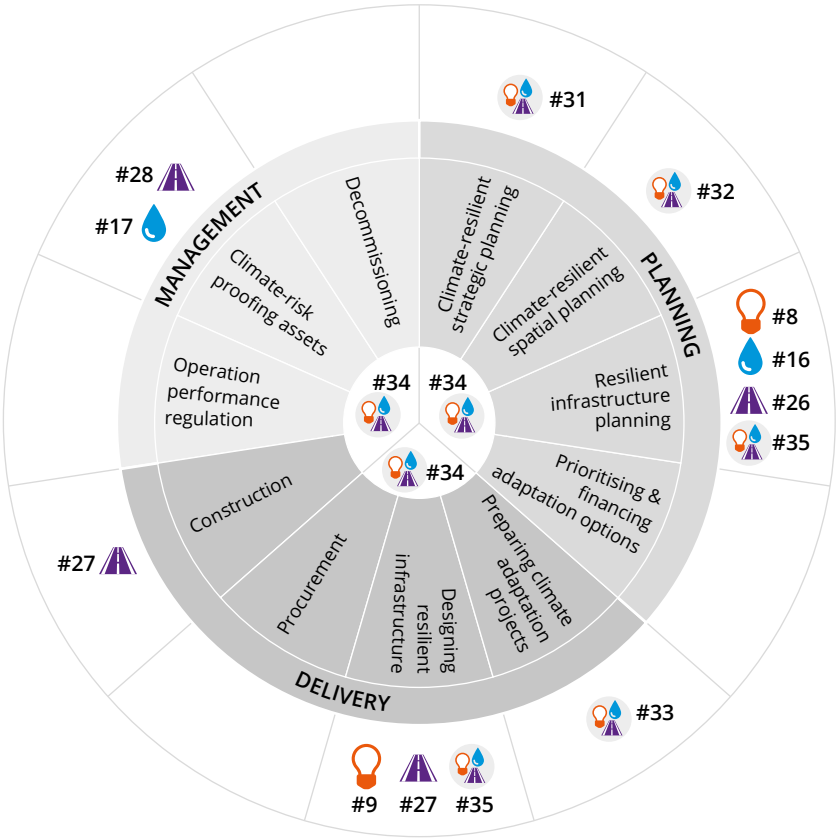
The 35 projects included in the roadmap are summarised here and detailed on the following pages as project concept notes (Figure 28). Projects focused primarily on the built and natural environments are shown geographically in terms of the location of key assets or districts affected. Enabling environment projects are shown in terms of their alignment with different stages of the infrastructure lifecycle.

**Table 2: Description of adaptation options proposed within the roadmap**

| Project type | | Description | Number of projects |
|---|---|---|---|
|  | **Traditional built environment projects** | These include investments in man made barriers, fortification, elevation, or relocation of assets, facility retrofits and upgrades, new structures, or the like. | **15** |
|  | **Nature-based solutions** | These focus on protecting, restoring, or enhancing natural infrastructure systems, such as coastal mangroves or reefs, around a particular asset. They also include catchment-level interventions (e.g. afforestation and river restoration) that reduce climate hazard risk more broadly around a watershed or geographical area, resulting in protection of a wider range of assets (i.e. an infrastructure system), including the natural infrastructure assets themselves. Nature-based solutions may have a wide range of social or economic co-benefits, which are described qualitatively throughout the project concepts. | **16** |
|  | **Urban resilience projects** | These are built, nature-based, or a combination of both, and target city-wide resilience to flooding, heat, or other climate hazards, with impacts across a range of urban assets including roads and buildings. | **5** |
|  | **Enabling environment** | These aim to build institutional and technical capacity that can support the successful planning and implementation of built and natural infrastructure projects, and may have broader impacts across all sectors. | **13** |
|  | **Gender and inclusivity projects** | All projects in this roadmap have considerations around gender and inclusivity of other vulnerable groups, which should be mainstreamed at all stages of the infrastructure lifecycle. | **35** |

**Figure 28:**
*Summary of project concepts for Ghana's resilient infrastructure roadmap, shown geographically (for built and natural projects) and across the infrastructure lifecycle (for enabling projects)*






**Legend**

- Cross-sectoral
- Energy
- Water
- Transport
- Nature-based solution
- Built infrastructure
- Urban protection
- Catchment scale
- Enabling environment

| | |
|---|---|
| 1 | Retrofitting adaptation measures in the Akosombo Dam |
| 2 | Natural flood adaptation of Bui dam |
| 3 | Coastal flood defence of thermal power plants in the Western region |
| 4 | Coastal flood protection of the Sunon-Asogli power plant |
| 5 | Safeguarding vulnerable substations against floods and landslides |
| 6 | Resilient cooling systems for thermal and solar plants |
| 7 | Resilient and green energy access in drought-prone districts |
| 8 | Capacity development and regulatory frameworks to support local renewable energy generation to enhance resilience of remote, vulnerable communities |
| 9 | Update energy sector design standards to incorporate climate adaptation risk |
| 10 | Natural flood adaptation of the Weija Dam through greening and vegetation along the Densu River |
| 11 | Flood resilience improvements to the Weija dam through release scheduling and spillway improvements |
| 12 | Natural restoration around Tono and Vea dams |

| | |
|---|---|
| 13 | Slope stabilisation, forestation, and terracing at Barekese dam |
| 14 | Catchment-level water management in the Accra plains |
| 15 | Water supply resilience through regional harvesting and storage solutions |
| 16 | Climate adaptation alignment across water ministries and planning mechanisms to ensure integrated water resource management |
| 17 | Proactive risk-informed asset management |
| 18 | Urban drainage measures in Accra |
| 19 | Green recreative areas and riparian vegetation to protect exposed road and rail between urban centres |
| 20 | Built and natural coastal defence options for Tema Port |
| 21 | Natural and built slope stabilisation measures along major highways |
| 22 | Airport flood resilience through elevation of runways and other vulnerable components |
| 23 | Bridges and underpasses to ensure community access to services |
| 24 | Nature-based adaptation through creation of intertidal habitat at Takoradi |
| 25 | Temporary barriers to protect railway lines during construction |
| 26 | Risk-informed, multi-modal transport master plan and investment plan |
| 27 | Supporting resilient design and construction of roads through research, capacity building, and the creation of a design manual |
| 28 | Climate-risk informed asset management system and operations and maintenance practices for roads |
| 29 | Upstream afforestation of the Volta River reservoir to build resilience to flood and drought |
| 30 | Sponge City measures to provide ecosystem-based urban adaptation to climate change |
| 31 | Centralised climate-risk data management system |
| 32 | Risk-resilient land management system |
| 33 | Mainstream resilience through climate risk assessments and EPA permitting process and strengthen enforcement for all infrastructure projects |
| 34 | Gender mainstreaming in adaptation planning, implementation and management |
| 35 | Prioritise nature-based solutions in planning, design and operation of infrastructure |

## Project concept notes for the resilient infrastructure roadmap

For each of the 35 priority adaptation investments and policies contained within the roadmap, a project concept note has been developed. The project concepts have been designed to communicate each infrastructure adaptation project's alignment with common requirements of potential financiers. Figure 29 highlights ten criteria typically used to assess concept stage projects and the extent to which each is used by infrastructure financing sources available to Ghana. These criteria informed selection of the roadmap projects and information displayed in the project concepts. Definitions of these criteria can be found in the Sustainable Infrastructure Financing Tool (SIFT) (Part 3), which will be handed over to the government as a part of this project.

Each adaptation option in the roadmap is described using a one-page concept note to communicate key information that will be critical to developing and implementing the projects in Ghana. Beyond the details of each project, these concept notes contain key pieces of information typically required by potential financiers, on topics such as climate resilience, social benefits, gender considerations, SDG alignment, and NDC alignment, among others (Table 3).

**Figure 29:**
*Inclusion of key financing criteria in funding available to Ghana.*

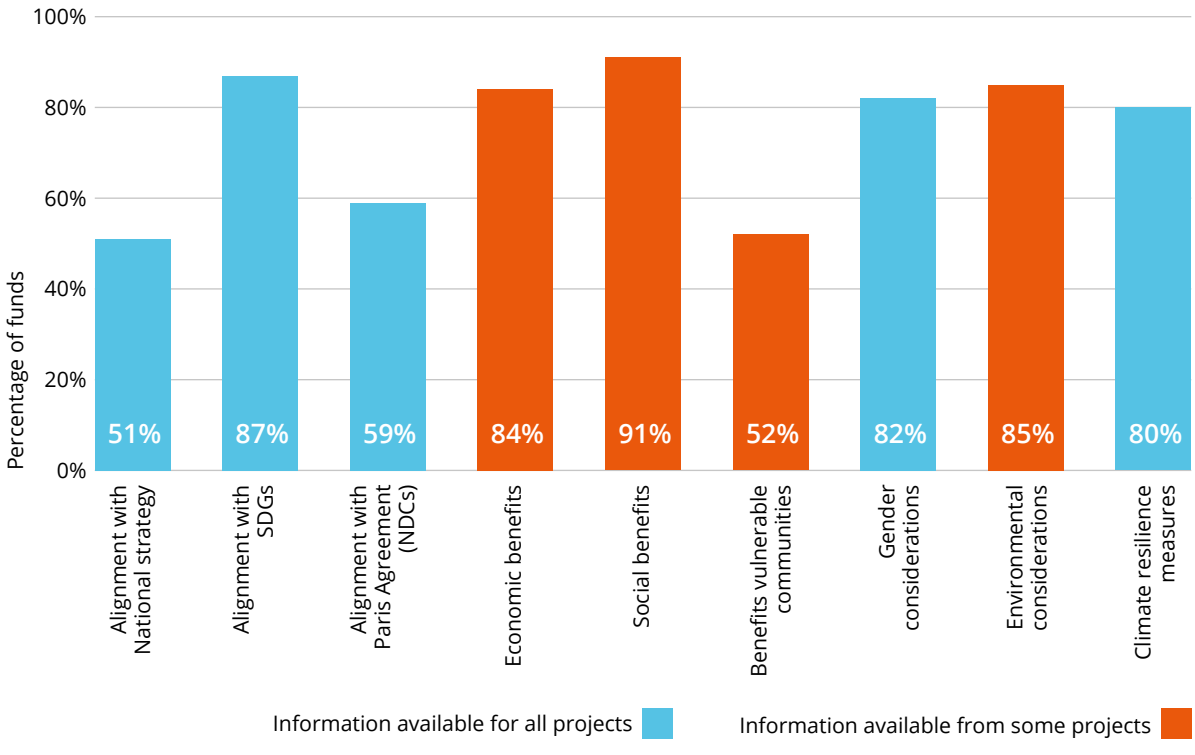


**Table 3: Project concept information for 35 adaptation options**

| Component | Explanation | Criteria captured |
|---|---|---|
| General project information | Description of the project requirements, components, and geographical or institutional scope<br>Adaptation need(s) and/or enabling environment gap(s) that the project is addressing, identified in the enabling institutional environment<br>Key assets, climate hazards, impacts to assets and services, and institutions | Alignment with national strategy, climate resilience measures |
| Potential financing sources | Indicative of potential sources of finance for each adaptation option | N/A |
| Cost and time estimates | **Capital/upfront costs**<br>• Low: Partial/no physical upgrades, little need for grading, materials, and construction<br>• Moderate: Substantive physical upgrades with grading, materials, and construction possible but lower costs than new or specialised facility construction<br>• High: Substantive physical upgrades with grading, materials, and construction costs. New and specialised facility costs<br>**Operational costs**<br>• Low: Little to no cost of ongoing monitoring, maintenance, and reporting in the near-term barring catastrophic failure<br>• Medium: Some monitoring, maintenance, and reporting costs expected<br>• High: High monitoring, maintenance, and reporting costs expected<br>**Implementation time**<br>• Low: Options that can be mobilised on an emergency basis (i.e. days), or implemented in up to 1 year<br>• Medium: Options that can be implemented in 2 to 5 years<br>• High: Options that can be implemented in over 5 years | N/A |
| Expected outputs and impacts | Projected improvements or co-benefits across asset function or institutional structures | Economic, social, environmental, vulnerable communities |
| Development benefits of adaptation | *Potential* distribution of impacts across key targets of the 17 Sustainable Development Goals | Alignment with SDGs |
| Expected NDCs impacts and mitigation co-benefits | Potential distribution of impacts across Ghana's NDC thematic areas (see Appendix B.5), and mitigation co-benefits | Alignment with Paris Agreement (NDCs) |
| Gender considerations | Project impacts for gender equality and ways of mainstreaming this in the project lifecycle | Gender considerations |
| Enabling or built and natural environment supporting actions | The enabling environment projects that support the success of built and natural adaptation projects; or the built and natural adaptation projects that are particularly relevant to the implementation of enabling environment options | N/A |

# ENERGY SECTOR

# 1. RETROFITTING ADAPTATION MEASURES IN THE AKOSOMBO DAM

The Akosombo dam, Ghana's largest hydroelectric generation asset, is located in the Volta River, South East of Ghana. The catchment area is exposed to drought under medium and high climate hazard scenarios by 2050, putting energy supply for over 8.6 million people at risk. In addition, fluvial sediment transport along the river reduces the dam's effectiveness in storage capacity, making it more vulnerable to droughts and affecting reliable generation of hydroelectricity.

## Adaptation investment recommendations

- Sediment management to retain dam capacity and function during drought
- Greening and tree planning around the river bank and catchment area to reduce sedimentation
- Enhance reservoir capacity through desilting and dredging

## Expected outputs and impacts

- Flood protection and reduced sediment flow, ensuring continued hydroelectric potential of the dam and increased absorption capacity of soil to reduce flood runoff
- Improvements in water quality, especially in response to pollutants from agricultural runoff
- Reduced costs of dam maintenance
- Biodiversity co-benefits resulting from increased forestation

## Gender considerations

- Women's participation should be incorporated in training, skills, and capacity building to mitigate flood risks, as well as in construction, operation, and maintenance of the dam asset as part of the appropriate committees.

## Enabling environment supporting actions

- Update energy sector design standards to incorporate climate adaptation risk ( #9)
- Climate adaptation alignment across water ministries and planning mechanisms ( #16)
- Mainstream resilience through climate risk assessments and EPA permitting process ( #33)

## Potential SDG targets influenced

4.1, 8.2, 9.1, 9.4, 11.1, 11.2, 11.5, 11.b, 11.c, 12.1, 13.1, 13.2, 13.3

Photo: René Mayorga on Flickr

**Option type:**

**Climate hazard:**

Reduced river flow and reservoir capacity reduces generation capacity

**Impacts of hazard on asset and services:**

- Energy supply for over 8.6 million people at risk
- Estimated asset damage repair cost of 3.5 billion USD

**Institutions:**

- Lead: Ministry of Energy
- Others: Ghana Water Company, Water Resources Commission

**Potential financing sources:**

- Existing project
- Climate grants
- Development banks
- Community-led

**NDC thematic areas and impacts:**

- #3: Integrated water resources management

**Mitigation co-benefits:**

- Scaled up renewable generation
- Energy efficiency improvements in power plants

**Capital / upfront costs**

**Operational costs**

**Implementation time**

**Key to symbols**

| | |
|---|---|
| Built | Drought |
| Natural | Landslide |
| Enabling | Flooding |

# 2. NATURAL FLOOD ADAPTATION OF BUI DAM

The Bui dam is Ghana's second-largest hydroelectric facility after the Akosombo dam. The Bui dam has a generation capacity of 400MW, provides electricity to over 1.7 million people and is highly vulnerable to flooding under a high climate hazard scenario by 2050. The project is located in the Black Volta River, at the southern end of Bui National Park and resulted in the flooding of a large part of the park, as well as the resettlement of several communities.

## Adaptation investment recommendations

- Flood protection mechanisms around the Bui dam through greening and tree planting along the reservoir and riverbanks, while allowing the river to flood its natural floodplain

## Expected outputs and impacts

- Flood protection and reduced sediment flow, ensuring continued hydroelectric potential of the dam and increased absorption capacity of soil to reduce flood runoff
- Improvements in water quality, especially in response to pollutants from agricultural runoff.
- Reduced costs of dam maintenance
- Biodiversity co-benefits resulting from increased forestation

## Gender considerations

- Reduced risk to women and vulnerable groups in informal downstream settlements
- Women should be represented in community leadership, participation and guardianship of natural flood management solutions

## Enabling environment supporting actions

- Update energy sector design standards to incorporate climate adaptation risk (#9)
- Climate adaptation alignment across water ministries and planning mechanisms (#16)
- Risk-resilient land management system (#34)

## Potential SDG targets influenced

1.4, 1.5, 2.1, 2.3, 2.4, 2.5, 3.3, 3.4, 3.8, 3.9, 4.7, 6.1, 6.2, 6.3, 6.4, 6.6, 7.1, 7.2, 9.1, 11.1, 11.4, 11.5, 11.6, 11.7, 11.b, 11.c, 12.1, 12.2, 12.3, 13.1., 13.2, 13.3, 15.1-15.5

Photo: NewsAfrica.com

**Option type:**

**Climate hazard:**

Increases sedimentation and reduces reservoir capacity, causing physical damage to assets and increasing risk of downstream floods.

**Impacts of hazard on asset and services:**

- Energy supply for over 1.7 million people at risk
- Estimated asset damage repair cost of 1.4 billion USD
- Loss of wildlife and biodiversity in Bui National Park

**Institutions:**

- Lead: Ministry of Energy
- Others: Ghana Water Company, Water Resources Commission

**Potential financing sources**

- Existing project
- Climate grants
- Development banks
- Community-led

**NDC thematic areas and impacts**

- #3: Integrated water resources management

**Mitigation co-benefits:**

- Scaled up renewable generation
- Energy efficiency improvements in power plants
- Sustainable utilisation of forest resources

**Capital / upfront costs**

**Operational costs**

**Implementation time**

# 3. COASTAL FLOOD DEFENCE OF THERMAL POWER PLANTS IN THE WESTERN REGION

Five thermal power plants concentrated at Aboadze in the Western region, are found to be among the highest exposed power plants to flood risk in the country.

## Adaptation investment recommendations

- Construction of a seawall barrier to safeguard operations, in addition to adjacent infrastructure assets and systems
- Natural buffers such as a reef or beach nourishment can also be implemented where feasible along the coastline to build long-term resilience and reduce future maintenance costs.

## Expected outputs and impacts

- Reduced exposure and flood protection to key power stations in the Western region
- As a barrier or buffer option it can also protect adjacent infrastructure assets and networks in the localised area – including buildings and housing

## Gender considerations

- Women's participation and voice should be reflected across the project lifecycle, including procurement, construction, operation, and maintenance of the asset.

## Enabling environment supporting actions

- Update energy sector design standards to incorporate climate adaptation risk s (Option #9)
- Centralised climate-risk data management system (Option #31)
- Mainstream resilience through climate risk assessments and EPA permitting process (Option #33)

## Potential SDG targets influenced

1.5, 4.a, 7.b, 8.2, 9.1, 9.4, 11.1, 11.2, 11.5, 11.b, 11.c, 12.1, 12.3, 12.4, 13.1, 13.2, 13.3

**Option type:**

**Climate hazard:**

Regular flooding and inundation of the power equipment and infrastructure result in shutdowns, loss of power supply, and physical damage to assets.

**Impacts of hazard on asset and services:**

- Energy supply for over 660,000 people at risk

**Assets:**

- Takoradi 1, 2, 3 and SIIF, Amandi
- Type: thermal power plants (gas & oil)
- Generation Capacity: 832 MW/ Aboadze with combined generation potential of 1035 MW

**Institutions:**

- Lead: Ministry of Energy

**Potential financing sources:**

- Existing project
- Government budget
- Climate grants
- Development banks
- Private sector
- Community-led

**NDC thematic areas and impacts**

- #1: City-wide resilient infrastructure planning

**Mitigation co-benefits:**

- Energy efficiency improvements in power plants

**Capital / upfront costs**

**Operational costs**

**Implementation time**

# 4. COASTAL FLOOD PROTECTION OF THE SUNON-ASOGLI POWER PLANT

The Sunon-Asogli power plant (560MW), serving 4.2 million people, is identified as the energy generation asset most exposed to river flooding. Its location near the coast makes it – and the nearby port and industrial infrastructure – also susceptible to coastal inundation.

## Adaptation investment recommendations

- A coastal defence programme can integrate a seawall designed to safeguard the power plant facility with a combination of natural buffers (such as mangroves, beach nourishment, or reefs) which protect the surrounding industrial and residential areas.

## Expected outputs and impacts

- May contribute to lower future costs and maintenance
- Employment benefits to local economy

## Gender considerations

- Women's participation should be reflected across the project lifecycle, including procurement, construction, operation, and maintenance of the asset

## Enabling environment supporting actions

- Update energy sector design standards to incorporate climate adaptation risk (#9)
- Centralised climate-risk data management system (#31)
- Mainstream resilience through climate risk assessments and EPA permitting process (#33)

## Potential SDG targets influenced

1.5, 4.a, 7.b, 8.2, 9.1, 11.1, 11.2, 11.5, 11.b, 11.c, 12.1, 12.3, 13.1, 13.2, 13.3

Photo: B&FT

**Option type:**

**Climate hazard:**

Regular flooding and inundation of the power equipment and infrastructure result in shutdowns, loss of power supply, and physical damage to assets.

**Impacts of hazard on asset and services:**

- Energy supply for over 4.2 million people at risk
- Estimated asset damage repair cost of 1.9 billion USD

**Institutions:**

- Lead: Ministry of Energy

**Potential financing sources**

- Existing project
- Climate grants
- Development banks
- Community-led

**NDC thematic areas and impacts**

- #1: City-wide resilient infrastructure planning

**Mitigation co-benefits:**

Energy efficiency improvements in power plants

**Capital / upfront costs**

**Operational costs**

**Implementation time**

# 5. SAFEGUARDING VULNERABLE SUBSTATIONS AGAINST FLOODS AND LANDSLIDES

Of Ghana's 76 substations, 23 are vulnerable to high flood and landslide hazards, causing potential electricity disruptions to approximately 6.9 million people. Notably, Ga West and Ga South together serve nearly two million people in the capital region and face a high risk of flooding under a high climate hazard scenario by 2050. The Hohoe substation in the Volta region is landslide-impacted and serves nearly a million people in a district with low adaptive capacity, while substations in the Western and Western North regions are also highly exposed.

## Adaptation investment recommendations

- Elevating substations and their components: This site-specific approach protects electricity systems from climate hazards by ensuring that control houses and transformers remain above expected flood levels.
- Relocation of substations: A more extensive, though costly, option for substations in high hazard zones is relocation away from the flood or landslide hazard.

## Expected outputs and impacts

- Increased resilience of the electricity transmission system at most vulnerable points in the network
- In addition to river flooding, provides protection against flooding from rainstorms and other severe weather events

## Gender considerations

- Safeguarding secure electrification to cities and communities provides health, safety, and socioeconomic benefits to women and girls.
- Women's participation and decision-making should be reflected across the project lifecycle, including procurement, construction, operation, and maintenance of the asset.

## Enabling environment supporting actions

- Update energy sector design standards to incorporate climate adaptation risk (Option #9)
- Proactive risk-informed asset management (Option #17)
- Climate risk assessment and EPA permit enforcement for new infrastructure (Option #33)

## Potential SDG targets influenced

1.5, 4.a, 7.b, 8.2, 9.1, 9.4, 11.b, 11.c, 12.1, 12.3, 13.1, 13.2, 13.3

**Option type:**

**Climate hazards:**

Flood and landslide hazards threaten the electricity transmission system. Notably, this can cause power disruptions to whole communities and districts as a result of a localised hazard event. This may affect critical functions such as health and emergency services.

**Impacts of hazard on assets and services:**

- Energy supply for over 6.9 million people at risk due to disruptions from high flood and landslide hazard scenarios

**Institutions:**

- Lead: Ministry of Energy

**Potential financing sources**

- Existing project
- Climate grants
- Development banks
- Community-led

**NDC thematic areas and impacts**

- #1: City-wide resilient infrastructure planning

**Mitigation co-benefits:**

- Clean energy for lighting and cooking through electrification

**Capital / upfront costs**

**Operational costs**

**Implementation time**

# 6. RESILIENT COOLING SYSTEMS FOR THERMAL AND SOLAR PLANTS

Power plants rely on large water inputs for cooling and the removal of waste heat. This water is often extracted from rivers, lakes, or nearby water sources through intake structures for once-through cooling, after which the water is discharged back to the source, causing severe environmental impacts. In order to conserve water resources threatened by an increased likelihood of drought hazard, there is a need to adapt major energy generation facilities to reduce these water requirements.

## Adaptation investment recommendations

- Water reuse systems for cooling: this could be in the form of tower cooling in which hot water used to cool turbines is sent to a cooling tower, reused several times and eventually discharged from the plant
- Dry cooling systems: though a more costly option, this reduces the need for a water source. While this option is applicable to all power plants, facilities can be prioritised in areas of reduced river runoff identified in Part 1.

## Expected outputs and impacts

- Adapt the power sector to more intense future droughts as predicted by climate hazard modelling
- Reduced freshwater reliance for energy generation (thermal and renewable)
- Positive impacts for communities and ecosystems that rely on river runoff, and less ecosystem damage from once-through discharge

## Gender considerations

- This project should be informed by participatory planning, including women and vulnerable groups who may directly or indirectly benefit from it
- Women's participation should be reflected across the project lifecycle, including procurement, construction, operation, and maintenance of the asset

## Enabling environment supporting actions

- Update energy sector design standards to incorporate climate adaptation risk (Option #9)
- Proactive risk-informed asset management (Option #17)
- Climate risk assessment and EPA permit enforcement for new infrastructure (Option #33)

## Potential SDG targets influenced

1.5, 4.a, 6.4, 7.b, 8.2, 9.1, 9.4, 11.1, 11.2, 11.5, 11.b, 11.c, 12.3, 12.4, 13.1, 13.2, 13.3, 15.1

**Option type:**

**Climate hazard:**

Drought conditions can result in reduced plant efficiency and generation capacity

**Impacts of hazard on assets and services:**

- Energy supply for millions of people at risk
- Energy sector revenue loss

**Asset:**

- All non-hydroelectric power plants, with priority to those in drought-affected regions

**Institutions:**

- Lead: Ministry of Energy

**Potential financing sources**

- Existing project
- Climate grants
- Development banks

**NDC thematic areas and impacts**

- #1: City-wide resilient infrastructure planning
- #3: Integrated water resources management

**Mitigation co-benefits:**

- Energy efficiency improvements in power plants

**Capital / upfront costs**

**Operational costs**

**Implementation time**

# 7. RESILIENT AND GREEN ENERGY ACCESS IN DROUGHT-PRONE DISTRICTS

While much of Ghana is connected to power stations through the electricity grid, communities in rural areas of the country, especially in the North and West regions. Communities in districts such as Wa East, Banda, Sissala West, Lawra, and Wa West have medium to high probability of exposure to drought, continue to rely on wood fuel to provide basic services, have low adaptive capacity, and suffer from interruptions to basic services. Droughts are expected to intensify in the future and that creates energy security and access risks which impact on the resilience of these remote and vulnerable communities.

## Adaptation investment recommendations

- Solar microgrids: protecting natural vegetation and installing new solar infrastructure can accelerate Ghana's focus on efficient, low-cost, and clean energy and the Scaling-up Renewable Energy Programme (SREP) by AfDB, taking advantage of favourable conditions for solar generation in parts of the country vulnerable to drought, in parallel to the ongoing rural gasification project.

## Expected outputs and impacts

- Increased resilience and adaptive capacity of communities currently reliant on wood fuel by switching to more reliable alternative energy sources
- Reduction of potential grid congestion, improving the stability and operation of local power grids
- Improved regeneration capacity of forests as fewer people depend on firewood as source of energy for basic household services, with associated biodiversity and climate mitigation benefits

## Gender considerations

- Promotion of gender inclusion by ending the need to collect firewood, which is often borne by women and girls, at the expense of schooling, employment, and other opportunities
- Aim to improve women's health impacts through elimination of harmful cooking fumes in the household

## Enabling environment supporting actions

- Capacity development and regulatory frameworks to support local renewable energy generation (Option #8)
- Update energy sector design standards to incorporate climate adaptation risk (Option #9)
- Gender mainstreaming in adaptation planning, implementation and management (Option #34)

## Potential SDG targets influenced

1.5, 4.a, 7.1, 7.2, 8.2, 9.1, 9.4, 11.1, 11.2, 11.b, 11.c, 12.1, 12.3, 12.4, 13.1, 13.3

**Option type:**

**Climate hazard:**

Affects the regeneration capacity of forests. It also increases their susceptibility to wildfires, pests, and disease.

