

Adapting Together, Thriving Tomorrow



GHANA: ROADMAP FOR RESILIENT INFRASTRUCTURE IN A CHANGING CLIMATE



ACKNOWLEDGEMENTS

The preparation of this resilient infrastructure roadmap has benefited greatly from the expertise provided by the Government of Ghana through its Technical Working Group for this study. This group comprised experts and stakeholders across a wide range of professions, knowledge and practice communities who participated in consultations, meetings, and workshops, while providing the data and information required to achieve this final output.

The study team is grateful for the contributions of representatives of the following Ministries, agencies, and organisations in Ghana: Ministry of Environment, Science, Technology and Innovation (MESTI); Ministry of Energy; Ministry of Finance; Ministry of Roads and Highways; Ministry of Transport; Ministry of Railways Development; Ministry of Sanitation and Water Resources; Ministry of Works and Housing; Ghana Water Company (GWCL); Ghana Environmental Protection Agency (EPA); Land Use and Spatial Planning Authority (LUSPA); Ghana Meteorological Agency; National Development Planning Commission (NDPC); National Disaster Management Organization (NADMO); Ghana Statistical Services (GSS); CSIR-Water Research Institute; Water Resources Commission (WRC); United Nations Development Programme (UNDP); ABANTU for Development; Kwame Nkrumah University of Science and Technology (KNUST); and the University of Ghana.

The following people have contributed to this project and report, by organisation. From MESTI: Peter Dery, Eric Twum, Gyimah Mohammed; from GCA: Nitin Jain, Danilo Cançado, Vera Klöttschen, Hafiz Lawal; from UNOPS: Scott Thacker, Apoorva Bajpai, Geoffrey Morgan, Nafisa Bhikhoo, David Boroto, Linda Agbesi; from the University of Oxford: Daniel Adshead, Lena Fuldauer, Sarah Gall, Nicholas Chow, Raghav Pant, Tom Russell, Jim W. Hall; from UNEP: Rowan Palmer.

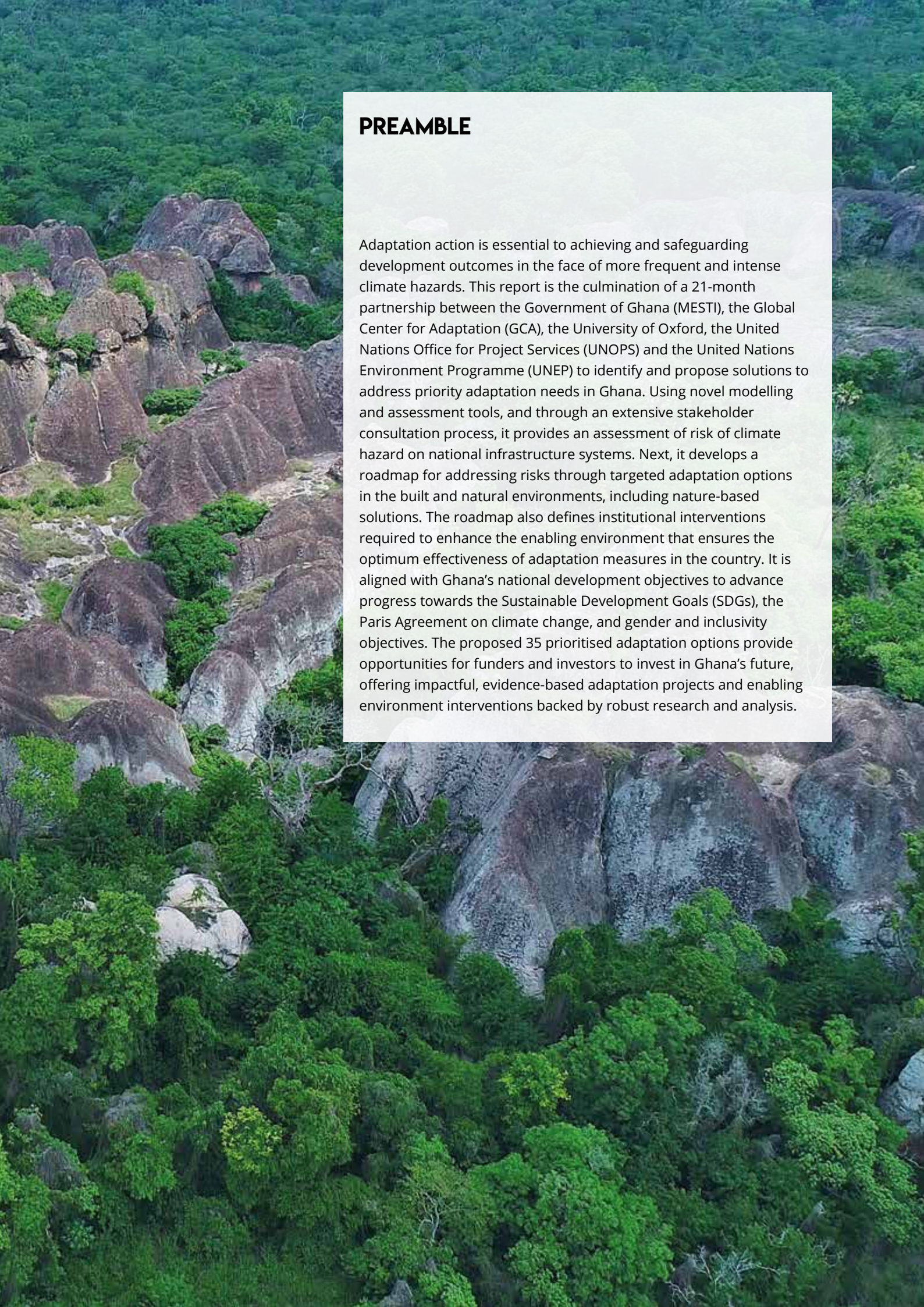
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This report may be cited as follows:

Adshead, D., Thacker, S., Fuldauer, L.I., Gall, S.S., Chow, N., Pant, R., Russell, T., Bajpai, A., Morgan, G., Bhikhoo, N., Boroto, D., Palmer, R., Cançado, D., Jain, N., Klöttschen, V., Lawal, H., Dery, P., Twum, E., Mohammed, G., Hall, J.W., and Agbesi, L. 2022. Ghana: Roadmap for resilient infrastructure in a changing climate. Ministry of Environment, Science, Technology & Innovation, Accra, Ghana.

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An aerial photograph of a rugged landscape. In the foreground and middle ground, there are large, reddish-brown, rounded rock formations. The rocks are partially covered with patches of green vegetation. Surrounding the rocks and filling the background is a dense, lush green forest. The lighting suggests a bright, sunny day, with some shadows cast by the rocks.

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

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.



Hon. (Dr.) Kwaku Afriyie

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

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: Virgil 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, Veia, 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.

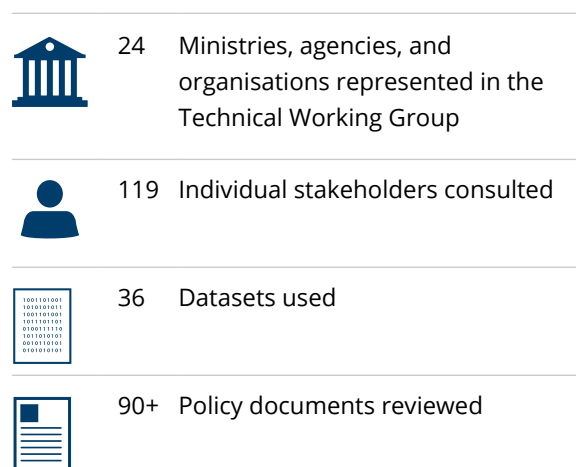
Ghana's commitment to climate resilient infrastructure

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).



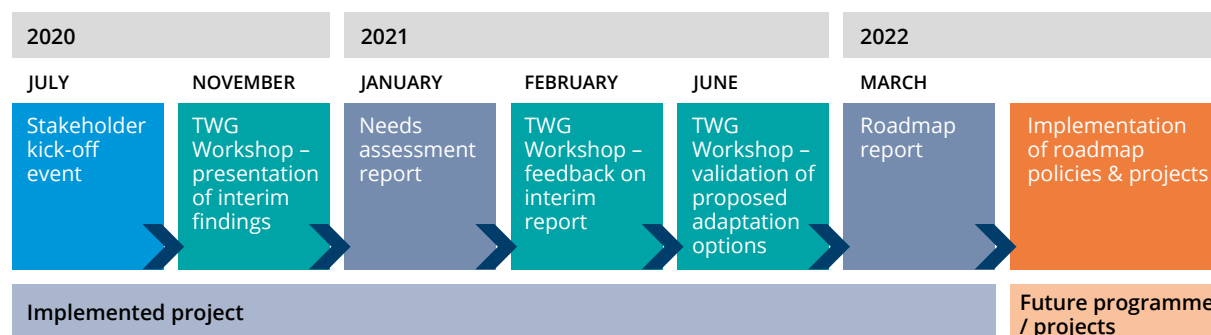
A systems-based approach to infrastructure adaptation in Ghana

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.



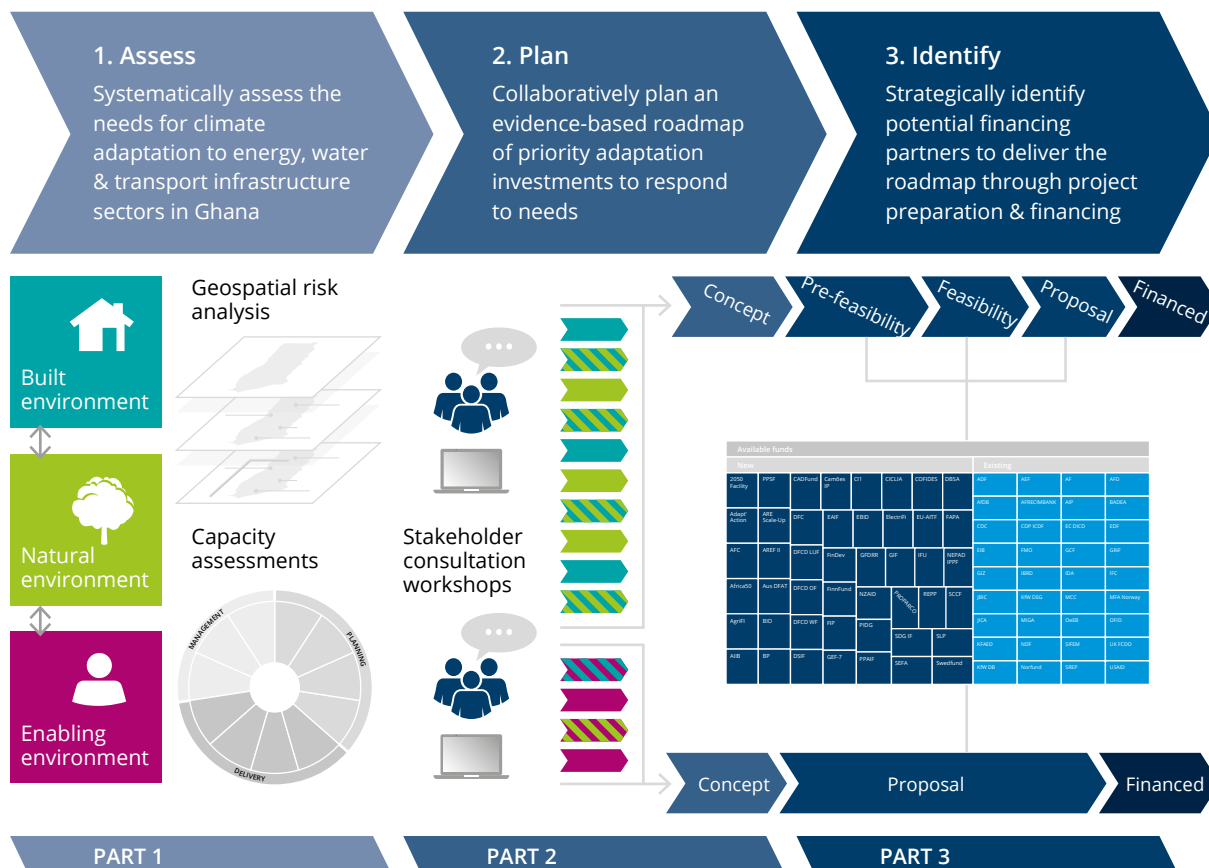


Figure 2:
Methodological process for the study.

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.

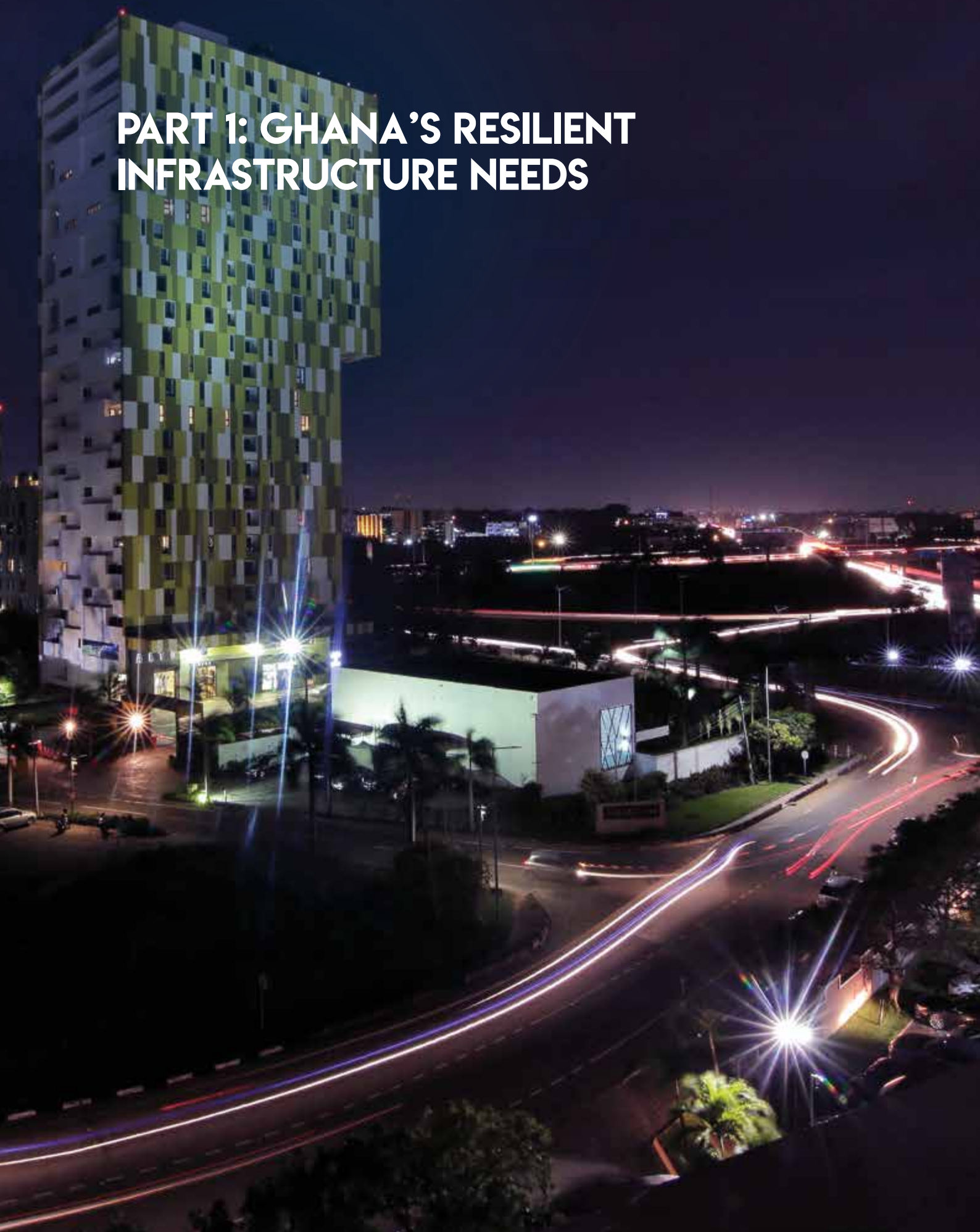
Following extensive consultation, 35 areas of critical need were selected for the roadmap. This number was determined by stakeholders to represent a manageable number of assets and areas that are candidates for adaptation through investment and policy development.

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.

