Transport and Energy

▶ KEY MESSAGES

- **Climate-related damage to infrastructure disrupts social services and exacts a significant short and long-term human and economic toll in Africa.** Moreover, in the aftermath of the damage, governments are forced to divert limited public funding to rebuild or reconstruct, instead of investing in new infrastructure to make up for existing deficits. This creates an "infrastructure trap" – vicious cycles of repeated climate shocks that risk halting economic growth and disrupting or even reversing progress towards achieving the Sustainable Development Goals.
- **Closing the infrastructure gap and enhancing climate resilience is critically important for economic development, improving the quality of life, and the growth of the private sector in Africa.** The good news is that infrastructure investments in Africa have risen increasingly over the past 15 years, and international and national investors have both the desire and the funds to spend much more across the continent. However, while investments in adaptation and resilience for energy and transport infrastructure are rising (from US$ 19 million to US$ 252 million between 2010 and 2019 for the energy sector; and from US$ 11 million to US$ 128 million in the same period for transport), they are still well below actual needs.

Photo: MehmetO/Shutterstock

- **Making infrastructure more climate resilient will have additional upfront costs of 3 percent,** but returns can be four times the initial investment, in addition to important social returns.
- **Proactive adaptation – modification of designs and incorporation of resilient construction norms at the very outset of infrastructure projects** – is a no-regret option in the energy and transport sectors, including for instance for hydropower and paved roads. Once these 'upstream' decisions on the location, nature, and design of infrastructure are made, the options for climate risk management narrow. Such proactive 'upstream' adaptation and resilience measures can increase up-front investment costs but reduce 'downstream' operations and maintenance costs.
- **The integration of nature-based solutions (NbS) in infrastructure planning and decision-making** can make infrastructure more sustainable and resilient and offer other co-benefits.
- **Leveraging public-private partnerships (PPPs) for climate-resilient infrastructure** can help countries in Africa to mobilize funds to bridge the existing infrastructure gap, while ensuring climate resilience. Uncertainty and the lack of political commitment remain key barriers for infrastructure PPPs.
- **Going forward, integrating climate risk in infrastructure planning; building data systems for investment planning; quantifying the benefits of NbS; leveraging PPPs; and reforms** for improved operations and maintenance of assets in a climate-compromised world are necessary.

INTRODUCTION

Poor infrastructure continues to hinder economic growth in most African countries. To close the infrastructure gap, investments in infrastructure in Africa must go up to about $150 billion per year (or 4.5 percent of GDP) from the past actual investment levels of about $75 billion per year.[1] Moreover, climate risks are affecting infrastructure development strategies and investments. Rising temperatures, changes in rainfall patterns and intensity, and the increasing frequency of extreme weather events are leading to losses in asset values, higher operating costs, and reductions in the economic benefits that infrastructure generates.

Infrastructure systems and their component assets, some of which are decades old, are not planned and built to withstand the impacts of climate change and climate hazards. They are also often distributed over large spatial domains, and inevitably exposed to climate hazards such as droughts, flooding, storms, heatwaves, wildfires, landslides, and sea-level rise. Damage to these assets not only disrupts social services in the short-term, but also exact a significant long-term human and economic toll.

Photo: GUDKOV ANDREY/Shutterstock

Drought-induced power shortages in Zimbabwe and Zambia, for instance, have had cascading impacts on water, health, connectivity, and supply chains and businesses. In Tanzania, businesses lose US$ 101 million, or 0.3 percent of the national GDP, annually due to power outages caused by rain and floods; and US$ 150 million, or 0.4 percent of the GDP annually, due to transport disruptions caused by flooding.[2] In South Sudan, before the World Bank helped build rural roads, farmers could not think beyond subsistence farming because they had no means to bring their crops to market. New routes and development corridors can make a difference between isolation and access to the global economy and social development.

In the aftermath of climate-related damage, governments are forced to divert what limited public funding there is to rebuild, or in more extreme cases, reconstruct, instead of investing in new infrastructure to make up for existing deficits. This combination creates an "infrastructure trap" – vicious cycles of repeated acute and chronic climate shocks that risk halting economic growth and disrupting or even reversing progress towards achieving the Sustainable Development Goals (SDGs).[3]

Investing in climate-resilient infrastructure is critical to adapting to a warming world. Infrastructure spending and access to infrastructure services is a key contributor to development, economic growth, and poverty alleviation in Africa.[4] Investments in rural infrastructure, in particular, can lead to higher farm and non-farm productivity, employment and income opportunities, and increased availability of wage goods, thereby reducing poverty by raising income and consumption.[5]