**Impacts of hazard on asset and services:**

- Reduced access to firewood for several remote rural communities needed to provide basic household services

**Assets:**

- This includes solar PVC panels, solar ovens, inverters and battery capacity to maintain reliability, and solar lamps and flashlights

**Institutions:**

- Lead: Ministry of Energy

**Potential financing sources**

- Existing project
- Government budget
- Climate grants
- Development banks
- Community-led

**NDC thematic areas and impacts**

- #4: Resilience for gender and the vulnerable
- Mitigation co-benefits:
- Scaled up renewable generation
- Sustainable utilisation of forest resources
- Cleaner household lighting and cooking solutions

**Capital / upfront costs**

**Operational costs**

**Implementation time**

# 8. CAPACITY DEVELOPMENT AND REGULATORY FRAMEWORKS TO SUPPORT LOCAL RENEWABLE ENERGY GENERATION TO ENHANCE RESILIENCE OF REMOTE, VULNERABLE COMMUNITIES

Implementation of climate adaptation options and achievement of climate resilient energy infrastructure systems is hindered by a centralised energy system with limited local capacity at the district level. Ghana is endowed with renewable energy resources which have not yet been fully exploited. There is a need for more diverse sources of financing, including from the private sector, to implement adaptation options in the energy sector.

## Expected outputs and impacts

- Together, a decentralised energy generation system strengthened by a robust ecosystem of renewable energy SMEs will create a resilient energy sector and facilitate investments in renewable energy infrastructure from non-governmental sources.
- Effective in enhancing resilience of remote, vulnerable communities.
- Active involvement of local businesses can maximise employment and safeguard economic benefits of infrastructure investments

## Enabling environment strategies:

- Build capacity at the district and local levels to support a decentralised energy generation system built upon renewable energy systems (e.g. Solar systems).
- Create policies and regulatory frameworks related to licensing and pricing to regulate district level renewable energy systems for climate adaptation.
- Alongside these actions, finance programs to strengthen the ecosystem of renewable energy small and medium enterprises (SMEs) in order to attract diversified sources of financing for climate adaptation, such as development finance institutions (DFIs) and private sector investors

## Gender considerations

- Renewable-based off-grid energy generation, including through women-owned SMEs, can help ensure energy security and enhance resilience of remote and vulnerable communities

## Built and natural environment supporting options

- Resilient and green energy access in drought-prone districts (Option #7)

## Potential SDG targets influenced

1.5, 1.b, 7.a, 7.b, 8.3, 9.a, 13.2, 13.3, 16.6, 17.8

**Option type:**

**Climate hazards:**

Flooding and droughts create energy security and access risks that impact the resilience of remote and vulnerable communities.

**Elements of the enabling environment:**

- Policy and regulatory frameworks, technical capacity, funding, stakeholder participation

**Institutions:**

- Lead: Ministry of Energy
- Others: Energy Commission

**Potential financing sources**

- Existing project
- Government budget
- Climate grants

**NDC thematic areas and impacts**

- #1: City-wide resilient infrastructure planning
- #4: Resilience for gender and the vulnerable
- #6: Technology and capacity development

**Capital / upfront costs**

**Operational costs**

**Implementation time**

# 9. UPDATE ENERGY SECTOR DESIGN STANDARDS TO INCORPORATE CLIMATE ADAPTATION RISK

In the absence of appropriate national design standards, designers often use international standards for the design of energy infrastructure at their discretion. However, they are not legally recognised or enforceable in the country, and also not relevant to climate adaptation challenges specific to Ghana's local context. This results in the design and implementation of energy infrastructure that is not climate resilient.

Capacity needs to be developed within Ghana Standards Authority to create, adopt and enforce nationally relevant gender-mainstreamed climate-resilient standards. Standard operating procedures and guidance for the use and enforcement of the updated codes and standards should be developed, and include gender considerations. The policy and regulatory framework will need to be updated to reflect the new design codes and standards

## Enabling environment strategies:

Develop and adopt climate-resilient, gender responsive design codes and standards for the energy sector, leveraging up-to-date climate risk and vulnerability data, as well as up-to-date weather forecasting and modeling data (temperature, winds, rain etc.). Specifically, focus on the following energy sub-sectors and asset types:

- Large scale energy infrastructure (e.g. dams)
- Decentralised, renewable energy infrastructure systems (e.g. solar mini-grids)
- Transmission and distribution infrastructure (including sub-stations, transmission lines, transformers, control systems and distribution poles)

## Expected outputs and impacts

- Design standards relevant to Ghana's local context and adaptation needs are developed and enforced, leading to climate adaptation being mainstreamed in the design of all new energy projects

## Gender considerations

- Mainstreaming gender consideration into the design codes and standards will help improve women's access to critical energy services and improve economic and health related outcomes.

## Built and natural environment supporting options

- Safeguarding vulnerable substations against floods and landslides (Option #5)
- Resilient cooling systems for thermal and solar plants (Option #6)

## Potential SDG targets influenced

1.5, 7.a, 11.5, 13.1

**Option type:**

**Climate hazards:**

**Elements of the enabling environment:**

- Policy and regulatory frameworks, institutional structures, standard operating procedures and guidelines, technical capacity

**Institutions:**

- Lead: Ghana Standards Authority

**Potential financing sources:**

- Existing project
- Government budget
- Climate grants

**NDC thematic areas and impacts:**

- #1: City-wide resilient infrastructure planning
- #4: Resilience for gender and the vulnerable
- #6: Technology and capacity development

**Capital / upfront costs**

**Operational costs**

**Implementation time**

# WATER SECTOR

# 10. NATURAL FLOOD ADAPTATION OF THE WEIJA DAM THROUGH GREENING AND VEGETATION ALONG THE DENSU RIVER

The Weija Dam, which supplies the Greater Accra area and its residents, is highly exposed to flooding under a high climate hazard scenario by 2050. Increased water velocity during high flow periods and rapid fluctuations in water levels threaten water supply infrastructure and communities bordering and downstream of the dam.

## Adaptation investment recommendations

- Restoration of natural vegetation as a flood control mechanism and implementation of NbS upstream of the dam, including extension of the tree and vegetation buffer around the Weija Reservoir and in the Atewa Forest, as well as shade grown cocoa for farmers

## Expected outputs and impacts

- Increased absorption capacity of soil to reduce flood runoff, allowing the river to flood its natural floodplain
- Reduced maintenance costs in the dam and increased quality and reliability of urban water supply due to less sedimentation
- Flood buffering, preventing flooding of water supply infrastructure and communities bordering and downstream of the dam.
- Biodiversity climate mitigation co-benefits resulting from increased forestation

## Gender considerations

- Women should be represented in community leadership, participation and guardianship of natural flood management solutions

## Enabling environment supporting actions

- Climate adaptation alignment across water ministries and planning mechanisms (Option #16)
- Nature-based solutions prioritised in planning, design and operation (Option #35)
- Risk-resilient land management system (Option #33)

## Potential SDG targets influenced

1.4, 1.5, 2.1, 2.3, 2.4, 2.5, 3.3, 3.4, 3.9, 4.7, 6.1, 6.2, 6.3, 6.4, 6.6, 7.1, 7.2, 7.b, 9.1, 11.1, 11.4, 11.5, 11.6, 11.7, 11.b, 11.c, 12.1, 12.2, 12.3, 13.1, 13.2, 13.3, 14.2, 13.5, 14.7, 15.1, 15.3, 15.4, 15.5

**Option type:**

**Climate hazard:**

During periods of high rainfall, the dam and the river are overwhelmed with storm water, exposing the Weija Township downstream to flood hazards and threatening the function of water supply infrastructure.

**Impacts of hazard on assets and services:**

- Approximately 80 percent of the potable water for the entire city of Accra and its surrounding areas, or approximately one million urban residents of the capital city.
- Water sector revenue loss to the government.

**Asset:**

- Weija Dam (treatment capacity of up to 206,000 $m^3$/ day)

**Institutions:**

- Lead: Ghana Water Company
- Others: Forestry Commission of Ghana, Water Resources Commission

**Potential financing sources:**

- Existing project
- Government budget
- Climate grants
- Community-led

**NDC thematic areas and impacts**

- #3: Integrated water resources management
- #4: Resilience for gender and the vulnerable

**Mitigation co-benefits:**

- Scaled up renewable generation
- Sustainable utilisation of forest resources

**Capital / upfront costs**

**Operational costs**

**Implementation time**

# 11. FLOOD RESILIENCE IMPROVEMENTS TO THE WEIJA DAM THROUGH RELEASE SCHEDULING AND SPILLWAY IMPROVEMENTS

The current operation of the Weija dam spillway causes flooding during periods of unexpectedly large inflows, with impacts on human settlements downstream. To address this, solutions can focus on the dam operation to prevent rapid increase of the water levels in the reservoir.

## Adaptation investment recommendations

- Enhance the release scheduling of the Weija dam, which requires technical capacity informed by data to better predict high flows.
- Building of additional spillway capacity to manage higher-intensity precipitation events on shorter notice, providing greater flexibility to the water management system.

## Expected outputs and impacts

- More flexibility in release of water in a short period in the case of heavy rainfall
- Reduction of risk to downstream settlements located in or near the floodplain

## Gender considerations

- Women's participation should be incorporated in training and capacity building to mitigate flood risks, as well as in construction, operation, and maintenance of the dam asset
- Reduced risk to women and vulnerable groups in informal downstream settlements

## Enabling environment supporting actions

- Climate adaptation alignment across water ministries and planning mechanisms (Option #16)
- Proactive risk-informed asset management (Option #17)
- Risk-resilient land management system (Option #32)

## Potential SDG targets influenced

1.5, 4.a, 7.b, 8.2, 9.1, 9.4, 11., 11.2, 11.5, 11.b, 11.c, 12.1, 12.3, 12.4, 13.1, 13.2, 13.3

*Photo: Pulse Ghana*

**Option type:**

**Climate hazard:**

During periods of high rainfall, the dam and the river are overwhelmed with storm water, exposing the Weija Township downstream to flood hazards and threatening the function of water supply infrastructure.

**Impacts of hazard on assets and services:**

- Flooding of infrastructures i.e. transport infrastructure, water infrastructure, energy infrastructure at Weija township downstream settlement resulting in disruptions in service.
- Disruptions of lives and livelihoods at the Weija downstream settlement.

**Asset:**

- Weija dam (treatment capacity of up to 206,000 $m^3$/ day)

**Institutions:**

- Lead: Ghana Water Company
- Others: Water Resources Commission

**Potential financing sources:**

- Existing project
- Government budget
- Climate grants
- Development banks
- Private sector
- Community-led

**NDC thematic areas and impacts**

- #2: Early warning and disaster prevention
- #3: Integrated water resources management
- #4: Resilience for gender and the vulnerable

**Mitigation co-benefits:**

- Scaled up renewable generation

**Capital / upfront costs**

**Operational costs**

**Implementation time**

# 12. NATURAL RESTORATION AROUND TONO AND VEA DAMS

The Vea and Tono dams are located in Ghana's North with estimated capacity of over 4.5 billion $m^3$. They are the second- and third-most exposed dams to both flood and drought impacts in Ghana and are the main source of water for household use and agricultural irrigation in neighbouring and downstream communities.

## Adaptation investment recommendations

- Broad afforestation to increase the absorption capacity of soils across the watershed, lessening runoff and decreasing flood flows.

## Expected outputs and impacts

- Increase of absorption capacity of soil to reduce flood runoff, allowing the river to flood its natural floodplain
- Reduction of sediment load and increased water quality due to less pollutants from agricultural runoff
- Improved ecosystem health, carbon sequestration

## Gender considerations

- This project should be informed by participatory planning, including women and vulnerable groups from neighbouring communities who may benefit from it
- Ensuring reliable water supply to households can empower women economically and socially

## Enabling environment supporting actions

- Proactive risk-informed asset management (Option #17)
- Nature-based solutions prioritised in planning, design and operation (Option #35)
- Gender mainstreaming in adaptation planning, implementation and management (Option #34)

## Potential SDG targets influenced

1.4, 1.5, 2.1, 2.3-2.5, 3.3, 3.4, 3.8, 3.9, 4.7, 6.1-6.4, 6.6, 7.1, 7.2, 9.1, 11.1, 11.4-11.7, 11.b, 11.c, 12.1-12.3, 13.1-13.3, 15.1-15.5

Photo: GIDA

**Option type:**

**Climate hazards:**

Heavy inflows caused by rain events in October 2019 washed away the retaining walls, the spillway, the dam floor and the embankment of the Tono dam, submerging about 850 hectares of farmland and flooded some homes.

Reduced river flow and reservoir capacity reduces water supply capacity

**Impacts of hazards on assets and services:**

- During periods of torrential rainfall, the dam is exposed to high risks of flooding which could ultimately lead to the destruction of the dam with secondary impacts of flooding of farmlands and settlements downstream.

**Asset:**

- Tono (3760 million $m^3$) and Vea (816 million $m^3$) dams

**Institutions:**

- Lead: Ghana Water Company
- Others: Water Resources Commission

**Potential financing sources:**

- Existing project
- Government budget
- Climate grants
- Community-led

**NDC thematic areas and impacts**

- #2: Early warning and disaster prevention
- #3: Integrated water resources management
- #4: Resilience for gender and the vulnerable

**Mitigation co-benefits:**

- Sustainable utilisation of forest resources

**Capital / upfront costs**

**Operational costs**

**Implementation time**

# 13. SLOPE STABILISATION, FORESTATION, AND TERRACING AT BAREKESE DAM

The Barekese dam, which provides approximately 80 percent of the total public pipe-borne water to the Kumasi metropolis, has seen persistent degradation of its watershed by anthropogenic activities in its catchment area which also decreases water quality. The Ghana Water Company in the Ashanti region has already embarked on a massive tree planting exercise in Barekese in order to save the dwindling levels of the Barekese dam, which has been badly affected by encroachers, farmers, illegal miners, illegal lumbering and estate developers.

## Adaptation investment recommendations

- Implementation of erosion control upstream of the Barekese dam in the form of forestation and vegetated terracing – both of which use plants and their root systems to stabilise soils and slopes and to reduce sediment load in rivers.

## Expected outputs and impacts

- Direct benefits to water storage levels in the Barekese dam through reduced sediment loads
- Revenue savings from expensive dredging requirements due to fine sediments.
- Improved ecosystem health in carbon sequestration.

## Gender considerations

- Natural restoration efforts should reflect women's participation in leadership and guardianship, with a role for women as members of operations and maintenance committees

## Enabling environment supporting actions

- Climate adaptation alignment across water ministries and planning mechanisms (Option #16)
- Nature-based solutions prioritised in planning, design and operation (Option #35)
- Risk-resilient land management system (Option #32)

## Potential SDG targets influenced

1.4, 1.5, 2.1, 2.3-2.5, 3.3, 3.4, 3.8, 3.9, 4.7, 6.1-6.4, 6.6, 7.1, 7.2, 9.1, 11.1, 11.4-11.7, 11.b, 11.c, 12.1-12.3, 13.1-13.3, 15.1-15.5

**Option type:**

**Climate hazard:**

Increases fluvial sediment and reduces reservoir capacity, causing physical damage to assets and downstream floods. While the dam is not projected to be exposed under a high hazard scenario, it does face flood exposure under a medium likelihood scenario and concern has been raised by practitioners in the water sector.

**Impacts of hazard on assets and services:**

- Floods result in the deposition of fine sediments that are difficult to dredge and can pose expensive challenges for water treatment facilities

**Asset:**

- Barekese dam (89.6 million $m^3$)

**Institutions:**

- Ghana Water Company
- Others: Water Resources Commission; Forestry Commission of Ghana

**Potential financing sources:**

- Existing project
- Government budget
- Climate grants
- Development banks
- Community-led

**NDC thematic areas and impacts**

- #3: Integrated water resources management
- #4: Resilience for gender and the vulnerable

**Mitigation co-benefits:**

- Sustainable utilisation of forest resources

**Capital / upfront costs**

**Operational costs**

**Implementation time**

# 14. CATCHMENT-LEVEL WATER MANAGEMENT IN THE ACCRA PLAINS

Over 16 deadly flood disasters have been recorded in Accra since 1959, all of which have caused severe damages to life and property (25 recorded deaths in the 2015 Accra floods). Catchment-level water management in the Accra plains can address flood risk to the capital city's infrastructure assets and population of nearly 4 million people, while retaining water to mitigate the impacts of droughts.

## Adaptation investment recommendations

- De-concretisation of channels and positioning of levees farther away from the river, allowing the waterway more access to its original floodplain and discouraging encroachment.
- Use of riparian vegetation to lessen flood intensity by strengthening embankments and reducing water speed.

## Expected outputs and impacts

- Reduced need for cost intensive, ad hoc solutions with very minimal long-term impacts, such as dredging to unblock major waterways and drainage systems
- Increased absorptive capacity of soil to reduce flood runoff, especially in response to pollutants from agricultural runoff, and improved water quality and ecosystem health

## Gender considerations

- Women's participation should be incorporated in training and capacity building to mitigate flood risks
- Women should be represented in community leadership, participation and guardianship of natural flood management solutions

## Enabling environment supporting actions

- Climate adaptation alignment across water ministries and planning mechanisms (Option #16)
- Proactive risk-informed asset management (Option #17)
- Risk-resilient land management system (Option #32)

## Potential SDG targets influenced

1.4, 1.5, 2.1, 2.3-2.5, 3.3, 3.4, 3.8, 3.9, 4.7, 6.1-6.4, 6.6, 7.1, 7.2, 7.b, 9.1, 11.1, 11.4-11.7, 11.b, 11.c, 12.1-12.3, 13.1-13.3, 14.2, 14.5, 14.7, 15.1-15.5

**Option type:**

**Climate hazards:**

Flooding occurs due to low-lying topography, increase rate of coastal erosion, frequency of torrential rainfall in recent years, combined with anthropogenic factors such as rapid urbanisation, choked drains, and blocked watercourses.

Limited absorptive capacity reduces ability to retain water during the dry season.

**Impacts of hazard on assets and services:**

- Infrastructure assets and population of nearly 4 million people exposed heavy traffic on roads, disruption to commercial activities, loss of lives, and reduced access to healthcare services

**Institutions:**

- Lead: Water Resources Commission

**Potential financing sources:**

- Existing project
- Government budget
- Climate grants
- Development banks
- Community-led

**NDC thematic areas and impacts**

- #2: Early warning and disaster prevention
- #3: Integrated water resources management
- #4: Resilience for gender and the vulnerable

**Mitigation co-benefits:**

- Sustainable utilisation of forest resources

**Capital / upfront costs**

**Operational costs**

**Implementation time**

# 15. WATER SUPPLY RESILIENCE THROUGH REGIONAL HARVESTING AND STORAGE SOLUTIONS

For both drinking and non-drinking uses, rural areas are much more reliant upon direct water extraction from natural resources. Increased projected drought hazards and a resulting reduction in river runoff puts many districts and communities in Ghana at risk. Many of these communities in districts such as Kpandai, Ho, Krachi East, Kwahu Affram Plains North, and East Gonja additionally have low adaptive capacity due to other socio-economic factors and are vulnerable to interruptions to basic services such as water provision.

## Adaptation investment recommendations

- Implementation of specific water harvesting measures to capture rainfall, or divert high flows, at a household or community level, during rainy periods.
- Capture of grey water supplies with rain barrels at the household level for non-potable uses like cleaning and toilet flushing.
- Construction of subsurface basins for larger-scale storage at the community level which may be used for irrigation or other uses.

## Expected outputs and impacts

- Increase in availability of natural (non-piped) water supply
- Saved time on water collection as rainwater harvesting tends to occur at or close the point of use
- Ecosystem benefits resulting from less river abstraction

## Gender considerations

- Promotion of gender inclusion by reducing the need to collect and transport water, which is often borne by women and girls, at the expense of schooling and other employment
- A reliable water supply has implications for women's health and hygiene needs

## Enabling environment supporting actions

- Climate adaptation alignment across water ministries and planning mechanisms (Option #16)
- Mainstream resilience through climate risk assessments and EPA permitting process (Option #33)
- Gender mainstreaming in adaptation planning, implementation and planning (Option #34)

## Potential SDG targets influenced

1.5, 6.1, 11.5, 11.b, 11.c, 13.1-13.3

**Option type:**

**Climate hazard:**

Reduction of river flows caused by drying trends. Drought patterns causing this hazard are expected to intensify in the coming decades.

**Impacts of hazard on assets and services:**

- Increased projected drought hazards and a resulting reduction in river runoff leaves households at risk of water insecurity

**Assets:**

- Natural — Watershed(s), Rivers, Streams

**Institutions:**

- Lead: Ghana Water Company

**Potential financing sources:**

- Existing project
- Government budget
- Climate grants
- Community-led

**NDC thematic areas and impacts**

- #3: Integrated water resources management
- #4: Resilience for gender and the vulnerable

**Capital / upfront costs**

**Operational costs**

**Implementation time**

# 16. CLIMATE ADAPTATION ALIGNMENT ACROSS WATER MINISTRIES AND PLANNING MECHANISMS TO ENSURE INTEGRATED WATER RESOURCE MANAGEMENT

Efforts to minimise the impacts of climate change are misaligned due to the absence of institutional and planning mechanisms, adaptation targets and criteria, and implementation and monitoring mechanisms.

## Enabling environment strategies:

- Build technical and institutional capacity to mainstream and implement adaptation measures through integrated water resource management (IWRM).
- Update the IWRM institutional framework to align roles and responsibilities (horizontally and vertically) to support coordination and implementation of adaptation planning across water sectors and water basins.
- Create adaptation targets and planning frameworks that require the coordinated planning of water resource management, flood risk management, drought management, irrigation water management, potable water management, and wastewater management as part of an IWRM program. Information on how women and girls use water infrastructure and how they may be impacted by climate related risks needs to be assessed and addressed as part of the IWRM planning process.

## Expected outputs and impacts

- Institutional coordination and alignment improved with climate risk integrated into water planning and decision-making processes. Increased effectiveness of climate adaptation measures and achievement of climate adaptation targets with special attention paid to the needs of women, girls, and other marginalised groups.

## Gender considerations

- Mainstreaming gender consideration into IWRM planning processes will improve women's access to critical water related services and improve economic and health related outcomes.

## Built and natural environment supporting options

- Natural flood adaptation of Bui dam (Option #2)
- Coastal flood protection of the Sunon-Asogli power plant (Option #4)
- Upstream afforestation of the Volta river reservoir (Option #29)

## Potential SDG targets influenced

5.1, 6.1, 6.2, 6.3, 6.4, 6.5, 6.6, 9.1, 11.5, 13.1, 13.2, 13.3

**Option type:**

**Climate hazards:**

**Elements of the enabling environment:**

- Institutional structures, planning frameworks, funding, standard operating procedures and guidelines, technical capacity building, data and information, stakeholder participation

**Institutions:**

- Lead: Ministry of Water and Sanitation
- Others: Ghana Water Company, Community Water and Sanitation Agency

**Potential financing sources:**

- Existing project
- Government budget
- Climate grants

**NDC thematic areas and impacts**

- #1: City-wide resilient infrastructure planning
- #2: Early warning and disaster prevention
- #3: Integrated water resources management

**Capital / upfront costs**

**Operational costs**

**Implementation time**

# 17. PROACTIVE RISK-INFORMED ASSET MANAGEMENT

Management of water infrastructure does not include environmental risk management processes and is reactionary, not proactive, resulting in increased flooding and disruptions to services, exacerbating the already strained public budget.

## Enabling environment strategies:

- Update the policy and regulatory framework for the creation of a risk-informed asset management system for relevant government institutions.
- Create asset management plans for all critical public water infrastructure assets.
- Allocate sufficient budget for logistics and technology support for routine maintenance, upgrade and retrofitting of all existing water sector assets, with a priority placed on critical public drainage and flood protection assets.
- Create maintenance procedures that prioritise and support the routine clearing of public waterways, reservoirs, and drainage channels of trash, silt, and other debris to reduce flood risk.
- Create early warning systems and service continuity plans where appropriate. Wherever applicable, data is disaggregated according to gender, vulnerable groups, and other relevant sociodemographic characteristics.

## Expected outputs and impacts

- Proactive, climate-risk informed asset management leading to longer asset life
- Fewer service disruptions, and more predictable and productive fiscal expenditures.

## Gender considerations

- Having gender differentiated data will help inform decision making to ensure women and other disenfranchised groups can access water related services.

## Built and natural environment supporting options

- Retrofitting adaptation measures in the Akosombo Dam (Option #1)
- Water supply resilience through regional harvesting and storage solutions (Option #15)
- Urban drainage measures in Accra (Option #18)

## Potential SDG targets influenced

5.1, 6.1, 6.2, 6.3, 6.4, 6.5, 6.6, 9.1, 11.5, 13.1, 13.2, 13.3, 14.1

**Option type:**

**Climate hazards:**

**Elements of the enabling environment:**

- Policy and regulatory frameworks, planning frameworks, standard operating procedures and guidelines, funding, data and information, technical capacity building, technology and logistical resources

**Institutions:**

- Lead: Ministry of Sanitation and Water Resources
- Others: Ghana Water Company, Community Water and Sanitation Agency

**Potential financing sources:**

- Existing project
- Government budget
- Climate grants

**NDC thematic areas and impacts**

- #1: City-wide resilient infrastructure planning
- #2: Early warning and disaster prevention
- #3: Integrated water resources management

**Capital / upfront costs**

**Operational costs**

**Implementation time**

# TRANSPORT SECTOR

# 18. URBAN DRAINAGE MEASURES IN ACCRA

Accra has a long history of flood-related disasters and threatens all exposed assets in the Accra metropolitan area (354 km of roads, plus rail and buildings infrastructure). This vulnerability is attributed to anthropogenic factors such as rapid urbanisation, choked drains, and blocked watercourses, in addition to natural factors and processes like its low-lying topography, increased rate of coastal erosion, and frequency of torrential rainfall in recent years.

## Adaptation investment recommendations

- A comprehensive programme to improve urban drainage, including upgrading drains and installing waste traps to prevent waste from entering drains
- NbS such as natural buffers (wetlands), and planting trees alongside the roads, which can also contribute to Ghana's targets on reforestation and green space.

## Expected outputs and impacts

- Reduced disruption to road transport, including access to healthcare for around 600 thousand people.
- Reduction in the impact of heatwaves in urban areas through the creation of shading
- Reduced flooding impacts on houses and disruption to the majority modal share of pedestrians and cyclists

## Gender considerations

- Women's participation and guardianship of nature-based and ecosystem assets should be incorporated.
- Gender-specific needs (e.g. access to health and employment) should be reflected in the design and application of adaptation measures.

## Enabling environment supporting actions

- Climate adaptation alignment across water ministries and planning mechanisms Option (#16)
- Proactive risk-informed asset management (Option #17)
- Supporting resilient design and construction of roads through research, capacity building, and the creation of a design manual (Option #27)

## Potential SDG targets influenced

1.4, 1.5, 2.1, 2.3-2.5, 3.3, 3.4, 3.8, 3.9, 4.7, 6.1-6.4, 6.6, 7.1, 9.1, 9.4, 9.a, 11.1, 11.4-11.7, 11.b, 11.c, 12.1-12.5, 13.1-13.3, 14.1, 14.2, 14.5, 15.1-15.5

**Option type:**

**Climate hazards:**

Inadequate urban drainage along roads and streets makes the city vulnerable to damage from pluvial and coastal flood hazards.

**Impacts of hazard on assets and services:**

- In Greater Accra, 22 percent of the road network is exposed to flood events with potential damage costs exceeding 130 million USD

**Assets:**

- Built (roals, rail and buildings) and natural infrastructure (green spaces)

**Institutions:**

- Lead: Ministry of Transport

**Potential financing sources:**

- Existing project
- Government budget
- Climate grants
- Development banks
- Commercial banks
- Private sector
- Community-led

**NDC thematic areas and impacts**

- #1: City-wide resilient infrastructure planning
- #3: Integrated water resources management
- #4: Resilience for gender and the vulnerable

**Mitigation co-benefits:**

- Enable more sustainable mass transportation
- Urban heat reduction and sustainable cooling
- Urban solid waste management solutions

**Capital / upfront costs**

**Operational costs**

**Implementation time**

# 19. GREEN RECREATIVE AREAS AND RIPARIAN VEGETATION TO PROTECT EXPOSED ROAD AND RAIL BETWEEN URBAN CENTRES

Segments of inter-city transport, including highways around Kumasi (551 km) and the Weija dam (1,108 km), and the Western (106 km) and Eastern (81 km) railway lines, are exposed to high flood risks. Flooding threatens critical passenger and freight transport services including access to electricity and healthcare in more rural districts.