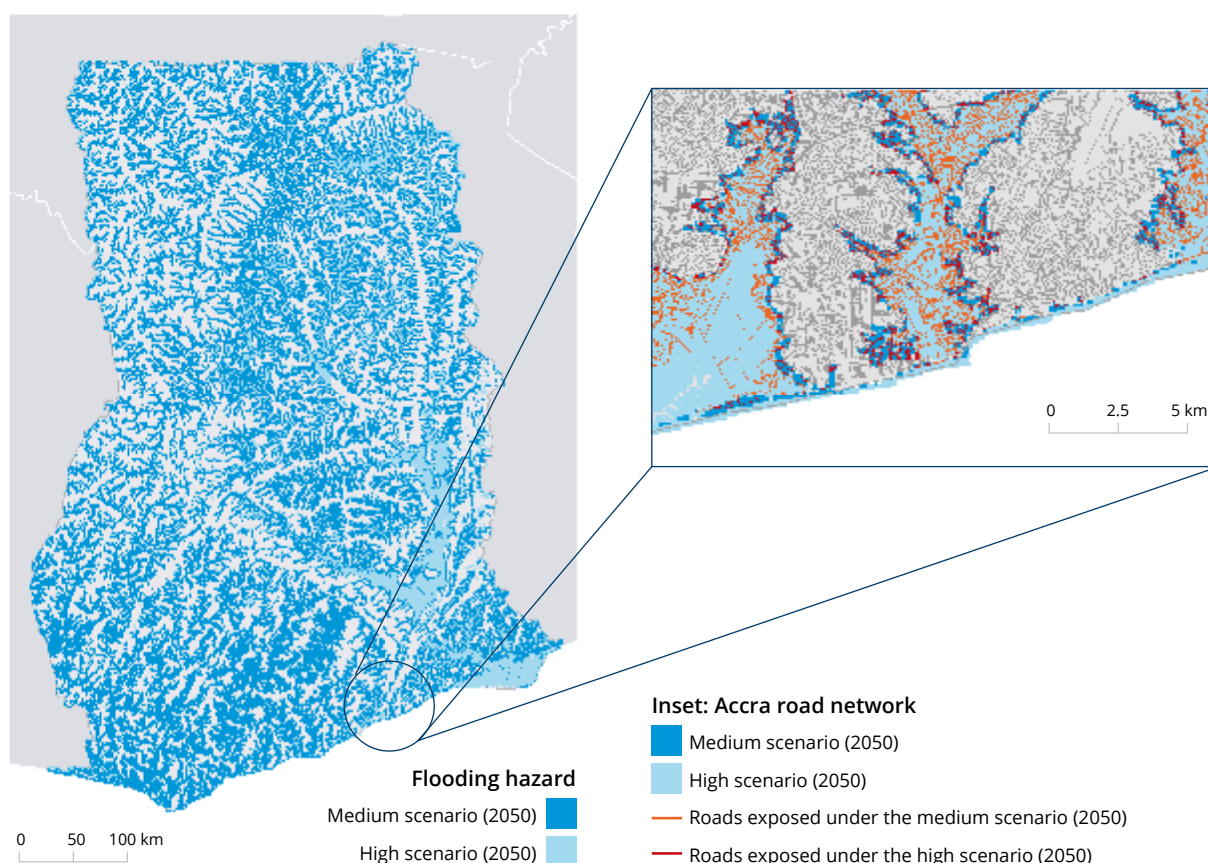


Drought scenarios are based on predictions for meteorological drought using evapotranspiration and rainfall data, and do not account for the impact of other hydrological states like groundwater levels or soil composition. This method places emphasis on cumulative rainfall deficit, consistent with the 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 km²); 12 percent as high hazard (29,000 km²); and 13 percent of the country as medium hazard regions (31,000km²). 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 km² of Ghana's total area of 238,000 km². 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.

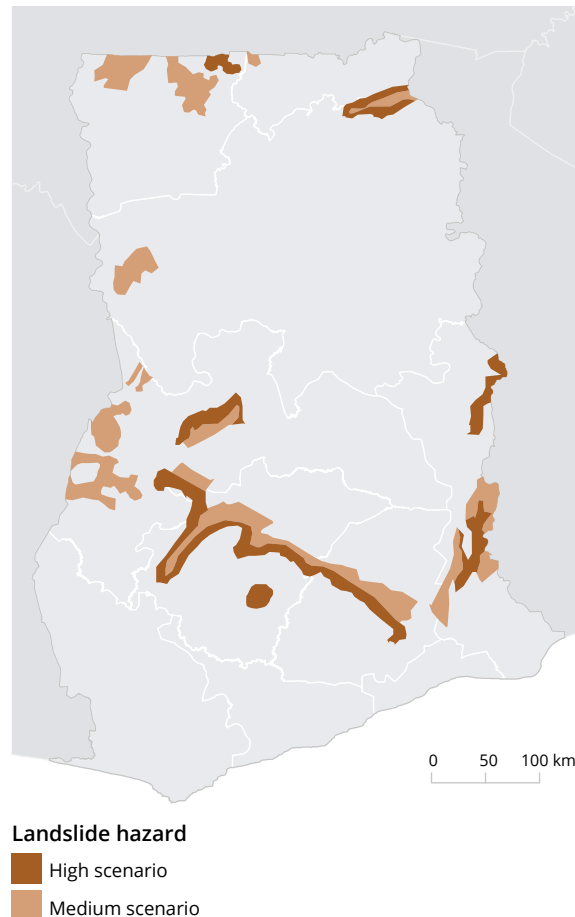
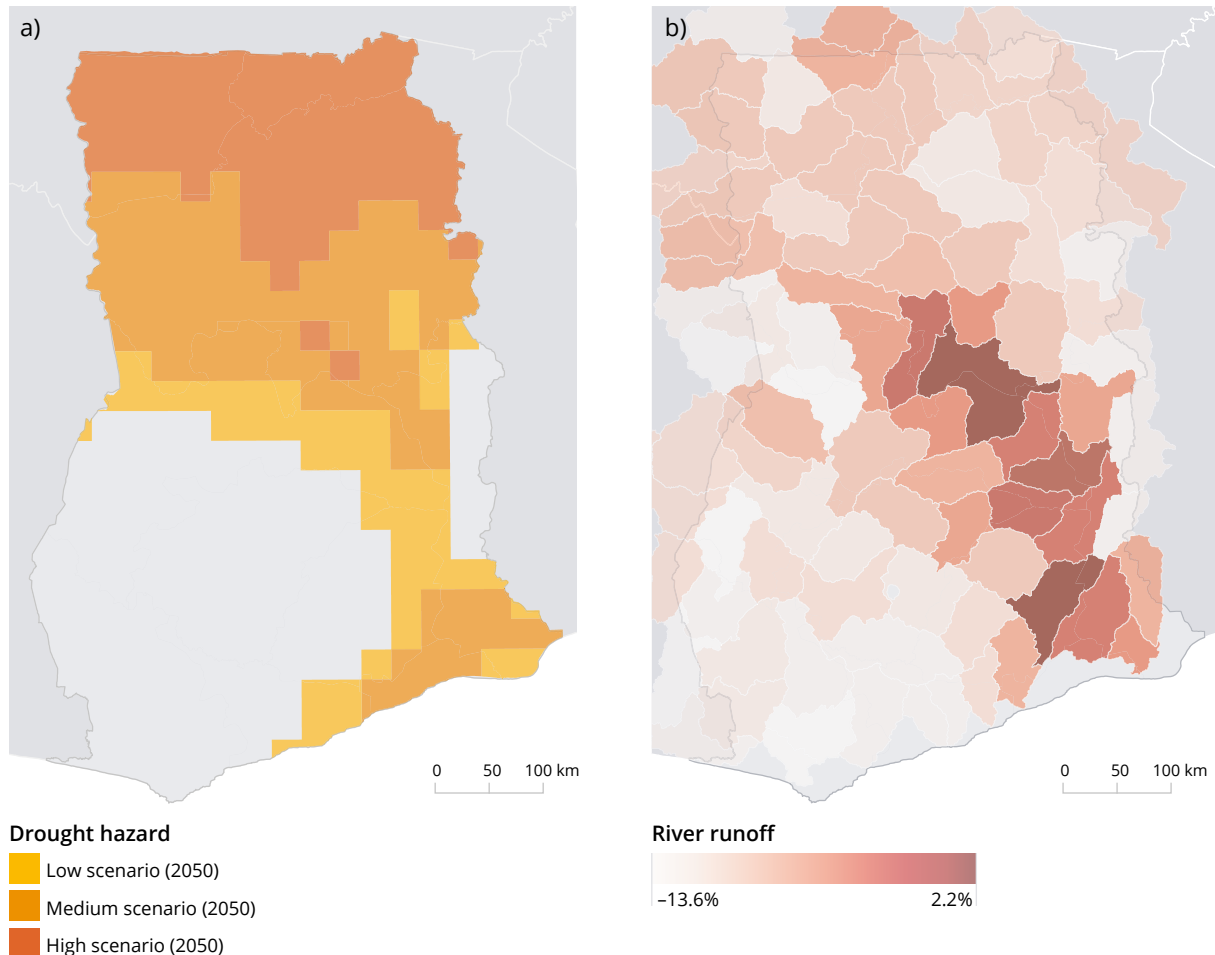


Figure 4:

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.

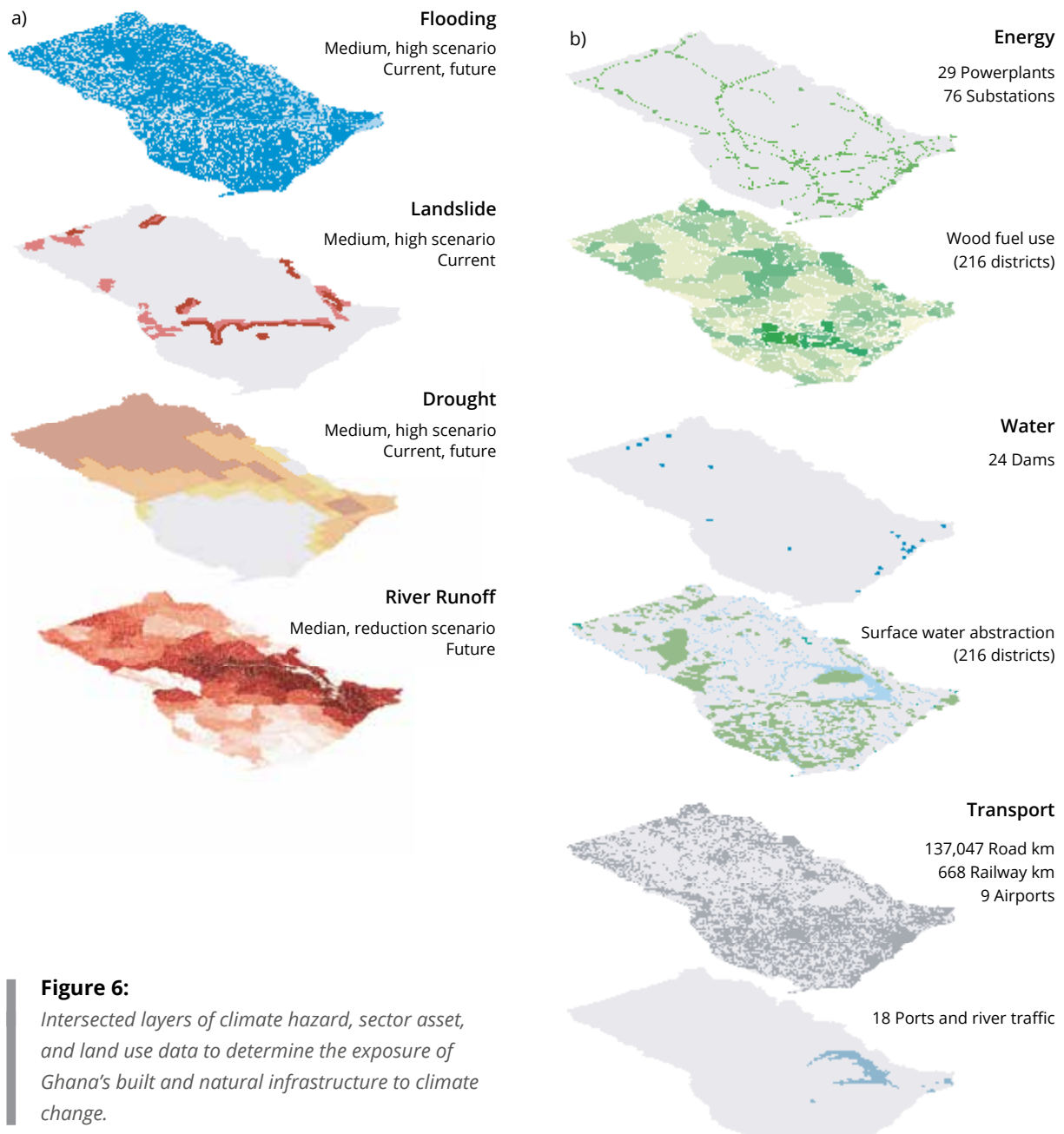
Physical assets and infrastructure systems

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.



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.

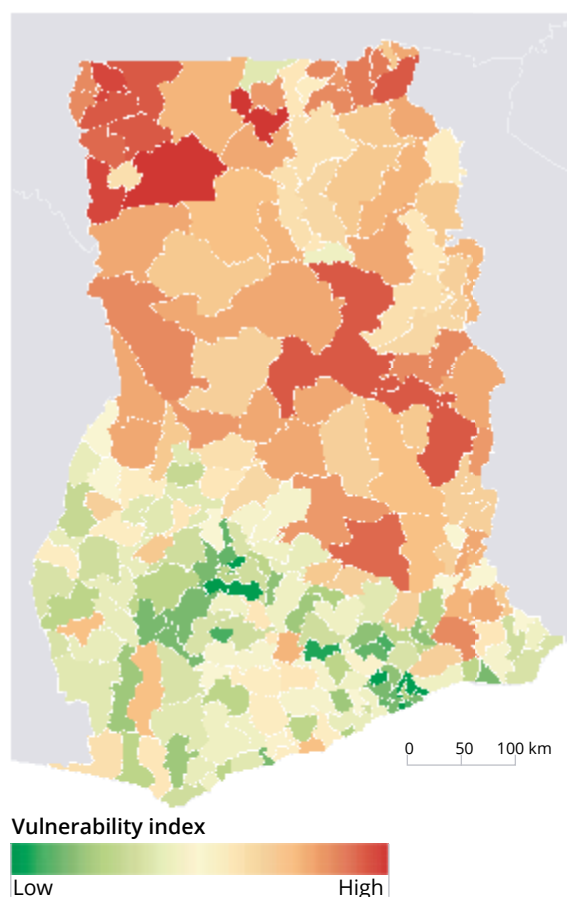
Subsector	Flood highest intensity	Drought highest intensity	Landslide highest likelihood	Reduced river runoff median reduction scenario	Exposure prioritised by:	Incorporate district vulnerability
Power plants	✓	✓			Population served	
Substations	✓		✓		Population served	✓
Wood fuel		✓			Prevalence of 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.

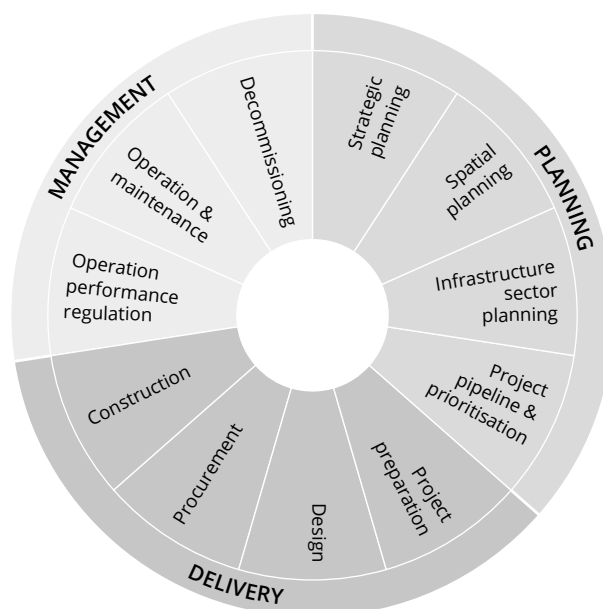


Figure 9:

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.

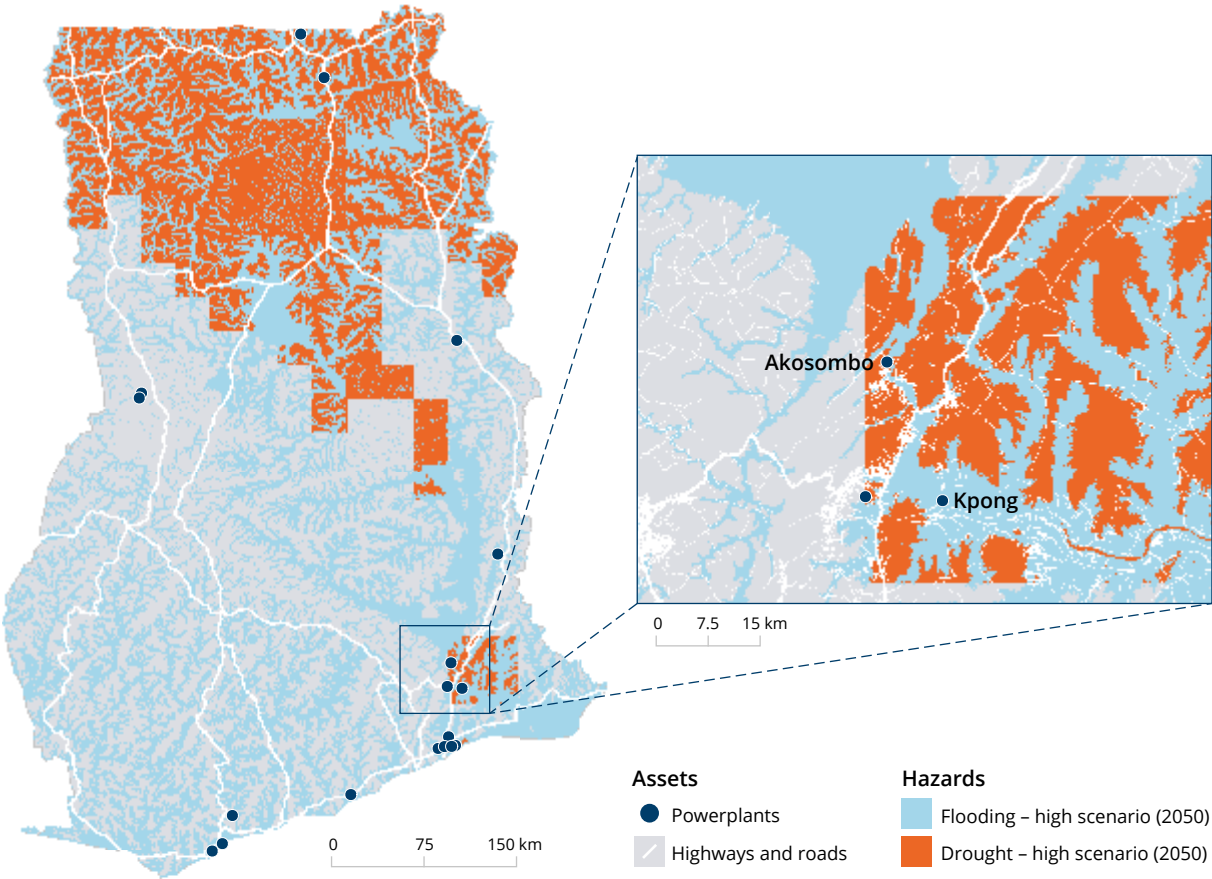
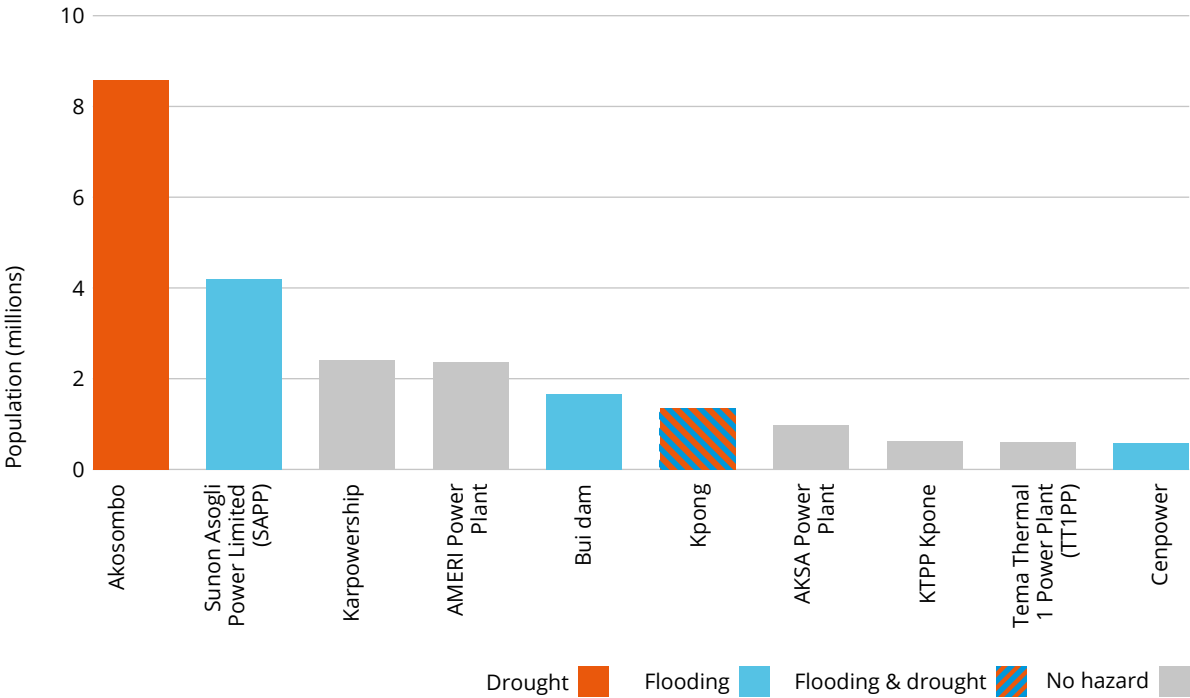