However, with governments already under pressure, the ability to invest in new infrastructure in Africa is further strained by climate-related impacts and by the repercussions of COVID-19, which caused the continent's first recession in half a century.[6] At the same time, foreign direct investment in Africa decreased from US$ 47 billion in 2019 to US$ 40 billion in 2020,[7] and official development assistance (ODA) has been on the decline for several years.[8]

It is crucial that investments in infrastructure in Africa are sustainable and resilient. This requires a fundamental systemic transformation. A revolution in the planning, design, financing, and delivery of infrastructure is urgently needed to meet the acute needs of a warming Africa. Climate-resilient infrastructure planning needs to begin ‘upstream’ in the early planning stages; be integrated across sectors and activities at a strategic level; make use of better analytical tools to understand climate risk at a systems level; and prioritize resources for building resilience. In addition, nature-based solutions for adaptation should be promoted, and engineering standards improved to enhance resilience of individual assets.

This chapter analyzes how climate change impacts infrastructure in Africa, with a focus on the energy and transport sectors, with sobering implications across social, economic, environmental, and development outcomes. It finds that while African governments need to integrate adaptation and resilience into infrastructure investments to minimize the harm caused by climate impacts and maximize development opportunities, they face significant challenges.[9]

Understanding the impacts of climate change on infrastructure in Africa

The Zambezi is the “Great River” to the Tonga people of Zambia and Zimbabwe, the river of life. It is also a lifeline for both national economies. When the river’s flow was affected by drought in 2014 and 2015, low water levels in Kariba Dam’s reservoir resulted in a 50 percent drop in electricity generation in hydropower-dependent Zambia. GDP growth in Zambia dropped from 6 percent to 2.6 percent.[10] In Zimbabwe, similarly, the 2019 drought led to reduced capacity of the Kariba Dam, and to subsequent losses of US$ 200 million in just three months (June-August) through lost production due to power shortages.[11]

The impacts of climate change on infrastructure can be acute or chronic. 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 (like coastal flooding) or may be very localized (as in a landslide). Chronic impacts of climate change can build up over time. Higher temperatures, for instance, can lower the generation efficiency of power grids over the years, increase losses in transmission and distribution, and decrease the lifetime of key equipment. High temperatures can also shift demand for certain types of infrastructure, for instance by creating additional demand for energy for cooling and air conditioning. While the demand for such infrastructure and the value it generates will increase with climate change, investing in climate resilient infrastructure will bring economic benefits and a range of other socio-economic gains.


Photo: Adam Jan Figel/Shutterstock

> **Failure to act now will be catastrophic in terms of the lives and livelihoods to billions of the world’s people who are at risk.”**
>
> **H.E. President Akufo-Addo of Ghana**
> Leader’s Dialogue on the Africa Covid-Climate Emergency, April, 2021

Disruptions in critical services

The disruptions caused by climate-related damage to infrastructure can cascade into major societal and economic disruption. The Zambia and Zimbabwe case study highlighted in this chapter (Box 1) is illustrative of these wider impacts, but there are numerous other examples in Africa, sometimes of countries facing repeated crises before they have a chance to fully recover. In Kenya, a drought in 2000 led to a 25 percent reduction in hydropower capacity, resulting in losses of more than US$ 442 million representing 1.5 percent of GDP in 2000.[12]

Flooding of road networks has significant implications for access to healthcare infrastructure. In Uganda's capital city of Kampala, for instance, it is estimated that a third of the inhabitants of inner Kampala will not be able to reach health facilities within the 'golden hour' – the 60 minutes that maximize the chance of survival – in the event of a major flood, due to disrupted travel networks. Main roads, such as motorways and trunk roads, are disproportionately at risk of flooding compared to residential and other roads, not only in Kampala, but also in other African cities such as Bamako in Mali, Dar es Salaam in Tanzania, and Kigali in Rwanda.[13] According to the World Bank, the costs of road maintenance will rise by 270 percent due to precipitation, flooding, and temperature stress in central, east, south, and west Africa.[14]

Climate impacts on infrastructure also pose significant barriers to the connectivity of supply chains. In 2000, flooding in south Mozambique destroyed road links between the capital city, Maputo, and the rest of the country for almost one year, including the rail line to Zimbabwe. This reportedly led to Mozambique's per capita economic growth to decline to one percent in 2000 – the lowest level in two decades. Similarly, in Dar es Salaam, flooding poses a significant risk to the port access road even with regular low intensity rainfall events (4-6 mm per hour over a 24-hour period, occurring every 2-10 years).[15] Recent studies have found that seven airports in Africa are at risk from sea level rise even with under 1.5°C of warming, rising to 24 airports under a high baseline emission scenario in which emissions continue to rise through the 21st Century.[16]