## Adaptation investment recommendations

- An afforestation project to create recreational green spaces along rivers that will safeguard exposed roads and rails.
- Protection of the riparian vegetation upstream of flood-prone areas.

## Expected outputs and impacts

- Protection and restoration of ecosystems and river capacity to absorb flood water, with biodiversity benefits
- Co-benefits include reduced impact of heatwaves near urban areas

## Gender considerations

- Adapting roads in rural districts can have benefits for women as footpaths are mainly used by girls and women (82 percent of the female rural population uses footpaths compared to 66 percent for males)
- Girls and women are more likely to suffer consequences in terms of economic or social outcomes from sustained damages.

## Enabling environment supporting actions

- Nature-based solutions prioritised in planning, design and operation (Option #35)
- Climate-risk informed asset management system and operations and maintenance practices for roads (Option #28)
- Supporting resilient design and construction of roads through research, capacity building, and the creation of a design manual (Option #27)

## Potential SDG targets influenced

1.4, 1.5, 2.1, 2.3-2.5, 3.4, 3.8, 3.9, 4.7, 11.1, 11.4-11.7, 11.b, 11.c, 12.1-12.3, 13.1-13.3, 14.2, 14.5, 15.1-15.5

**Option type:**

**Climate hazard:**

Flooding threatens damage to roads and interruption of transport services in Ghana

**Impacts of hazard on assets and services:**

- Total damage to the road network due to floods may reach 3.9 billion USD by 2050.

**Assets:**

- Roads, highways, rail and surrounding natural assets (forest and vegetation)

**Institutions:**

- Lead: Ghana Forestry Commission , Ministry of Roads and Highways

**Potential financing sources:**

- Existing project
- Government budget
- Climate grants
- Development banks
- Community-led

**NDC thematic areas and impacts**

- #1: City-wide resilient infrastructure planning
- #3: Integrated water resources management
- #4: Resilience for gender and the vulnerable
- Mitigation co-benefits:
- Enable more sustainable mass transportation
- Sustainable utilisation of forest resources
- Urban solid waste solutions (collection and transport)

**Capital / upfront costs**

**Operational costs**

**Implementation time**

# 20. BUILT AND NATURAL COASTAL DEFENCE OPTIONS FOR TEMA PORT

Located in the industrial city of Tema, the port is the largest in Ghana, averaging 1511 vessel calls per year. The port serves as a logistic point for inland clearance, container storage, freight forwarders, and related service centres, but is vulnerable to coastal and river flooding. Given its importance as a major international container facility and logistics hub, this has impacts on the movement of cargo and passenger services. Adaptation of this key economic asset is critical to safeguard industrial activity in the city, with wider implications for Ghana's economy.

## Adaptation investment recommendations

- Fortification or construction of existing or new breakwater, jetty, or seawall barriers where appropriate.
- Supplementing this with feasible NbS, such as protecting or restoring reefs or dunes, should be explored, which can also protect other infrastructure in the city, including energy generation and local roads.

## Expected outputs and impacts

- Protection of the critical Tema Port and surrounding area from flooding
- Added resilience to the operation of Tema Port which is projected to expand into the coming years
- Protection of economic value associated with the transport of cargo and passengers.

## Gender considerations

- Women's participation should be reflected across the project lifecycle, including procurement, construction, operation, and maintenance of the asset

## Enabling environment supporting actions

- Proactive risk-informed asset management (Option #17)
- Centralised climate-risk data management system (Option #31)
- Mainstream resilience through climate risk assessments and EPA permitting process (Option #33)

## Potential SDG targets influenced

1.5, 4.a, 7.b, 8.2, 9.1, 9.4, 11.1, 11.2,11.5, 11.b, 11.c, 12.1, 12.3, 12.4, 13.1-13.3

**Option type:**

**Climate hazard:**

Coastal and river flooding affects the port facility and surrounding infrastructure.

**Impacts of hazard on assets and services:**

- Risk of critical freight transport exposure to flood risks
- Port sector revenue loss to government

**Assets:**

- Tema port and adjacent industrial infrastructure

**Institutions:**

- Lead: Ghana Ports and Harbours Authority

**Potential financing sources:**

- Existing project
- Government budget
- Climate grants
- Development banks
- Commercial banks
- Private sector
- Community-led

**NDC thematic areas and impacts**

- #1: City-wide resilient infrastructure planning
- #2: Early warning and disaster prevention
- #3: Integrated water resources management

**Capital / upfront costs**

**Operational costs**

**Implementation time**

# 21. NATURAL AND BUILT SLOPE STABILISATION MEASURES ALONG MAJOR HIGHWAYS

The impact of landslides is most pronounced in the mid-west and south-east of Ghana, with severe impacts on highway routes in these regions. More specifically, key sections of highway identified through geospatial exposure analysis and verified by stakeholder feedback: N6 (all exposed to landslides ~15 km), N10 Mid-West (~ 60km), N2 South-East (~85km). These routes are essential for transporting cargo throughout Ghana and, therefore, adaptation of the transport network has important benefits for the economy.

## Adaptation investment recommendations

- Implementation of built and natural landslide-stabilisation measures which include natural terracing and natural slope stabilisation, retaining walls, and gabions.

## Expected outputs and impacts

- Protect Ghana's passenger and freight transport along the major south-north routes with natural terracing
- Improved ecosystem health with benefits for biodiversity and to slow down and drain away water runoff
- Employment benefits including for women's participation in the workforce

## Gender considerations

- Adapting roads in rural districts have gender-differentiated impacts as men and women use transport modes differently to reach jobs, healthcare, or other services.

## Enabling environment supporting actions

- Supporting resilient design and construction of roads through research, capacity building, and the creation of a design manual (Option #27)
- Climate-risk informed asset management system and operations and maintenance system for roads (Option #28)
- Nature-based solutions prioritised in planning, design and operation (Option #35)

## Potential SDG targets influenced

1.4, 1.5, 2.1, 2.3-2.5, 3.3, 3.4, 3.8, 3.9, 4.7, 4.a, 6.1-6.4, 6.6, 7.1, 7.2, 8.2, 9.1, 9.4, 11.1, 11.2, 11.4-11.7, 11.b, 11.c, 12.1-12.4, 13.1-13.3, 15.1-15.5

**Option type:**

**Climate hazard:**

Disruption of major transport routes and destruction of buildings and communities. Risks are compounded by rain and flooding.

**Impacts of hazard on assets and services:**

- Disruption of vital commercial and economic activities which these highway routes support
- Loss of transport sector revenue to the government.

**Assets:**

- Highways N6, N10 Mid-West, N2 South-East

**Institutions:**

- Lead: Ministry of Roads and Highways and Ministry of Transport

**Potential financing sources:**

- Existing project
- Government budget
- Climate grants
- Commercial banks
- Private sector
- Community-led

**NDC thematic areas and impacts**

- #1: City-wide resilient infrastructure planning
- #4: Resilience for gender and the vulnerable
- Mitigation co-benefits:
- Enable more sustainable mass transportation
- Urban solid waste solutions (collection and transport)

**Capital / upfront costs**

**Operational costs**

**Implementation time**

# 22. AIRPORT FLOOD RESILIENCE THROUGH ELEVATION OF RUNWAYS AND OTHER VULNERABLE COMPONENTS

Flooding impacts on airports can result in significant delays for passenger, tourism, as well as cargo transport. Two airports in Ghana are identified as particularly vulnerable to inland river flooding (Ho and Tamale) as well as a coastal airport (Takoradi), which should be prioritised for flood adaptation as these airports represent a total of 460,403 total annual passenger trips.

## Adaptation investment recommendations

- Elevation of runways at flood-exposed airports in order to reduce the risk of interruption to air transport services within the country. To reduce disruption, runway elevation may be undertaken in combination with periodic requirements for re-paving and maintenance.
- Focus on targeted adaptation measures for its most vulnerable components to avoid the large capital costs involved in relocating entire airports.
- NbS including afforestation and reforestation next to airports can improve "sponge" functioning of the surrounding land

## Expected outputs and impacts

- Protection of airports against increasing flooding impacts, thereby ensuring future climate resilience as passenger and freight volumes increase
- Ensure uninterrupted services for movement of goods (imports, exports), people (tourists), and emergency supplies

## Gender considerations

- Women's participation should be reflected across the project lifecycle, including procurement, construction, operation, and maintenance of the asset

## Enabling environment supporting actions

- Climate adaptation alignment across water ministries and planning mechanisms (Option #16)
- Proactive risk-informed asset management (Option #17)
- Centralised climate-risk data management system (Option #31)

## Potential SDG targets influenced

1.5, 4.a, 7.b, 8.2, 9.1, 9.4, 11.1, 11.2, 11.5, 11.b, 11.c, 12.1, 12.3, 12.4, 13.1-13.3

**Option type:**

**Climate hazard:**

Many airports are located on areas of flat land, making them particularly vulnerable to flooding – this includes reclaimed land such as marshlands or near large bodies of water.

**Impacts of hazard on assets and services:**

- Disruption to commercial flights and economic activity across the country, and loss of air transport sector revenue to government and private investors
- Estimated asset damage costs of over 2 billion USD for the three airports

**Assets:**

- Ho, Tamale, and Takoradi airports

**Institutions:**

- Ministry of Transport

**Potential financing sources:**

- Existing project
- Government budget
- Climate grants
- Development banks
- Commercial banks
- Private sector
- Community-led

**NDC thematic areas and impacts**

- #1: City-wide resilient infrastructure planning
- #3: Integrated water resources management

**Capital / upfront costs**

**Operational costs**

**Implementation time**

# 23. BRIDGES AND UNDERPASSES TO ENSURE COMMUNITY ACCESS TO SERVICES

Flooding threatens critical passenger and freight transport services, including major highways and the Western and Eastern rail lines. This built environment adaptation option can play a critical role especially in the construction of new railway lines and roads that are located alongside rivers.

## Adaptation investment recommendations

- Construction of bridges and/or underpasses for critical road and railway assets to reduce the impact of flooding on these assets. This includes incorporating these types of structures into the design of planned new assets, and well as building them into existing infrastructure systems
- Upgrading critical existing bridges (e.g. the Adomi bridge).

## Expected outputs and impacts

- Reduction of the impacts of flooding on critical road segments into the future
- Employment benefits for local workforce

## Gender considerations

- This option may provide women with increased and quicker accessibility to economic and social services, particularly in rural areas. Importantly, this includes access to health care centres, which can be disrupted by flooding.

## Enabling environment supporting actions

- Proactive risk-informed asset management (Option #17)
- Climate-risk informed asset management system and operations and maintenance practices for roads (Option #28)
- Gender mainstreaming in adaptation planning, implementation and management (Option #34)

## Potential SDG targets influenced

1.5, 4.1, 7.b, 8.2, 9.1, 9.4, 11.1, 11.2,11.5, 11.b, 11.c, 12.1, 12.3-12.4, 13.1-13.3

**Option type:**

**Climate hazard:**

Flooding cuts off key transport links, including in rural districts, which can limit local access to social and economic services (such as healthcare).

**Impacts of hazard on assets and services:**

- Disruption of vital commercial and economic activities which these transport links support.
- Revenue loss for both government and private investors.

**Assets:**

- Prioritised roads (350 km in Accra); planned railways; and strengthening Adomi bridge

**Institutions:**

- Lead: Ministry of Roads and Highways

**Potential financing sources:**

- Existing project
- Government budget
- Climate grants
- Development banks
- Commercial banks
- Private sector

**NDC thematic areas and impacts**

- #1: City-wide resilient infrastructure planning
- #3: Integrated water resources management
- #4: Resilience for gender and the vulnerable
- Mitigation co-benefits:
- Enable more sustainable mass transportation
- Urban solid waste solutions (collection and transport)

**Capital / upfront costs**

**Operational costs**

**Implementation time**

# 24. NATURE-BASED ADAPTATION THROUGH CREATION OF INTERTIDAL HABITAT AT TAKORADI

The Takoradi area is not only impacted by coastal flooding, but also by river flooding that threatens its transport network. In particular, the airport located in the river delta as well as its surrounding roads are susceptible to flooding. A nature-based coastal resilience programme around the Takoradi area can focus on its exposed transport assets and facilities.

## Adaptation investment recommendations

- Protect and strengthen natural buffers by creating and expanding intertidal habitats to protect the Takoradi area from floods.

## Expected outputs and impacts

- Safeguarding of air passenger trips (113,803 annual)
- Potential co-benefits of urban heat reduction
- Protection and restoration of important aquatic ecosystems, with benefits for biodiversity and potential recreation and tourism benefits

## Gender considerations

- Natural restoration efforts can provide an opportunity to enhance women's leadership, participation and guardianship, with a strong role throughout the planning and implementation process

## Enabling environment supporting actions

- Climate adaptation alignment across water ministries and planning mechanisms (Option #16)
- Nature-based solutions prioritised in planning, design and operation (Option #35)
- Risk-informed, multi-modal transport master plan and investment plan (Option #26)

## Potential SDG targets influenced

1.4, 1.5, 2.1, 2.3-2.5, 3.3, 3.4, 3.9, 4.7, 6.1-6.4, 6.6, 7.1, 7.2,7.b, 9.1, 11.1, 11.4-11.7, 11.b, 11.c, 12.1-12.3, 13.1-13.3, 14.2, 14.5, 14.7, 15.1, 15.3 -15.5

**Option type:**

**Climate hazard:**

River flooding and coastal inundation which puts infrastructure assets at risk of damage.

**Impacts of hazard on assets and services:**

- Disruption of air and highway transport
- Loss of air and highway sector revenue to government and private investors.

**Assets:**

- Takoradi airport; exposed roads in Takoradi (516 km, including residential roads); other urban assets and natural habitats

**Institutions:**

- Lead: Ministry of Transport

**Potential financing sources:**

- Existing project
- Government budget
- Climate grants
- Development banks
- Commercial banks
- Private sector
- Community-led

**NDC thematic areas and impacts**

- #3: Integrated water resources management
- #4: Resilience for gender and the vulnerable

**Mitigation co-benefits:**

- Enable more sustainable mass transportation through road protection
- Sustainable utilisation of forest resources

**Capital / upfront costs**

**Operational costs**

**Implementation time**

# 25. TEMPORARY BARRIERS TO PROTECT RAILWAY LINES DURING CONSTRUCTION

To enhance transport connectivity for people and freight, Ghana has committed to the extension of its railway system, including the Western and Eastern rail lines. Cost-effective flood protection measures are required to safeguard work sites from flooding.

## Adaptation investment recommendations

- A programme of installing temporary barriers to protect critical assets, which can be constructed and utilised particularly in the rainy season and during construction of new infrastructure.

## Expected outputs and impacts

- Cost-effectiveness, portability and ease of relocation: barriers can be placed wherever they are most needed, particularly to highly-exposed sections of rail, providing a flexible adaptation option.

## Gender considerations

- Expansion of rail assets can have implications for women's economic empowerment, such as better access to employment opportunities
- Women's participation should be reflected across the project lifecycle, including procurement, construction, operation, and maintenance of the asset.

## Enabling environment supporting actions

- Proactive risk-informed asset management (Option #17)
- Risk-informed, multi-modal transport master plan and investment plan (Option #26)
- Centralised climate-risk data management system (Option #31)

## Potential SDG targets influenced

1.5, 4.1, 7.b, 8.2, 9.1, 9.4, 11.1, 11.2, 11.5, 11.b, 11.c, 12.1, 12.3, 12.4, 13.1, 13.2, 13.3

**Option type:**

**Climate hazard:**

Construction of transport assets can be disrupted during the rainy season, when flooding is most likely.

**Impacts of hazard on assets and services:**

- Disruption in construction activities on transport assets could lead to extension of infrastructure project delivery timeline as well as the increase in the cost of project delivery, all of which impacts on vital commercial and economic activities.

**Assets:**

- Takoradi to Kojokrom section of the Western rail line (~92 km); Accra to Tema section of the Eastern rail line (~34 km).
- Freight railway operational lines are from Manso to Takoradi port for the haulage of Manganese (~160 km).

**Institutions:**

- Lead: Ministry of Transport

**Potential financing sources:**

- Existing project
- Government budget
- Climate grants
- Development banks
- Commercial banks
- Private sector

**NDC thematic areas and impacts**

- #1: City-wide resilient infrastructure planning
- #3: Integrated water resources management
- #4: Resilience for gender and the vulnerable

**Mitigation co-benefits:**

- Provide intercity mass transportation
- Enable renewable energy uptake (electrification of transport)

**Capital / upfront costs**

**Operational costs**

**Implementation time**

# 26. RISK-INFORMED, MULTI-MODAL TRANSPORT MASTER PLAN AND INVESTMENT PLAN

There is the need to mainstream climate adaptation and resilience in the existing institutional framework, including sectoral and infrastructure-related regulation such as Public-Private Partnerships, to ensure coordination of adaptation measures across sector and sub-sector institutions and governance levels, as well as sector plans and expenditure frameworks to address adaptation needs and gender-differentiated impacts of climate change.

## Enabling environment strategies:

- Mainstream climate adaptation and resilience through a multi-modal transport master plan and investment plan that provides an integrated, risk-based planning and implementation framework that ensures coordination between different entities.
- Integration with risk-informed land use planning, prioritising NbS, and retrofitting and upgrading of existing infrastructure to withstand climate change impacts over new public and private infrastructure development, and addressing gender-differentiated vulnerabilities and needs of persons with disabilities.

## Expected outputs and impacts

- Multi-modal plan can provide an institutional framework for improving coordination and mainstreaming of climate adaptation in transport planning and implementation across sub-sectors (roads, rail, ports, airports) and all governance levels (MMDAs).
- A supporting investment plan can ensure the implementation of the plan.
- Integration of climate adaptation and resilience into public and private infrastructure investments with support from partners through technical assistance and capacity building programs

## Gender considerations

- Addressing gender-differentiated vulnerabilities based on travel patterns to ensure continued access to health, education and economic opportunities for women and girls.

## Built and natural environment supporting options

- Airport flood resilience through elevation of runways (Option #22)
- Bridges and underpasses (Option #23)
- Temporary barriers to protect railway lines (Option #25)

## Potential SDG targets influenced

1.5, 1.a, 9.1, 9.a, 10.3, 11.3, 11.5, 13.2, 16.6, 16.7, 17.3

**Option type:**

**Climate hazards:**

**Elements of the enabling environment:**

- Institutional structures, planning frameworks, funding, stakeholder participation

**Institutions:**

- Lead: Ministry of Transport, Ministry of Roads and Highways, Ministry of Railways Development, and Ministry of Aviation

**Potential financing sources:**

- Existing project
- Government budget
- Climate grants
- Development banks

**NDC thematic areas and impacts**

- #1: City-wide resilient infrastructure planning
- #4: Resilience for gender and the vulnerable
- #5: Mobilising investment

**Capital / upfront costs**

**Operational costs**

**Implementation time**

# 27. SUPPORTING RESILIENT DESIGN AND CONSTRUCTION OF ROADS THROUGH RESEARCH, CAPACITY BUILDING, AND THE CREATION OF A DESIGN MANUAL

There is a need to enhance technical capacity to integrate climate risk considerations during the design process that can inform implementation as well as increase the use of resilient materials.

## Enabling environment strategies:

- A program that mainstreams resilience in road design and implementation, including through standards and guidance for climate-resilient infrastructure and the integration of NbS measures.
- Research and development (drawing on global research) on contextually appropriate, cost-effective, resilient design of road surfaces that withstand high rainfall and temperature rise (e.g. composition and design of the paving material used to surface the road, shape of the road surface, etc.); and disseminating findings and best practices through guidance and training courses for technical project officers and environmental safeguard officers.

## Expected outputs and impacts

- Locally relevant design standards and materials that are responsive to climate risks are developed, implemented and enforced, leading to adaptation being mainstreamed in design of all new roads
- Enhanced technical capacity of transport sector staff lead to the design and implementation of climate-resilient roads

## Gender considerations

- Capacity development of transport sector staff on gender-mainstreaming in the design and construction of roads can ensure that mobility needs of women and girls are addressed, and that they can access health, education and economic opportunities.

## Built and natural environment supporting options

- Urban drainage measures in Accra (Option #18)
- Natural and built slope stabilisation along major highways (Option #21)
- Sponge City measures (Option #30)

## Potential SDG targets influenced

9.1, 9.a, 11.5, 13.1, 13.2, 13.3, 17.6, 17.16

**Option type:**

**Climate hazards:**

**Elements of the enabling environment:**

- Standard operating procedures and guidelines, funding, technical capacity, research and development

**Institutions:**

- Lead: Ministry of Roads and Highways, Ghana Highway Authority, Department of Feeder Roads, Department of Urban Roads, Ghana Standards Authority, Building and Road Research Institute

**Potential financing sources:**

- Existing project
- Government budget
- Climate grants
- Development banks

**NDC thematic areas and impacts**

- #6: Technology and capacity development

**Capital / upfront costs**

**Operational costs**

**Implementation time**

# 28. CLIMATE-RISK INFORMED ASSET MANAGEMENT SYSTEM AND OPERATIONS AND MAINTENANCE PRACTICES FOR ROADS

Procedures used to carry out periodic assessments of the condition of existing assets are inconsistent and not informed by climate risks, which increases the risk exposure of the high proportion of unpaved roads in Ghana that are vulnerable to increasing precipitation levels. Increases in precipitation, flooding and temperature accelerate the rate of asset deterioration and should be factored into the operations and maintenance system and its funding of the asset over its lifecycle.If no adaptation measures are implemented, Ghana's estimated spending on road maintenance and repairing the damage caused by climate change impacts from 2020 to 2100 may reach 473 million USD.

## Enabling environment strategies:

- Establish a unified GIS-based roads asset management system that includes information on asset condition and vulnerability to risks and registry of natural assets (eg. trees planted along roadside)
- Review and update of existing maintenance policies, guidelines and manuals based on current and projected climate risks, including the use of ICT, sensors and technology to increase preventive inspection and maintenance.
- Enhancing the resilience of existing roads with contingency planning to allow for safe failure in the short-term (eg. service continuity plans, re-routing plans when infrastructure becomes temporarily non-operational) and preventive maintenance to address long-term chronic stress that can lead to asset failure.

## Expected outputs and impacts

- Climate-risk informed roads asset management leads to the improved maintenance of road infrastructure and decreased exposure to climate risks.
- Improved maintenance system for existing roads that includes climate risk considerations, thereby reducing the impacts of increased precipitation, flooding and temperatures.
- Contingency plans will increase the adaptive capacity of the system by enabling more rapid and efficient response to climate change-induced events.

## Gender considerations

- Participation of women should be reflected in operation and management committees.

## Built and natural environment supporting options

- Green recreative green areas and riparian vegetation along exposed roads (Option #19)
- Natural and built slope stabilisation (Option #21)
- Bridges and underpasses (Option #23)

## Potential SDG targets influenced

1.5, 9.1, 9.a, 11.5, 13.1, 13.2, 13.3, 17.6, 17.16

**Option type:**

**Climate hazards:**

**Elements of the enabling environment:**

- Policy and regulatory frameworks, planning frameworks, standard operating procedures and guidelines, funding, data and information, technology and logistical resources

**Institutions:**

- Lead: Ministry of Roads and Highways, Ghana Highway Authority, Department of Feeder Roads, Department of Urban Road

**Potential financing sources:**

- Existing project
- Government budget
- Climate grants
- Development banks

**NDC thematic areas and impacts**

- #1: City-wide resilient infrastructure planning
- #6: Technology and capacity development

**Capital / upfront costs**

**Operational costs**

**Implementation time**

# CROSS-SECTORAL PROJECTS

Photo: Julianna Corbett on Unsplash

# 29. UPSTREAM AFFORESTATION OF THE VOLTA RIVER RESERVOIR TO BUILD RESILIENCE TO FLOOD AND DROUGHT

The Volta River is the main river system in Ghana and provides a key water transport route through the country – ports along the Volta account for 3.4 million passenger trips in total. It also includes a large reservoir and multiple dams generating hydroelectric power and water supply. Many of these assets situated along the river are exposed to a high risk of flooding, such as the Akosombo and Kpong hydroelectric plants (1,180 MW), as well as increased drought hazards.

## Adaptation investment recommendations

- A NbS programme to restore and better manage land upstream of the Volta reservoir through afforestation, which builds on existing tree-planting efforts along the river boundaries.

## Expected outputs and impacts:

- Safeguarding electricity generation of the Akosombo hydroelectric dam, which supplies a large share of Ghana's electricity as well as to neighbouring countries, and reduction of maintenance costs in dams.
- Enhancement of the river's capacity to absorb flood water and limiting erosion, silting, and mudslides
- Improved ecosystem and benefits for biodiversity, mitigation, human health, and safeguarding livelihoods

## Gender considerations

- Afforestation efforts should aim to enhance community leadership, participation and guardianship, with a role for women as members of design, planning, operations, and maintenance committees.

## Enabling environment supporting actions

- Climate adaptation alignment across water ministries and planning mechanisms (Option #16)
- Risk-resilient land management system (Option #32)
- Gender mainstreaming in adaptation planning, implementation and management (Option #34)

## Potential SDG targets influenced

1.4, 1.5, 2.3-2.5, 3.3, 3.4, 3.8, 3.9, 4.7, 6.1-6.4, 7.1,7.2, 9.1, 11.1, 11.4-11.7, 11.b, 11.c, 12.1-12.3, 13.1-13.3, 15.1-15.5

**Option type:**

**Climate hazards:**

Flooding: increases fluvial sediment and reduces reservoir capacity; physical damage to assets including river ports; downstream floods.

Drought: reduced river flow and reservoir capacity reduces generation capacity

**Impacts of hazard on assets and services:**

- Disruption of critical services such as water transportation, power generation and water supply all of which are essential and vital for daily sustenance of human activities. activities.

**Assets:**

- Volta river ports and near roads, Akosombo and Kpong hydropower plants, and green/ blue infrastructure

**Institutions:**

- Lead: Ghana Forestry Commission, Land Use and Spatial Planning Authority

**Potential financing sources:**

- Existing project
- Government budget
- Climate grants
- Development banks
- Commercial banks
- Private sector
- Community-led

**NDC thematic areas and impacts**

- #3: Integrated water resources management
- #4: Resilience for gender and the vulnerable
- Mitigation co-benefits:
- Enable sustainable inland waterway transportation
- Sustainable utilisation of forest resources

**Capital / upfront costs**

**Operational costs**

**Implementation time**

# 30. SPONGE CITY MEASURES TO PROVIDE ECOSYSTEM-BASED URBAN ADAPTATION TO CLIMATE CHANGE

The need for drainage system improvement in Accra and Takoradi has been emphasised in the Ministry's 2021 flood control program (Takoradi Market Circle drainage system reconstruction). Measures to ecological infrastructure and drainage systems, with focus on NbS, in the urban context can address a variety of hazards including flooding, drought, and heat. This provides absorption of heat and capture of rainwater and moisture.

## Adaptation investment recommendations

- Adoption of a Sponge City approach in coastal cities, including Accra and Sekondi-Takoradi.
- These measures may include vegetated greenways, bioswales and retention facilities, engineered wetlands, permeable pavement (sidewalks and roadways), on-site water harvesting, and green roof spaces.
- Infiltration facilities to move stormwater flows from the natural course without the intention of treating it, and having a permeable base which allows the water to percolate naturally back to groundwater flows.

## Expected output and impacts:

- Diminished flood intensity and frequency in Accra through reduced and shifted peak runoff flows
- Increased water quality and groundwater, with co-benefits to ecosystems, health and recreation.

## Gender considerations

- Women's participation in the construction and guardianship of nature-based and ecosystem assets should be incorporated.
- Gender-specific needs (e.g. health) should be reflected in project design and across the project lifecycle.

## Enabling environment supporting actions

- Climate adaptation alignment across water ministries and planning mechanisms (Option #16)
- Nature-based solutions prioritised in planning, design and operation (Option #35)
- Supporting resilient design and construction of roads through research, capacity building, and the creation of a design manual (Option #27)

## Potential SDG targets influenced

1.4, 1.5, 2.1, 2.3-2.5, 3.3, 3.4, 3.8, 3.9, 4.7, 4.a, 6.1-6.4, 6.6, 7.1, 7.2, 8.2, 9.1, 9.4, 11.1, 11.2, 11.4-11.7, 11.b, 11.c, 12.1-12.4, 13.1-13.3, 14.2, 14.5, 14.7,14.b, 15.1-15.5

**Option type:**

**Climate hazards:**

Flooding: vulnerability to damage from pluvial and coastal flood due to inadequate drainage.