Figure 10 (above):

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.

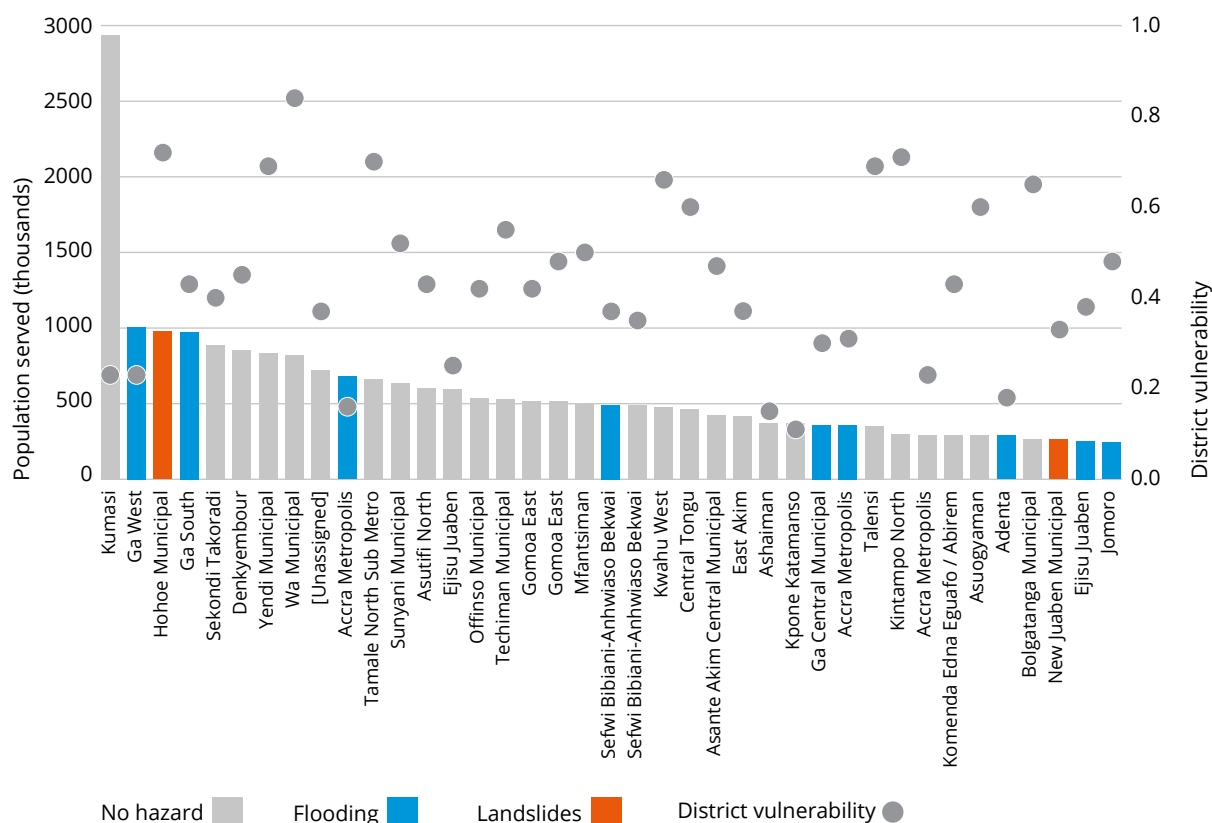


Figure 12:

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).

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.

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.

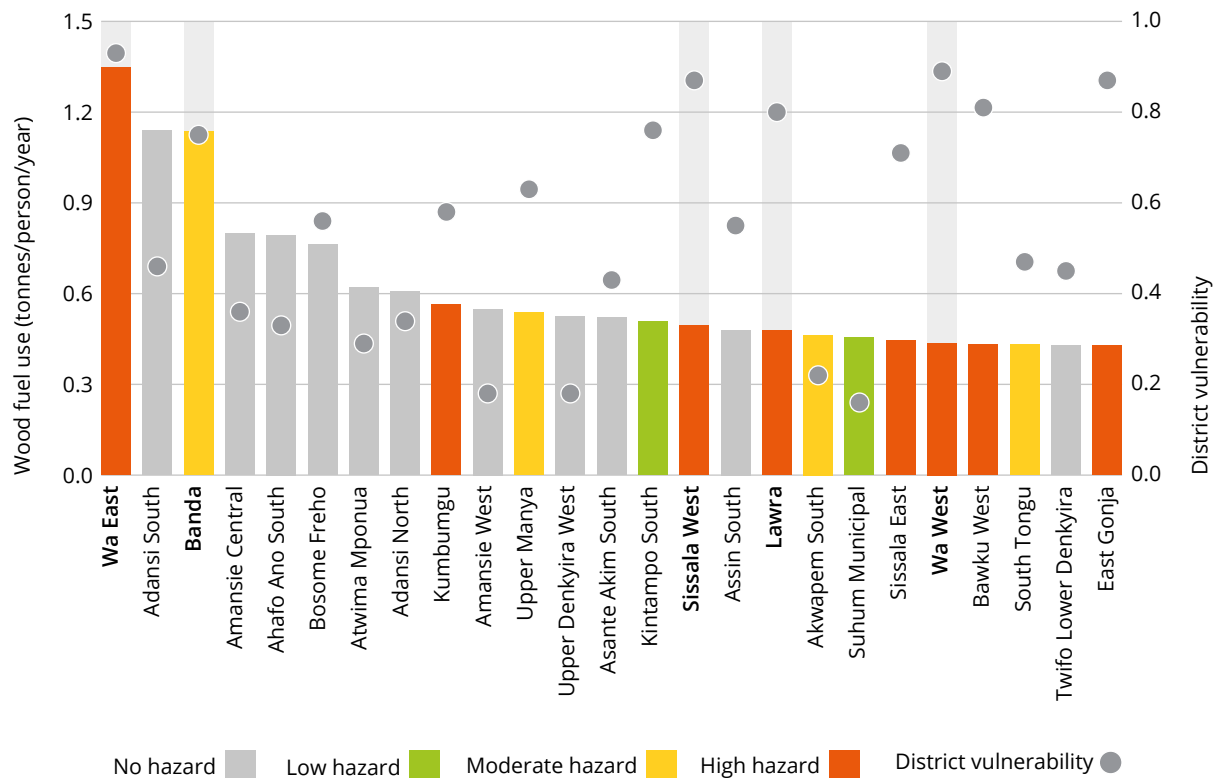


Figure 13:

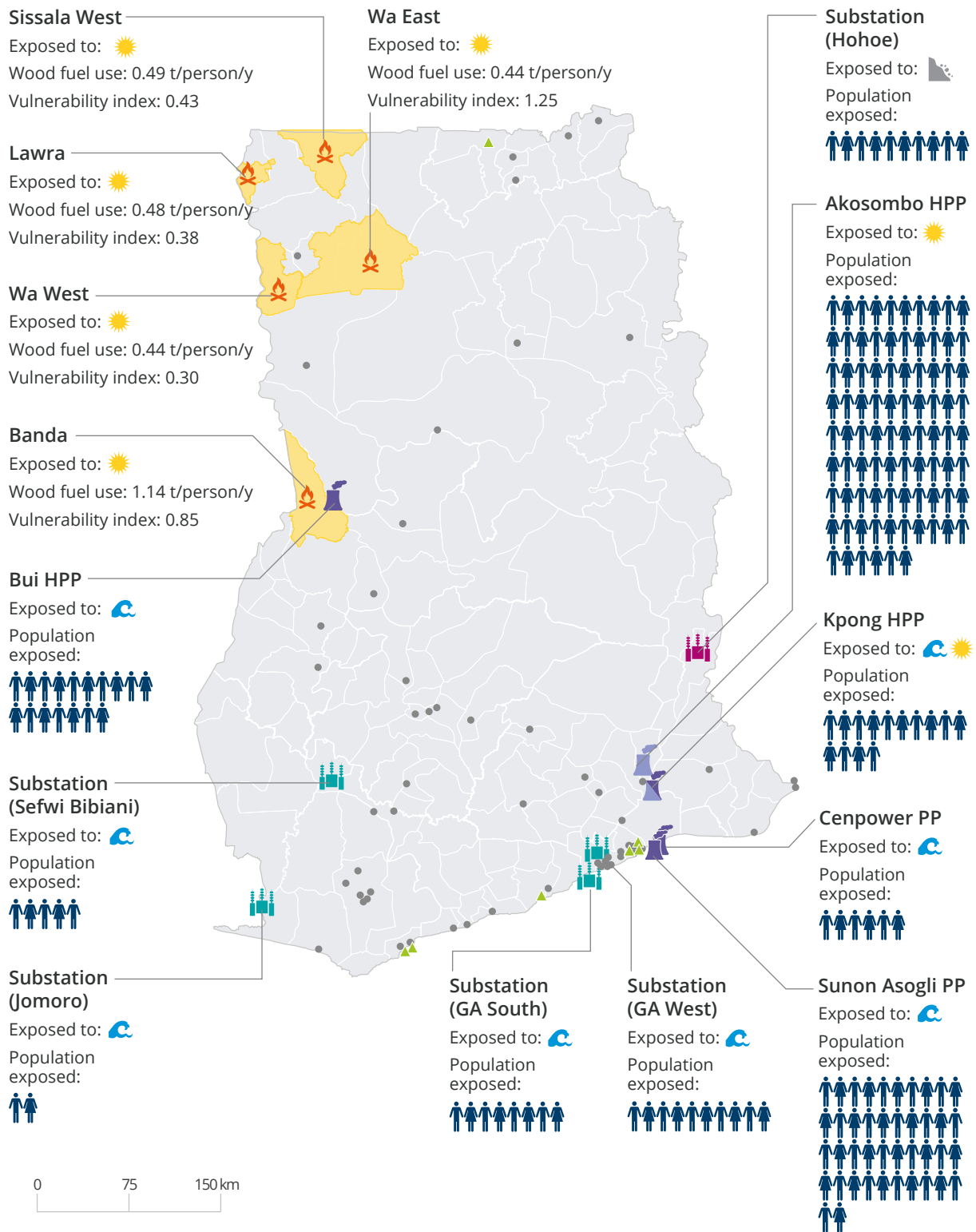
Districts exposed to drought hazards under a high 2050 scenario: wood fuel use (left y-axis), with district vulnerability to hazard impacts shown (right y-axis). Note: the top five exposed districts, accounting for the highest combination of all three of these factors, are highlighted in bold.

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 droughts
-  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, ESIA's 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 - Adaptation targets, implementation plan & investment plan - Capacity development for decision makers	Gender-differentiated and vulnerability not represented	#4 Resilience for gender & vulnerable #5 Mobilising investment #7 Monitoring, report & verification	1 NO POVERTY 2 ZERO HUNGER 3 GOOD HEALTH AND WELL-BEING 4 QUALITY EDUCATION
Project pipeline & prioritisation - Mainstreaming adaptation in project pipeline - Incentives for private sector investment	- Gender-blind budgeting - Delayed release of funds	#4 Resilience for gender & vulnerable #5 Mobilising investment	5 GENDER EQUALITY 6 CLEAN WATER AND SANITATION 7 AFFORDABLE AND CLEAN ENERGY 8 DECENT WORK AND ECONOMIC GROWTH
Project preparation - Integrating climate risk assessment in ESIA for projects of all scales - Enforcement of ESIA		#4 Resilience for gender & vulnerable #6 Technology & capacity development	9 INDUSTRY, INNOVATION AND INFRASTRUCTURE 10 REDUCED INEQUALITIES 11 SUSTAINABLE CITIES AND COMMUNITIES 12 RESPONSIBLE CONSUMPTION AND PRODUCTION
Design Climate-resilient national standards for large-scale infrastructure & renewables	Under-representation of women engineers	#1 Climate-resilient infrastructure #4 Resilience for gender & vulnerable	13 CLIMATE ACTION 14 LIFE BELOW WATER
Operations & maintenance - Finance earmarked for retrofitting with climate risk assessment - Maintenance procedures for renewable systems		#4 Resilience for gender & vulnerable #6 Technology & capacity development	15 LIFE ON LAND 16 PEACE, JUSTICE AND STRONG INSTITUTIONS 17 PARTNERSHIPS FOR THE GOALS



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.

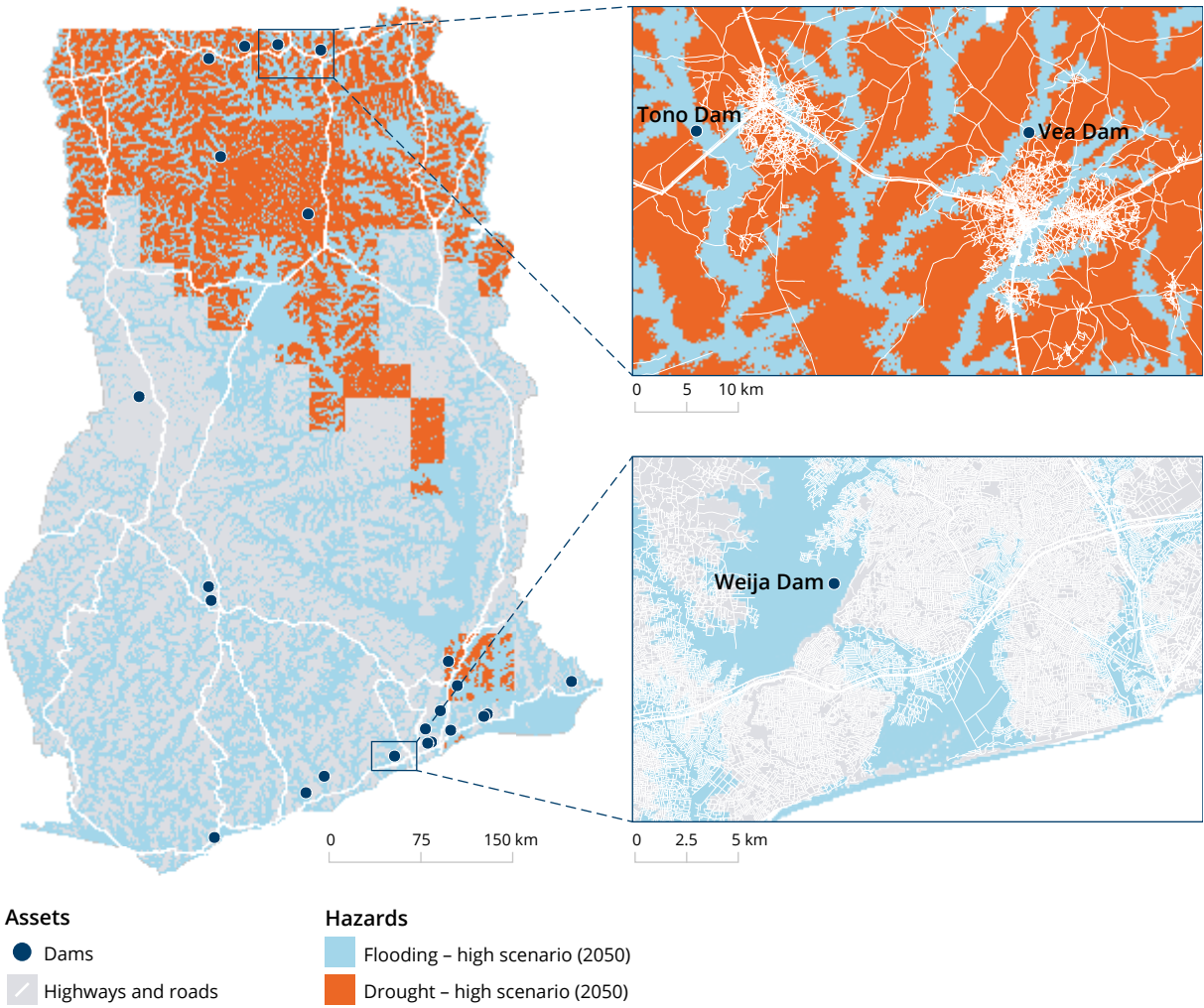


Figure 16:
Inset shows the intersection of selected water supply assets and their hazard exposure: Tono and Vea dams (top); Weija dam (bottom).