Several coastal African countries rely almost exclusively on maritime transport for imports and exports, many from a single port, and could suffer crippling disruptions in trade due to sea level rise and flooding. Guinea, Liberia, Mauritania, and Sierra Leone, for example, transfer more than 97 percent of all imported goods through ports.[17]

Photo: bolarzeal/Shutterstock

Box 1: Cascading impacts of climate change: The case of Zambia and Zimbabwe


Photo: Kariba Dam, Zambezi River

Zimbabwe and Zambia – two countries that rely on energy from the same hydroelectric power assets on the Zambezi River – suffered the impacts of drought on energy production at the same time but followed different trajectories. Zimbabwe was pushed further into the infrastructure-climate trap, while Zambia was able to strengthen its resilience by diversifying its energy mix.

The Kariba Dam is located along the Zambezi River, on the border of Zambia and Zimbabwe, and is the main source of electricity for both countries. In 2015, the Dam accounted for 97 percent of energy generated in Zambia, and more than 50 percent in Zimbabwe. When reservoir levels dropped to 12 percent due to low rainfall in 2014 and 2015; and again, to 9 percent in 2019, both countries faced extreme power shortages. Zambia experienced a deficit of between 20-40 percent of peak energy demand, while Zimbabwe's deficit was more than a quarter of peak demand.

Both countries initiated emergency measures to make up for the deficits. Zambia, normally an exporter, was forced to import electricity, including from diesel generators on a ship docked at Beira port in Mozambique. Zimbabwe spent US$ 200 million to set up the Dema Emergency Power Plant – consisting of 230 diesel generators producing 200 MW of electricity. Both countries also imported from South Africa's sole provider Eskom, although South Africa was also suffering power cuts. Despite this, drastic steps were needed to reduce demand, with up to 15 hours of load shedding per day in Zambia, and 18 hours in Zimbabwe. Zambia initially excluded copper mines (accounting for 77 percent of its exports) from load shedding, although they consume more than 60 percent of the nation's electricity but was eventually forced to reduce their supply by 30 percent.

Long-term impacts

While Zimbabwe has had trouble attracting investments in energy infrastructure in the aftermath of the energy shortages due to its fragile status, corruption levels, and poor credit rating, Zambia was able to diversify its energy sources and reduce its dependence on hydropower. Two solar power plants were launched in 2019 through the International Finance Corporation's (IFC) Scaling Solar program; and Maamba Collieries Ltd, its first coal-fired power plant, was set up to provide 10 percent of the country's electricity needs. Despite this, Zambia's GDP growth rates dropped to below 3 percent (from 10 percent earlier), and the national currency saw a depreciation of 47 percent against the dollar.

Both countries raised electricity tariffs to cover the costs of expensive alternatives – by as much as 200 percent in Zambia – with important implications for national economic growth and creditworthiness. Despite the higher tariffs, the Zambian utility ZESCO accumulated millions of dollars in debt and experienced a significant deterioration in financial performance (exacerbated by the fall in the currency) because tariffs were still lower than the costs of imports. ZESCO's uncertain financial performance was one factor that led to a suspension of the second phase of the Scaling Solar program.

In both countries, national efforts to expand energy access have been impacted. Zambia's Rural Electrification Fund needs US$ 50 million annually for its energy access targets but is severely underfunded, spending only US$ 15 million per year. The crisis has also diverted investments from the maintenance and expansion of existing assets.

Impacts have inevitably cascaded to other sectors. In Zambia, municipal water supply and boreholes reliant on electricity were affected, resulting in water supply shortages. In Zimbabwe, queues for water stretched more than 50 meters, creating an additional work burden for women. Zimbabwe's largest mobile operator, Econet Wireless, struggled to maintain its network, with 25 percent of its base stations forced to run on diesel generators for more than 18 hours a day. Healthcare facilities, especially in suburbs and rural areas, were affected. Workers were forced to work at night when electricity returned for a few hours. Supply chains and businesses were impacted, with reduced productivity, lost produce (particularly produce reliant on cold storage), and redundancies.