Drought: Decreased urban water supply due to drought periods

**Impacts of hazard on assets and services:**

- Lessened severity and intensity of floods as the runoff peak will be diminished and offset.
- Greater local water storage capacity for capture, retention or infiltration, with co-benefits in addition to flood and drought management.
- Water quality increases and localised and city-wide evaporative cooling.

**Assets:**

- All assets exposed to flood in Accra and Takoradi, such as roads, buildings and natural areas

**Institutions:**

- Lead: Ministry of Transport, Ghana Water Company; Water Resources Commission

**Potential financing sources:**

- Existing project
- Government budget
- Climate grants
- Development banks
- Commercial banks
- Private sector
- Community-led

**NDC thematic areas and impacts**

- #1: City-wide resilient infrastructure planning
- #2: Early warning and disaster prevention
- #3: Integrated water resources management
- #4: Resilience for gender and the vulnerable

**Mitigation co-benefits:**

- Enable public transport and solid waste services
- Urban heat reduction and sustainable cooling
- Sustainable utilisation of forest resources

**Capital / upfront costs**

**Operational costs**

**Implementation time**

# 31. CENTRALISED CLIMATE-RISK DATA MANAGEMENT SYSTEM

Lack of access to data on water, climate risk and natural infrastructure, and scenario models by sector institutions to inform long-term, evidence-based, risk-informed infrastructure planning, delivery, and management.

## Enabling environment strategies:

- Update supporting policy and regulatory frameworks, institutional structures, decision making frameworks and standard operating procedures.
- Development of a platform to share flood and drought, hazards, vulnerability and risk maps at current (2010) and future scenarios (2050) for all districts, and make them readily available to relevant technical staff in energy, transport and water sectors (NADMO).
- Develop capacity in the collection, management, updating, sharing and use of climate-risk data. Ensuring that data is disaggregated according to gender, PWDs, LGBTQI and other groups, wherever applicable.

## Expected outputs and impacts

- Access to and use of climate change data enables the assessment of climate change risks and vulnerabilities for infrastructure planning, delivery and management processes, resulting in more climate-resilient infrastructure that better addresses risks and protects other critical infrastructure sector assets and communities.
- By having a centralised data source, everyone will be using the same, non-conflicting, data and it will also reduce the expense of having multiple data centres. It will also highlight any data gaps that need filling or updating which will further support climate resilience. This will also support other infrastructure sectors by allowing them access to this critical data to make risk-informed decisions.

## Gender considerations

- The use of socially- (including gender) disaggregated data can enhance the understanding of risks and vulnerabilities of different groups and ensure design-making that leaves no one behind

## Built and natural environment supporting options

- All natural and built environment solutions

## Potential SDG targets influenced

9.1, 9.a, 13.3, 16.10, 17.18

**Option type:**

**Climate hazards:**

**Elements of the enabling environment:**

- Policy and regulatory frameworks, institutional structures, standard operating procedures and guidelines, funding, technical capacity, data and information, technology and logistical resources, stakeholder participation

**Institutions:**

- Lead: National Disaster Management Organization, Ministry of Environment, Science Technology and Innovation, sector institutions and MDAs

**Potential financing sources:**

- Existing project
- Government budget
- Climate grants

**NDC thematic areas and impacts**

- #4: Resilience for gender and the vulnerable
- #7: Monitoring Report and Verification (MRV)

**Capital / upfront costs**

**Operational costs**

**Implementation time**

# 32. RISK-RESILIENT LAND MANAGEMENT SYSTEM

Difficulties in enforcing land use plans and regulation leads to non-compliance, and widespread encroachment and loss of protected land and deforestation, resulting in increased flood risk. Due to the current land tenure system, areas designated as buffers to protect dams have been encroached and developed on. This solution aligns to the ongoing GARED project which uses drones to fly over the Odaw river to map the specific encroachments around the river catchment area.

## Enabling environment strategies:

- Mainstreaming resilience through land use planning and building regulations (classification of high risk areas and restricting development)
- Strengthen the enforcement mechanisms for land use and building regulations by imposing stringent penalties for violation
- Improving capacity for enforcement at the district and municipal levels by investing in human, logistical and technology resources.
- Adopt land-based financing measures to enhance revenue streams for getting resources to improve the enforcement of regulations.
- Build the capacity and knowledge of developers and landowners on the importance and process of acquiring development and building permits.
- Implement land tenure reform to ensure clarity in land ownership and prevent the sale of land without approval, to protect areas of high biodiversity and natural capital, and also to secure women's land rights.
- Strategies for dealing with encroachments in the river catchment area are needed across different assemblies.

## Expected outputs and impacts

- Climate-risk informed land-use planning leads to future infrastructure site selection that avoids high climate exposure risks.
- Strengthened and improved enforcement of land use regulations and land tenure reform leads to greater protection of environmentally sensitive areas

## Gender considerations

- This can help in enhancing women's access to land through land reform process.

## Built and natural environment supporting options

- Coastal defence of thermal power plants in Western Region (Option #3)
- Natural restoration around Vea and Tono dams (Option #12)
- Slope stabilisation, forestation, and terracing at Barekese dam (Option #13)

## Potential SDG targets influenced

1.4, 5.a, 5.c, 13.1, 16.b

**Option type:**

**Climate hazards:**

**Elements of the enabling environment:**

- Policy and regulatory frameworks, planning frameworks, standard operating procedures and guidelines, funding, technical capacity, technology and logistical resources, stakeholder participation

**Institutions:**

- Lead: Ministry of Lands and Natural Resources, Land Use and Spatial Planning Authority

**Potential financing sources:**

- Existing project
- Government budget
- Climate grants

**NDC thematic areas and impacts**

- #4: Resilience for gender and the vulnerable
- #6: Technology and capacity development

**Capital / upfront costs**

**Operational costs**

**Implementation time**

# 33. MAINSTREAM RESILIENCE THROUGH CLIMATE RISK ASSESSMENTS AND EPA PERMITTING PROCESS AND STRENGTHEN ENFORCEMENT FOR ALL INFRASTRUCTURE PROJECTS

Climate risk assessments are not completed at the project preparation stage for all projects since the requirement does not exist (the requirement only exists for completing ESIAs). EPA permits are not secured for all infrastructure projects, specifically small-scale projects, due to limited funds and resources, challenges with enforcement, lack of access to climate risk data and low technical capacity. The enforcement of existing environmental regulations and permitting processes is also a challenge due to limited resources.

## Enabling environment strategies:

- Build capacity in the sector institutions for completing climate risk assessments at the project identification and preparation stage and put-in place mechanisms to integrate adaptation and resilience.
- Invest funds to increase human, logistical and technological resources available within EPA to monitor and enforce the permitting process. Invest resources to improve enforcement through mechanisms such as on-site monitoring and spot checks. Perform capacity building for EPA technical staff to carry out enforcement of existing regulations, specifically for small-scale projects.
- Engage the small-scale infrastructure developers through public awareness campaigns to sensitise them to the importance of climate risk assessments and environmental regulations.
- Create public reporting mechanisms for citizens and community leaders to notify the government of infrastructure being built without EPA permits.
- Assess how the financial performance of public and private infrastructure projects will be affected if a wider range of environmental and socio-economic costs and co-benefits (externalities) are integrated into investment decisions. Ensure that such 'enhanced' cost-benefit analysis is carried out for projects to improve the understanding that climate-resilient (and NbS-aligned) infrastructure delivers better value-for-money for citizens and investors. Invest in skills, data and budget for these valuations.

**Option type:**

**Climate hazards:**

**Elements of the enabling environment:**

- Policy and regulatory frameworks, institutional structures, standard operating procedures and guidelines, funding, data and information, technical capacity, technology and logistical resources

**Institutions:**

- Lead: Environmental Protection Agency (EPA)

**Potential financing sources:**

- Existing project
- Government budget
- Climate grants

**NDC thematic areas and impacts**

- #6: Technology and capacity development
- #7: Monitoring Report and Verification

**Capital / upfront costs**

**Operational costs**

**Implementation time**

## Expected outputs and impacts

- Increased capacity and resources to conduct and enforce climate risk assessments, and more frequent completion of climate risk assessments as a part of all infrastructure projects, regardless of scale. Ghana's infrastructure is more resilient to the impacts of climate change as a result.

## Gender considerations

- Women should be equally represented in teams conducting climate risk assessments.
- Climate risk assessments should be designed with a gender lens, with capacity- and skill-building of all team members in this regard.

## Built and natural environment supporting options

- Solar microgrids in drought-prone districts (Option #7)
- Green recreative green areas along exposed roads (Option #19)
- Tema Port: Built and natural coastal defence options (Option #20)

## Potential SDG targets influenced

9.1, 9.a, 13.1, 13.2, 13.3

*Photo: Gilbert Duodu on Unsplash*

# 34. GENDER MAINSTREAMING IN ADAPTATION PLANNING, IMPLEMENTATION AND MANAGEMENT

Policy and planning instruments do not represent gender-differentiated vulnerabilities to climate change or provide measures to manage these risks. The implementation of gender mainstreaming activities is hampered by inadequate budgeting processes and delayed release of funding. Inadequate women's representation in public sector institutions reinforces hurdles in gender mainstreaming and hampers the ability to achieve gender equality in the design process.

## Enabling environment strategies:

- Updating policies, as well as planning, decision-making and regulatory frameworks, including the ones related to infrastructure development, to mainstream gender by including gender-differentiated vulnerabilities and reporting requirements related to climate change activities and impacts.
- Updating human resource and recruitment policies and practices to set gender diversity and gender balance targets, and assign responsibility to oversee their achievement.
- Improvements to data collection practices to include gender-disaggregated data related to climate change impacts, as well as on internal institutional progress towards implementing gender mainstreaming activities and achieving gender diversity.
- Capacity building is needed to sensitise decision-makers and managerial staff on the importance of gender mainstreaming in climate adaptation, and to facilitate organisational change.

## Expected outputs and impacts

- Gender differentiated vulnerabilities to climate change are represented and addressed in infrastructure planning.
- Improved gender mainstreaming in design processes.
- Adequate funding allocated and disbursed for gender mainstreaming in projects, enabling gender mainstreaming actions to be successfully implemented within projects.
- Increased gender diversity in public sector institutions.
- Overall, women and girls have more reliable access to infrastructure services in the face of a changing climate

## Gender considerations

- Mainstreaming gender-related considerations across the infrastructure lifecycle is a prerequisite to understanding and addressing gender-differentiated vulnerabilities to the impacts of climate change.

## Built and natural environment supporting options

- All natural and built environment solutions

## Potential SDG targets influenced

1.5, 1.b, 5.5, 5.a, 5.c, 6.b, 7.a, 8.3, 9.1, 10.3, 11.3, 11.5, 13.1, 13.3, 16.7, 16.b, 17.18

**Option type:**

**Climate hazards:**

**Elements of the enabling environment:**

- Policy and regulatory frameworks, institutional structures, planning frameworks, technical capacity, data and information, funding, stakeholder participation

**Institutions:**

- Lead: The three sector and sub-sector ministries; Ministry of Gender, Children and Social Protection

**Potential financing sources:**

- Existing project
- Government budget
- Climate grants

**NDC thematic areas and impacts**

- #4: Resilience for gender and the vulnerable

**Capital / upfront costs**

**Operational costs**

**Implementation time**

# 35. PRIORITISE NATURE-BASED SOLUTIONS IN PLANNING, DESIGN AND OPERATION OF INFRASTRUCTURE

Planning and design processes, standards, and guidance do not include climate adaptation considerations or promote NbS that can help Ghana combat risks to infrastructure assets and service delivery.

## Enabling environment strategies:

- Mainstream the use of natural infrastructure and climate adaptation within planning, regulatory, and enforcement framework, standard operating procedures, codes and standards.
- Set-up cross-sectoral coordination mechanism to leverage the positive impact that NbS can have for service delivery and protection of services and infrastructure.
- Create guidance for planning, designing, constructing and maintaining climate compatible drainage infrastructure, including NbS as water resource management will have a linkage and impact other sectors.
- Promote and enable the use of NbS by adopting a framework to quantify the values of ecosystem services and incorporate them into policy-making and project cost-benefit analysis.

## Expected outputs and impacts

- Improved flood risk management that is informed by climate adaptation considerations.
- Reduced runoff volumes and flow rates from hard surfaces.
- Enhanced water quality management by reducing the impact of diffuse pollution.
- Increased habitat and ecosystem health, with numerous co-benefits for biodiversity, climate mitigation, human health, livelihoods, recreation, and provision of other ecosystem services
- Water resource augmentation through recharge of groundwater supplies. Reduced impacts of climate change on key populations, in particular women and girls.

## Gender considerations

- Mainstreaming gender consideration into the planning and design process will improve women's access to critical water related services and improve economic and health related outcomes.

## Built and natural environment supporting options

- Natural flood adaptation of the Weija Dam (Option #10)
- Nature-based adaptation through creation of intertidal habitat at Takoradi (Option #24)
- Sponge City measures (Option #30)

## Potential SDG targets influenced

1.5, 5.1, 6.6, 9.1, 11.5, 11.7, 11.b, 13.1, 13.2, 13.3, 14.1, 15.1

**Option type:**

**Climate hazards:**

**Elements of the enabling environment:**

- Policy and regulatory frameworks, planning frameworks, funding, standard operating procedures and guidelines, data and information, technical capacity building

**Institutions:**

- Lead: Ministry of Water Resources and Sanitation, Ghana Water Company, Ministry of Roads and Highways, Ghana Highways Authority, Department of Feeder Roads, Department of Urban Roads, Council for Scientific and Industrial Research

**Potential financing sources:**

- Existing project
- Government budget
- Climate grants

**NDC thematic areas and impacts**

- #3: Integrated water resources management
- #6: Technology and capacity development

**Capital / upfront costs**

**Operational costs**

**Implementation time**

# PART 3: SCALING UP CLIMATE ADAPTATION IN GHANA

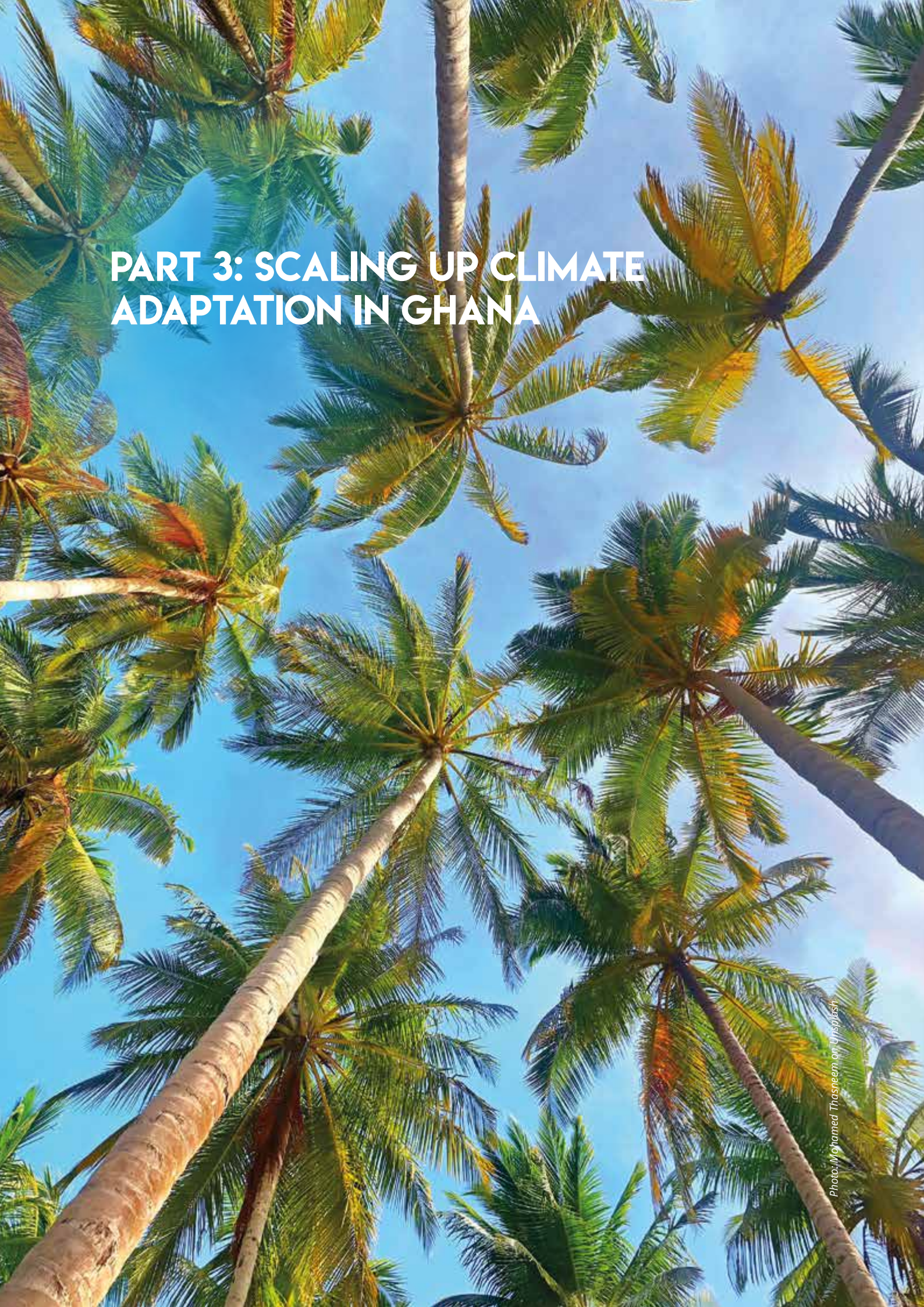


Photo: Mohamed Thasneem on Unsplash

# ACTIONS TO IMPLEMENT THE ROADMAP AND SCALE UP ADAPTATION ACTION IN GHANA

Part 3 of this report addresses how the Government of Ghana, in collaboration with its partners, can leverage this study to scale up adaptation action in Ghana. This can be achieved through the key actions summarised as follows: (i) Delivering the roadmap projects defined in Part 2 of this report, by further developing and securing financing for project implementation; (ii) Mainstreaming the roadmap projects, and key information from this study, into policy processes that include the NDC and NAP; and (iii) Ensuring a legacy of resilient infrastructure planning in Ghana using the methods, tools and training resources made available through this study. The following subsections of this report provide detailed information to support the Government of Ghana in these three areas.

## Strategically identifying financing to implement the roadmap

The primary action of the Government, along with its partners, is to secure financing to implement the roadmap to address Ghana's most critical infrastructure adaptation needs. Doing so will require the development of the projects: from robustly justified project concepts (described in Part 2) to fully prepared projects that are suitable for financing. The extent of project preparation required for each project depends on whether that project targets the built, natural or enabling environment (Figure 30). For projects targeting the built and natural environments, financing is first required for project preparation, which includes all activities that advance projects from concept stage to full proposals that can be assessed for feasibility, among other things. Once a project is fully prepared, financing must then be sought to deliver it. Projects targeting the enabling environment often require less budget, are less risky and typically do not require feasibility-related assessments – they are therefore candidates for project delivery funding only.

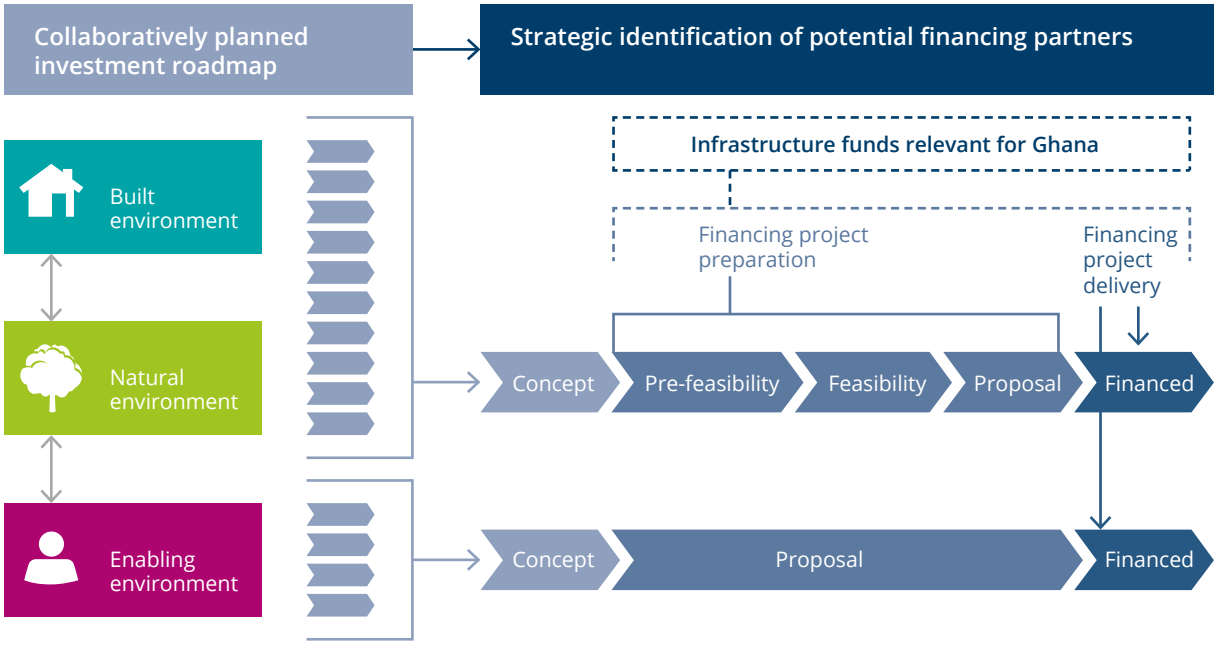



**Figure 30:**
*Framework for identifying financing partners for the roadmap.*

Financing of project preparation activities and for project delivery can come from a variety of sources, including government budgetary expenditure, traditional development financiers, and private sector investors. The choice of the source of financing, as well as financing modality, is based on a complex range of contextual factors. The following paragraphs provide a description of the financing landscape for Ghana to help facilitate the Government in taking the next steps towards project preparation and financing.

One important source of finance is the Government's own public expenditure. Ghana's Adaptation Strategy and Action Plan recognises the need for increased government spending on climate adaptation. In 2015 Ghana established the National Climate Change Policy (NCCP) Master Plan, which outlined a 5-year action plan to tackle climate change (mitigation and adaptation) and increase annual public spending on climate initiatives six-fold to GH¢ 4.1 billion (approximately, 695 million USD).[15] However, actual expenditures and budget allocations have fallen short of this target. The country's 2020 SDG Budget report estimates that GH¢221 million (approximately 37 million USD) was allocated to the achievement of SDG 13: Climate Action, which amounts to 0.4 percent of total budget allocations and 5 percent of the target.[16]

Increased public expenditure on climate change initiatives will be essential to finance the resilient infrastructure roadmap. However, increased fiscal pressures caused by the Covid-19 pandemic highlight the need for additional sources of financing.

One additional source of financing comes from traditional development financiers, including: development banks, government agencies, development finance institutions and multilateral development funds. Many of these financiers are already engaged in climate financing in Ghana; approximately 18 percent of funding for SDG 13 in 2020 came from external development partners.[17] These financiers can also be leveraged to attract private sector financing. As Ghana progresses its Beyond Aid agenda and inflows of Official Development Assistance (ODA) decline, the private sector will play an increasingly important role in climate finance. Though inflows of foreign direct investment (FDI) declined in 2020, alongside most African countries, Ghana remains one of the highest recipients of FDI on the continent.[17] The emergence of innovative financing mechanisms to blend public and private financing, de-risk investments, and incentivise private sector involvement highlight the potential for private sector engagement. For example, the global market for green bonds, including in emerging markets, has increased substantially from 3 billion in 2011 to 163 billion USD in 2018.[16]

Government initiatives are already underway to foster a conducive environment for private sector investment through the Public Investment and Assets Division (PIAD) within the Ministry of Finance and the Ghana Investment Promotion Centre (GIPC). Public and private sector collaboration, including through Public-Private Partnerships (PPPs), will be essential to mobilise financing for the resilient infrastructure roadmap. Further development of the enabling environment for PPPs, including through initiatives such as the GCA's Climate Resilient Infrastructure Office programme,[18] are key to ensuring that this important area of financing is advanced in Ghana. Several projects within the roadmap demonstrate potential for private sector investment, especially those focused on increasing the resilience of hydroelectric dams (projects #1, #2), power plants (#3, #4, #6), ports (#20), and road (#19, #21) infrastructure. The proliferation of solar microgrids through project #7 may also be particularly attractive for the private sector. Traditional development financiers can support the government to engage the private sector for the resilient infrastructure roadmap, leveraging their own finances to de-risk investments and attract private investment.

As part of this study, an exploration of options for financing the resilient infrastructure roadmap has been carried out using the Sustainable Infrastructure Financing Tool (SIFT). Developed by UNOPS, in collaboration with the University of Oxford, SIFT provides a structured and strategic approach for identifying potential sources of financing for sustainable infrastructure projects. Underpinning SIFT is a global database of 134 infrastructure funds, of which 82 are applicable for funding Ghana's. A fund's applicability to Ghana was determined based on the fund's listed countries of operation. Data in SIFT was collected through a comprehensive review of publicly available information on infrastructure funds.

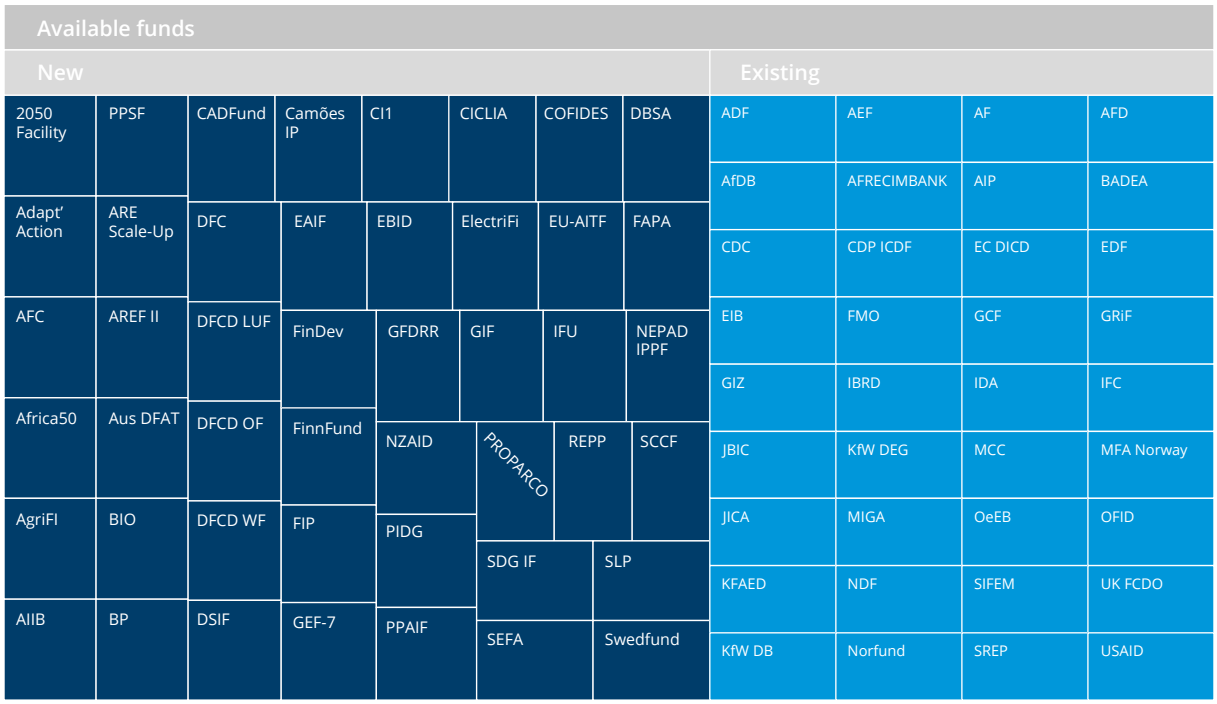



**Figure 31:**
*New opportunities and existing relationships available for infrastructure financing in Ghana*

The primary source of data used was the fund or funder website, including available documentation such as annual reports, financial statements, or strategy documents; where such lists were not available, applicability was determined based on the fund's regional or income-status scope. SIFT focuses on global and regional financiers that operate in multiple countries, excluding UN agencies. A detailed explanation of the SIFT methodology is provided in Appendix A.4.