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 m³ 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 m³, is the country's most exposed to flood hazards. In the Upper East region, the Tono (3.8 billion m³) and the Veia (816 million m³) dams are both drought- and flood-exposed, with large implications for agricultural irrigation in addition to local water supply. Along the Densu river, the Weiija dam, serving the capital Accra, faces flood exposure affecting its 115 million m³ capacity. The Barekese dam (90 million m³), 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.

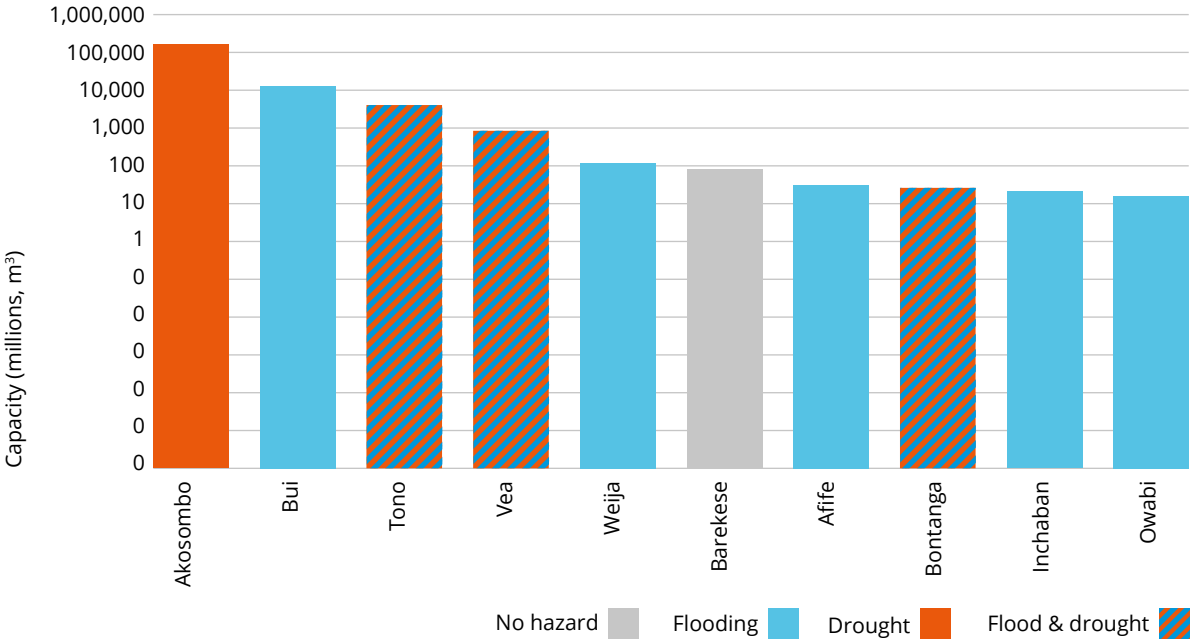


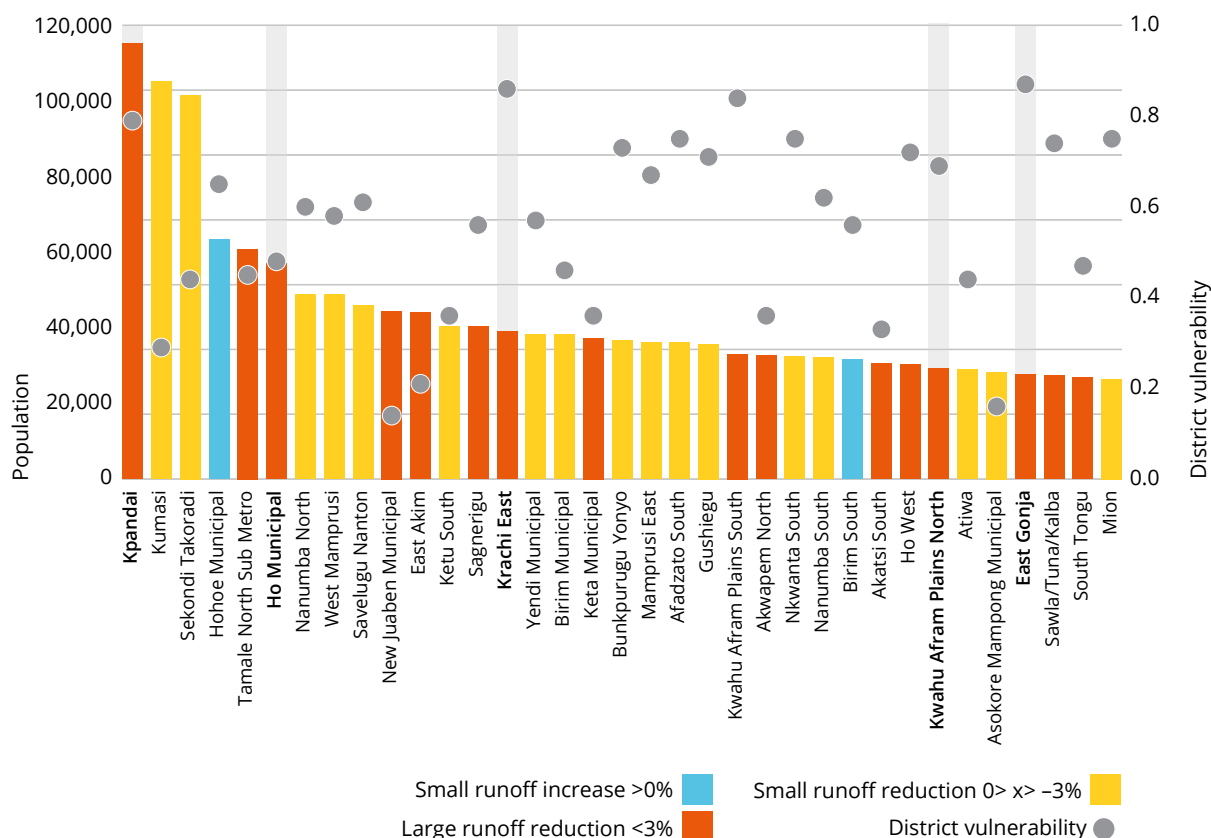
Figure 17:
*Dams exposed to flood and drought hazards under a high 2050 scenario, ranked by dam capacity (y-axis).
Note: capacity shown in log scale.*

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:

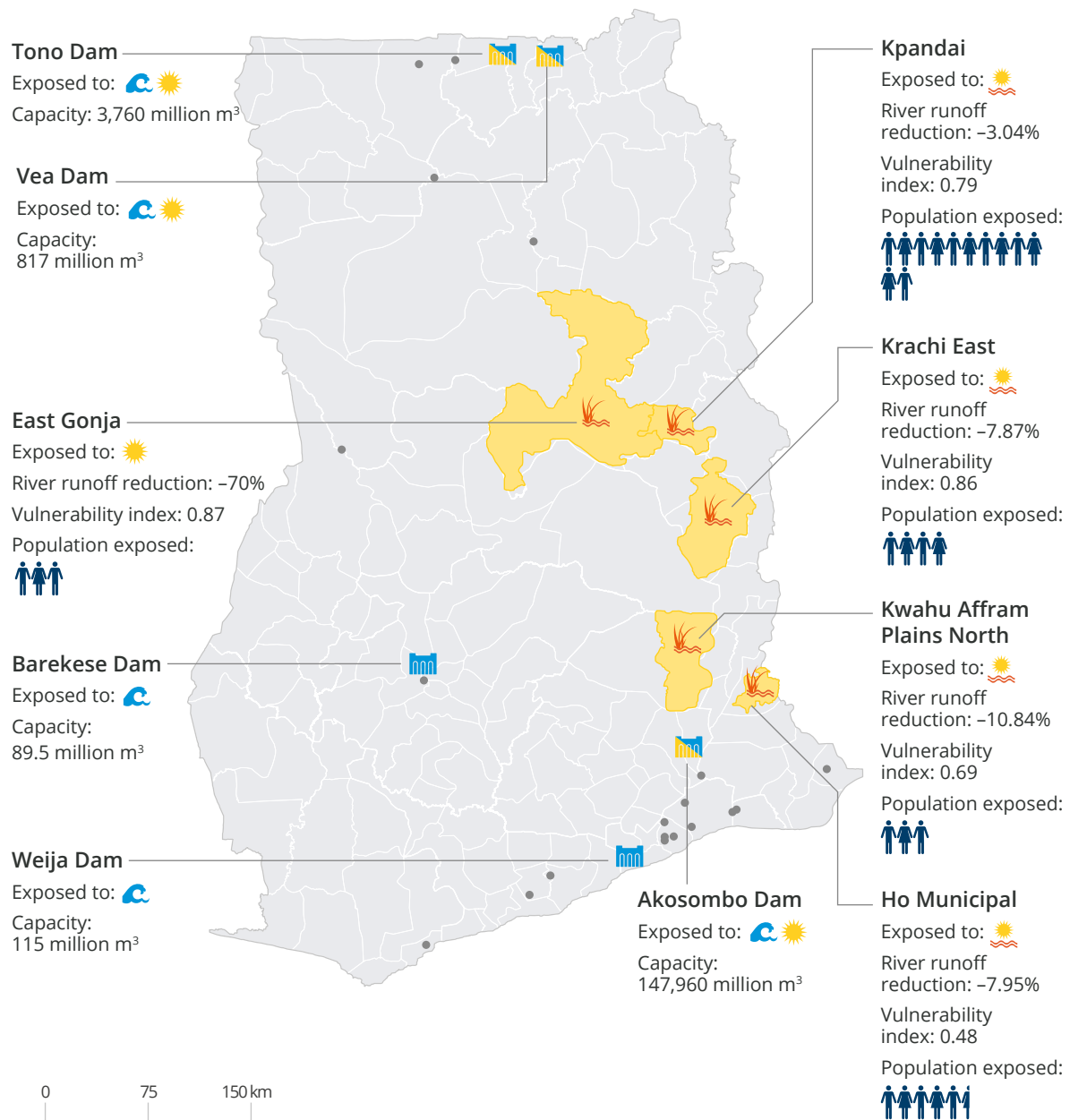
- **Kpandai:** Large reduction, population impacted 115,283, vulnerability 0.79;
- **Ho Municipal:** Large reduction, population impacted 56,946, vulnerability 0.48;
- **Krachi East:** Large reduction, population impacted 39,102, vulnerability 0.86;
- **Kwahu Afram Plains North:** Large reduction, population 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.

**Dams**

- Prioritised dams exposed to flooding
- Prioritised dams exposed to flooding and droughts
- Other dams

Districts with high rates of water abstraction from surface water bodies

- Prioritised districts exposed to reduced river runoff
- Population using drinking water directly from surface water bodies (representing 10,000 people)

Exposure

- Exposed to flooding
- Exposed to droughts
- Exposed to reduced runoff

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.

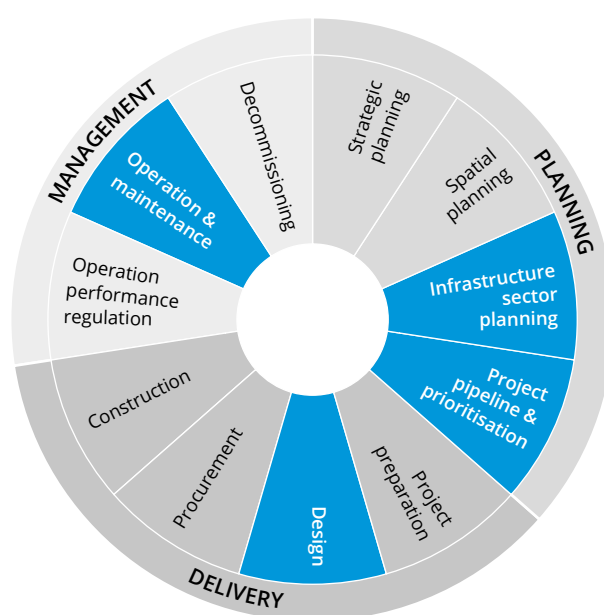


Figure 20:

Water sector needs in the enabling environment

Adaptation needs – water sector	Gender-related needs	NDC thematic area addressed	Potential SDG impacts
Infrastructure sector planning - Adaptation targets, prioritisation of long-term goals into sector plans - Uniform climate data and models to inform plans		#1 & #2 Climate resilient infrastructure #3 Water resources	1 NO POVERTY 2 ZERO HUNGER 3 GOOD HEALTH AND WELL-BEING 4 QUALITY EDUCATION
Project pipeline & prioritisation Aligning adaptation activities in project pipeline	- Gender-blind budgeting - Delayed release of funds	#1 & #2 Climate resilient infrastructure #3 Water resources #4 Resilience for gender & vulnerable	5 GENDER EQUALITY 6 CLEAN WATER AND SANITATION 7 AFFORDABLE AND CLEAN ENERGY 8 DECENT WORK AND ECONOMIC GROWTH
Design - Climate-resilient national standards for grey and green infrastructure systems - Technical capacity in implementing nature-based solutions		#1 & #2 Climate resilient infrastructure #3 Water resources #6 Technology & capacity development	9 INDUSTRY, INNOVATION AND INFRASTRUCTURE 10 REDUCED INEQUALITIES 11 SUSTAINABLE CITIES AND COMMUNITIES 12 RESPONSIBLE CONSUMPTION AND PRODUCTION
Operations & maintenance - Finance earmarked for maintenance with climate risk assessment - Assessment management systems integrated with early warning systems for flood prevention and a water management		#1 & #2 Climate resilient infrastructure #3 Water resources	13 CLIMATE ACTION 14 LIFE BELOW WATER 15 LIFE ON LAND 16 PEACE, JUSTICE AND STRONG INSTITUTIONS 17 PARTNERSHIPS FOR THE GOALS



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-Takoradi:** 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.

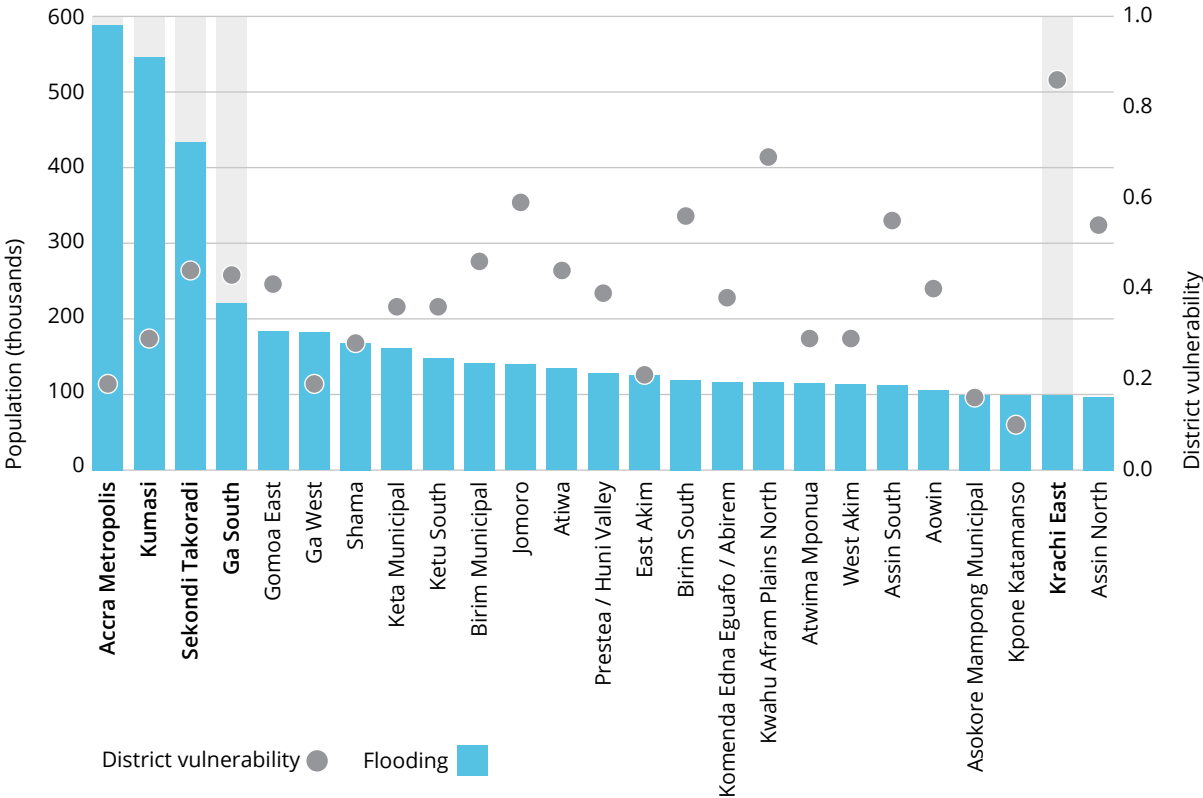


Figure 21:
Districts exposed to flood hazards on roads under a high 2050 scenario, ranked as a function of potential population loss of access to healthcare services (left y-axis) and district vulnerability (right y-axis). Note: the top five exposed districts, accounting for all three of these factors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