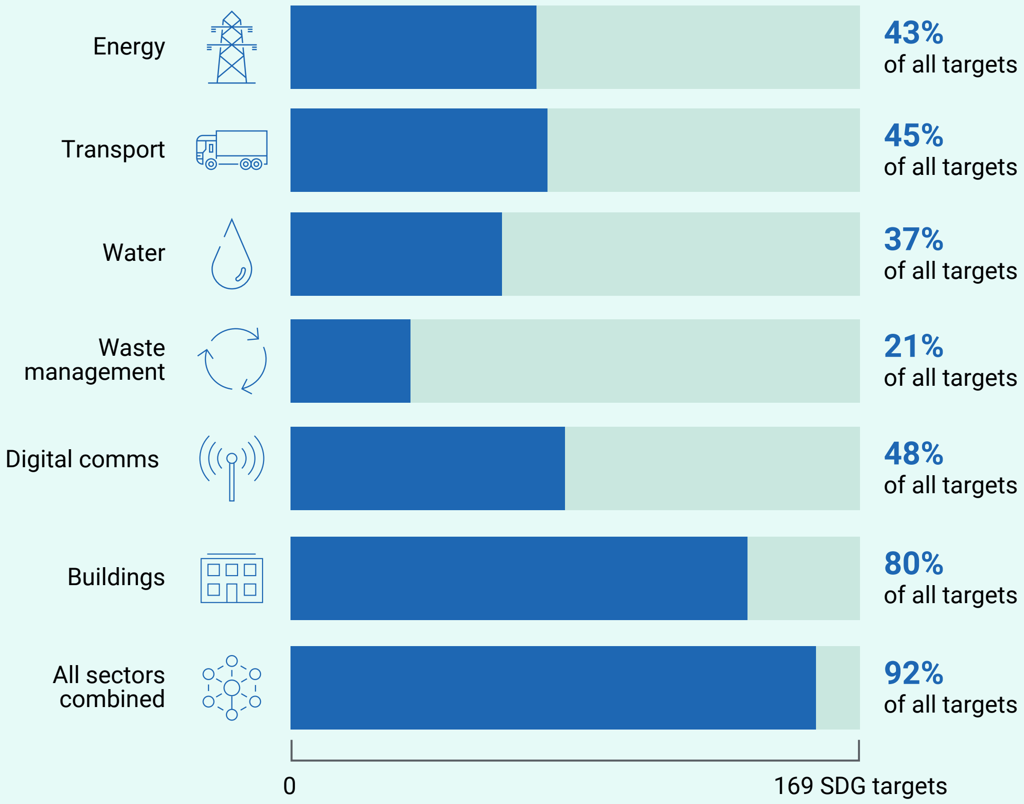
Although Zambia has managed to diversify its energy sources to some extent, both countries are likely to continue to face the consequences of the droughts for decades to come. Without urgent interventions and support from the global community to break the cycle of this climate infrastructure trap, it is unlikely that they will be able to meet either national or global goals for sustainable development.

Long-term socio-economic impacts

Disruptions in energy and transport infrastructure can quickly cascade into unforeseen disruptions on wider socio-economic development, including in key sectors like healthcare (SDG 3), education (SDG 4) and agriculture (SDG 2). They can exacerbate and further entrench existing barriers to Africa's integration and competitiveness in global markets. Seemingly minor disruptions can have significant repercussions on supply chains. One study in 23 African countries found that even a one percent increase in the frequency of power outages can reduce the sales shares of companies from exports by 0.12 percent; and reduce the likelihood of entrepreneurs starting their own business by almost 50 percent (excluding the farming sector).[18]

Photo: Felix Lipov/Shutterstock

Box 2: Infrastructure and the SDGs



Source: Adapted from Thacker et al.(2021)[19]

While infrastructure is addressed specifically in SDG 9, investments in infrastructure influence progress towards all 17 SDGs and 121 (72 percent) of the 169 SDG targets.[20]

SDG 9 recognizes that building resilient infrastructure, promoting sustainable industrialization, and fostering innovation unleashes dynamic and competitive economic forces that generate employment and income; play a key role in introducing and promoting new technologies; and facilitate international trade and enable the efficient use of resources.

In addition to SDG 9, infrastructure influences all the targets of four SDG goals – SDG 3 on good health and wellbeing; SDG 6 on clean water and sanitation; SDG 7 on affordable and clean energy; and SDG 11 on sustainable cities and communities. For 15 SDGs, more than 50 percent of targets are influenced by infrastructure.

Energy infrastructure has the largest direct influence on individual SDGs, notably SDG 7 (affordable and clean energy), while transport infrastructure has wide indirect benefits through its role in facilitating social and economic access and integration. The indirect benefits of transport infrastructure, for instance, impact on SDG 3 (health, for example through impacts on air quality), SDG 14 and 15 (natural environment, including marine and terrestrial ecosystems), SDG 11 (sustainable cities and communities), SDG 13 (climate change), SDG 10 (inequality), and SDG 5 (gender equality).