Data analysis from SIFT reveals that of the 82 funds applicable for Ghana, the Government has existing relationships with 36 of them, which is defined as the government having received financing from the fund in the past ten years.

The analysis highlights the scale of funding opportunities from existing sources (44 percent) and the opportunities to establish new relationships (56 percent) with financiers for infrastructure financing. Funds' relationship with the government was determined in collaboration with PIAD through a survey and by querying the Ghana Development Cooperation Management Information System (Gh-DCMIS). A summary of new and existing funds is presented in Figure 31. Of these funds, 61 provide loans and 53 provide grants – an important financing mechanism for Ghana given budgetary constraints that have emerged due to the Covid-19 pandemic. In total, 78 funds (95 percent) provide funding for projects from the built and natural environment, whereas 58 (71 percent) provide funding for enabling environment activities. Lastly, 51 funds (62 percent) were identified as being able to provide project preparation financing. More details on these funds are provided in Appendix D.

Strategically planning the financing for projects within the roadmap can help accelerate action towards a more climate resilient future. The fund information contained within SIFT highlights the magnitude of financing opportunities for the roadmap. The appropriateness of any one source of finance for a given project in the roadmap is determined by multiple factors, which include: the type of project being funded, the timing and thematic focus of funding cycles (for example – the country strategies of Multilateral Development Banks), the ability to provide grants and the strength of existing relationships.

Financing built and natural environment projects requires funding for project preparation as well as for project delivery, and these can come from different sources. Figure 32 provides an overview of the funds that are available for financing these types of projects in Ghana. Across all sectors, 42 are sources of funding for project preparation and project delivery, 9 relate only to project preparation, and 27 are only for project delivery. Of the available funds, 36 have provided financing to the government within the last 10 years, indicating an existing relationship. When evaluated by sector, 69 are applicable for energy projects, while 51 and 54 are applicable for the water and transportation sectors, respectively. A total of 45 funds are applicable for all three sectors and provide options to fund cross-sectoral projects. In addition, 48 funds were identified that finance NbS and natural infrastructure related to climate adaptation or disaster risk reduction. Grants are offered by 49 of the funds, of which the government has an existing relationship with 25.

**Figure 32:**
*Financing options for built and natural environment adaptation in Ghana.*

* Sectoral coverage, financing mechanisms offered and ability to finance enabling activities were determined based on a review of fund websites and publicly available documentation.

** Fund relationship with the government was determined in consultation with the Ministry of Finance, based on whether or not the fund has provided financing to the government in the past 10 years.

**Finance both project preparation and project delivery**

| Fund | Fund name | Transport* | Energy* | Water* | Climate* | Grants* | Loans* | Finances enabling environment* | Provided finance in past 10 years** |
|---|---|---|---|---|---|---|---|---|---|
| ADF | African Development Fund | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| AIP | Africa Investment Platform | ■ | ■ | ■ | ■ | ■ | | | ■ |
| AFD | Agence Française de Développement | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| AfDB | African Development Bank | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| BADEA | Arab Bank for Economic Development in Africa | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| CDC | Commonwealth Development Corporation | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| GCF | Green Climate Fund | ■ | ■ | ■ | ■ | ■ | ■ | | ■ |
| JICA | Japan International Cooperation Agency | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| KFAED | Kuwait Fund For Arab Economic Development | ■ | ■ | ■ | | ■ | ■ | ■ | ■ |
| NDF | Nordic Development Fund | ■ | ■ | | ■ | ■ | ■ | ■ | ■ |
| OeEB | Development Bank of Austria | ■ | ■ | | ■ | ■ | ■ | ■ | ■ |
| OFID | OPEC Fund for International Development | ■ | ■ | ■ | | ■ | ■ | ■ | ■ |
| SREP | Scaling Up Renewable Energy Program in Low Income Countries | | ■ | | | ■ | ■ | ■ | ■ |
| ARE Scale-Up | African Renewable Energy Scale-Up Facility | | ■ | | | ■ | ■ | | |
| BIO | Belgian Investment Company for Developing Countries | ■ | ■ | ■ | | ■ | ■ | ■ | |
| COFIDES | Compania Espanola de Financiacion del Desarrollo | ■ | ■ | ■ | ■ | ■ | ■ | ■ | |
| DFC | U.S. International Development Finance Corporation | ■ | ■ | | | ■ | ■ | ■ | |
| DFCD WF | DFCD Water Facility | | | ■ | | ■ | ■ | | |
| DSIF | Danida Sustainable Infrastructure Finance | ■ | ■ | ■ | | ■ | ■ | ■ | |
| EBID | ECOWAS Bank for Investment and Development | ■ | ■ | ■ | ■ | ■ | ■ | ■ | |
| FIP | Forest Investment Program | | | | ■ | ■ | ■ | ■ | |
| GEF-7 | Global Environment Facility Trust Fund | ■ | ■ | ■ | ■ | ■ | ■ | ■ | |
| IFU | Investment Fund for Developing Countries | ■ | ■ | ■ | | ■ | ■ | ■ | |
| PIDG | Private Infrastructure Development Group | ■ | ■ | ■ | | ■ | ■ | ■ | |
| PROPARCO | Promotion et Participacion pour la Coopération économique (France) | ■ | ■ | ■ | | ■ | ■ | ■ | |
| SEFA | Sustainable Energy Fund for Africa | | ■ | | | ■ | ■ | ■ | |
| EU-AITF | EU-Africa Infrastructure Trust Fund | ■ | ■ | ■ | | ■ | | ■ | |
| CDP ICDF | CDP International Cooperation and Development Finance | ■ | ■ | | ■ | | ■ | ■ | ■ |
| EIB | European Investment Bank | ■ | ■ | ■ | ■ | | ■ | ■ | ■ |
| FMO | Dutch Development Bank | | ■ | | | | ■ | ■ | ■ |
| IFC | International Finance Corporation | ■ | ■ | | | | ■ | ■ | ■ |
| Norfund | Norwegian Investment Fund | | ■ | ■ | ■ | | ■ | ■ | ■ |
| AFC | Africa Finance Corporation | ■ | ■ | | | | ■ | ■ | |
| AIIB | Asian Infrastructure Investment Bank | ■ | ■ | ■ | ■ | | ■ | | |
| CI1 | Climate Investor One | | ■ | | | | ■ | ■ | |
| DBSA | Development Bank of Southern Africa | ■ | ■ | ■ | ■ | | ■ | | |
| EAIF | Emerging Africa Infrastructure Fund | ■ | ■ | ■ | | | ■ | ■ | |
| FinnFund | Finnish Fund | | ■ | | ■ | | ■ | | |
| REPP | Renewable Energy Performance Platform | | ■ | | | | ■ | ■ | |
| SDG IF | Danish SDG Investment Fund | | ■ | ■ | | | ■ | ■ | |
| Africa50 | Africa50 Infrastructure Fund | ■ | ■ | ■ | | | | | |
| AREF II | Africa Renewable Energy Fund II | | ■ | | ■ | | | | |

■ Evidence suggests that the fund finances projects in this sector
■ Evidence suggests that the fund offers this financing mechanism or finances enabling activities
■ Evidence suggests that the fund has provided financing to the government in the past ten years
■ Evidence not found to suggest that the fund provides this type of financing

**Finance project delivery only**

| Fund | Fund name | Transport* | Energy* | Water* | Climate* | Grants* | Loans* | Finances enabling environment* | Provided finance in past 10 years** |
|---|---|---|---|---|---|---|---|---|---|
| EC DICD | European Commission Department of International Cooperation & Development | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| EDF | European Development Fund | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| IBRD | International Bank for Reconstruction and Development | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| IDA | International Development Association | ■ | ■ | ■ | ■ | ■ | ■ | | ■ |
| KfW DB | KfW Development Bank | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| UK FCDO | UK Foreign, Commonwealth & Development Office | ■ | ■ | ■ | ■ | ■ | ■ | | ■ |
| AF | Adaptation Fund | | | ■ | ■ | ■ | | | ■ |
| MCC | Millennium Challenge Corporation | ■ | ■ | ■ | | ■ | | | ■ |
| MFA Norway | Ministry of Foreign Affairs Norway | ■ | | ■ | | ■ | ■ | ■ | ■ |
| USAID | United States Agency for International Development | | | ■ | ■ | ■ | | ■ | ■ |
| Aus DFAT | Australia Department of Foreign Affairs and Trade | ■ | ■ | ■ | ■ | ■ | ■ | ■ | |
| DFCD LUF | DFCD Land Use Facility | | | | ■ | ■ | ■ | | |
| NZAID | New Zealand Aid Program | | ■ | | | ■ | ■ | | |
| SCCF | Special Climate Change Fund | ■ | ■ | ■ | ■ | ■ | | ■ | |
| AEF | Access to Energy Fund | | ■ | | | | ■ | ■ | ■ |
| JBIC | Japan Bank for International Cooperation | ■ | ■ | ■ | ■ | | ■ | | ■ |
| KfW DEG | KfW Development Finance Institution | ■ | ■ | ■ | ■ | | ■ | ■ | ■ |
| SIFEM | Swiss Investment Fund For Emerging Markets | ■ | ■ | | | | ■ | | ■ |
| MIGA | Multilateral Investment Guarantee Agency | ■ | ■ | ■ | ■ | | | | ■ |
| AFREXIMBANK | African Export-Import Bank | ■ | ■ | | | | ■ | | ■ |
| AgriFI | Agriculture Financing Initiative | | | | | | ■ | | |
| BP | Building Prospects Fund | ■ | ■ | ■ | ■ | | ■ | | |
| ElectriFI | Electrification Financing Initiative | | ■ | | ■ | | ■ | | |
| FinDev | FinDev Canada | ■ | ■ | ■ | ■ | | ■ | | |
| SLP | Sovereign Loans Program | ■ | ■ | ■ | ■ | | ■ | | |
| Swedfund | Swedfund International AB | | ■ | | ■ | | ■ | ■ | |
| CADFund | China-Africa Development Fund | ■ | ■ | | | | | | |

**Finance project preparation only**

| Fund | Fund name | Transport* | Energy* | Water* | Climate* | Grants* | Loans* | Finances enabling environment* | Provided finance in past 10 years** |
|---|---|---|---|---|---|---|---|---|---|
| GRiF | Global Risk Financing Facility | | | | ■ | ■ | | ■ | ■ |
| GIZ | Deutsche Gesellschaft für Internationale Zusammenarbeit | ■ | ■ | ■ | | ■ | | ■ | ■ |
| DFCD OF | DFCD Origination Facility | | | ■ | ■ | ■ | ■ | ■ | |
| FAPA | Fund for African Private Sector Assistance | ■ | ■ | ■ | ■ | ■ | | ■ | |
| GFDRR | Global Facility for Disaster Reduction and Recovery | ■ | ■ | ■ | ■ | ■ | | ■ | |
| GIF | Global Infrastructure Facility | ■ | ■ | ■ | ■ | ■ | | ■ | |
| NEPAD IPPF | NEPAD Infrastructure Project Preparation Facility | ■ | ■ | ■ | | ■ | | ■ | |
| PPSF | Project Preparation Special Fund | ■ | ■ | ■ | ■ | ■ | | | |
| Adapt'Action | Adapt'Action Facility | | | | ■ | | ■ | ■ | |

■ Evidence suggests that the fund finances projects in this sector

■ Evidence suggests that the fund offers this financing mechanism or finances enabling activities

■ Evidence suggests that the fund has provided financing to the government in the past ten years

■ Evidence not found to suggest that the fund provides this type of financing

Financing enabling environment projects represents a quick win opportunity to enhance capacity in climate adaptation. Given that enabling environment projects do not require extensive project preparation, they represent a cost-effective route to make quick progress on enhancing the resilience of infrastructure in Ghana that can facilitate the implementation and effectiveness of built and natural adaptation options in the future. Figure 33 shows funds that provide finance for enabling environment activities in Ghana, highlighting opportunities to advance the resilient infrastructure roadmap.

The government has an existing relationship with 28 of these funds. Fund availability is presented by sector, showing opportunities to secure funding for the energy (51), water (37), transport (40) sectors, as well as across all three sectors (33). Funds were also identified that finance climate change related infrastructure (36). With respect to financing instruments, 44 funds offer grants; the government has an existing relationship with 21 of them.

**Figure 33:**
*Financing options for enabling environment adaptation in Ghana.*

**Financing options for enabling environment adaptation**

| Fund | Fund name | Transport* | Energy* | Water* | Climate* | Grants* | Loans* | Provided financing in past 10 years** |
|---|---|---|---|---|---|---|---|---|
| AFD | Agence Française de Développement | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| AfDB | African Development Bank | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| BADEA | Arab Bank for Economic Development in Africa | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| CDC | Commonwealth Development Corporation | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| EC DICD | European Commission Department of International Cooperation & Development | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| EDF | European Development Fund | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| IDA | International Development Association | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| IBRD | International Bank for Reconstruction and Development | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| JICA | Japan International Cooperation Agency | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| KFAED | Kuwait Fund For Arab Economic Development | ■ | ■ | ■ |  | ■ | ■ | ■ |
| KfW DB | KfW Development Bank | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| MCC | Millenium Challenge Corporation | ■ | ■ | ■ |  | ■ |  | ■ |
| MFA Norway | Ministry of Foreign Affairs Norway |  | ■ |  | ■ | ■ | ■ | ■ |
| NDF | Nordic Development Fund | ■ | ■ |  | ■ | ■ | ■ | ■ |
| OeEB | Development Bank of Austria | ■ | ■ |  | ■ | ■ | ■ | ■ |
| OFID | OPEC Fund for International Development | ■ | ■ | ■ |  | ■ | ■ | ■ |
| SREP | Scaling Up Renewable Energy Program in Low Income Countries |  | ■ |  |  | ■ | ■ | ■ |
| GRiF | Global Risk Financing Facility |  |  |  | ■ | ■ |  | ■ |
| GIZ | Deutsche Gesellschaft für Internationale Zusammenarbeit | ■ | ■ | ■ |  | ■ |  | ■ |
| USAID | United States Agency for International Development |  |  | ■ | ■ | ■ |  | ■ |

■ Evidence suggests that the fund finances projects in this sector
■ Evidence suggests that the fund offers this financing mechanism or finances enabling activities
■ Evidence suggests that the fund has provided financing to the government in the past ten years
■ Evidence not found to suggest that the fund provides this type of financing

**Financing options for enabling environment adaptation**

| Fund | Fund name | Transport* | Energy* | Water* | Climate* | Grants* | Loans* | Provided financing in past 10 years** |
|---|---|---|---|---|---|---|---|---|
| ADF | African Development Fund | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Aus DFAT | Australia Department of Foreign Affairs and Trade | ■ | ■ | ■ | ■ | ■ | ■ | |
| BIO | Belgian Investment Company for Developing Countries | ■ | ■ | ■ | | ■ | ■ | |
| COFIDES | Compania Espanola de Financiacion del Desarrollo | ■ | ■ | ■ | ■ | ■ | ■ | |
| DFC | U.S. International Development Finance Corporation | ■ | ■ | | | ■ | ■ | |
| DFCD OF | DFCD Origination Facility | | | ■ | ■ | ■ | ■ | |
| DSIF | Danida Sustainable Infrastructure Finance | ■ | ■ | ■ | | ■ | ■ | |
| EBID | ECOWAS Bank for Investment and Development | ■ | ■ | ■ | ■ | ■ | ■ | |
| FIP | Forest Investment Program | | | | ■ | ■ | ■ | |
| GEF-7 | Global Environment Facility Trust Fund | ■ | ■ | ■ | ■ | ■ | ■ | |
| IFU | Investment Fund for Developing Countries | ■ | ■ | ■ | | ■ | ■ | |
| PIDG | Private Infrastructure Development Group | ■ | ■ | ■ | | ■ | ■ | |
| PROPARCO | Promotion et Participacion pour la Coopération économique (France) | ■ | ■ | ■ | | ■ | ■ | |
| SEFA | Sustainable Energy Fund for Africa | | ■ | | | ■ | ■ | |
| 2050 Facility | 2050 Facility | ■ | ■ | | ■ | ■ | | |
| Camões IP | Camões IP | | ■ | | ■ | ■ | | |
| CICLIA | Cities and Climate in Africa | ■ | ■ | ■ | ■ | ■ | | |
| EU-AITF | EU-Africa Infrastructure Trust Fund | ■ | ■ | ■ | | ■ | | |
| FAPA | Fund for African Private Sector Assistance | ■ | ■ | ■ | ■ | ■ | | |
| GFDRR | Global Facility for Disaster Reduction and Recovery | ■ | ■ | ■ | ■ | ■ | | |
| GIF | Global Infrastructure Facility | ■ | ■ | ■ | ■ | ■ | | |
| NEPAD IPPF | NEPAD Infrastructure Project Preparation Facility | ■ | ■ | ■ | | ■ | | |
| PPIAF | Public-Private Infrastructure Advisory Facility | ■ | ■ | ■ | ■ | ■ | | |
| SCCF | Special Climate Change Fund | ■ | ■ | ■ | ■ | ■ | | |
| AEF | Access to Energy Fund | | ■ | | | | ■ | ■ |
| CDP ICDF | CDP International Cooperation and Development Finance | ■ | ■ | | ■ | | ■ | ■ |
| EIB | European Investment Bank | ■ | ■ | ■ | ■ | | ■ | ■ |
| FMO | Dutch Development Bank | | ■ | | | | ■ | ■ |
| IFC | International Finance Corporation | ■ | ■ | | | | ■ | ■ |
| KfW DEG | KfW Development Finance Institution | ■ | ■ | ■ | ■ | | ■ | ■ |
| Norfund | Norwegian Investment Fund | | ■ | ■ | ■ | | ■ | ■ |
| Adapt'Action | Adapt'Action Facility | | | | ■ | | ■ | |
| AFC | Africa Finance Corporation | ■ | ■ | | | | ■ | |
| CI1 | Climate Investor One | | ■ | | | | ■ | |
| EAIF | Emerging Africa Infrastructure Fund | ■ | ■ | ■ | | | ■ | |
| REPP | Renewable Energy Performance Platform | | ■ | | | | ■ | |
| SDG IF | Danish SDG Investment Fund | | ■ | ■ | | | ■ | |
| Swedfund | Swedfund International AB | | ■ | | ■ | | ■ | |

■ Evidence suggests that the fund finances projects in this sector

■ Evidence suggests that the fund offers this financing mechanism or finances enabling activities

■ Evidence suggests that the fund has provided financing to the government in the past ten years

■ Evidence not found to suggest that the fund provides this type of financing

## Mainstreaming the roadmap into policy processes

The findings of this national assessment can be mainstreamed into Ghana's national development framework through major policy processes and other initiatives, such as the National Adaptation Plan and the revised Nationally-Determined Contributions.

The projects contained within the roadmap provide a well justified, government-led strategy ready for implementation that aligns with Ghana's NAP framework. Beyond this, the study's data, assessment methodology and results can help inform its development. It provides the cornerstone of an adaptation implementation strategy for Ghana's key infrastructure sectors to address medium- and long-term development concerns, taking into account future and potential vulnerabilities to climate change. The roadmap aligns with the Environmental Protection Agency (EPA) and MESTI's work to strengthen the resilience of energy, water and transportation infrastructure to the impacts of climate change through a 5- to 10-year investment plan. Notably, it provides the government with methodology, tools and knowledge to implement resilient infrastructure projects, based on evidence-based adaptation research, while integrating gender considerations into adaptation responses. The implementation of this roadmap should consider guiding principles of ensuring participatory decision-making, involving youth, considering co-benefits, and treating infrastructure adaptation as a cross-sectoral and multi-dimensional process, among other things.

Similarly, Ghana has launched its NDC revision process with new climate action related targets in the dual areas of mitigation and adaptation, with a focus on gender responsiveness. The projects in this roadmap are directly aligned with key strategic areas of Ghana's NDCs, as outlined in Appendix B.5.

Approximately 12.8 billion USD investment will be needed across these three sectors to achieve NDC objectives – the projects in this roadmap serve as good candidates for potential investors and can ultimately lead to the mobilisation of much-needed resources to propel the achievement of the SDGs in Ghana.

## Ensuring a legacy of resilient infrastructure in Ghana

Capacity building will be key to maintaining the legacy of this novel study in Ghana, by providing infrastructure analysts in the Government of Ghana with the ability to conduct further assessment of the country's infrastructure resilience in years to come, integrating new and updated data as it becomes available. This can help address limitations of this current study and report, where asset data obtained in certain subsectors was not sufficient to conduct an adaptation prioritisation analysis, or to quantify evolving economic or social impacts of climate hazards through disrupted infrastructure services. Periodic reviews and updates of the resilient infrastructure roadmap will ensure its continued relevance to Ghana's adaptation needs and emerging global priorities. Knowledge management will be important to ensure the continued use of the evidence-based methods and tools across the government.

Specifically, this entails the transfer of knowledge to interested stakeholders in-country through a handover of datasets and training in open-source tools used to conduct the resilience analysis. These will be conducted during targeted training sessions organised by MESTI, and will accompany the completion and release of this report. Throughout this study, each section produced findings relying heavily on a suite of assessment tools, which were applied to assess Ghana's specific infrastructure challenges.

- Parts 1 and 2 utilised the National Infrastructure Systems Model (NISMOD), developed by the University of Oxford, to integrate geospatial datasets on assets and hazards in the country to identify exposed assets and districts as well as to explore potential adaptation solutions.
- In addition, Parts 1 and 2 used the Capacity Assessment Tool for Infrastructure (CAT-I) Adaptation Theme, developed by UNOPS, to gather evidence on the challenges and needs within the enabling environment to plan, deliver, and manage sustainable, resilient, and inclusive infrastructure systems.
- Part 3 involved use of the Sustainable Infrastructure Financing Tool (SIFT), developed by UNOPS, to strategically identify financing opportunities and fund criteria for specified project types.

These tools are designed to be used in an integrated analysis, and to bring together data and information on Ghana's infrastructure sectors as well as its physical assets, natural land uses, and institutional and governance structures. Importantly, they allow users to best align decisions on infrastructure with Ghana's strategic vision for achieving the global agendas including the SDGs, the Paris Agreement, and government priorities on mainstreaming gender equality targets and other outcomes. In addition to their application to Ghana, these tools are broadly applicable to other countries and contexts and contribute to an emerging tradition of capacity development and knowledge transfer through open-source software.

This study is the first comprehensive, cross-sectoral, and systematic approach to assessing infrastructure resilience in Ghana.

This report has detailed the study methods and findings following a three-phase approach to identifying and proposing solutions to address climate adaptation challenges in the country through strategic investments in natural and built infrastructure, and the enabling institutional and policy environment. Using novel modelling and assessment tools, and through an extensive stakeholder consultation process, it provided an assessment of the risk of various climate hazards on national built and natural infrastructure systems over the coming decades. Next, a resilient infrastructure roadmap was developed for addressing risks through prioritised investments in the built and natural environments, including NbS, which can achieve and safeguard development outcomes in the face of more frequent and intense climate hazards. The roadmap also includes interventions to enhance the enabling environment and to build long-term resilience into Ghana's institutional capacity to respond to climate change. Finally, the strategic identification of potential financing sources for projects contained within the roadmap was explored, suggesting opportunities for funds to support Ghana's future resilience.

While climate change will continue to pose challenges for Ghana's infrastructure, decision-makers in the country can now be better prepared to respond to them. In particular, they can be equipped with the knowledge and tools necessary to prioritise needs and gaps through informed investments that are more cost-effective in the long-term, including through nature-based solutions. In addition, the solutions arrived at can be tailored to meet explicit financing criteria to ensure that project concepts are carried through to implementation. By recognising its responsibility to commit to purposeful, robust, and evidence-based infrastructure adaptation planning, the Government of Ghana has embraced an opportunity to build a more sustainable, resilient, inclusive, and prosperous society.

# TECHNICAL APPENDICES

Photo: Owen Ojr on Unsplash

# APPENDIX A: DETAILED METHODS AND TOOLS USED IN THIS STUDY

## A.1. Framing the components of the infrastructure system

The study uses a systems approach to identifying climate risks, and therefore adaptation needs, and prioritises infrastructure adaptation interventions across three main components of the infrastructure system that enable adaptation outcomes: the built environment, the natural environment, and the enabling environment.

**The built environment**: The built environment comprises physical infrastructure assets and structures such as generation and treatment facilities, transmission networks, and buildings supplied by infrastructure services, as well as spaces modified to support human activity – for example, within urban systems. While it enables a wide range of infrastructure services such as thermal comfort, accessibility, communication, and waste removal, physical infrastructure is highly susceptible to the impacts of destructive climate events.

**The natural environment**: The natural environment provides many services essential for humans and ecosystems, including the provisioning of food and water, regulation of climate, nutrient cycling, pollination, and biomass production. In many cases, these natural functions can supplement or even substitute for services provided by the built environment, such as through flood defence. Investing in the protection and restoration of elements of the natural environment can therefore deliver services, including providing built infrastructure with an increased level of resilience to climate hazards, often at lower cost and with fewer long-term maintenance requirements than built alternatives. Nature-based solutions*,[19] can also enhance development outcomes through additional co-benefits such as improved health outcomes or job creation.

* Nature-based solutions (NbS) are "actions to protect, sustainably manage and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits". Nature-based solutions for infrastructure include the use of natural and hybrid infrastructure to meet infrastructure service needs (e.g. protecting a natural watershed to ensure drinking water quality).