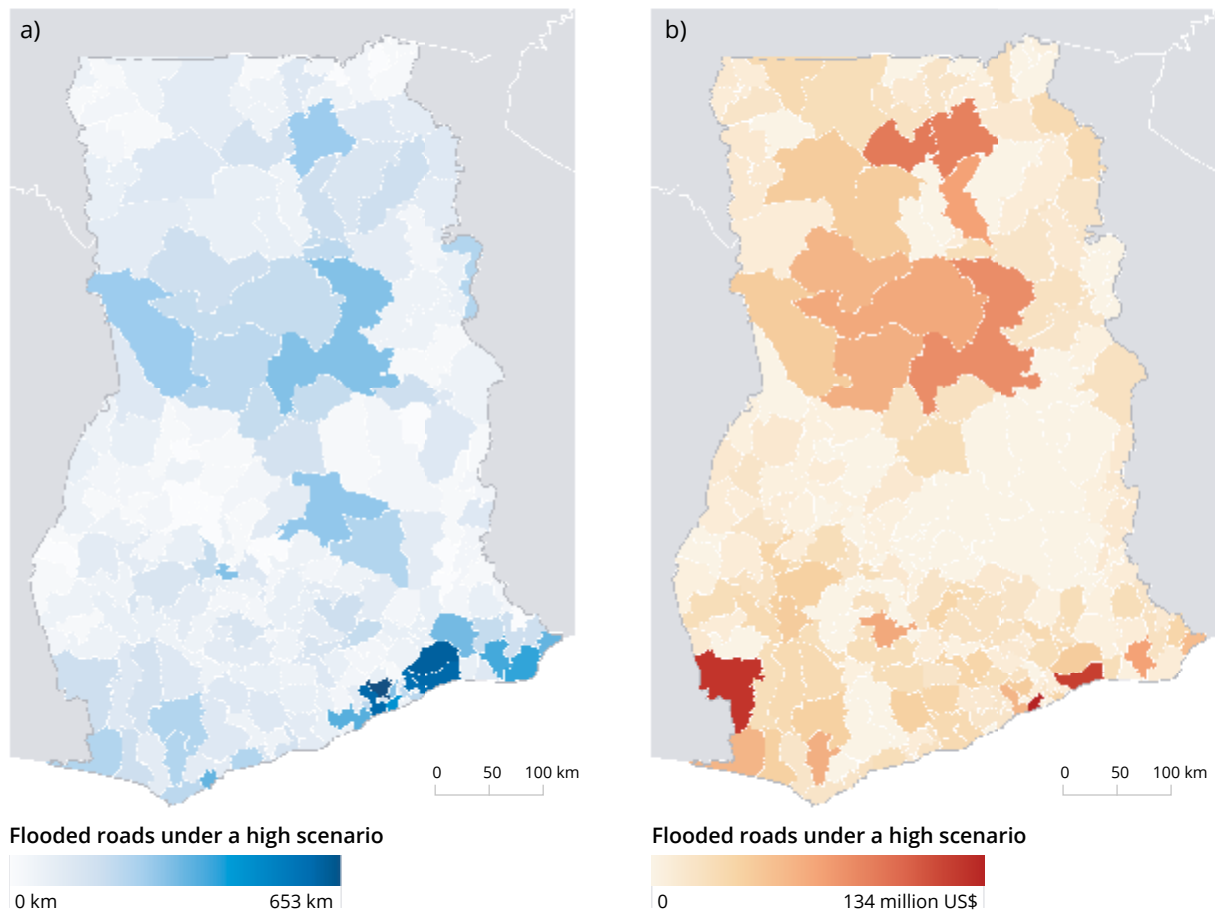


Figure 22:

(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.

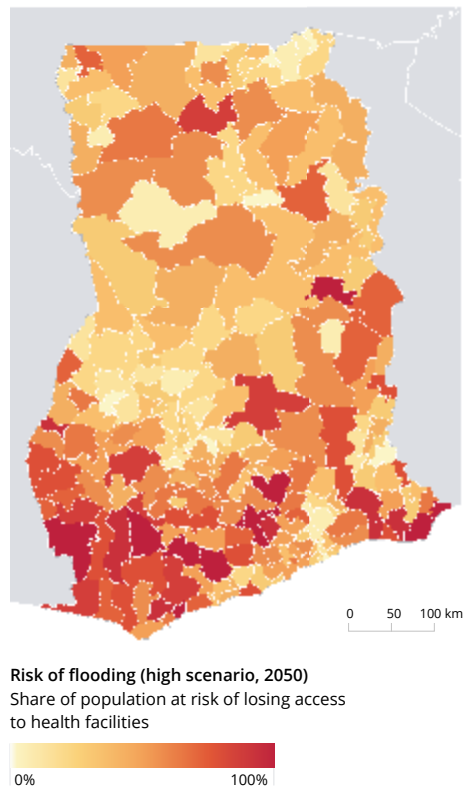


Figure 23:

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.

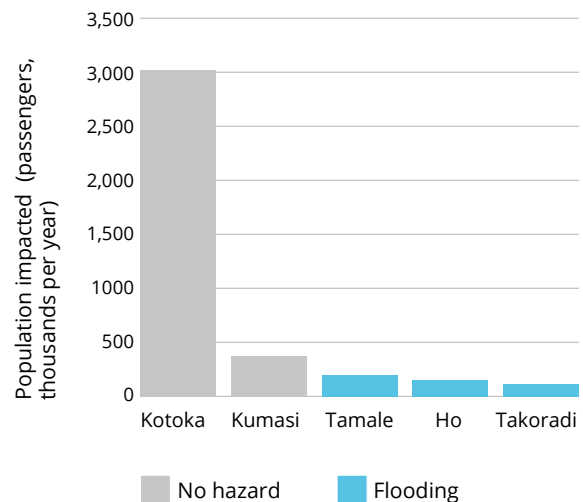


Figure 24:

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 km² 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**.

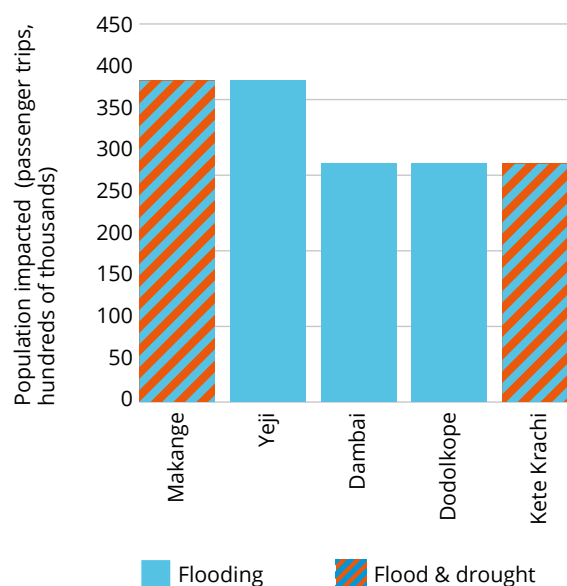
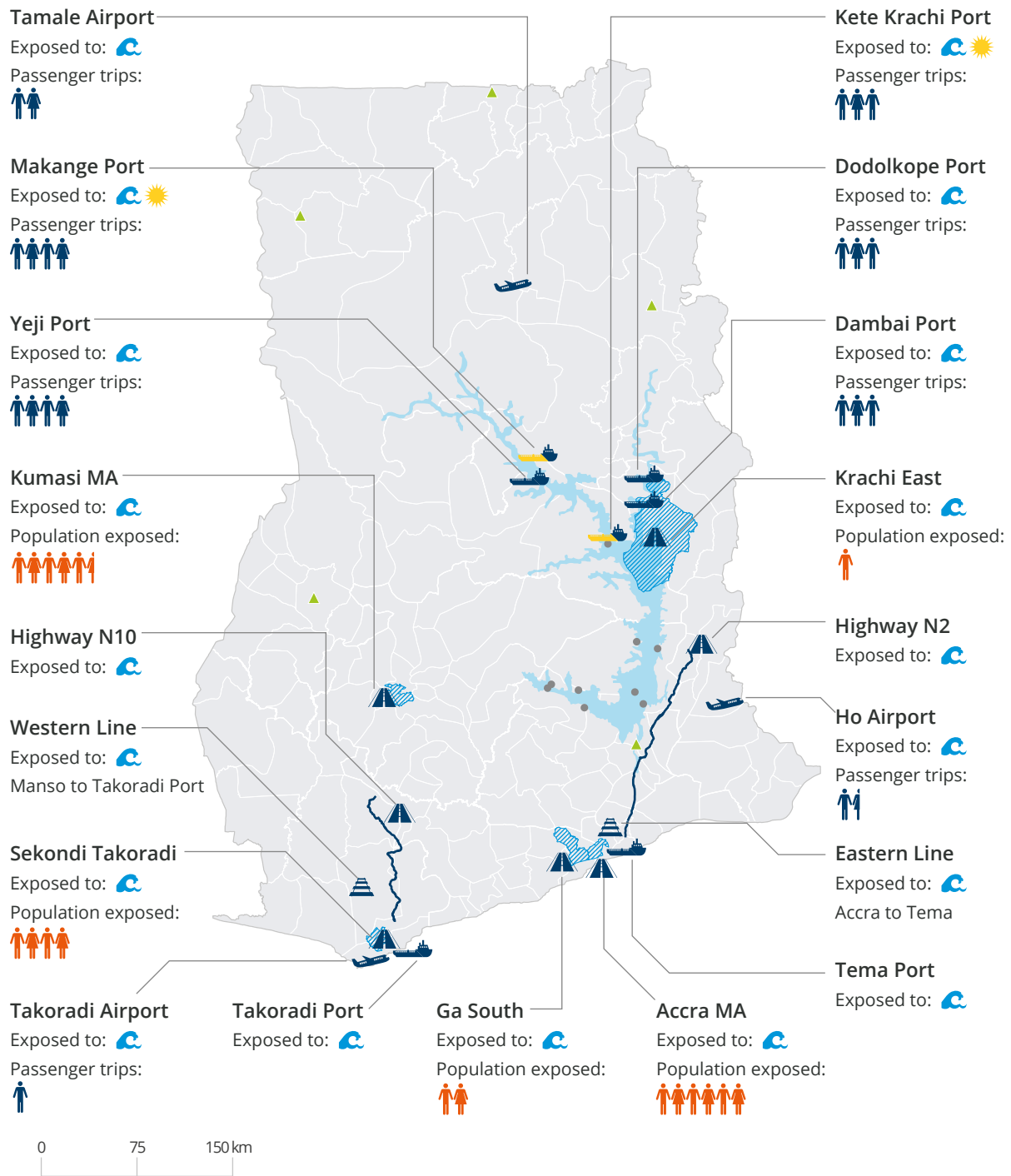


Figure 25:

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.

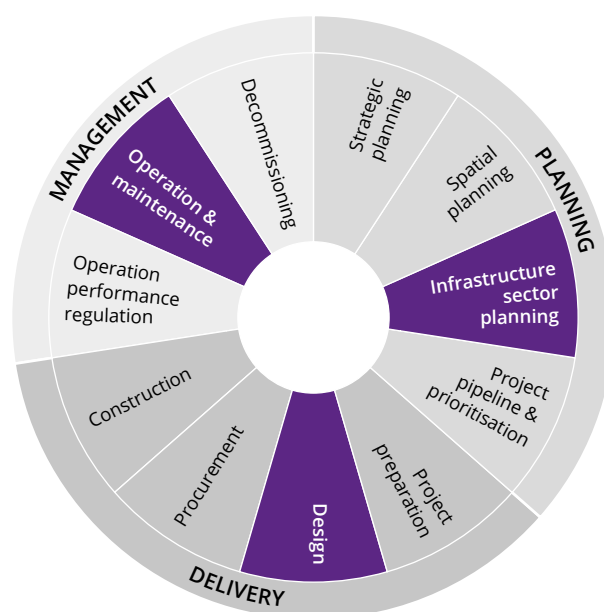
For example, following the devastating floods in 2015, in the absence of contingency funds, the Government of Ghana had to secure funding of USD 6.4 million for emergency repairs of drainage systems, buildings, and roads in Accra from an ongoing World Bank-funded project, causing that project to be negatively 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 - Institutional framework for coordinating adaptation across sub-sectors - Framework for mainstreaming adaptation measures & targets in sector & sub-sector plans	- Under-representation of women in public institutions - Gender-blind plans and expenditure framework	#4 Resilience for gender & vulnerable #5 Mobilising investment #7 Monitoring, report & verification	1 NO POVERTY 2 ZERO HUNGER 3 GOOD HEALTH AND WELL-BEING 4 QUALITY EDUCATION 5 GENDER EQUALITY 6 CLEAN WATER AND SANITATION 7 AFFORDABLE AND CLEAN ENERGY 8 DECENT WORK AND ECONOMIC GROWTH 9 INDUSTRY INNOVATION AND INFRASTRUCTURE 10 REDUCED INEQUALITIES 11 SUSTAINABLE CITIES AND COMMUNITIES 12 RESPONSIBLE CONSUMPTION AND PRODUCTION 13 CLIMATE ACTION 14 LIFE BELOW WATER 15 LIFE ON LAND 16 PEACE, JUSTICE AND STRONG INSTITUTIONS 17 PARTNERSHIPS FOR THE GOALS SUSTAINABLE DEVELOPMENT GOALS
Project pipeline & prioritisation - Climate-resilient national standards for roads - Technical capacity to integrate climate risk considerations		#1 Climate resilient infrastructure #4 Resilience for gender & vulnerable #6 Technology & capacity development	
Design - Climate-risk informed asset management - 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.

An aerial photograph showing a large, multi-level highway interchange with several overpasses and ramps. The roads are filled with cars and trucks. The surrounding area is densely packed with small, colorful buildings, mostly with red or orange roofs, typical of an informal settlement. There are some green trees and patches of vegetation interspersed among the buildings. The overall scene depicts a major transportation hub in a rapidly growing urban environment.

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

Sector & sub-sector	Asset/s or areas	Justification for prioritised adaptation need
Energy Power plants – thermal	Western region (Aboadze)	Hazard: Flooding Five thermal power plants serving over 900 thousand people (including the Takoradi PPs) are at risk of coastal flooding. Other considerations: Energy sector stakeholders identified this as a high priority for adaptation because of recent flooding of these facilities
Energy Power plants – thermal	Sunon-Asogli power plant	Hazard: Flooding Most significant thermal power plant vulnerable to river flooding, serving 4.2 million people. Other considerations: In addition to river flooding, it is also at risk of coastal flooding due to sea level rise
Energy Substations	Key substations in Ga South and West, Hoehoe, Bibiani/Anhwiaso/Bekwal, and others	Hazards: Flooding and landslides - 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) - 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 - Substations in the Western and Western North regions are also highly exposed
Energy Power plants – thermal and solar	All non-hydroelectric power plants, with priority to those in drought-affected regions	Hazard: Drought Drought conditions causing depleted water resources can result in reduced plant efficiency and generation capacity. Other considerations: Large water requirements for power plant cooling and removal of waste heat impact negatively on communities and ecosystems that rely on river runoff.
Energy Wood fuel	Key districts in the Upper West, Savannah, and Bono regions	Hazard: Drought The following districts: 1) face increased drought hazard; 2) rely heavily on wood fuel; and 3) are socio-economically vulnerable: - 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.