Infrastructure is fundamental to sustainable outcomes, particularly when interdependencies are considered. This points to the need for a planning approach which recognizes the synergies between infrastructure sectors and opportunities to contribute to sustainable development outcomes.

Critically, the cost of repairing and building back assets after they are hit by climate hazards diverts funding from building forward. In a world without climate change, Sub-Saharan Africa would need US$ 20 billion between 2015-2025 to address climate-induced damages to roads and bridges, according to estimates from the Programme for Infrastructure Development in Africa (PIDA), an initiative by the African Union to improve access to infrastructure networks and services in Africa. In a climate-compromised world, however, and in the absence of adaptative measures, this will cost US$ 74 billion. Malawi, Mozambique, and Zambia alone face a potential US$ 596 million price tag to maintain and repair roads under median climate scenarios until 2050, as a result of damages directly related to potential temperature and precipitation changes due to climate change.[21] These figures do not consider costs associated with expansion of new roads or improvement of existing roads to meet road standards. The opportunity cost of these expenditures is of particular concern in Africa because they will divert funding away from investment in new infrastructure development. If no proactive adaptation measures are implemented in Malawi, Mozambique, and Zambia, the opportunity costs will equate with the lost potential of expanding the existing paved road network (either with new roads or with upgrades to existing unpaved roads) in each of these countries respectively by 3,530, 3,213, and 8,760 km of paved road.[22]

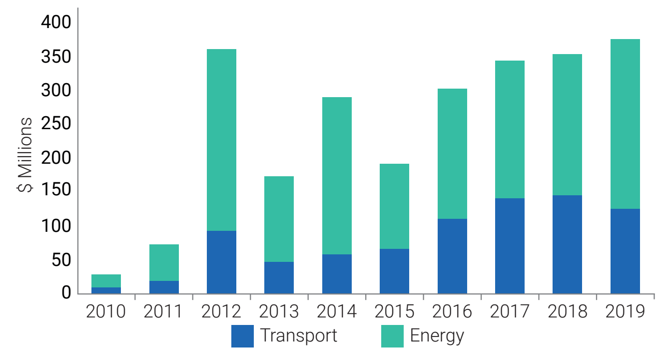
Investments fall short of need

The benefits of investing in climate adaptation and resilience are increasingly becoming clear. Research from the GCA finds that making infrastructure more climate resilient will have additional upfront costs of three percent but returns can be four times the initial investment.[23] In addition to quantitative economic returns, these investments also have important social returns, influencing the attainment of most of the SDGs.

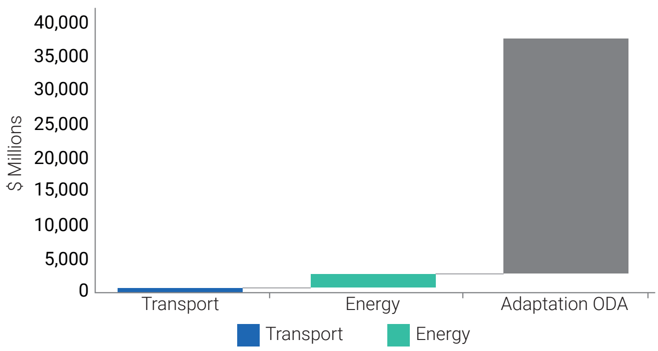
Despite evidence of these benefits, investments in improving the climate resilience of infrastructure in Africa are well below the needs. Only 2.3 percent of total ODA for Africa was allocated for investments in infrastructure adaptation between 2010 to 2019. Of this, 6.3 percent, or US$ 831 million, was allocated for the transport sector, and 12.9 percent, or US$ 1,694 million, for the energy sector. Domestic resource commitments form a large proportion of infrastructure investments in Africa, totaling US$ 37.5 billion, or 37 percent of total infrastructure investments in 2018.[24] While these investments are not screened for adaptation and resilience, ODA sponsors are increasingly calling for such screening, supporting a positive trend where total adaptation investments in energy increased from US$ 19 million to US$ 252 million between 2010 and 2019, while transport sector investments increased from US$ 11 million to US$ 128 million in the same period (Figure 1).[25]