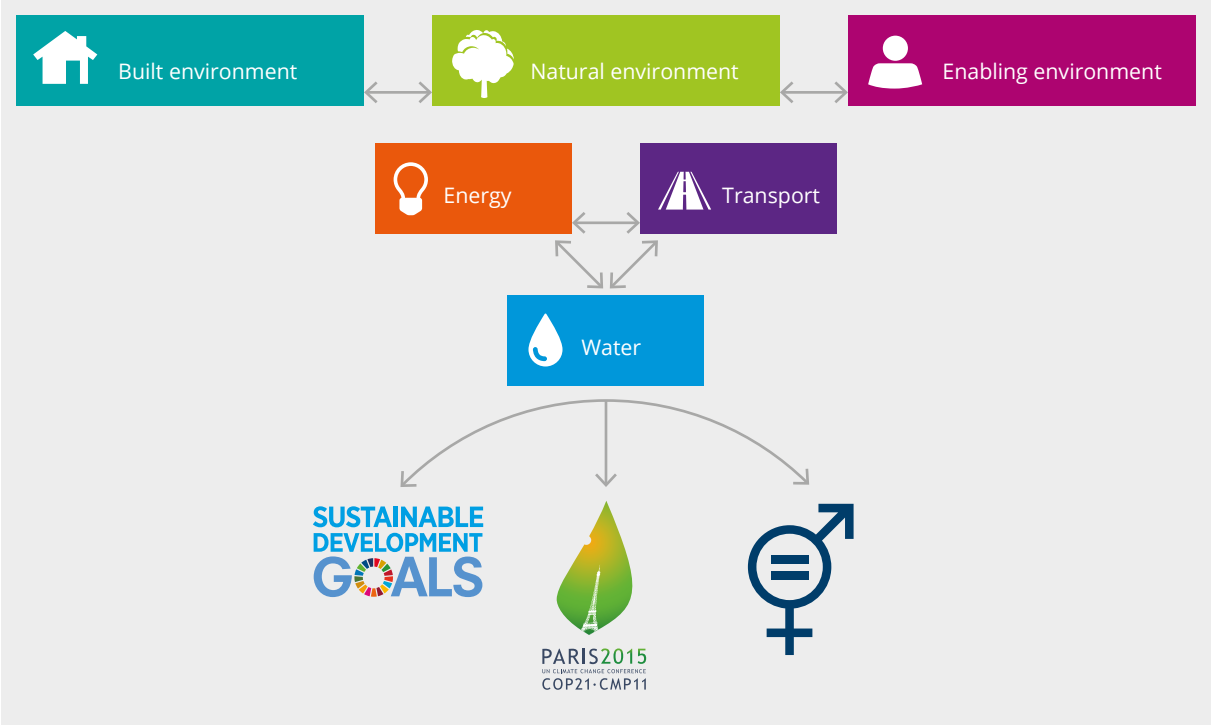


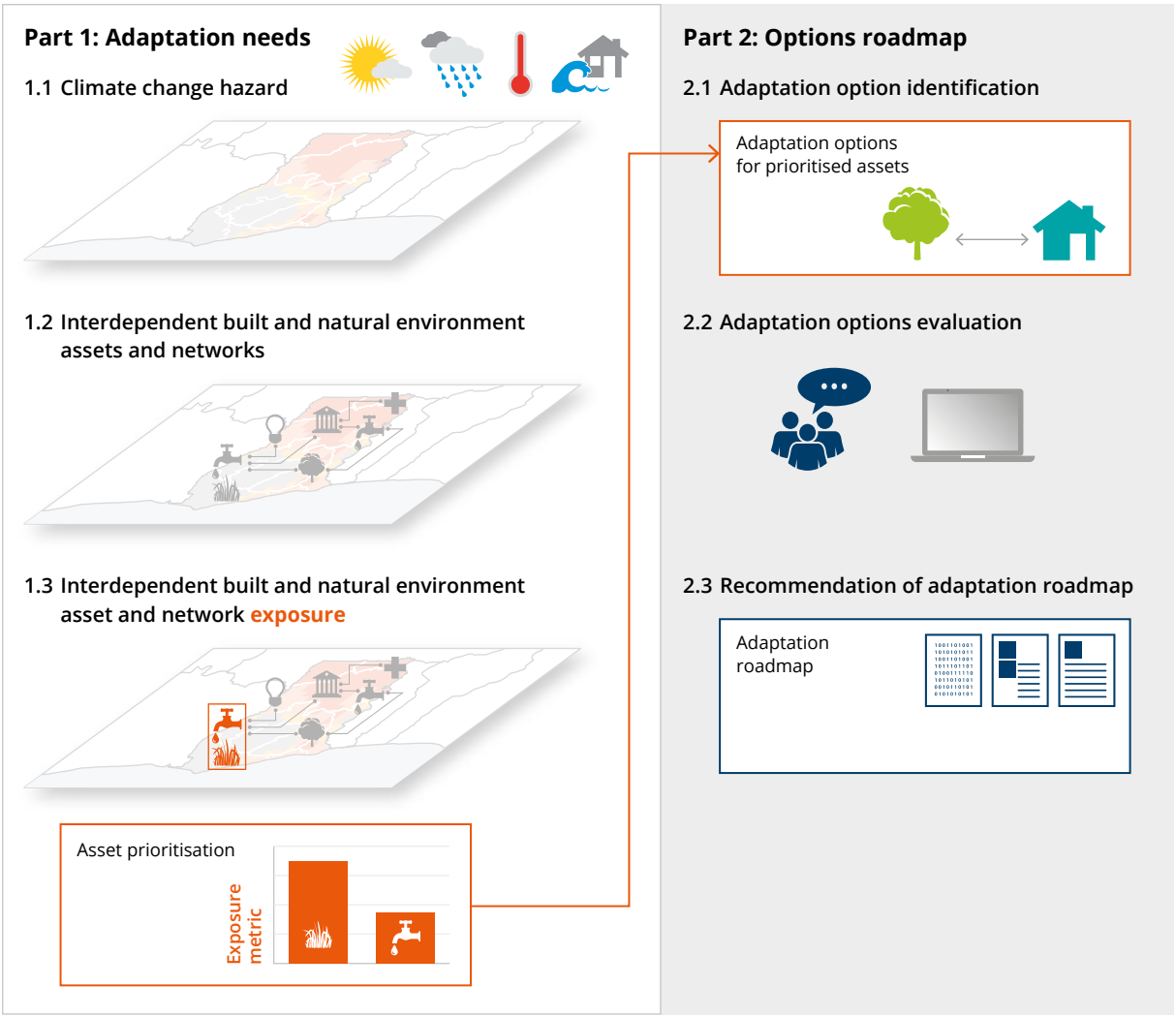

**Figure 34:**
*The natural, built, and enabling environments delivering development outcomes through infrastructure.*

**The enabling environment**: The enabling environment is composed of structural elements that include institutional arrangements, policies, regulations, laws, human resources, financial resources, processes, tools, and information. A cohesive enabling environment creates the framework for the planning, delivery, and management of a more sustainable, resilient, and inclusive infrastructure system. It requires the effective allocation of resources to both upstream planning and downstream implementation activities, creating optimum functionality and maximum benefit realisation from investments.

Together, these components work in concert to enable and deliver development benefits linked to climate adaptation. These benefits and considerations are described for each adaptation option in the roadmap.

## A.2. The National Infrastructure Systems Model (NISMOD)

This assessment uses a toolkit of models and methods developed by the University of Oxford, known as the National Infrastructure Systems Model, or NISMOD. The analysis conducted for the built and natural environment components of this report uses the NISMOD approach to assess infrastructure needs in the context of climate adaptation. The NISMOD database stores data on cross-sectoral infrastructure assets and networks, exogenous factors such as climate hazards, and geo-referenced socio-economic data, where available, providing an output repository for hazard exposure and vulnerability models under various future scenarios.




An asset prioritisation function uses this data to perform a systematic assessment of exposed assets and districts according to selected criteria. A visualisation function allows for the presentation of model outputs in the form of maps and other graphics.

The NISMOD analysis applied in this study is conducted according to the steps below. A full description of the methods for each step, as applied to the built and natural environments in the Ghana resilience study, is provided below.

**Figure 35:**
*The National Infrastructure Systems Model (NISMOD), application to a national climate adaptation context for the built and natural environments.*

## Part 1: Adaptation needs

This part of the analysis used an extensive range of data collected in-country to systematically assess the exposure of built and natural assets to several climate hazards, and to characterise the impacts of this exposure on Ghana's population using appropriate criteria.

### 1.1 Climate hazard identification: Data collection and characterisation

Part 1.1. determined priority climate-driven hazards with in-country stakeholders and collected relevant hazard datasets. This study used hazard maps without any probabilistic flood information obtained from the National Disaster Management Organisation (NADMO, 2015). Instead, the flood maps gave the areas identified as having *medium* and *high likelihood* of flooding, which have been used in previous studies in Ghana.

- Two flood map timelines were considered in the underlying flood map – a *current* flooding (in 2010) based on historic data and a *future* flooding (in 2050) based on climate projections.
- Landslide maps obtained from NADMO gave areas identified as having medium and high susceptibility to landslides.
- Drought maps, which refer to a rainfall deficit, reflect medium and high drought hazard maps for a current and future (2050) timeline based on NADMO's A1B climate projection. These scenarios are based on the number of days that cumulative rainfall deficit exceeds a threshold of 600mm: Medium (20-17), or High (>70).
- Reduced river runoff is represented by a probabilistic scenario which refers to the change in future mean annual discharge in percentage (2046-2065 vs. 1998-2014) for the p50 simulation using 30 climate model runs of the CORDEX-Africa ensemble (RCP4.5 and RCP8.5)2

### 1.2 Infrastructure systems: Data collection and characterisation

Part 1.2 collected information on the location of assets providing infrastructure services from the built and natural environment (e.g. roads, hydropower dams, rivers, forest reserves). In the absence of national geospatial datasets, this information was geo-referenced. Information on socio-economic service provision was also collected (e.g. demand for wood fuel) for built and natural assets or networks providing infrastructure services, as well as usage information by gender.

Information on costs (e.g. damage costs of roads) was gathered based on some high-level assumptions for different classes of assets. In addition, admin level populations and important locations of accessibility such as health centres or economic hubs were determined. Accessibility metrics, such as connectivity to the nearest health centre, were developed.

### 1.3 Direct climate hazard impact assessment: Calculation and analysis

Part 1.3. overlaid climate hazard data layers with infrastructure network data layers from the built and natural environment (as defined in step 1 and 2), identifying infrastructure directly affected by the respective climate hazards (e.g. electricity power plants inundated as a result of a flood exposure). The percentage of national capacity or service provision exposed to each of the different climate hazards was computed, as were further usage disruption metrics, such as numbers of people affected.

This data was overlaid with a measure of *district vulnerability* (calculated as the inverse of a community's adaptive capacity as defined in the *Fourth National Communication*, see Box 3) to better estimate district-level risk. Potential targets of the Sustainable Development Goals directly and indirectly affected were estimated, based on published literature.[20,2]

### Part 2: Adaptation options

This part of the analysis followed a participatory approach to identifying adaptation options, assessing their benefits and trade-offs, and designing a prioritised investment roadmap to address the needs identified in Part 1.

#### 2.1 Adaptation options identification

- Drawing on academic and grey literature, a comprehensive list was identified representing a broad range of adaptation options for flood, drought, and landslide hazards (see Appendix C1). Adaptation options are here defined as measures to reduce climate hazard asset exposure, including: a) built options (engineered options) such as seawalls or asset fortifications; and b) NbS, comprised of 'actions to protect, sustainably manage and restore natural or modified ecosystems'.[21]
- This exercise incorporated members of the Technical Working Group as well as other organisations specialised in adaptation.

#### 2.2 Adaptation options evaluation

- Metrics and data for adaptation option evaluation were collected, including on costs, implementation time, SDG co-benefits, gender impacts, and others. Alignment with proposed enabling environment options to improve the institutional landscape was assessed (Appendix C2).
- A participatory workshop with members of the TWG was held to discuss the suitability of shortlisted projects, and their feasibility in the Ghana context across economic, technological, political, and social considerations. Stakeholder feedback was obtained through ranked survey responses.

#### 2.3 Adaptation options recommendations

- A final list of options was developed to address identified needs while broadly representing Ghana's geographical regions (including both urban and rural areas), ecological zones (forest, savannah, river, coastal), district vulnerabilities, and differentiated economic and social needs, such as gender equality or access to jobs. Some of these options comprise a suite of built or natural projects, or a combination of both, and may impact assets across multiple sectors.

## A.3. The Capacity Assessment Tool for Infrastructure (CAT-I)

This assessment used the Capacity Assessment Tool for Infrastructure (CAT-I), developed by UNOPS, to gather evidence on the challenges and needs within the enabling environment to plan, deliver and manage sustainable, resilient, and inclusive infrastructure systems. For this assessment the Adaptation Theme within the CAT-I tool was used.

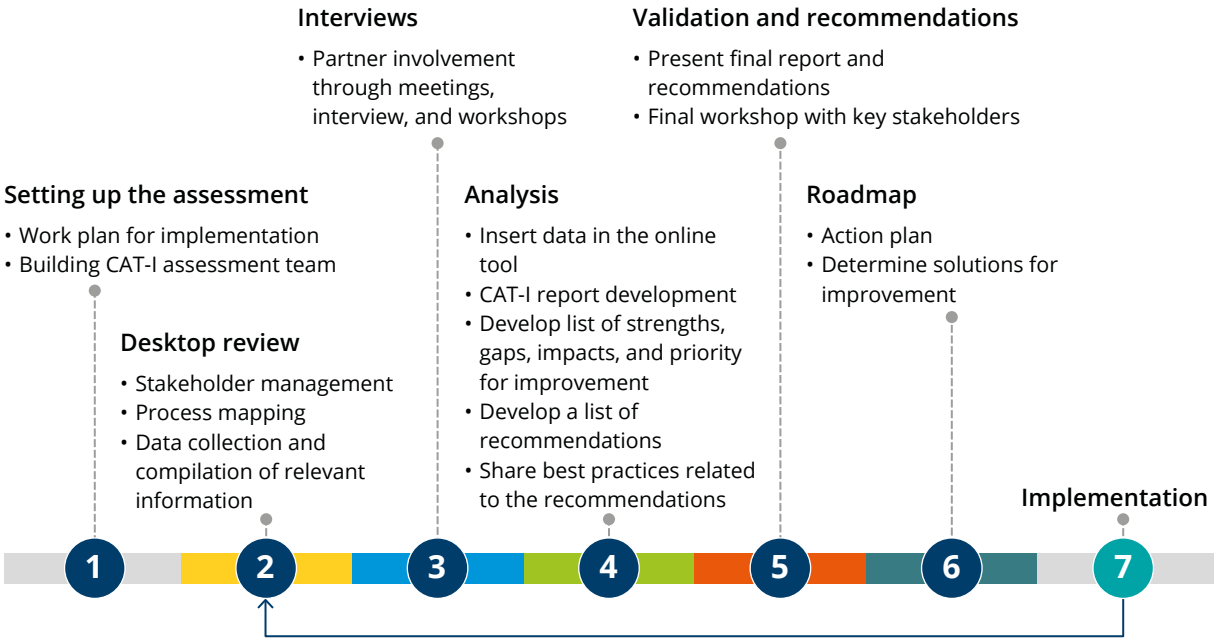



**Figure 36:**
*Steps of the CAT-I methodology.*

The specific objectives of CAT-I are to:

1. Create a common language and framework around the infrastructure enabling environment;
2. Identify challenges within the enabling environment for the planning, delivery and management of infrastructure systems;
3. Support the identification of potential solutions to enhance the enabling environment;
4. Create implementation plans to enhance the enabling environment and build capacity for the partner government; and
5. Show progress against a measured baseline.

## Conceptual Framework

CAT-I covers the entire lifecycle of infrastructure, recognising the importance and interdependence of three distinct stages of implementation: planning, delivery and management. Each stage is broken down into a number of indicators which represent processes, each of which are required to develop and implement that particular stage of the infrastructure lifecycle.

## Methodology

The methodology used for the Ghana infrastructure capacity assessment is based on six key steps:

### Step 1: Set up

The first stage of the assessment determined the purpose, scope and objectives of examining the enabling environment for infrastructure adaptation in Ghana. It also involved identifying resources, research methods and timelines to accomplish the assessment.

**Step 2: Desk review**

The desk review was completed by collecting, organising and assessing the information on energy, transport, and water infrastructure and construction practices from different sources to:

1. Gain an understanding of the sector-specific country context; and
2. Identify needs in the country to plan, develop, and deliver resilient infrastructure.

The project team collected and reviewed over 90 documents, including policies, legislation and regulations, and sector plans.

**Step 3: Key Stakeholders Interview**

During the desk review, the assessment team identified key stakeholders to interview and approach them for cross-sector and sector-specific information. The questions were aimed at eliciting the description and evaluation of the adaptation planning processes and infrastructure development processes in the country. Overall, 20 interviews were conducted where stakeholders from government institutions shared their insights and views on the strengths and challenges during planning, delivery and management stages of mainstreaming adaptation in infrastructure development.

**Step 4: Analysis**

The online platform was used to analyse the collated information and identify capacity-related strengths and challenges.

**Step 5: Validation and recommendations**

The progress achieved on the assessment and the preliminary results were presented to the key stakeholders in December 2020 at the Technical Working Group meeting. Additional feedback will be collected from the review of this report by key stakeholders and incorporated into the final product and next stage.

**Step 6: Adaptation options**

Based on further discussions with the technical working group on needs, the assessment team will create a prioritised list of recommended adaptation options to address the selected needs.

## A.4. The Sustainable Infrastructure Financing Tool (SIFT)

The Sustainable Infrastructure Financing Tool (SIFT), developed by UNOPS, supports governments by providing a structured and strategic approach to identifying and prioritising potential sources of financing for sustainable infrastructure. SIFT aims to bridge the gap between governments and infrastructure financiers in order to accelerate the implementation of infrastructure projects for sustainable, resilient, and inclusive development.

SIFT is underpinned by a growing global database of 134 sustainable infrastructure funds. Fund-level data in SIFT is used to understand the financiers' scope in-country. An overview of the infrastructure financing landscape and potential financing opportunities is developed for projects at various stages of development using the fund data contained in SIFT, which includes the following:

- **General fund information**: including fund name, description, thematic focus, website, contact information, proposal guidelines (where available), and fund-specific eligibility criteria.
- **Type of organisation**: seven types of financiers, including government agencies, development banks, development finance institutions, multilateral organisations, and private sector firms.

- **Sectoral coverage**: 15 infrastructure sectors covered, including energy, transport, water, wastewater, solid waste, education, digital communications, health, rule of law, government buildings, housing, climate, disaster, green infrastructure, and agriculture.
- **Financing mechanisms offered**: 7 mechanisms used by funds, including grants, loans, equity investments, project finance, guarantees, budget support and bonds.
- **Financing criteria assessed**: 15 criteria used by funds to make financing decisions, categorised into 5 general criteria, used to assess technical and financial viability of projects, and 10 sustainability criteria, used to assess economic, social, and environmental benefits, as well as alignment with the global agendas.
- **Activities financed**: highlighting available financing for project implementation, project preparation, and enabling activities that build institutional capacity.
- **Additional information**: Blended finance options, co-financing requirements, and requirements for private sector involvement.

# APPENDIX B: SUPPLEMENTARY DATA AND INFORMATION FOR PART 1

## B.1. Complete data sources for built and natural asset and land use data and hazards

The data table in this section uses the following colour scheme to assess data confidence based on its relevance to Ghana.

**Table A1**

| Confidence level of source | | Source example |
|---|---|---|
| | High | Primary source from in-country stakeholder |
| | Medium | Literature based on regional context |
| | Low | Literature based on world average<br>Anonymous primary source |

**Table A2: Hazard data**

| Hazard | Scenarios | Source |
|---|---|---|
| Flooding | Medium and High; 2010 and 2050 | 1 |
| Drought | Medium and High; 2010 and 2050 | 1 |
| Landslides | Existing | 1 |
| River Runoff | 2010 and 2055 runoff reduction p50 median values | 2 |

**Key:**

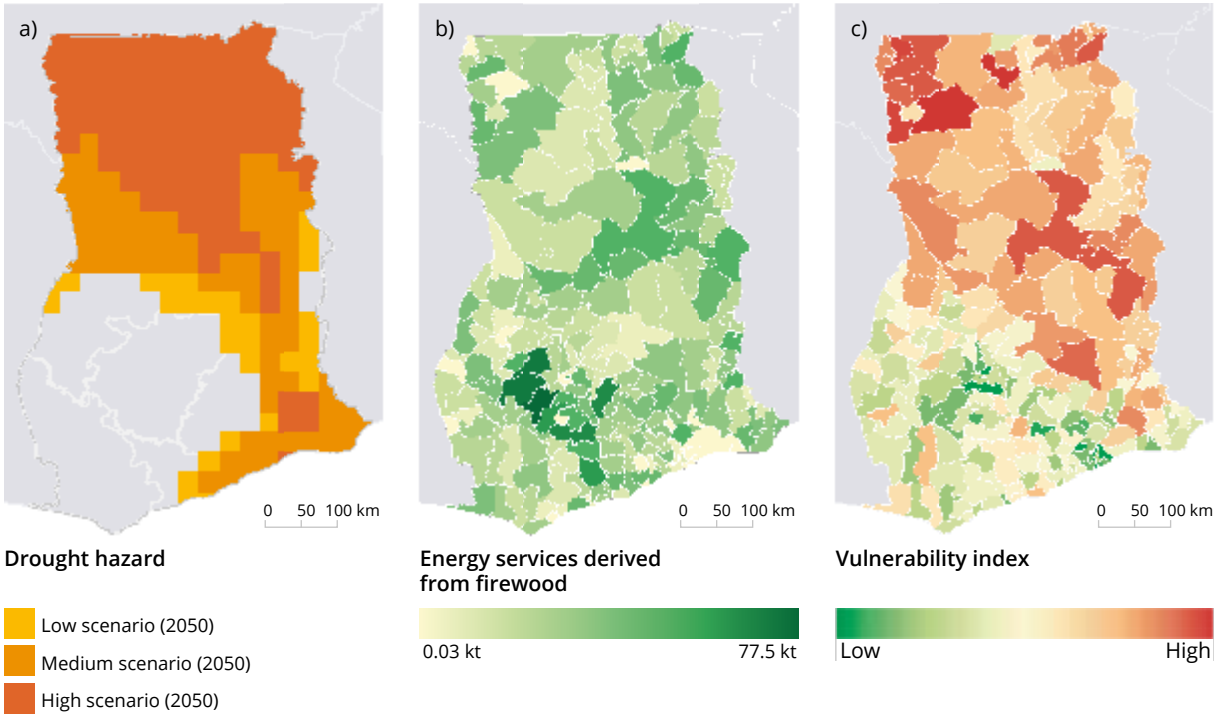
1. National Disaster Management Organization (NADMO) (2015)
2. ECOWREX: ecowrex.org
3. World Bank Data Catalog: datacatalog.worldbank.org
4. Gridfinder: gridfinder.org
5. Open Street Map: www.openstreetmap.org
6. Energy Commission (2019) Energy Profile Districts in Ghana.
7. Protected Planet (UNEP): www.protectedplanet.net/en
8. Ghana Statistical Service (2019) Ghana Living Standards Survey
9. National Development Planning Commission (NDPC) (2017). Transport Infrastructure Framework of the Ghana Infrastructure Plan.
10. World Health Organization (WHO): data.humdata.org/dataset/health-facilities-in-sub-saharan-africa
11. Ghana Statistical Service. Ghana Open Data Initiative: data.gov.gh
12. Facebook, Data for Good: dataforgood.fb.com/tools/population-density-maps
13. United States Census Bureau: www2.census.gov
14. AfDB (2014) Study on Road Infrastructure Costs: Analysis of Unit Costs and Cost Overruns of Road Infrastructure Projects in Africa.
15. Government of Ghana. Fourth National Communication to the United Nations Framework Convention on Climate Change.
16. Personal communication with TWG.

## Table A3: Assets

| Sector | Sub-sector | Number of assets | Source |
|---|---|---|---|
| Energy | Power plants | 29 total<br>23 operational | 2, 3 |
| | Transmission lines | 9911.94 km | 3, 4 |
| | Sub-stations | 76 | 5 |
| | Firewood | All districts | 6 |
| Water | Dams | 24 | 3, 16 |
| | Protected Areas | 38 146.3 km² | 7 |
| | Rivers | 110 956 km | 2 |
| | Households with drinking water supply from natural sources | 216 districts | 8 |
| Transport | Airports | 9 | 3, 5 |
| | Ports | 18 | 3, 9 |
| | Rail lines existing | 668 km | 3, 5 |
| | Proposed rail lines | 2,475 km | 3 |
| | Roads (highways) | 137,047.4 km<br>4543.78 km | 3, 5 |

## Table A4: Socio-economic data

| Sector or theme | Sub-sector | Number of assets | Source |
|---|---|---|---|
| Healthcare | NA | 1878 | 10 |
| Administrative areas | Districts | 216 | 11 |
| Population | NA | NA | 12, 13 |
| Transport | Roads (economic cost) | NA | 14 |
| Adaptive capacity | Inclusive of:<br>• District League table score<br>• Night-time light intensity<br>• % of population under poverty line<br>• Number of people under poverty line<br>• Poverty depth<br>• Poverty severity<br>• Gini coefficient | | 15 |




## B.2. Extended calculations on population exposure, built and natural environment

### B.2.1 Drought impact on wood fuel

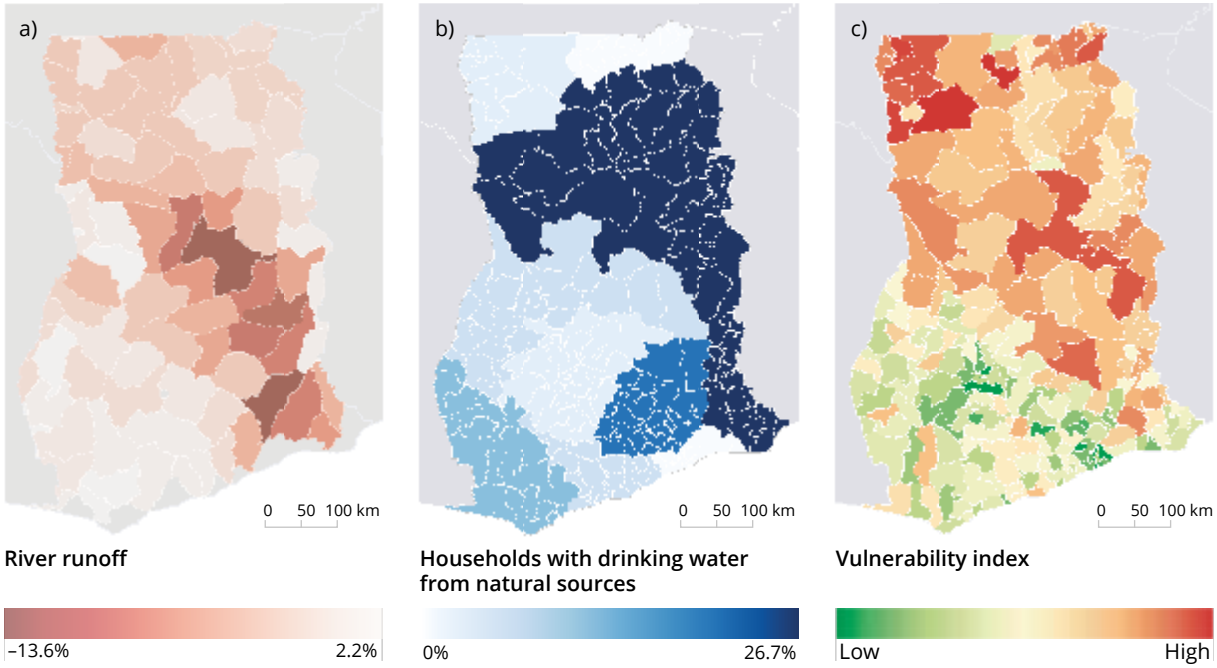
This analysis identifies the potential impact of drought on forests and agricultural land, which parts of the population rely on for wood fuel collection.

**Figure 37:**
*(a) Drought hazard level (2050); (b) Amount of household energy service derived from the burning of wood fuel; (c) District vulnerability index (data refers to the inverse of adaptive capacity in the Fourth National Communication p.188ff).*

**Methods:**

1. Drought levels – **low**, **medium**, and **high**
   - Allocated the numbers 0 – 3 to the districts depending on the area exposed to the three different drought hazard levels (0 = no drought hazard; 1 = low drought hazard; 2 = moderate drought hazard; 3 = high drought hazard)
2. Firewood demand in **kilotonnes per district**, geo-referenced from the Energy Profile of Districts in Ghana (2019).
3. A '*district vulnerability index*' was derived by inversing the **adaptive capacity score** for each district, taken from the *Fourth National Communication* (p.188ff).

The *risk index* is thus calculated by multiplying (1) drought level; (2) wood fuel demand; and (3) district vulnerability index and normalised to a range of 0 – 100.




### B.2.2. Drought impact on surface water

This analysis identifies the potential impact of reduced river runoff (ECOWREX, 2050 scenario, p50 value) on the population which relies on natural sources for drinking water.

**Methods:**

1. **River runoff change in 2050** – p50 (median) value per sub-catchment area extracted from ECOWREX. The percent of runoff change within the 216 districts was calculated by intersecting both data layers and calculating the overall change per district.
2. Regional **rural water river** use was assigned to each district within that region (using total natural source) based on water usage data from the 7th Living Standards Survey.
3. A '*district vulnerability index*' was derived by inversing the adaptive capacity score for each district, taken from the *Fourth National Communication* (p.188ff).

**Figure 38:**
*(a) Regional reduction of river runoff due to climate change (2055); (b) Percentage of households with drinking water supply from natural sources; (c) District vulnerability index (data refers to the inverse of adaptive capacity in the Fourth National Communication).*

The *risk index* is thus calculated by multiplying (1) change in river runoff (between 2010 and 2055 in percent for runoff in the different sub-catchment areas); (2) percent of population using river water; and (3) the district vulnerability index, and normalised to a range from 0 – 100.

The Upper Manya district in the Eastern Region

(–13.4 percent) and the South Dayi District in the Volta Region (–13.0 percent), projects the largest reduction of surface water runoff in the intersecting sub-catchment areas due to climate change (2050, high scenario) (Figure a). Figure b shows where the rural populations from different districts rely on natural sources for their water provision, with the largest percentage of households with drinking water supply from natural sources, including rivers, in the north, east and south-west of the country. Figure c) highlights district vulnerability, where population has least capacity to adapt.