Sector & sub-sector	Asset/s or areas	Justification for prioritised adaptation need
Energy 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. • 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 Enabling environment	Design standards	• Not incorporating climate risks into design standards exposes all assets to climate hazards. • Use of international design standards in the absence of appropriate national and context-specific standards. • May not be legally recognised and therefore, not enforceable in the country.
Water Dam	Weija dam	Hazard: Flooding Flood waters threaten the dam infrastructure and surrounding residential areas. Other considerations: • 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 Dam	Northern dams (Vea, Tono)	Hazards: Flooding and drought 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. Other considerations: • Include the second- and third-most exposed dams to both flood and drought impacts in Ghana (Vea and Tono) • Provide the main source of water for household use and agricultural irrigation in the Northern region, with up to 4.5 billion m³ capacity
Water Dam	Barekese dam	Hazard: Flooding Increases fluvial sediment and reduces reservoir capacity, causing physical damage to assets and downstream floods. Other considerations: • 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 All urban assets	Accra plains	Hazards: Flooding and drought 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. Other considerations: 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 Surface water, e.g. rivers	Key districts in the Savannah, Northern, Eastern, and Volta regions	Hazards: Drought and reduced river runoff The following districts: 1) face large runoff reductions; 2) rely heavily on surface water abstraction for household use; and 3) are socio-economically vulnerable: - 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 Afram Plains North: High hazard, population impacted 29,245, vulnerability 0.69; - East Gonja: High hazard, population impacted 27,722, vulnerability 0.87.
Water 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 Enabling environment	Asset management	- Water infrastructure management that is reactionary, not proactive, increases both the risks to hazards as well as their impacts. - There is no risk-informed asset management system for relevant government institutions.
Transport Road, rail	Accra urban	Hazard: Flood Inadequate urban drainage along roads and streets makes the city vulnerable to damage from pluvial and coastal flood hazards. Other considerations: - In Greater Accra, 22 percent of the road network is exposed to flood events with potential damage costs exceeding 130 million USD. - 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 Road, rail	Kumasi, Weija highways; Western and Eastern railway lines	Hazard: Flooding Threatens damage to roads and interruption of transport services in Ghana. Other considerations: • Total damage to the road network due to floods may reach 3.9 billion USD by 2050. • Disruption of vital commercial and economic activities which this infrastructure supports.
Transport Port	Tema port	Hazard: Flooding Coastal and river flooding affects the port facility and surrounding infrastructure. Other considerations: • 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 Road	Major highways: N6 (all exposed to landslides ~15 km), N10 Mid-West (~ 60km), N2 South-East (~85km)	Hazard: Landslides Landslide risks intensified by increased rain and flooding disrupt major transport routes, as well as causing destruction to buildings and communities. Other considerations: • Disruption of vital commercial and economic activities which these highway routes support.
Transport Airport	Airports: Ho, Tamale, Takoradi	Hazard: Flooding 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. Other considerations: • Disruption to commercial flights and economic activity across the country • Loss of air transport sector revenue to government and private investors
Transport Road, rail	Prioritised roads in Accra; planned railways; Adomi bridge	Hazard: Flooding Cuts off key transport links, including in rural districts, which can limit local access to social and economic services (such as healthcare). Other considerations: • 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 Airport, road	Takoradi airport and exposed roads	Hazard: Flooding River flooding and coastal inundation which puts infrastructure assets at risk of damage. Other considerations: • Disruption of air and highway transport • Loss of air and highway sector revenue to government and private investors.
Transport 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 Construction of transport assets can be disrupted during the rainy season, when flooding is most likely. Other considerations: • 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 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 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. • Locally relevant design standards and materials including the use of NbS can help to maximise responsive to climate risks.
Transport 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. • Contingency plans will increase the adaptive capacity of the system by enabling more rapid and efficient response to climate change-induced events.
Cross-sectoral Power plant – hydroelectric, dams, roads, river ports	Volta River reservoir	Hazards: Flooding and drought Flooding increases fluvial sediment and reduces reservoir capacity; physical damage to assets including river ports; downstream floods. Droughts affect river flow and reservoir capacity which reduce generation capacity. Other considerations: • 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 Roads, buildings, natural features	Accra/Takoradi urban areas	Hazards: Flooding and drought 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 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 • Sub-optimal data management practices increase the costs of storing and using data. • Decentralised data management makes it hard to identify gaps that need filling or updating
Cross-sectoral 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. • Lack of climate-risk informed land-use planning can lead to future infrastructure site selection that exposes assets to high climate risks. • Lack of enforcement of land use regulations and land tenure reform exposes environmentally sensitive areas to higher risks.
Cross-sectoral 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. • 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 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 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.

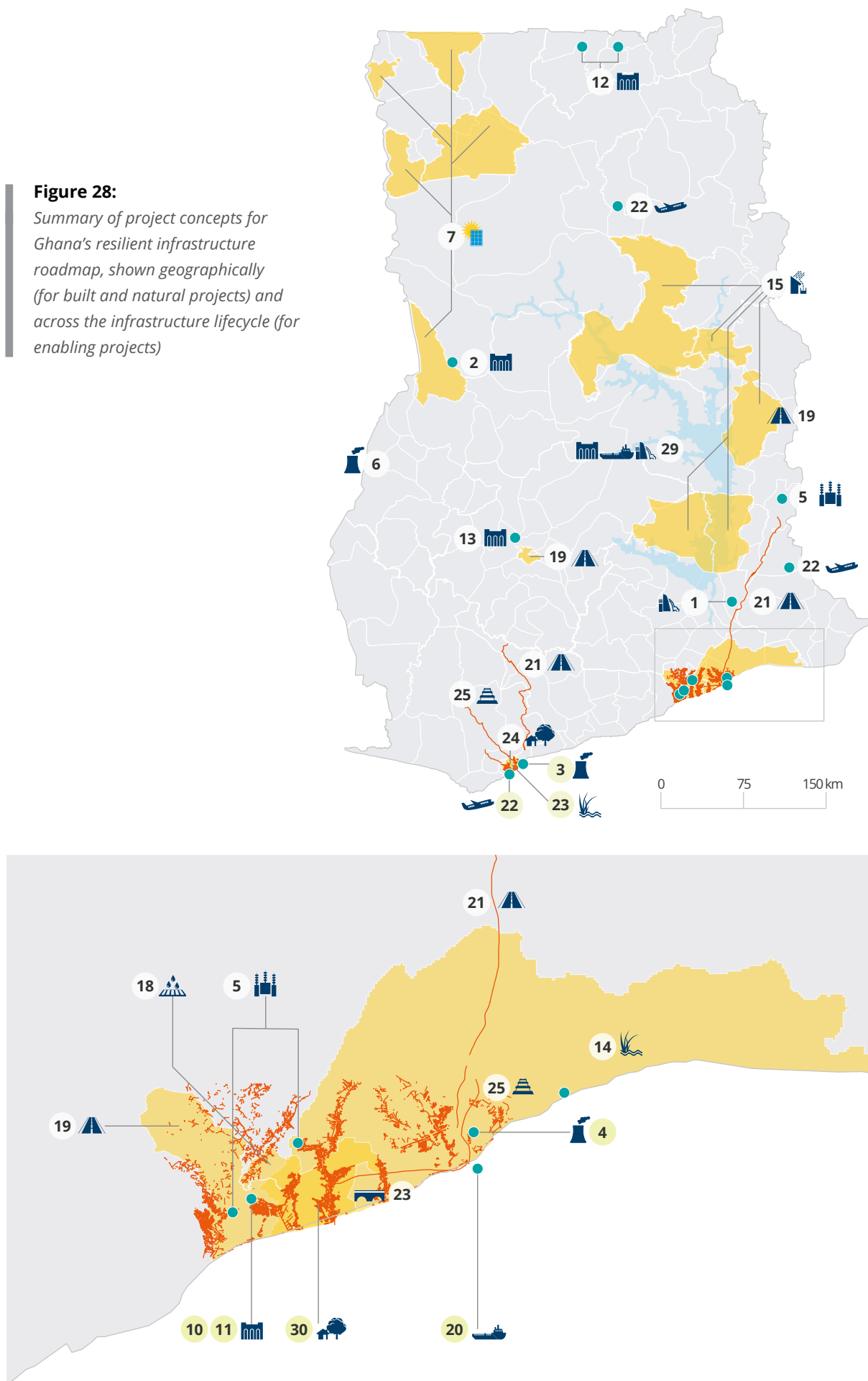
The 35 projects included in the roadmap are summarised here and detailed on the following pages as project concept notes (Figure 28). Projects focused primarily on the built and natural environments are shown geographically in terms of the location of key assets or districts affected. Enabling environment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

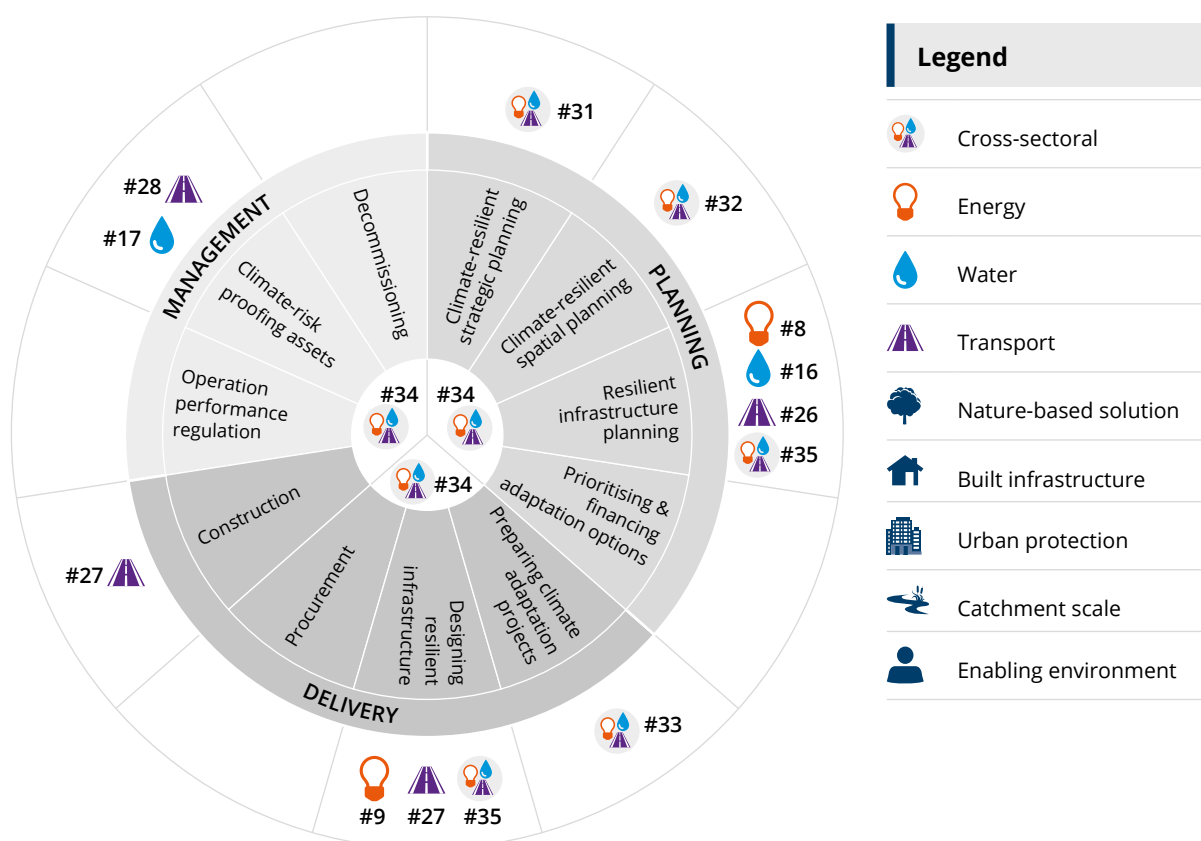
Table 2: Description of adaptation options proposed within the roadmap

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)





			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 Veia 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.

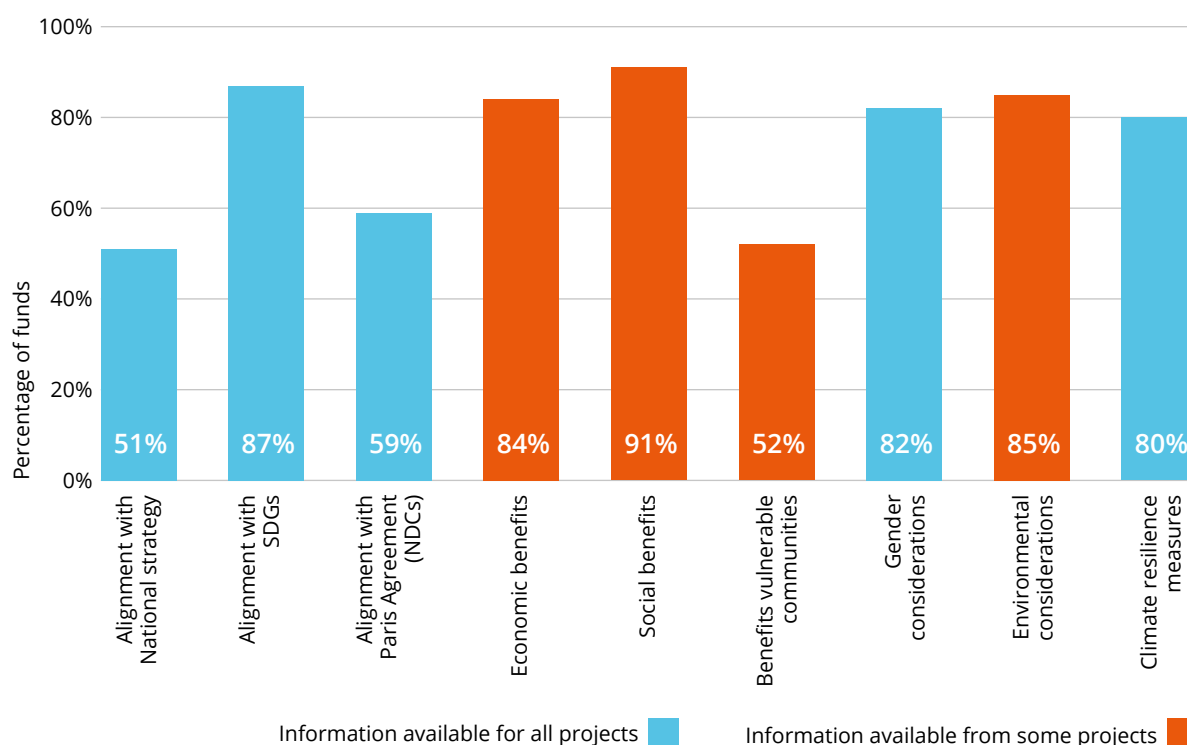


Table 3: Project concept information for 35 adaptation options

Component	Explanation	Criteria captured
General project information	Description of the project requirements, components, and geographical or institutional scope Adaptation need(s) and/or enabling environment gap(s) that the project is addressing, identified in the enabling institutional environment 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 • Low: Partial/no physical upgrades, little need for grading, materials, and construction • Moderate: Substantive physical upgrades with grading, materials, and construction possible but lower costs than new or specialised facility construction • High: Substantive physical upgrades with grading, materials, and construction costs. New and specialised facility costs Operational costs • Low: Little to no cost of ongoing monitoring, maintenance, and reporting in the near-term barring catastrophic failure • Medium: Some monitoring, maintenance, and reporting costs expected • High: High monitoring, maintenance, and reporting costs expected Implementation time • Low: Options that can be mobilised on an emergency basis (i.e. days), or implemented in up to 1 year • Medium: Options that can be implemented in 2 to 5 years • 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	<i>Potential</i> 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 risks (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



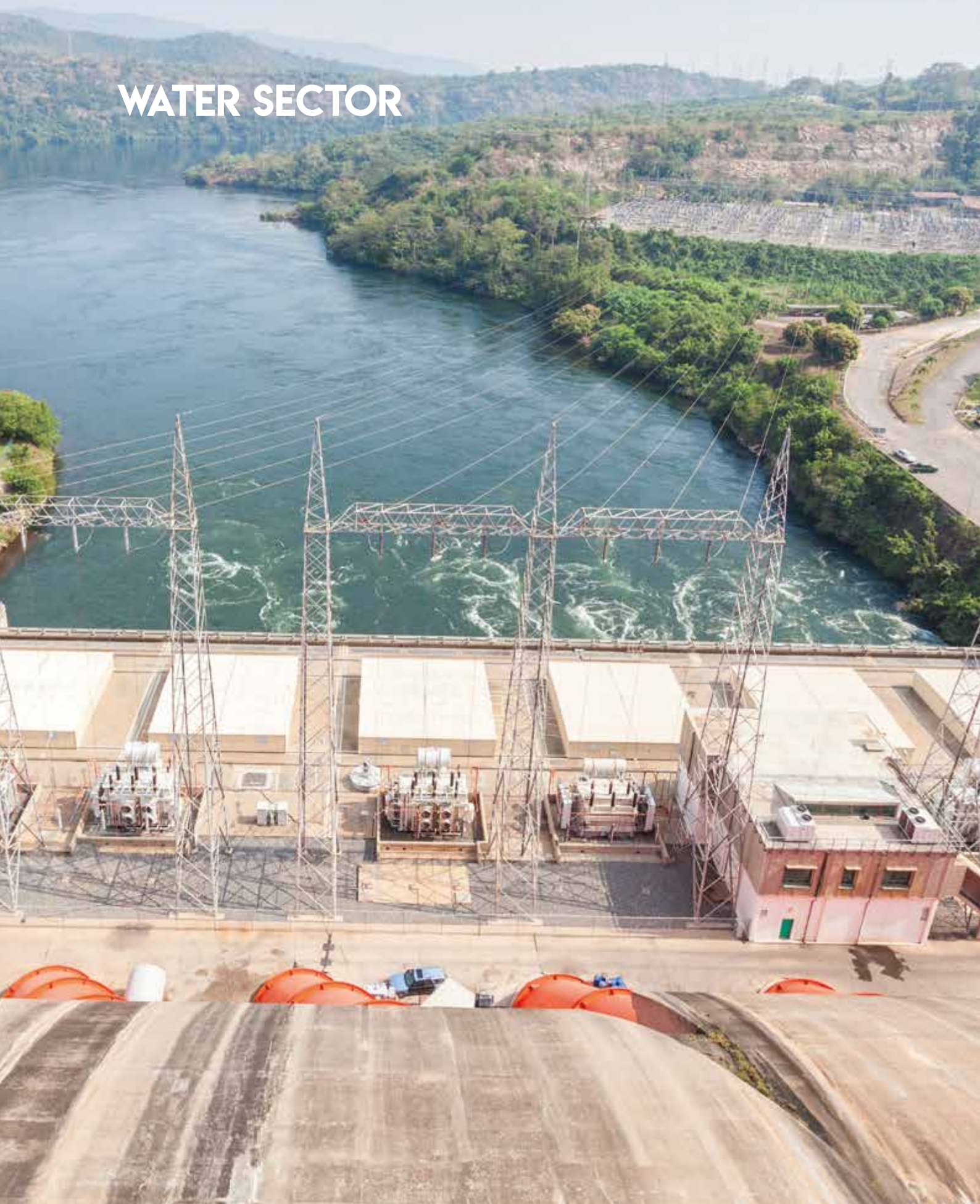
Operational costs



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 m³/ 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 m³/ 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 m³. 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 m³) and Vea (816 million m³) 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 m³)

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 Afram 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 (roads, 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.