Figure 1: Adaptation ODA for transport and energy

(a) Distribution per year



(b) Total between 2010-2019



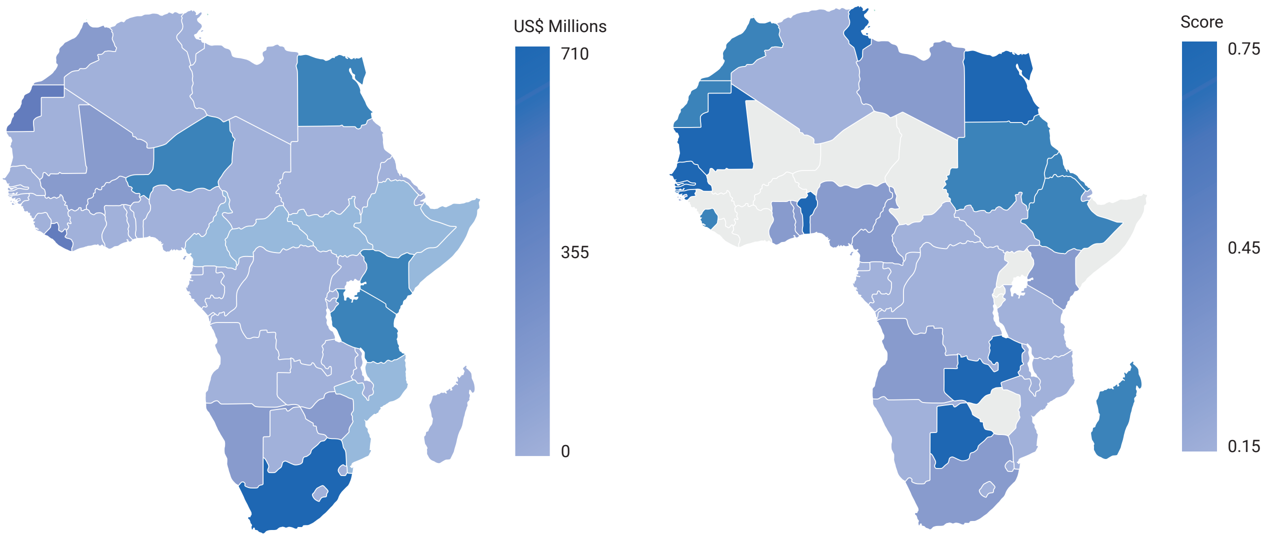
Source: Authors, with data from OECD (2021). OECD.Stat database

Existing investments in making infrastructure climate resilient also hide significant regional and socio-economic disparities, exacerbating gaps in access to basic infrastructure services. A comparison of the total flow of global funding for adaptation for the transport and energy sectors with the vulnerability of infrastructure calculated by the Notre Dame Global Adaptation Initiative (ND-GAIN) index highlights that the most vulnerable countries received the least investments (Figure 2).[26] For example, Mauritania had an exposure of 52 percent but received US$ 1 million, while South Africa had an exposure of 25 percent but received a total of US$ 710 million for adaptation investments.

Finally, infrastructure access gaps are endemic in fragile states but investments to build climate resilient infrastructure remain extremely low in these contexts. Extremely fragile countries receive only 13 percent and 1 percent of total adaptation investments in transport and energy, respectively. However, least developed countries do receive a significant proportion of global adaptation investments in the transport sector (Figure 3).

Figure 2: Regional distribution of global funding for adaptation and vulnerability of infrastructure

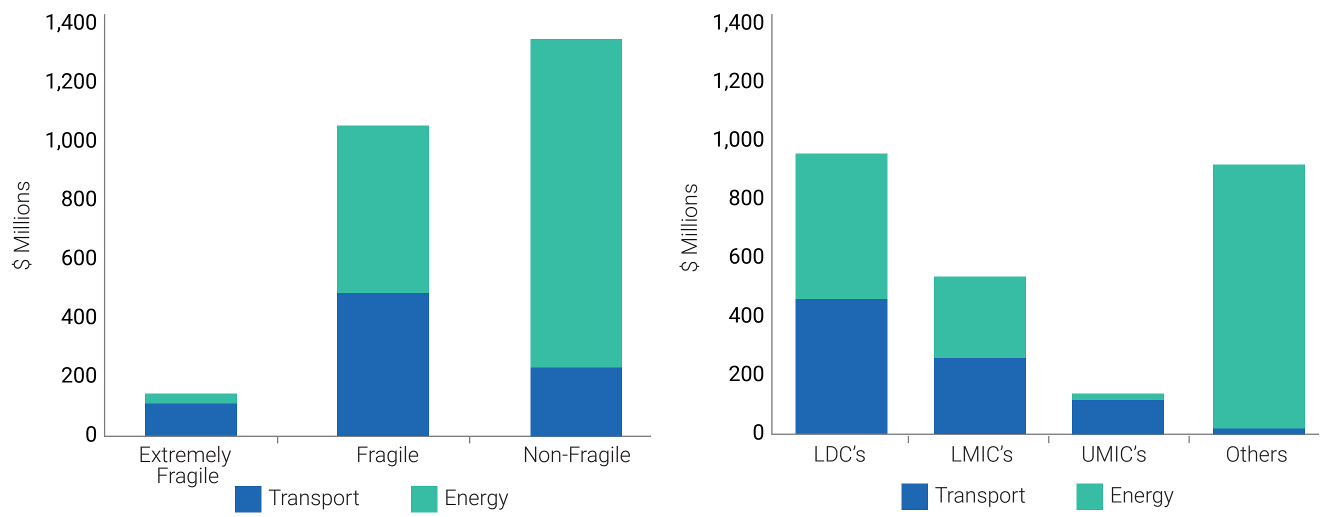
(a) Transport and energy adaptation ODA | *(b) Vulnerability*