### B.2.3 Economic and social impacts of transport exposure to flooding

#### Road network

OpenStreetMap (OSM) data was translated into a connected network of 598,505 links connecting 446,915 nodes for facilitating travel across the country. In the absence of any further information in the OSM dataset, the speeds, paved conditions (paved and unpaved), number of lanes and rehabilitation costs were assigned onto the roads based on the following broad assumptions:

1. **Speeds** – Based on some general information,[22] speeds on all motorways and trunk roads were assumed to be 100 km/hr. Primary roads speeds were assumed to be 90 km/hr, while secondary and tertiary roads speeds were assumed to 80 km/hr and 50 km/hr respectively. Residential, tracks and unclassified roads had speeds of 30 km/hr and the rest were assigned speeds of 10 km/hr.
2. **Pavement conditions and lanes** – Due to lack of any information on the road pavement conditions all motorways, trunk and primary roads in Ghana were assumed to be paved 2-lane roads, while every other types of roads were unpaved and 1-lane roads. In the road network model only about 8,400 kilometres (6.11 percent) of roads were paved, which is an underestimation of kilometres of paved roads in Ghana. As per recent estimates, out of 72,381 km of urban, feeder and highway roads, 23 percent (or ~16,650 kilometres) were paved in Ghana.[23]
3. **Rehabilitation costs** – Rehabilitation costs are an indication of the value of the assets (roads segments), which were used to estimate the direct damages costs to roads exposed to flooding. Based on road project data collected by the African Development Bank (AfDB)[24] two levels of rehabilitation costs were considered based on the road pavement condition (paved or unpaved). The rehabilitation costs of all paved roads were estimated to be 500,000 USD per lane-kilometre and for all unpaved roads the re-graveling costs were assumed to 11,000 USD per lane-kilometres.

**Table A5: Ghana's roads**

| Road type | Length (km) | Lanes | Speed (km/hr) | Condition | Rehabilitation costs (USD/lane-km) |
|---|---|---|---|---|---|
| Motorway/Trunk | 4,237 | 2 | 100 | Paved | 500,000 |
| Primary | 4,151 | 2 | 90 | Paved | 500,000 |
| Secondary | 6,258 | 1 | 80 | Unpaved | 11,000 |
| Tertiary | 13,781 | 1 | 50 | Unpaved | 11,000 |
| Residential | 46,953 | 1 | 30 | Unpaved | 11,000 |
| Tracks | 8,546 | 1 | 30 | Unpaved | 11,000 |
| Unclassified | 47,093 | 1 | 30 | Unpaved | 11,000 |
| Other (Footway, Path, Steps, Cycleway) | 6,028 | 1 | 10 | Unpaved | 11,000 |
| **Total** | **137,047** | | | | |

## Description of the road network data created for the study

### Population and health services

The population datasets were obtained from Facebook[25] which gave population density estimates at 30-meter gridded resolution for the whole of Ghana. We used population maps estimated from 2019, which covered about 27,401,000 of population of the country. Population maps specific to gender (women and men) and age (children under 5, youth 15-24, women of reproductive age 15-49, and elderly above 60) were also available.

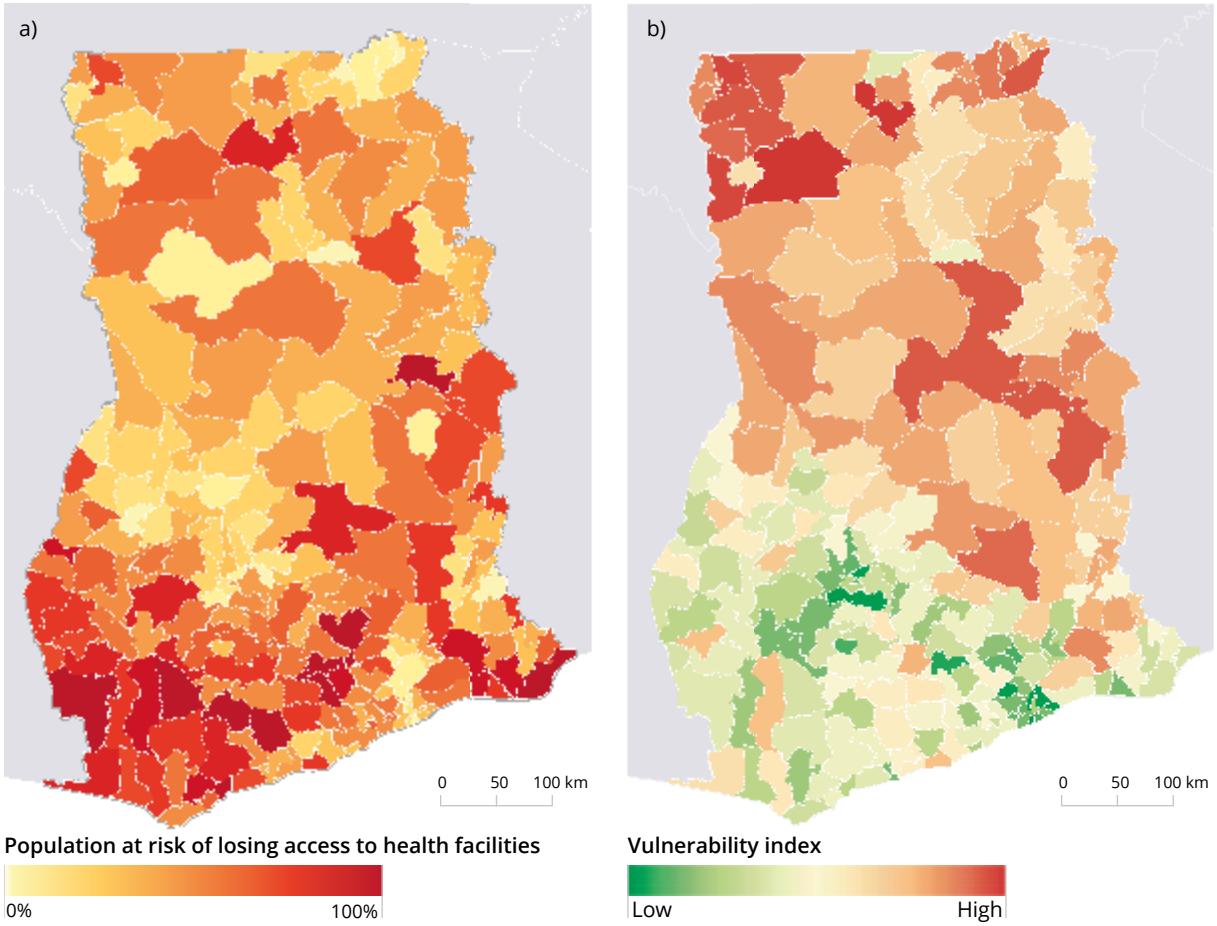
Point locations of 1,878 health service centres across Ghana were obtained from a World Health Organisation (WHO) dataset[26] that contained information on different types of health services that could be used by the population. These include – Clinics, Polyclinics, Community-based Health Planning services, Health Centres, Municipal Hospital, District Hospitals, Regional Hospital, General Hospitals.

## Road sector accessibility and district vulnerability analysis

This analysis identifies the potential risk of floods on road accessibility to healthcare services.

**Methods:**

- Intersected flood and road data and road in combination with routing to health care facilities to calculate the share of population per district that might lose access to health care facilities because they are either cut off from the rest of the road network or there is no alternative route for them reach the health care facilities.




- Combined the share of the population per district that could lose access to healthcare facilities due to flooding of the road network with the Adaptive capacity from the *Fourth* National Communication.

The *risk index* is thus calculated by multiplying (1) flood level; (2) accessibility; and (3) the district vulnerability index and normalised to a range from 0 – 100.

**Figure 39:**
*(a) Risk of flooding on healthcare access, calculated using intersection of flood data and road data in combination with routing to health care facilities; (b) District vulnerability index (data refers to the inverse of adaptiv capacity in the Fourth National Communication).*

## B.3 Complete prioritised list of assets or districts ranked by selected criteria, by subsector

### B.3.1 Energy

**Table A6: Power plants**

| Number | Name | Type | Location | Size (MW) | Population served | Flood | Drought | Landslide |
|---|---|---|---|---|---|---|---|---|
| 1 | Akosombo | Hydro | Asuogyaman | 1020 | 8,590,110 | | X | |
| 2 | Sunon Asogli Power Limited (SAPP) | Gas | Kpone Katamanso | 560 | 4,197,880 | X | | |
| 3 | Karpowership | Gas | | 470 | 2,417,679 | | | |
| 4 | AMERI Power Plant | Thermal (NG) | | 250 | 2,374,775 | | | |
| 5 | Bui Dam | Hydro | Bole | 400 | 1,671,180 | X | | |
| 6 | Kpong | Hydro | Lower Manya | 160 | 1,347,958 | X | X | |
| 7 | AKSA Power Plant | Thermal | Kpone Katamanso | 370 | 973,988 | | | |
| 8 | KTPP Kpone | Thermal (Oil) | Kpone Katamanso | 220 | 629,154 | | | |
| 9 | Tema Thermal 1 Power Plant (TT1PP) | Diesel | Kpone Katamanso | 110 | 604,020 | | | |
| 10 | Cenpower | Thermal (NG / oil) | Kpone Katamanso | 360 | 574,723 | X | | |
| 11 | Cenit Energy Ltd | Gas & oil | Kpone Katamanso | 110 | 293,605 | | | |
| 12 | Takoradi 1 | Gas & oil | Shama | 330 | 264,617 | | | |
| 13 | Takoradi 2 | Gas & oil | Shama | 330 | 264,617 | X | | |
| 14 | Amandi | Thermal (NG / oil) | Shama | 203 | 238,214 | X | | |
| 15 | Tema Thermal 2 Power Plant (TT2PP) | Gas | Kpone Katamanso | 87 | 221,565 | | | |
| 16 | Tema Early Power Project (Bridge Power Project) | Thermal (Gas) | | 200 | 160,374 | | | |
| 17 | Takoradi 3 | Gas & oil | Shama | 132 | 105,847 | X | | |
| 18 | Pwalugu (hydropower component) | Hydro | Talensi | 60 | 48,112 | | X | |
| 19 | Bui Power Authority PV plant | PV Solar | Banda | 50 | 40,093 | X | | |
| 20 | Takoradi siif | Gas & oil | Shama | 40 | 31,995 | X | | |
| 21 | Gomoa Onyaadze | PV Solar | Gomoa West | 20 | 16,037 | | | |
| 22 | Oyandze | PV Solar | Gomoa West | 20 | 16,037 | | | |
| 23 | Navrongo Solar | PV Solar | Kasena Nankana East | 3 | 2,005 | | | |
| 24 | Safisana | Waste-to-energy | | 0.10 | 80 | | | |
| 25 | Tsatsadu Generating Station (TGS) | Small-hydro | Hohoe Municipal | 0.05 | 36 | X | | X |

## Table A7: Substations

| Number | Name (with district) | Population served | District vulnerability | Flood | Landslide |
|---|---|---|---|---|---|
| 1 | 44 (Ga West) | 1,003,308 | 0.721 | X | |
| 2 | 63 (Hohoe Municipal) | 972,138 | 0.43 | | X |
| 3 | 67 (Ga South) | 833,589 | 0.233 | X | |
| 4 | 43 (Accra Metropolis) | 680,855 | 0.374 | X | |
| 5 | 42 (Sefwi Bibiani-Anhwiaso Bekwai) | 486,959 | 0.475 | X | |
| 6 | 65 (Accra Metropolis) | 359,375 | 0.306 | X | |
| 7 | 51 (Ga Central Municipal) | 359,375 | 0.161 | X | |
| 8 | 49 (Adenta) | 288,518 | 0.298 | X | |
| 9 | 68 (New Juaben Municipal) | 260,365 | 0.739 | | X |
| 10 | 58 (Jomoro) | 240,226 | 0.393 | X | |
| 11 | 62 (Keta Municipal) | 233,013 | 0.325 | X | |
| 12 | 19 (Upper Denkyira East) | 196,077 | 0.424 | X | |
| 13 | 11 (Accra Metropolis) | 167,989 | 0.627 | X | |
| 14 | 64 (Accra Metropolis) | 167,989 | 0.455 | X | |
| 15 | 59 (Ellembelle) | 131,873 | 0.423 | X | |
| 16 | 71 (Gonja Central) | 129,188 | 0.183 | X | |
| 17 | 29 (Ketu South) | 126,485 | 0.19 | X | |
| 18 | 3 (Lower Manya) | 112.148 | 0.19 | X | |
| 19 | 72 (Accra Metropolis) | 90,007 | 0.19 | X | |
| 20 | 12 (Accra Metropolis) | 43,567 | 0.477 | X | |
| 21 | 60 (Kpone Katamanso) | 25,164 | 0.201 | X | |

**Table A8: Districts relying on wood fuel (top 35 districts)**

| Number | District name | Drought level (0=no hazard, 1=low, 3=high) | Wood fuel use (t/year, thousands) | Population | Wood fuel tonnes/ person | District vulnerability |
|---|---|---|---|---|---|---|
| 1 | Wa East | 3 | 40.62 | 30,140 | 1.348 | 0.93 |
| 2 | Adansi South | 0 | 64.90 | 57,042 | 1.138 | 0.46 |
| 3 | Banda | 2 | 5.91 | 5,200 | 1.137 | 0.75 |
| 4 | Amansie Central | 0 | 59.99 | 75,057 | 0.799 | 0.36 |
| 5 | Ahafo Ano South | 0 | 70.99 | 89,368 | 0.794 | 0.33 |
| 6 | Bosome Freho | 0 | 37.92 | 49,690 | 0.763 | 0.56 |
| 7 | Atwima Mponua | 0 | 71.50 | 115,151 | 0.621 | 0.29 |
| 8 | Adansi North | 0 | 50.37 | 82,971 | 0.607 | 0.34 |
| 9 | Kumbumgu | 3 | 11.10 | 19,645 | 0.565 | 0.58 |
| 10 | Amansie West | 0 | 77.46 | 141,175 | 0.549 | 0.18 |
| 11 | Upper Manya | 2 | 34.89 | 64,874 | 0.538 | 0.63 |
| 12 | Upper Denkyira West | 0 | 32.84 | 62,624 | 0.524 | 0.18 |
| 13 | Asante Akim South | 0 | 62.98 | 120,884 | 0.521 | 0.43 |
| 14 | Kintampo South | 1 | 42.07 | 83,005 | 0.507 | 0.76 |
| 15 | Sissala West | 3 | 25.85 | 52,344 | 0.494 | 0.87 |
| 16 | Assin South | 0 | 57.17 | 119,118 | 0.480 | 0.55 |
| 17 | Lawra | 3 | 25.91 | 54,103 | 0.479 | 0.80 |
| 18 | Akwapem South | 2 | 8.89 | 19,198 | 0.463 | 0.22 |
| 19 | Suhum Municipal | 1 | 35.67 | 78,467 | 0.455 | 0.16 |
| 20 | Sissala East | 3 | 26.5 | 59,694 | 0.444 | 0.71 |
| 21 | Wa West | 3 | 43.96 | 100,697 | 0.437 | 0.89 |
| 22 | Bawku West | 3 | 40.37 | 93,688 | 0.431 | 0.81 |
| 23 | South Tongu | 2 | 43.43 | 100,859 | 0.431 | 0.47 |
| 24 | Twifo Lower Denkyira | 0 | 21.51 | 50,206 | 0.428 | 0.45 |
| 25 | East Gonja | 3 | 46.71 | 109,141 | 0.428 | 0.87 |
| 26 | Nkoranza North | 2 | 30.59 | 72,275 | 0.423 | 0.59 |
| 27 | Kasena Nankana West | 3 | 30.46 | 72,737 | 0.419 | 0.40 |
| 28 | Adaklu | 3 | 18.14 | 43,783 | 0.414 | 0.73 |
| 29 | Yilo Krobo | 1 | 31.89 | 77,309 | 0.413 | 0.29 |
| 30 | Ahafo Ano North | 0 | 49.94 | 122,084 | 0.409 | 0.67 |
| 31 | Kwahu South | 0 | 26.91 | 66,118 | 0.407 | 0.64 |
| 32 | Kadjebi | 0 | 23.47 | 57,857 | 0.406 | 0.77 |
| 33 | Jasikan | 2 | 22.98 | 56,959 | 0.403 | 0.65 |
| 34 | Jirapa | 3 | 42.60 | 107,558 | 0.396 | 0.86 |
| 35 | Jaman South | 1 | 36.93 | 93,632 | 0.394 | 0.42 |

### B.3.2 Water

**Table A9: Dams**

| Number | Name | River Name | Watershed | Dam capacity ($m^3$) | Flood | Drought |
|---|---|---|---|---|---|---|
| 1 | Akosombo | Volta | Volta | 147,960,000,000 | | X |
| 2 | Bui | Volta | Mouhoun | 12,570,000,000 | X | |
| 3 | Tono | Tono | Nakambe | 3,760,286,000 | X | X |
| 4 | Vea | Vea | Volta | 816,000,000 | X | X |
| 5 | Weija | Densu | Densu | 115,000,000 | X | |
| 6 | Barekese | Offin | Pra | 89,588,520 | | |
| 7 | Afife | Kplipa | Volta | 29,450,000 | X | |
| 8 | Bontanga | Botanga | Nakambe | 25,350,000 | X | X |
| 9 | Inchaban | Anankwari | Pra | 19,973,100 | X | |
| 10 | Owabi | Offin | Pra | 15,329,910 | X | |
| 11 | Kwanyaku | Ayensu | Coastal | 14,931,770 | | |
| 12 | Dawhenya | - | Densu | 5,800,000 | X | |
| 13 | Mankessim | Amisa | Densu | 5,670,000 | | |
| 14 | Ashaman | - | - | 6,200 | X | |

**Table A10: Districts relying on surface water abstraction (top 35 districts)**

| Number | District Name | Runoff reduction (%) | Population | District vulnerability |
|---|---|---|---|---|
| 1 | Kpandai | -3.0361068 | 115,283 | 0.79 |
| 2 | Kma | -0.9482059 | 105,240 | 0.29 |
| 3 | Sekondi Takoradi | 0 | 101,571 | 0.44 |
| 4 | Hohoe Municipal | 0.72241797 | 63,444 | 0.65 |
| 5 | Tamale North Sub Metro | -4 | 60,855 | 0.45 |
| 6 | Ho Municipal | -7.9542551 | 56,946 | 0.48 |
| 7 | Nanumba North | -2.9244721 | 48,863 | 0.6 |
| 8 | West Mamprusi | -1.0287705 | 48,782 | 0.58 |
| 9 | Savelugu Nanton | -0.9156679 | 45,849 | 0.61 |
| 10 | New Juaben Municipal | -5.3577813 | 44,455 | 0.14 |
| 11 | East Akim | -4.1140806 | 43,981 | 0.21 |
| 12 | Ketu South | 0 | 40,440 | 0.36 |
| 13 | Sagnerigu | -3.8520221 | 40,370 | 0.56 |
| 14 | Krachi East | -7.8741711 | 39,102 | 0.86 |
| 15 | Yendi Municipal | -0.6790287 | 38,336 | 0.57 |
| 16 | Birim Municipal | -0.8109409 | 38,246 | 0.46 |
| 17 | Keta Municipal | -8.0453005 | 37,316 | 0.36 |
| 18 | Bunkpurugu Yonyo | -2.8981488 | 36,588 | 0.73 |
| 19 | Mamprusi East | -2.243362 | 36,115 | 0.67 |
| 20 | Afadzato South | -1.1149528 | 36,106 | 0.75 |
| 21 | Gushiegu | -1.5851969 | 35,711 | 0.71 |
| 22 | Kwahu Afram Plains South | -6.5310916 | 33,068 | 0.84 |
| 23 | Akwapem North | -11.147803 | 32,620 | 0.36 |
| 24 | Nkwanta South | -1.8706346 | 32,340 | 0.75 |
| 25 | Nanumba South | -2.715557 | 32,260 | 0.62 |
| 26 | Birim South | 0.10119446 | 31,619 | 0.56 |
| 27 | Akatsi South | -6.3909055 | 30,571 | 0.33 |
| 28 | Ho West | -9.148334 | 30,389 | 0.72 |
| 29 | Kwahu Afram Plains North | -10.844809 | 29,245 | 0.69 |
| 30 | Atiwa | -1.4817422 | 28,979 | 0.44 |
| 31 | Asokore Mampong Municipal | -1.4 | 28,328 | 0.16 |
| 32 | East Gonja | -8.6966547 | 27,722 | 0.87 |
| 33 | Sawla/Tuna/Kalba | -3.3777909 | 27,347 | 0.74 |
| 34 | South Tongu | -7.5409952 | 26,929 | 0.47 |
| 35 | Mion | -2.6453552 | 26,630 | 0.75 |

### B.3.3 Transport

**Table A11: Roads (top 35 districts)**

| Number | District name | Population losing access to healthcare | District vulnerability |
|---|---|---|---|
| 1 | Accra Metropolis | 588,528 | 0.19 |
| 2 | Kumasi | 545,259 | 0.29 |
| 3 | Sekondi Takoradi | 432,837 | 0.44 |
| 4 | Ga South | 220,319 | 0.43 |
| 5 | Gomoa East | 182,917 | 0.41 |
| 6 | Ga West | 182,445 | 0.19 |
| 7 | Shama | 168,029 | 0.28 |
| 8 | Keta Municipal | 161,062 | 0.36 |
| 9 | Ketu South | 148,007 | 0.36 |
| 10 | Birim Municipal | 141,747 | 0.46 |
| 11 | Jomoro | 139,819 | 0.59 |
| 12 | Atiwa | 134,765 | 0.44 |
| 13 | Prestea / Huni Valley | 127,846 | 0.39 |
| 14 | East Akim | 125,077 | 0.21 |
| 15 | Birim South | 119,250 | 0.56 |
| 16 | Komenda Edna Eguafo / Abirem | 115,822 | 0.38 |
| 17 | Kwahu Afram Plains North | 115,570 | 0.69 |
| 18 | Atwima Mponua | 115,239 | 0.29 |
| 19 | West Akim | 113,750 | 0.29 |
| 20 | Assin South | 111,886 | 0.55 |
| 21 | Aowin | 105,760 | 0.4 |
| 22 | Asokore Mampong Municipal | 99,385 | 0.16 |
| 23 | Kpone Katamanso | 99,297 | 0.1 |
| 24 | Krachi East | 98,208 | 0.86 |
| 25 | Assin North | 96,643 | 0.54 |
| 26 | Asikuma / Odoben / Brakwa | 93,710 | 0.46 |
| 27 | Ga Central Municipal | 93,019 | 0.16 |
| 28 | Tema Metropolis | 92,157 | 0.19 |
| 29 | Asunafo North | 90,109 | 0.33 |
| 30 | South Tongu | 89,652 | 0.47 |
| 31 | Kpandai | 87,528 | 0.79 |
| 32 | La Dade Kotopon | 87,519 | 0.05 |
| 33 | West Mamprusi | 86,575 | 0.58 |
| 34 | Twifo Atti-Morkwa | 86,218 | 0.29 |
| 35 | Nkwanta South | 86,051 | 0.75 |

### Table A12: Airports

| Number | Name | Type | Annual passenger trips | Flood |
|---|---|---|---|---|
| 1 | Kotoka | International | 3,019,000 | |
| 2 | Kumasi | International | 376,823 | |
| 3 | Tamale | International | 196,600 | X |
| 4 | Ho | Regional | 150,000 | X |
| 5 | Takoradi | International | 113,803 | X |
| 6 | Sunyani | International | 653 | |

### Table A13: Ports

| Number | Name | Type | Annual passenger trips | Flood | Drought |
|---|---|---|---|---|---|
| 1 | Yeji | Volta Crossing | 425,000 | X | |
| 2 | Makange | Volta Crossing | 425,000 | X | X |
| 3 | Kete Krachi | Volta Crossing | 315,000 | X | X |
| 4 | Dambai | Volta Crossing | 315,000 | X | |
| 5 | Kojokrom | Volta Crossing | 315,000 | X | X |
| 6 | Dodolkope | Volta Crossing | 315,000 | X | |
| 7 | Agordeke | Volta Crossing | 250,000 | X | |
| 8 | Galilea | Volta Crossing | 250,000 | X | |
| 9 | Kpando-Torkor | Volta Crossing | 250,000 | X | |
| 10 | Dzemenl | Volta Crossing | 250,000 | X | |
| 11 | Adawso | Volta Crossing | 250,000 | X | |
| 12 | Ekye Amanfrom | Volta Crossing | 250,000 | X | |

## B.4 List of gender-differentiated impacts of disrupted infrastructure services

**Table 14:**

| Infrastructure sector: Service disruption | Direct impacts | | Indirect impacts | |
|---|---|---|---|---|
| | Well-being and social | Economic | Well-being and social | Economic |
| Energy: Power outage, disrupted electricity access | Life threat for pregnant women reliant on electricity- powered medical devices for delivery<br>Reduced study time for girls<br>Increase in time needed for domestic work<br>Increased time spent on fuel collection<br>Increased exposure to gender-based violence in poorly-lit public spaces | Decrease in female labour force participation rate due to non-operational household appliances | Prevention from sexual exploitation and abuse in the workplace | Decrease in labour force participation due to lost productive hours |
| Water: Household water supply disruption, potable water scarcity | Increased time and energy spent on water provision (household / agriculture)<br>Increased work-burden for women who are primarily responsible for water collection | | Reduced study time for girls<br>Loss of time for women caring for household members suffering from waterborne diseases | Decrease in women's labour force participation due to lost productive hours |
| Transport: Pedestrian and intermediate transport in rural areas, public transport in urban areas | Decreased female education attainment due to reduced safe access to schools<br>Life threat for pregnant women reliant on access to community clinics<br>Increased exposure to gender-based violence on unsafe travel routes | Reduced female labour force participation due to lack of safety on travel routes to farms, markets, and income sources | | |

## B.5. Nationally-Determined Contribution (NDC) thematic areas

**Table 15: NDC thematic areas**

| | NDC Thematic Area Number | NDC Thematic Area | NDC Policy Actions | Programme of Actions (POA) | Investment needs (million USD) |
|---|---|---|---|---|---|
| Sectors and strategic areas in the adaptation goals table in the NDC document | 1 | Resilient infrastructure in built environment | City-wide resilient infrastructure planning | Building standards for strategic infrastructure adopted in 10 urban administrative regions in<br>• transport<br>• energy | 3,558 |
| | 2 | Built environment | Early warning and disaster prevention | Expand and modernise the current 22 synoptic stations based on needs assessment, and increase the number to 50 stations for efficient weather information management | 403 |
| | 3 | Water resources | Integrated water resources management | Strengthen equitable distribution and access to water for 20% of the population living in climate change risk communities | 1,919 |
| | 4 | Gender and vulnerable | Resilience for Gender and the Vulnerable | Implementation of community led adaptation and livelihood diversification for vulnerable groups | 1,023 |
| Additional themes in the NDC document | 5 | Mobilising investment | | Total (mitigation and adaptation) – USD 22.6 billion<br>Adaptation – USD 12.79 billion<br>(USD 4.21 billion/ 34% – national; USD 8.27 billion international) | 12,790<br>(includes all sectors, not just Energy, Water, Transport) |
| | 6 | Technology and capacity development | | International partnerships for technology development and transfer and continuous up-skilling in the priority INDC sectors | |
| | 7 | Monitoring Report and Verification (MRV) | | MRV system for the INDC will build on the existing sector-based Annual Progress Report (APR) system by enhancing the technical functionalities and with proper institutional coordination. | |