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 Veia 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

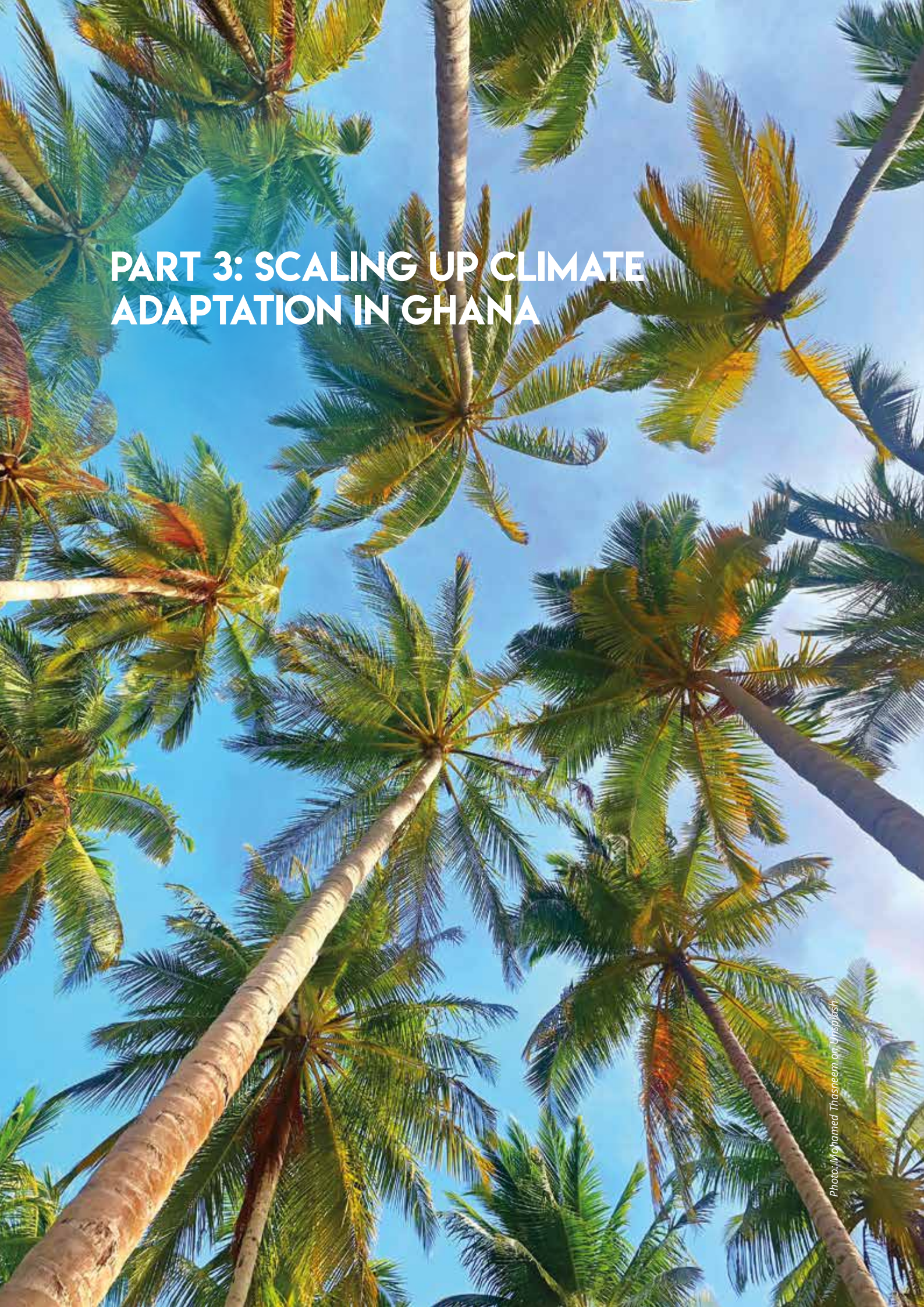


Operational costs



Implementation time





PART 3: SCALING UP CLIMATE ADAPTATION IN GHANA

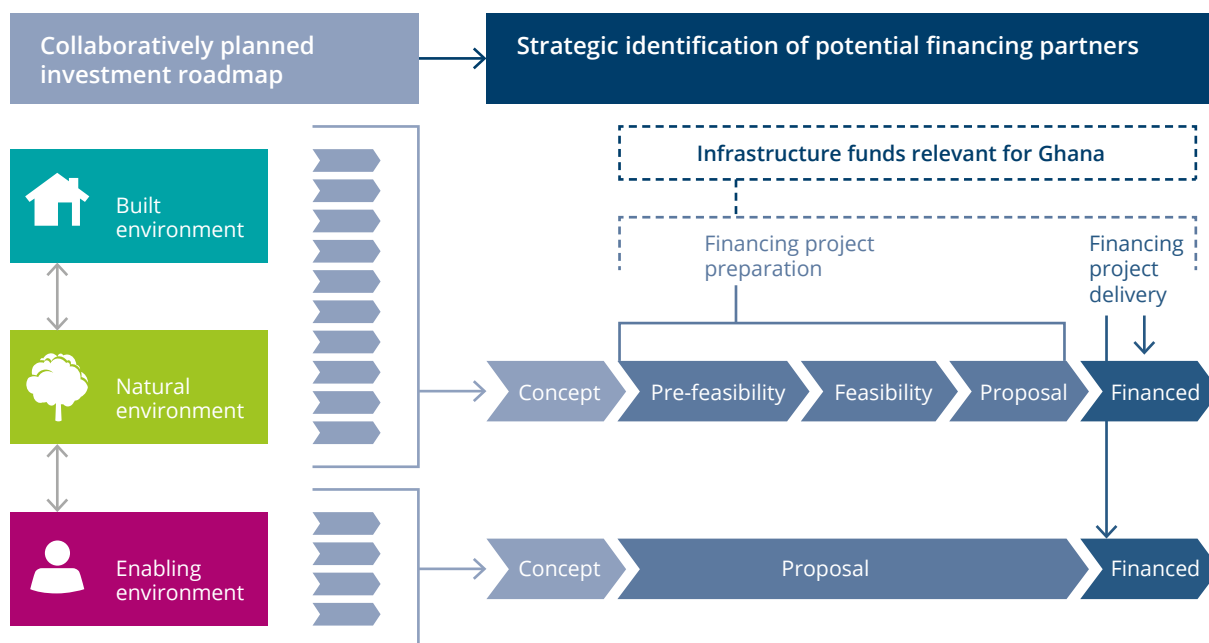


ACTIONS TO IMPLEMENT THE ROADMAP AND SCALE UP ADAPTATION ACTION IN GHANA

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.

Available funds											
New								Existing			
2050 Facility	PPSF	CADFund	Camões IP	CI1	CICLIA	COFIDES	DBSA	ADF	AEF	AF	AFD
Adapt' Action	ARE Scale-Up	DFC	EAIF	EBID	ElectriFi	EU-AITF	FAPA	AFDB	AFRECIMBANK	AIP	BADEA
								CDC	CDP ICDF	EC DICD	EDF
AFC	AREF II	DFCD LUF	FinDev	GFDRR	GIF	IFU	NEPAD IPPF	EIB	FMO	GCF	GRiF
Africa50	Aus DFAT	DFCD OF	FinnFund	NZAID	PROPARGO	REPP	SCCF	GIZ	IBRD	IDA	IFC
AgriFI	BIO	DFCD WF	FIP	PIDG		SDG IF	SLP	JBIC	KfW DEG	MCC	MFA Norway
AIIB	BP	DSIF	GEF-7	PPAIF	SEFA	Swedfund		JICA	MIGA	OeEB	OFID
								KFAED	NDF	SIFEM	UK FCDO
								KfW DB	Norfund	SREP	USAID

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*
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*
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





APPENDIX A: DETAILED METHODS AND TOOLS USED IN THIS STUDY

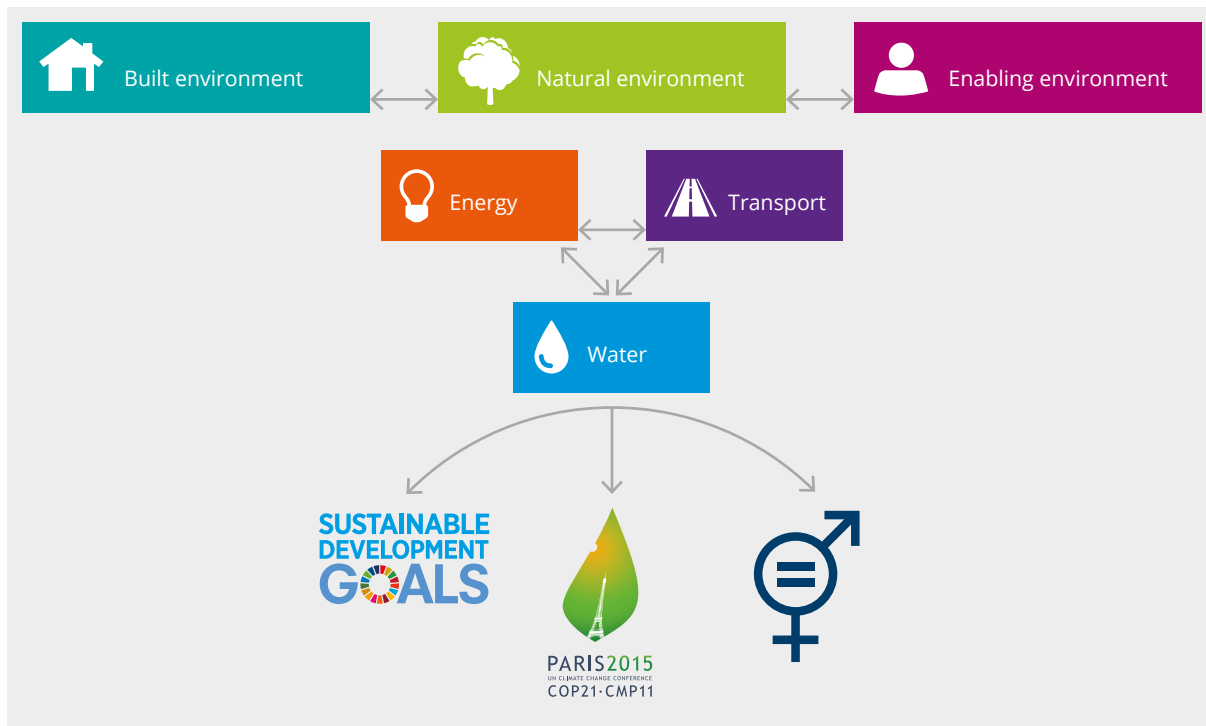
A.1. Framing the components of the infrastructure system

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:**

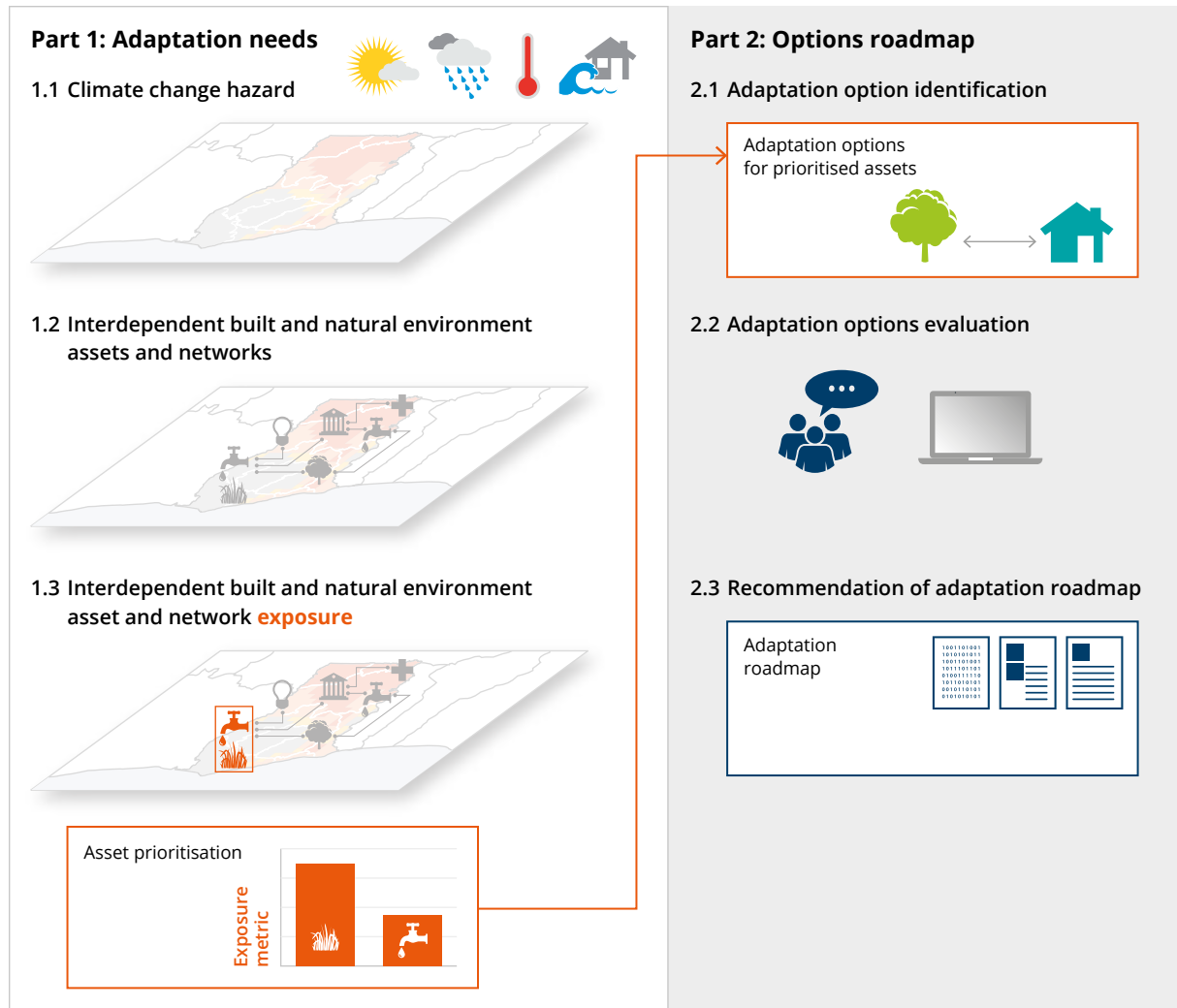
The natural, built, and enabling environments delivering development outcomes through infrastructure.

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.

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.

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 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 NISM 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 (NISM), 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).

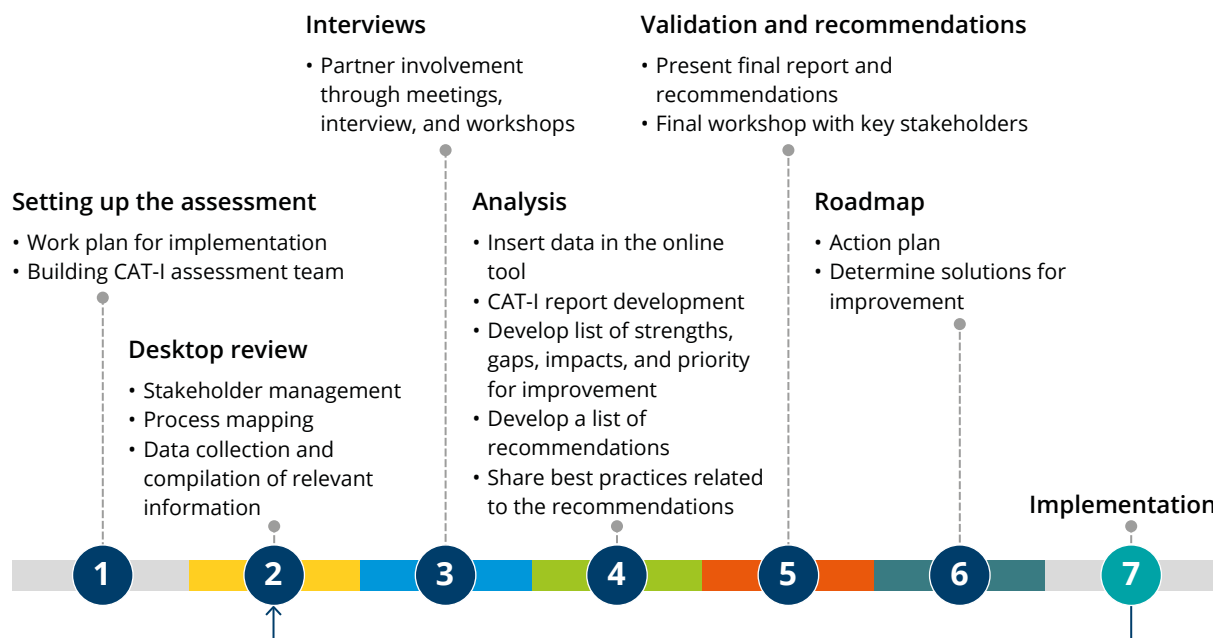
- A participatory workshop with members of the TWG was held to discuss the suitability of shortlisted projects, and their feasibility in the Ghana context across economic, technological, political, and social considerations. Stakeholder feedback was obtained through ranked survey responses.

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.