Source: Authors, with data from OECD (2021). OECD.Stat database; and University of Notre Dame (2021). ND-GAIN: Notre Dame Adaptation Initiative – Country Index

Figure 3: Allocation of adaptation ODA in the transport and energy sectors

(a) per income group | *(b) per fragility level*



Source: Authors, with data from OECD (2021). OECD.Stat database

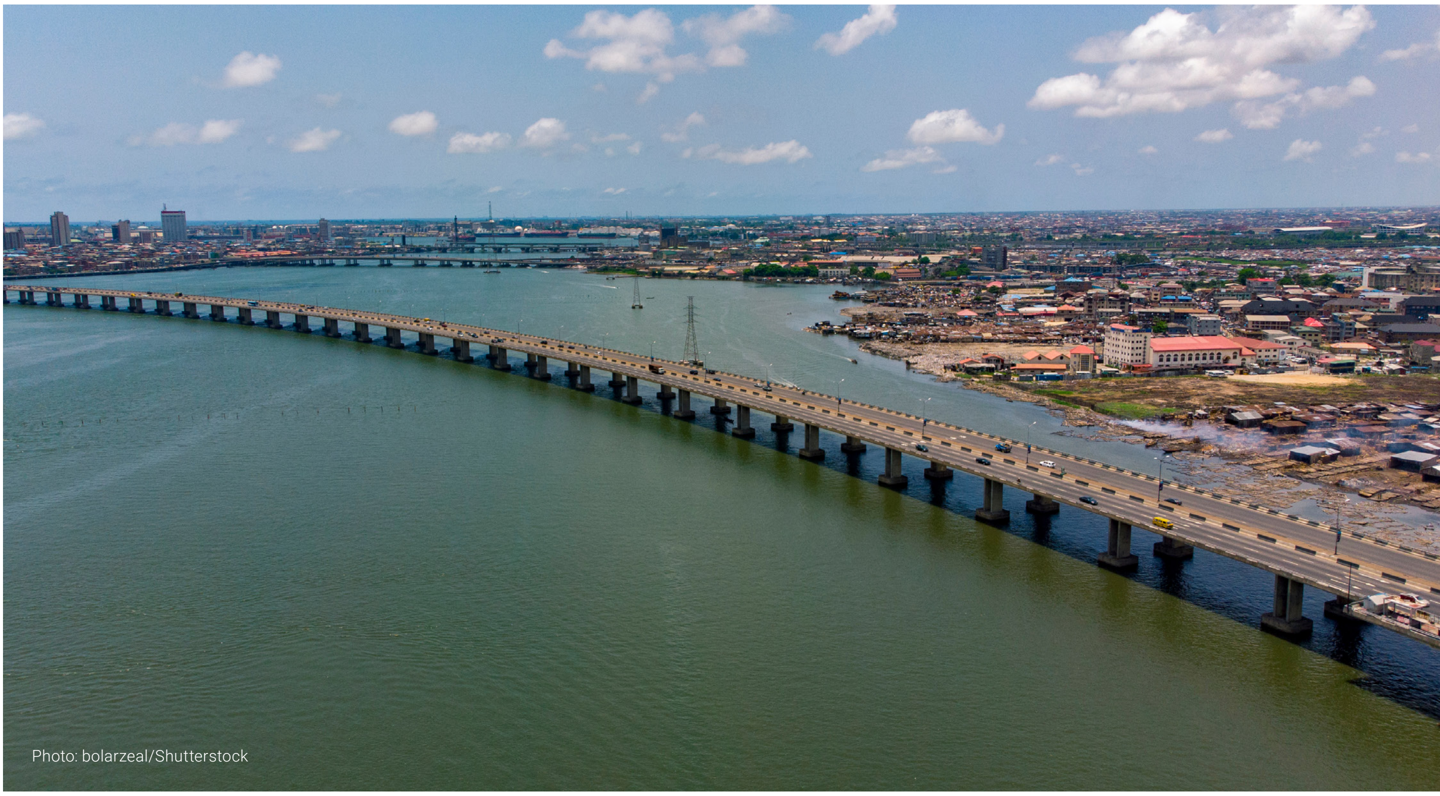


Photo: bolarzeal/Shutterstock

KEY CONSIDERATIONS FOR MAKING INFRASTRUCTURE RESILIENT

As African governments take on the daunting task of building resilience into infrastructure, they will face many difficult decisions and challenges. This section highlights key elements to maximize effectiveness.