Photo: Yoel Winkler on Unsplash

# APPENDIX C: SUPPLEMENTARY DATA AND INFORMATION FOR PART 2

## C.1 Complete list of potential built and natural adaptation options considered for roadmap

**Table A16: Built adaptation options**

| Adaptation option | Subsector(s) | Hazard type(s) | Description |
|---|---|---|---|
| Bioswales (storm water management system) | All urban assets | Flood | Bioswales are typically part of a large stormwater management system. They are able to absorb runoff from small rain events and treat larger amounts of runoff which are then directed to a larger stormwater management system, reducing the overall runoff volume and flow rate. |
| Breakwater or jetty construction | Port | Flood | Protection of navigation channels from siltation |
| Bridges and underpasses | Road, Rail | Flood | Divert road traffic over or under flood risk areas |
| By-pass channels or tunnels | Hydroelectric, Dam | Flood | Route sediment laden flows around the reservoir directly to the downstream reaches, or divert clear water into the reservoir. |
| Coastal seawall | Power plants, Transmission, Road, Rail | Flood | Mitigate threats to coastal infrastructure |

| Adaptation option | Subsector(s) | Hazard type(s) | Description |
|---|---|---|---|
| Construction or enlargement of dikes or levees | Power plants, Transmission, Road, Rail, Airport | Flood | Protect against inundation of coastal transport infrastructure |
| Dock modifications | Port | Drought | Accommodate the change in elevation between the vessel and cargo area |
| Drainage improvements and rerouting and isolation of water pipes | Power plants | Flood | Prevent inundation of plant sites |
| Drainage trenches to reduce ground water levels | Road | Landslide | Reduce groundwater saturation in hillsides to reduce the risk of landslides |
| Dry-proofing critical building components | Airport | Flood | Through waterproof barriers or locating critical infrastructure components on roof/higher level |
| Early warning systems | All coastal or river assets | Flood, Landslide | Incorporate advanced, real time alerts to local populations.Most effective with well-developed digital communications infrastructure. |
| Elevate or relocate substations | Transmission | Flood, Landslide | Reduce potential flooding or landslide hazards |
| Enhance defence structures for dams and turbines | Hydroelectric | Flood | Floods can damage dam walls and turbines directly and indirectly by mobilising debris in flooded areas upstream |
| Ex situ water harvesting - flow diversion | Surface water | Drought | Collecting flows from a river, stream or other natural watercourse (sometimes called floodwater harvesting). This technique often includes an earthen or other structure to dam the watercourse and form “small reservoirs.” |
| Ex situ water harvesting - rainwater harvesting | Surface water | Drought | Collecting rainfall from ground surfaces utilising “micro-catchments” to divert or slow runoff so that it can be stored before it can evaporate or enter watercourses |
| Floating roads | Road | Flood | Prevent disruption from floods |
| Guy wires for utility poles | Transmission | Flood | Install guy wires to poles and other structures in high climate risk areas. |

| Adaptation option | Subsector(s) | Hazard type(s) | Description |
|---|---|---|---|
| Improved or iincreased drainage channels | Road | Flood | Convey floodwaters away from site more effectively |
| Improved protection for fuel storage | Power plants | Flood, Landslide | Reinforcement of fuel storage tanks |
| Increase capacity of stormwater systems | All urban assets | Flood | Through drainage structures and pumping systems |
| Increase spillway or reservoir capacity | Hydroelectric, Dam | Flood, Drought | Modify operation of the existing reservoirs and spillways to take into consideration variable and changing flow amounts (flood or drought). Retain more water from high flow yields to be utilised during dry periods. |
| Install spare and emergency capacity | Rail | Flood, Landslide | For safety and operational systems (pass-by trucks, switches, operation on opposite lane) to back up the capacity affected by extreme weather |
| Integrate proper water management into facilities | Power plants | Flood | Use of pumps, etc., to prevent inundation of plant sites |
| Localised battery storage | Wood fuel | Drought | Enables storage of “excess” energy, especially on less connected sub-grids. Can be useful for islanding. |
| Pavement sealing | Road | Drought | Prevent loss of soil moisture from evaporation and dust and loose soil from eroding the road |
| Permeable paving | Airport, Road | Flood | Allow absorption, drainage, and conveyance of excess water. permeable pavement catches precipitation & surface runoff, storing it in the reservoir while allowing it to infiltrate into the soil or discharge via a drain tile. |
| Raise elevation of backup diesel generators | Power plants | Flood | Protection of diesel generators within facility |
| Raised or partially elevated runways | Airport | Flood | Could be coordinated with periodic re-paving needs |
| Redundant substation construction | Transmission | Flood, Landslide | Ensure continued service provision in the case of geographically limited hazards |
| Reinforce facility structure and walls | Power plants, Dam | Flood, Landslide | Reinforce structural walls to avoid critical collapse or facility shutdown |

| Adaptation option | Subsector(s) | Hazard type(s) | Description |
|---|---|---|---|
| Relocate or reinforce towers and poles | Transmission | Landslide | Relocate, or reinforce or replace towers/poles with stronger materials or additional support to decrease susceptibility to damage. |
| Replacement services for passenger or cargo | Rail | Flood, Landslide | Integration of other assets (roads) to provide replacement services in case of disruption |
| Retaining walls | Hydroelectric, Road, Rail, Airport, Dam | Landslide | Protect local infrastructure and facilities from landslide destruction |
| Retention Chambers | All urban assets | Flood | Can be used in hard landscape construction to provide aquifer recharge |
| Retrofit power plants with water-saving cooling technology (wastewater, closed-loop, hybrid wet-dry, or recovered evaporated water), or dry cooling technologies | Power plants | Drought | Reduce reliance of assets on water supply to ensure continued service during interdependant infrastructure service interruptions |
| River bank stabilisation | Road | Flood | Limit destructive flood capability on roads |
| River channel dredging | Port | Drought | Lower water levels cause restrictions for inland navigation and effects on estuarine ports |
| Road elevation | Road | Flood | Repave roads at higher elevation to reduce exposure to flood waters of a fixed magnitude |
| Sediment expulsion technology | Hydroelectric | Flood | Removal of sediment accumulated due to flooding or increased rainfall intensity |
| Slope stabilisation - anchors or bolts | Hydroelectric, Road, Dam | Landslide | Stabilise soil through built interventions near critical assets |
| Solar-powered microgrids | Wood fuel | Drought | Increase off-grid electrification in rural areas |
| Underground cabling | Transmission | Flood, Landslide | Protect transmission system against collapse caused by flooding or landslide events |
| Upgrade flood resistant doors | Power plants | Flood | Prevent inundation of plant sites |

| Adaptation option | Subsector(s) | Hazard type(s) | Description |
|---|---|---|---|
| Uphill reservoir storage | Hydroelectric | Drought | Fed by gravity to ensure distributon system pressurisation even without energy service |
| Use of temporary barriers or modular floodwalls | Airport | Flood | Can be erected along sections crossing flight paths only for the duration of the threat of flooding, and can be removed when not required, leaving flight paths clear again |
| Watercourse rehabilitation, e.g. check or sediment storage dams | Hydroelectric, Dam | Flood, Drought, Landslide | Limit catchment erosion and excess sedimentation. Preserve reservoir capacity by transporting, trapping, or flushing sediment during high flow periods |

### Table A17: Natural adaptation options

| Adaptation option | Subsector(s) | Hazard type(s) | Description |
|---|---|---|---|
| Beach nourishment | All coastal assets | Flood | Repetitive artificial replenishment of beaches to rebuild eroding beaches |
| Cobble berm and artificial dune | All coastal assets | Flood | Cobble berm acts like a dynamic revetment & reduces wave energy & stops coastal erosion |
| Construct windbreaks to reduce evaporation | Dam | Drought | Reduce evaporation by humidifying the air passing through the trees due to their transpiration, and then enhancing the moisture blanket over the water surface and decreasing the humidity gradient |
| Coral reefs | All coastal assets | Flood | Buffers shorelines against waves, storms, and floods, helping to prevent loss of life, property damage, and erosion |
| Create new intertidal habitat | All coastal assets | Flood | Through afforestation, or planting of saltmarsh or seagrass at appropriate elevations in the tidal frame. |
| Flood control reservoirs, ponds or channels | Power plants | Flood | Protection of facility |
| Flood plain areas (parks) | All urban assets | Flood | Absorb high water levels |
| Gully improvement | Dam | Flood | Prevent soil transportation through vegetation cover or barriers |

| Adaptation option | Subsector(s) | Hazard type(s) | Description |
|---|---|---|---|
| In situ water harvesting | Surface water | Drought | Increase water uptake through soil surface, rooting system and groundwater |
| Increase use of recreative green areas along the river/ water collection channels | All urban assets | Flood | Limits potential damages of flooding and to reconnect citizens with rivers and increase awareness |
| Natural buffer (forest or mangrove) | Road, Rail, Airport, Port | Flood | Reduce storm surge which can impact coastal transport assets, including roads, rail, airport structures, ports |
| Natural slope stabilisation, forestation, or terracing | Road, Rail, Hydroelectric, Dam | Landslide | Forest protection has been demonstrated to be sufficient protection against rock fall, without need of grey protection measures |
| Natural slope stabilisation, forestation, or terracing | Dam | Flood, Drought | Reduce erosion, improve slope stabilisation and retain water runoff around critical dam structures and prevent against undercutting. Preserve reservoir capacity by transporting, trapping, or flushing sediment during high flow periods |
| Permeable surfaces in urban areas | All urban assets | Flood | Allow absorption, drainage, and conveyance of excess water. permeable pavement catches precipitation & surface runoff, storing it in the reservoir while allowing it to infiltrate into the soil or discharge via a drain tile. |
| Pocket beaches | All coastal assets | Flood | Provides protection to Coastal road and the infrastructure behind the road, while also providing a sandy beach for tourists. The beach and vegetation provide intertidal habitat and shore bird habitat. |
| Protect intertidal muds, saltmarshes & mangroves from further degradation and loss | All coastal assets | Flood | Protecting existing saltmarsh or seagrass at appropriate elevations in the tidal frame. |
| Re-meander rivers | All river assets | Flood | Where they have been artificially straightened to help reduce speed and height of flood peaks |
| Reduce canalisation & create channel diversity | All river assets | Flood | Reduces the speed of flood transmission |
| Relocate dikes | All river assets | Flood | To make more space for the rivers |

| Adaptation option | Subsector(s) | Hazard type(s) | Description |
|---|---|---|---|
| Riparian vegetation and restoration along river beds | All river assets | Flood, Landslide | Aided channel stability |
| Riparian vegetation and restoration along river beds | All river assets | Flood, Landslide | Aided channel stability |
| River restoration | All river assets | Flood | Reduces the speed of flood transmission |
| Rock Filled Gabions & Tree Planting | All urban assets | Landslide | Rock-filled gabions and trees reduces landslide & erosion hazard in nature reserve |
| Sponge City measures | All urban assets | Flood, Drought | Sponge cities are designed to soak up as much extra water as possible. The designs are mixture of green & grey solutions, including urban forests and parks |
| Targeted planting for catching precipitation | Wood fuel | Drought | Retain precipitation for forest regrowth |
| Trough-trench system | All urban assets | Flood | Reduce flow rates and volumes in urban areas |
| Upstream afforestation | Hydroelectric, Surface water | Flood, Drought | Restore and better manage upstream land including afforestation to reduce floods, erosion, silting, and mudslides, and to maintain upstream water balance. |

## C.2. Complete list of potential enabling environment options considered for the roadmap

**Table A18: Enabling environments**

| | Priority areas | Enabling environment solutions |
|---|---|---|
| **Energy sector** | Resilient infrastructure planning | Mainstream Climate Adaptation in Policy and Planning Instruments |
| | Prioritising and financing adaptation options | Prioritise Pipeline of Adaptation Options and Make Accessible to Investors |
| | Preparing climate adaptation projects | Prioritise and Enforce the Implementation of Environmental and Social Impact Assessments in all Energy Projects |
| | Designing and implementing resilient infrastructure | Develop Localised Design Standards that Incorporate Climate Adaptation |
| | Climate-risk proofing assets | Incorporate Potential Impacts of Extreme Events in Planned Retrofits of Assets for Risk-Informed Asset Management |
| **Water sector** | Resilient infrastructure planning | Require the Adoption and Use of Climate Data and Modelling for Planning within Policy and Planning Instruments |
| | | Mainstream Climate Adaptation in Policy and Planning Instruments and Create Institutional Alignment |
| | Prioritising and financing adaptation options | Develop Criteria for Project Prioritisation for both Flood and Water Management to Maximise Co-Benefits |
| | Designing and implementing resilient infrastructure | Mainstream Climate Adaptation in Design Codes and Processes |
| | | Incorporate Nature-Based Solutions into Design Processes and Standards |
| | Climate-risk proofing assets | Proactive Maintenance and Asset Management |
| | | Incorporate Risk Management and Early Warning systems into Asset Management |

| | Priority areas | Enabling environment solutions |
|---|---|---|
| **Transport sector** | Resilient infrastructure planning | Institutional Coordination to Mainstream Climate Adaptation and Gender in Policy and Planning Instruments |
| | Designing and implementing resilient infrastructure | Develop Localised Design Standards that Incorporate Climate Adaptation |
| | | Build Technical Capacity to Integrate Climate Risk Considerations in Design Process |
| | Climate-risk proofing assets | Prioritise Proactive Climate Risk Informed Asset Management |
| **Cross-sectoral** | Climate-resilient spatial development | Strengthen Enforcement of Land Use Regulations |
| | Climate resilient strategic planning | Strengthen and Enforce Strategic Environmental Assessments and Associated Social and Environmental Protection Laws |
| | | Strengthen Collection and Sharing of Climate Risk Data |
| | | Track Progress of Climate Adaptation Financing and Project Implementation |
| | Prioritising and financing adaptation options | Incorporate Climate Risks into Project Whole Life Cost-Benefit Analyses |
| | | Incentivise Private Sector Investment |
| | Mainstreaming adaptation in project preparation | Mainstream Climate Risk into Environmental and Social Impact Assessment Laws and Regulations |
| | | Incorporate Climate Risk Scenario-Based Approaches into Environmental and Social Impact Assessment Process |
| | | Incorporate Climate Risk Scenario-Based Assessments into the Project Planning Approvals Process |
| | Gender mainstreaming climate adaptation | Mainstream Gender in Policy and Planning Instruments |
| | | Prioritise Gender Mainstreaming in Budgeting |
| | | Mainstream Gender in the Design and procurement Process |


# APPENDIX D: SUPPLEMENTARY DATA AND INFORMATION FOR PART 3

## D.1. Details of funds relevant for climate adaptation in Ghana

**Table A19: Funds**

| Fund | Fund Name | Financier Name | Fund Website |
|---|---|---|---|
| 2050 Facility | 2050 Facility | Agence Française de Développement | www.afd.fr/en/2050-facility |
| Adapt'Action | Adapt'Action Facility | Agence Française de Développement | www.afd.fr/en/adaptaction |
| ADF | African Development Fund | African Development Bank | www.afdb.org/en/about-us/corporate-information/african-development-fund-adf |
| AEF | Access to Energy Fund | Dutch Development Bank | aef.fmo.nl/2019/ |
| AF | Adaptation Fund | Global Environment Facility | www.adaptation-fund.org |
| AFC | Africa Finance Corporation | Africa Finance Corporation | www.africafc.org |
| AFD | Agence Française de Développement | Agence Française de Développement | www.afd.fr/en/agence-francaise-de-developpement |
| AfDB | African Development Bank | African Development Bank | www.afdb.org/en/about/mission-strategy |

| Fund | Fund Name | Financier Name | Fund Website |
|---|---|---|---|
| AFREXIMBANK | African Export-Import Bank | African Export-Import Bank | www.afreximbank.com |
| Africa50 | Africa50 Infrastructure Fund | Africa50 Infrastructure Fund | www.africa50.com/focus-areas-projects |
| AgriFI | Agriculture Financing Initiative | European Development Finance Institutions | www.agrifi.eu |
| AIIB | Asian Infrastructure Investment Bank | Asian Infrastructure Investment Bank | www.aiib.org |
| PPSF | Project Preparation Special Fund | Asian Infrastructure Investment Bank | www.aiib.org/en/projects/preparation-special-fund/index.html |
| AIP | Africa Investment Platform | European Investment Bank | www.eib.org/en/products/blending/aip/index.htm |
| ARE Scale-Up | African Renewable Energy Scale-Up Facility | PROPARCO | www.proparco.fr/en/are-scale |
| AREF II | Africa Renewable Energy Fund II | Berkley Energy | www.berkeley-energy.com/energy-funds/ |
| Aus DFAT | Australia Department of Foreign Affairs and Trade | Australia Department of Foreign Affairs and Trade | www.dfat.gov.au/aid/topics/investment-priorities/infrastructure-trade-facilitation-international-competitiveness/infrastructure/Pages/infrastructure |
| BADEA | Arab Bank for Economic Development in Africa | Arab Bank for Economic Development in Africa | www.badea.org/index.htm |
| BIO | Belgian Investment Company for Developing Countries | Belgian Investment Company for Developing Countries | www.bio-invest.be/en/infrastructure |
| BP | Building Prospects Fund | Dutch Development Bank | www.fmo.nl/building-prospects |
| CADFund | China-Africa Development Fund | China Development Bank | en.cadfund.com/ |
| Camões IP | Camões IP | Camões IP | www.instituto-camoes.pt/en/activity-camoes/what-we-do/co-operation |
| CDC | Commonwealth Development Corporation | Commonwealth Development Corporation | www.cdcgroup.com/en/ |
| CDP ICDF | CDP International Cooperation and Development Finance | Cassa Depositi y Prestiti | www.cdp.it/sitointernet/en/cooperazione_internazionale.page |

| Fund | Fund Name | Financier Name | Fund Website |
|---|---|---|---|
| CI1 | Climate Investor One | Climate Fund Managers | climatefundmanagers.com/funds/#CIO |
| CICLIA | Cities and Climate in Africa | Agence Française de Développement | www.afd.fr/en/project-preparation-funds |
| COFIDES | Compania Espanola de Financiacion del Desarrollo | Compania Espanola de Financiacion del Desarrollo | www.cofides.es |
| DBSA | Development Bank of Southern Africa | Development Bank of Southern Africa | www.dbsa.org/EN/Pages/default.aspx |
| DFC | U.S. International Development Finance Corporation | U.S. International Development Finance Corporation | www.dfc.gov |
| DFCD LUF | DFCD Land Use Facility | Dutch Fund for Climate Development | thedfcd.com/our-approach/#LandUse |
| DFCD OF | DFCD Origination Facility | Dutch Fund for Climate Development | thedfcd.com/our-approach/#Origination |
| DFCD WF | DFCD Water Facility | Dutch Fund for Climate Development | thedfcd.com/our-approach/#Water |
| DSIF | Danida Sustainable Infrastructure Finance | Investment Fund for Developing Countries | www.ifu.dk/en/danida-sustainable-infrastructure-finance-en/ |
| EAIF | Emerging Africa Infrastructure Fund | Private Infrastructure Development Group | www.eaif.com/ |
| EC DICD | European Commission Department of International Cooperation and Development | European Union | ec.europa.eu/international-partnerships/our-work_en |
| EBID | ECOWAS Bank for Investment and Development | Economic Community of West African States | bidc-ebid.org/en/ |
| EDF | European Development Fund | European Union | ec.europa.eu/info/strategy/eu-budget/eu-budget-news-events-and-publications/documents/european-development-fund_en |
| EIB | European Investment Bank | European Investment Bank | www.eib.org |
| ElectriFI | Electrification Financing Initiative | European Development Finance Institutions | www.electrifi.eu |

| Fund | Fund Name | Financier Name | Fund Website |
|---|---|---|---|
| EU-AITF | EU-Africa Infrastructure Trust Fund | European Investment Bank | www.eib.org/en/products/blending/donor-partnerships/trust-funds/eu-africa-infrastructure-trust-fund.htm |
| FAPA | Fund for African Private Sector Assistance | African Development Bank | www.afdb.org/en/topics-and-sectors/initiatives-partnerships/fund-for-african-private-sector-assistance |
| FinDev | FinDev Canada | FinDev Canada | www.findevcanada.ca/en |
| FinnFund | Finnish Fund | Finnish Fund | www.finnfund.fi/en/ |
| FIP | Forest Investment Program | Climate Investment Funds | www.climateinvestmentfunds.org/topics/sustainable-forests |
| FMO | Dutch Development Bank | Dutch Development Bank | www.fmo.nl/ |
| GCF | Green Climate Fund | Green Climate Fund | www.greenclimate.fund/about |
| GEF-7 | Global Environment Facility Trust Fund | Global Environment Facility | www.thegef.org |
| GFDRR | Global Facility for Disaster Reduction and Recovery | Global Facility for Disaster Reduction and Recovery | www.gfdrr.org/en |
| GRiF | Global Risk Financing Facility | World Bank Group | www.globalriskfinancing.org |
| GIF | Global Infrastructure Facility | World Bank Group | www.globalinfrafacility.org/#1 |
| GIZ | Deutsche Gesellschaft für Internationale Zusammenarbeit | Deutsche Gesellschaft für Internationale Zusammenarbeit | www.giz.de/en/html/index.html |
| IBRD | International Bank for Reconstruction and Development | World Bank Group | www.worldbank.org/en/who-we-are/ibrd |
| IDA | International Development Association | World Bank Group | ida.worldbank.org/about/what-is-ida |
| IFC | International Finance Corporation | World Bank Group | www.ifc.org/wps/wcm/connect/corp_ext_content/ifc_external_corporate_site/home |
| IFU | Investment Fund for Developing Countries | Investment Fund for Developing Countries | www.ifu.dk/en/services/ |
| JBIC | Japan Bank for International Cooperation | Japan Bank for International Cooperation | www.jbic.go.jp/en/about/index.html |

| Fund | Fund Name | Financier Name | Fund Website |
|---|---|---|---|
| JICA | Japan International Cooperation Agency | Japan International Cooperation Agency | www.jica.go.jp/english/index.html |
| KFAED | Kuwait Fund For Arab Economic Development | Kuwait Fund For Arab Economic Development | www.kuwait-fund.org/en/web/kfund/home |
| KfW DB | KfW Development Bank | KfW Development Bank | www.kfw-entwicklungsbank.de/International-financing/KfW-Development-Bank/Tasks-and-goals/ |
| KfW DEG | KfW Development Finance Institution | Deutsche Investitions- und Entwicklungsgesellschaft | www.deginvest.de/International-financing/DEG/Unsere-L%C3%B6sungen/Projektfinanzierungen/ |
| MCC | Millennium Challenge Corporation | Millennium Challenge Corporation | www.mcc.gov/ |
| MFA Norway | Ministry of Foreign Affairs Norway | Ministry of Foreign Affairs Norway | www.regjeringen.no/en/topics/foreign-affairs/development-cooperation/id1159/ |
| MIGA | Multilateral Investment Guarantee Agency | World Bank Group | www.miga.org |
| NDF | Nordic Development Fund | Nordic Development Fund | www.ndf.fi |
| NEPAD IPPF | NEPAD Infrastructure Project Preparation Facility | African Development Bank | www.nepadippf.org |
| Norfund | Norwegian Investment Fund | Norwegian Investment Fund | www.norfund.no |
| NZAID | New Zealand Aid Program | New Zealand Aid Program | www.mfat.govt.nz/en/aid-and-development |
| OeEB | Development Bank of Austria | Development Bank of Austria | www.oe-eb.at/en/about-oeeb/oeeb-at-a-glance.html |
| OFID | OPEC Fund for International Development | OPEC Fund for International Development | opecfund.org |
| PIDG | Private Infrastructure Development Group | UK Foreign, Commonwealth & Development Office | www.pidg.org |
| PPIAF | Public-Private Infrastructure Advisory Facility | Public-Private Infrastructure Advisory Facility | ppiaf.org/ |

| Fund | Fund Name | Financier Name | Fund Website |
|---|---|---|---|
| PROPARCO | Promotion et Participacion pour la Coopération économique (France) | Agence Française de Développement | www.proparco.fr |
| REPP | Renewable Energy Performance Platform | Camco Clean Energy | repp.energy/about-repp/ |
| SCCF | Special Climate Change Fund | Global Environment Facility | www.thegef.org/topics/special-climate-change-fund-sccf |
| SDG IF | Danish SDG Investment Fund | Investment Fund for Developing Countries | www.ifu.dk/en/danish-sdg-investment-fund-2/ |
| SEFA | Sustainable Energy Fund for Africa | African Development Bank | www.afdb.org/en/topics-and-sectors/initiatives-partnerships/sustainable-energy-fund-for-africa |
| SIFEM | Swiss Investment Fund For Emerging Markets | Swiss Investment Fund For Emerging Markets | www.sifem.ch |
| SLP | Sovereign Loans Program | Global Affairs Canada | www.international.gc.ca/world-monde/funding-financement/slp-pps.aspx?lang=eng#a1 |
| SREP | Scaling Up Renewable Energy Program in Low Income Countries | Climate Investment Funds | www.climateinvestmentfunds.org/topics/energy-access |
| Swedfund | Swedfund International AB | Swedfund International AB | www.swedfund.se/en/ |
| UK FCDO | UK Foreign, Commonwealth & Development Office | UK Foreign, Commonwealth & Development Office | www.gov.uk/guidance/funding-for-development-research |
| USAID | United States Agency for International Development | United States Agency for International Development | www.usaid.gov |

# REFERENCES


1 Thacker, S., Adshead, D., Morgan, G., Crosskey, S., Bajpai, A., Ceppi, P., Hall, J.W. and O'Regan, N. 2018. Infrastructure: Underpinning sustainable development. Copenhagen, Denmark: United Nations Office for Project Services.

2 Cardona, O.D., van Aalst, M.K., Birkmann, J., Fordham, M., McGregor, G., Perez, R., Pulwarty, R.S., Schipper, E.L.F. and Sinh, B.T. 2012. Determinants of risk: exposure and vulnerability. In: Managing the risks of extreme events and disasters to advance climate change adaptation [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)]. A special report of working groups I and II of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press, Cambridge, UK, and New York, NY, USA. pp. 65–108.

3 Government of Ghana, 2017. Medium Term Expenditure Framework (MTEF) for 2017 to 2019. Accra: National Development Planning Commission (NDPC).

4 Obeng Bekoe, E. and Yaw Logah, F. 2013. The Impact of droughts and climate change on electricity generation in Ghana. *Environmental Sciences*, 1 (1): 13–24. doi: 10.12988/ES.2013.13002

5 Government of Ghana, 2020. Ghana's Fourth National Communication to the United Nations Framework Convention on Climate Change. National Climate Change Report.

6 Government of Ghana, 2017. Medium Term Expenditure Framework (MTEF) for 2017 to 2019. Accra: Ministry of Energy.

7 Government of Ghana, 2020. Ghana's Adaptation strategy and action plan for the infrastructure sector (Water, Energy, and Transport Sectors). Accra: Environmental Protection Agency.

8 Government of Ghana, 2017. Water Sector Medium Term Development Plan (SMTDP): 2018–2021. Accra: Ministry of Works and Housing.

9 Poku-Boansi, M., Amoako, C., Owusu-Ansah, J.K., et al. 2020. What the state does but fails: Exploring smart options for urban flood risk management in informal Accra, Ghana. *City and Environment Interactions,* **5**: 100038. doi: 10.1016/j.cacint.2020.100038.

10 Government of Ghana, 2020. National Transport Policy.

11 Government of Ghana, 2020. Medium Term Expenditure Framework (MTEF) for 2020–2023. Accra: Ministry of Roads and Highways.

12 Twerefou, D.K., Adjei-Mantey, K., and 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. Helsinki: UNU-WIDER. doi: 10.35188/UNU-WIDER/2014/753-0

13 Maritz, J., Arnold, K., Roux, M., Le Roux, A., and Verhaeghe, B. 2018. Climate change adaptation in the African roads sector: Constraints, opportunities and policy challenges. In: Proceedings of the 26th PIARC World Road Congress, 6–10 October 2019, Abu Dhabi, United Arab Emirates.

14 Ghana Institution of Engineers (GhIE), 2016. Ghana Infrastructure Report Card 2016. Roads & bridges, electric power and potable water. doi: 10.13140/RG.2.2.27160.70409

15 Asante, F., Bawakyillenuo, S., Bird, N., Trujillo, N., Tagoe, C. and Ashiabi, N. 2015. Climate change finance in Ghana. Overseas Development Institute (ODI), London and the Institute of Statistical, Social and Economic Research (ISSER), University of Ghana. p.44.

16 Government of Ghana, 2020. Ghana's 2020 SDGs Budget Report. Accra: Ministry of Finance. p.57.

17 UNCTAD, 2021. World Investment Report 2021. New York: United Nations Conference on Trade and Development. p.38.

18 Global Center on Adaptation. 2021. Climate Resilient Infrastructure Officer Handbook. Rotterdam, Netherlands: Global Centre on Adaptation.

19 ICUN, 2016. Defining nature-based solutions. IUCN Resolution WCC-2016-Res-069-EN. Gland, Switzerland: International Union for Conservation of Nature.

20 Thacker, S., Adshead, D., Fay, M., Hallegatte, S., Harvey, M., Meller, H., O'Regan, N., Rozenberg, J., Watkins, G., and Hall, J.W. 2019. Infrastructure for sustainable development. *Nature Sustainability*, **2** (4): 324–331. doi: 10.1038/s41893-019-0256-8

21 Cohen-Shacham, E., Walters, G., Janzen, C. and Maginnis, S. (eds.) 2016. Nature-based Solutions to address global societal challenges. Gland, Switzerland: International Union for Conservation of Nature.

22 Wikipedia, 2020. Ghana Road Network.

23 GhanaWeb, 2020. It's a shame only 23% of our entire road network is paved – Roads Minister. Amsterdam: AfricaWeb Publishing B.V.

24 AfDB. 2014. Study on road infrastructure costs: Analysis of unit costs and cost overruns of road infrastructure projects in Africa. Abidjan, Côte d'Ivoire: Africa Development Bank Group.

25 Facebook, 2020. Data for Good. Menlo Park, California: Meta.

26 World Health Organisation, 2020. Spatial database of health facilities. Geneva: World Health Organization.

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