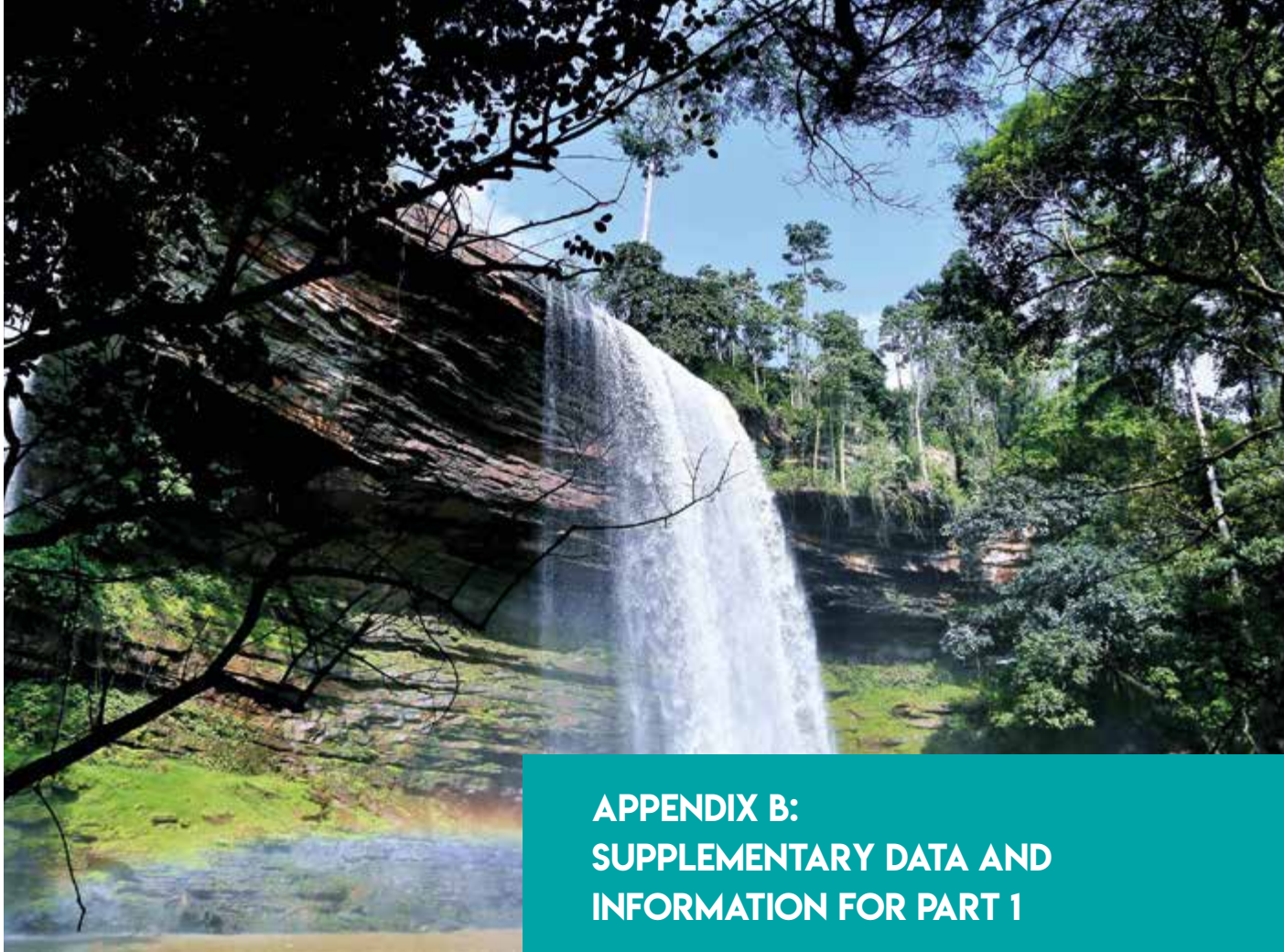
A.4. The Sustainable Infrastructure Financing Tool (SIFT)

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 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:

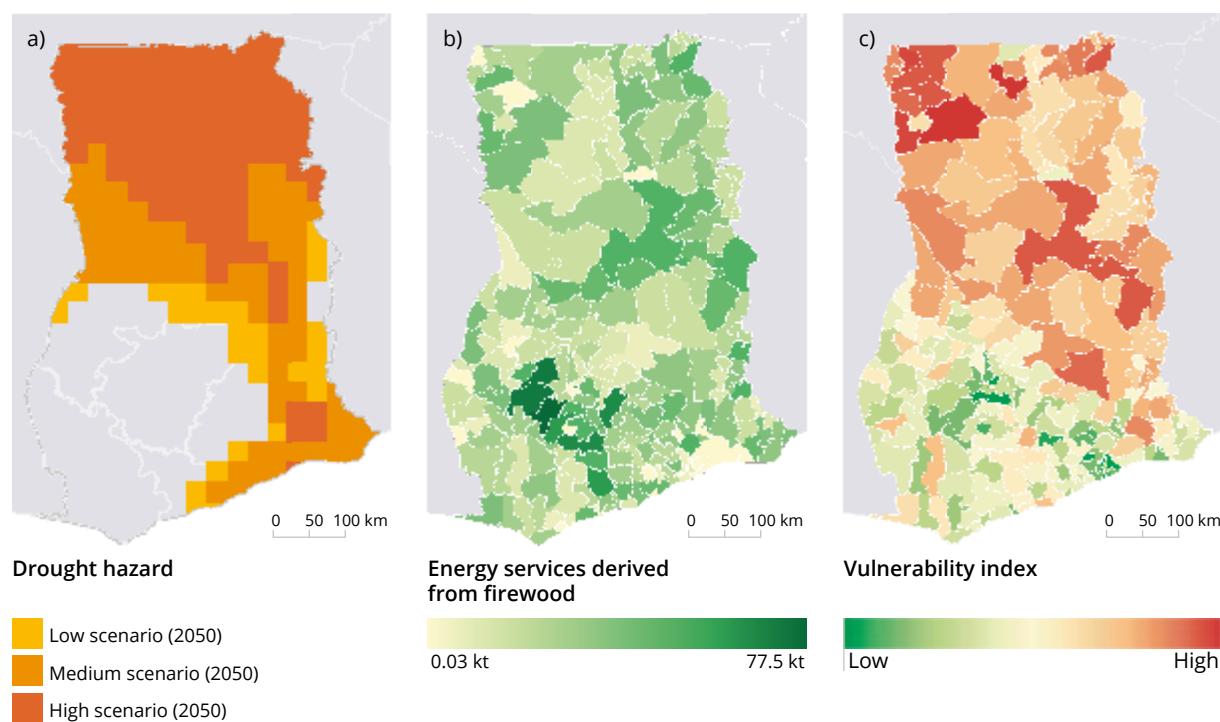
1. National Disaster Management Organization (NADMO) (2015)
2. ECOWREX: ecowrex.org
3. World Bank Data Catalog: datacatalog.worldbank.org
4. Gridfinder: gridfinder.org
5. Open Street Map: www.openstreetmap.org
6. Energy Commission (2019) Energy Profile Districts in Ghana.
7. Protected Planet (UNEP): 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 23 operational	2, 3
	Transmission lines	9911.94 km	3, 4
	Sub-stations	76	5
Water	Firewood	All districts	6
	Dams	24	3, 16
	Protected Areas	38 146.3 km ²	7
Transport	Rivers	110 956 km	2
	Households with drinking water supply from natural sources	216 districts	8
	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 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: • District League table score • Night-time light intensity • % of population under poverty line • Number of people under poverty line • Poverty depth • Poverty severity • 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.

Methods:

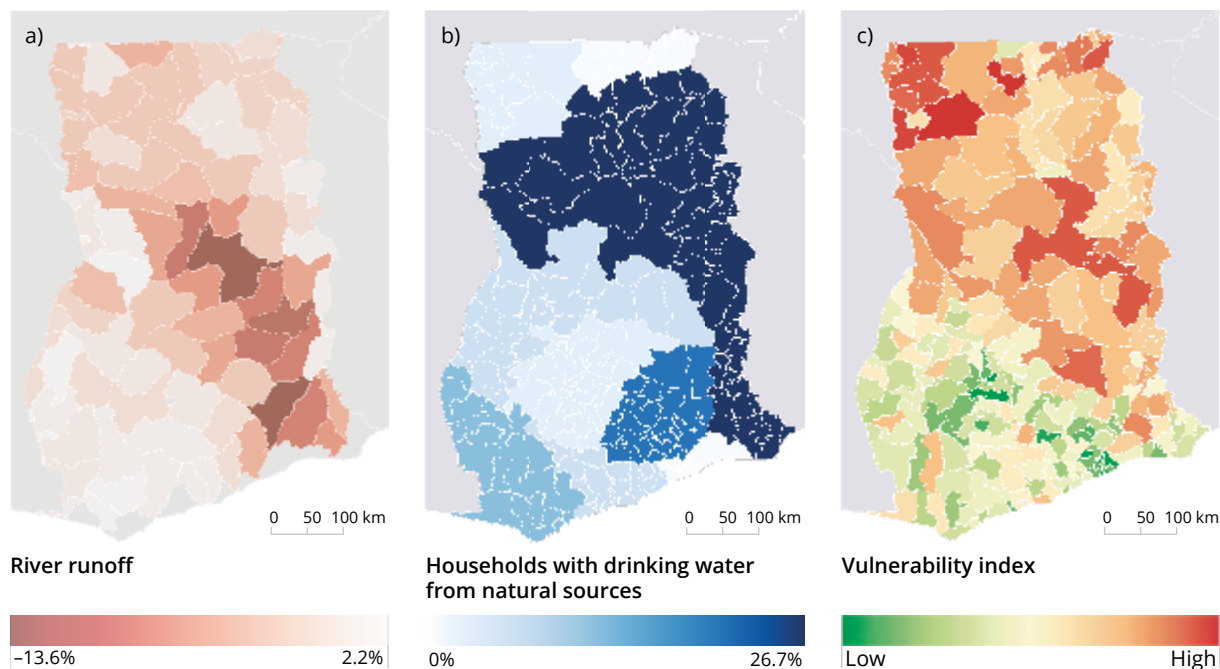
1. Drought levels – **low, medium, and high**
 - Allocated the numbers 0 – 3 to the districts depending on the area exposed to the three different drought hazard levels (0 = no drought hazard; 1 = low drought hazard; 2 = moderate drought hazard; 3 = high drought hazard)
2. Firewood demand in **kilotonnes per district**, geo-referenced from the Energy Profile of Districts in Ghana (2019).

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).

3. A 'district vulnerability index' was derived by inverting 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 inverting 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 be 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 Facebook²⁵ 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) dataset²⁶ that contained information on different types of health services that could be used by the population.

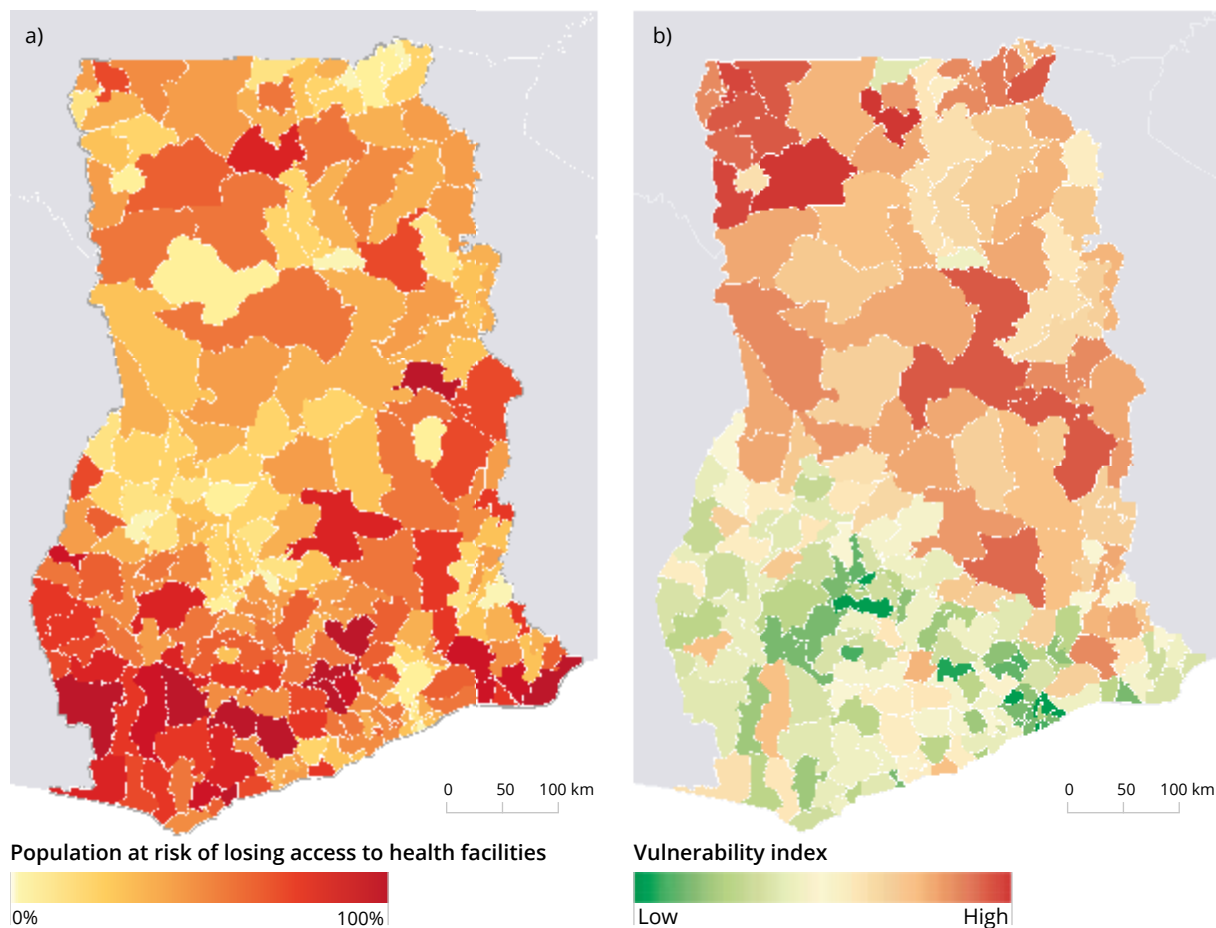
These include – Clinics, Polyclinics, Community-based Health Planning services, Health Centres, Municipal Hospital, District Hospitals, Regional Hospital, General Hospitals.

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 adaptive 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	Kumbungu	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

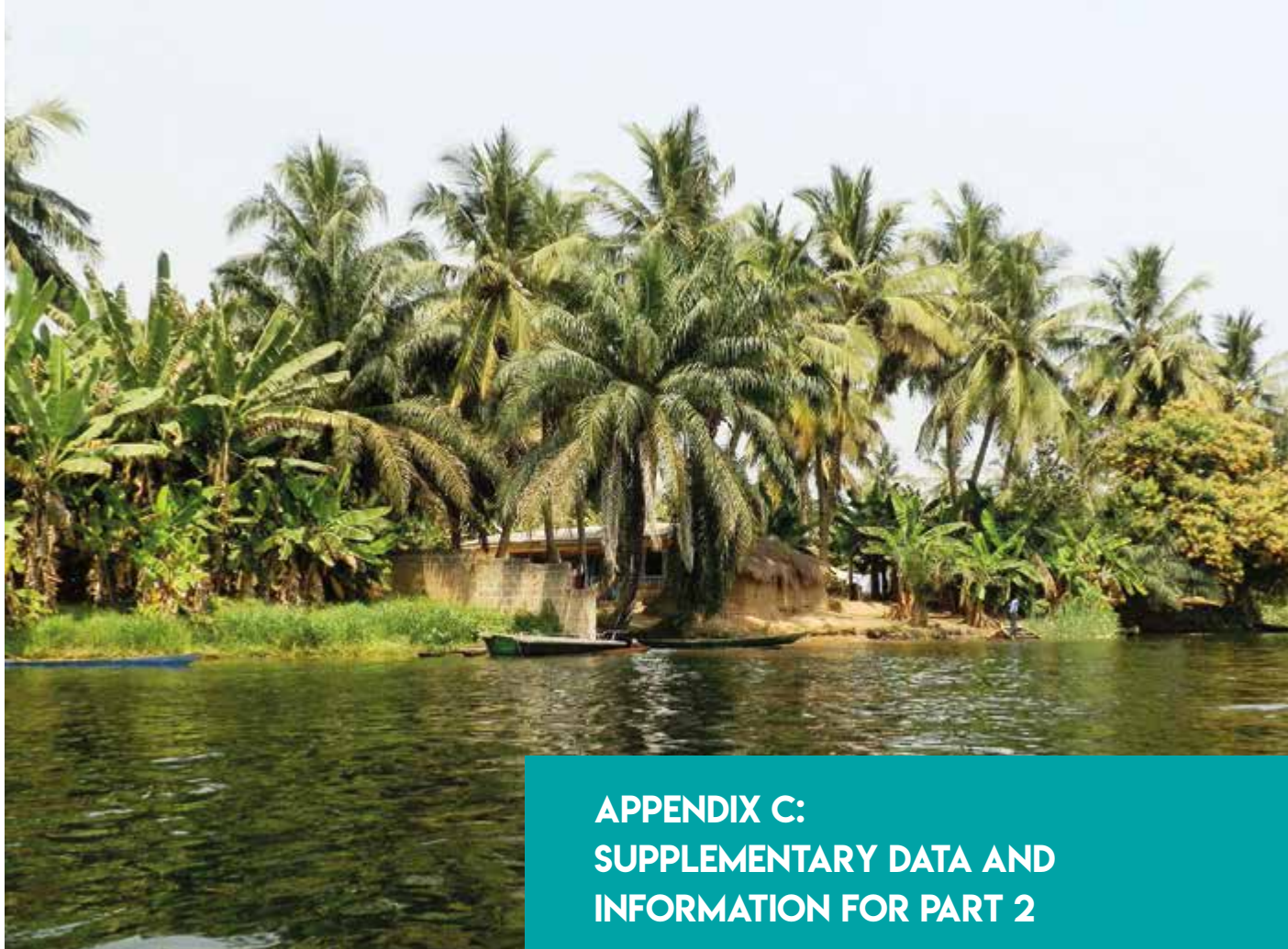
Table 14:

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 Reduced study time for girls Increase in time needed for domestic work Increased time spent on fuel collection 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) Increased work-burden for women who are primarily responsible for water collection		Reduced study time for girls 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 Life threat for pregnant women reliant on access to community clinics 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 • transport • 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 Adaptation – USD 12.79 billion (USD 4.21 billion/ 34% – national; USD 8.27 billion international)	12,790 (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.	



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 increased 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 distribution 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.africaafc.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 Participation 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

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