Begin at the beginning

The best opportunity for managing climate risks is when infrastructure projects are being conceived. Adaptation and resilience should be proactively embedded throughout the life cycle of infrastructure planning, project preparation, finance, design, delivery, operation, and maintenance. This requires a strong commitment from governments (national, city, and local), who play leading roles in steering the provision of infrastructure, and in mainstreaming sustainability through adaptation. Decision-makers need to recognize that infrastructure assets that may exist for decades, face a very uncertain future. Infrastructure investments need to be designed and implemented to cope with unpredictable threats and extreme events, and design standards and codes of practice need to incorporate the effects of climate change.

Such 'proactive adaptation' in the energy and transport sectors in response to climate change is a no-regret option. For instance, the exposure of infrastructure to the impacts of climate change depends on its location. The decision on the location, made early in the planning process, is therefore critical for determining the level of exposure, and taking climate projections into account during this stage can reveal opportunities for making infrastructure more resilient. (Although, in some cases, the choices may be limited – ports, for example, must be located on the coast or along inland waterways). Energy supply in low-income African countries is particularly vulnerable due to their higher dependence on hydroelectricity and biomass energy supplies. According to the World Bank, the early integration of resilience in hydropower infrastructure, considering the river basin level and predicted changes in rainfall patterns in the pre-feasibility, planning and design stages, can considerably reduce and mitigate future climate risks in a cost-effective manner.[27] Examples of no-regret options in the African context include early warning systems, and the diversification of energy sources.[28]

Account for uncertainty

Investment decisions need to account for the significant uncertainty and local variability associated with climate change in Africa. For example, although the mean costs of reactive responses to climate change are US$ 56 billion[29] over 2015-2050 for the PIDA+ road network[30] (instead of US$ 15 billion without climate change)[31] the World Bank highlights that there is significant uncertainty, ranging from almost no increase to as much as three times the mean.[32] This uncertainty highlights the need to optimize investments under a range of projected climate scenarios.

The impacts and nature of climate change will not be equally distributed across Africa. Zambia, for instance, is projected to experience more extreme climate events than neighboring Malawi and Mozambique.[33] Countries such as Angola, Nigeria, Botswana, Togo, South Sudan, Mozambique, Benin, and Cameroon will be exposed to significant precipitation-related disruption even from moderate climate changes.[34]

These geographic differences have implications for the design of adaptation responses. Revenue losses from climate-related damage to hydropower can range from anywhere between 5-60 percent,[35] depending on the location of the asset and the water basin, with climate projections suggesting that countries in east and southern Africa will be most at risk. Losses are projected to be higher for higher temperature increase scenarios. For example, Morocco's hydropower capacity will decrease by 9 percent (relative to today) under a scenario of lower warming (RCP 2.6); and by 24 percent in a higher warming scenario (RCP 6.0). In contrast, hydropower capacity is projected to increase by 0-2 percent under RCP 2.6 in the Nile Basin Countries (Egypt, Kenya, Sudan, and Uganda), and increase by 4-8 percent at RCP 6.0.[36]

Consider indirect costs

Investments in proactive adaptation (which anticipates climate change and incorporates upstream resilience into the design, construction, and rehabilitation of infrastructure) often don't seem justifiable. For example, unpaved roads are more likely to be damaged by floods, but proactive adaptation (paving the roads) is prohibitively costly and does not generate sufficient cost savings from reduced maintenance costs. However, if the service disruptions across sectors (such as disruptions in trade and healthcare) caused by damage to unpaved roads are quantified and considered, proactive adaptation may become justifiable. In Nigeria and the Democratic Republic of the Congo, for example, proactive adaptation for key bridges is likely to be economically justifiable because they provide critical links within the countries, and there are no alternative routes.[37]

The first step is to understand these wider, indirect impacts and costs. Ghana is taking the lead in assessing systemic risk by enhancing capacity to assess how climate change will impact existing and planned energy, transport, and water infrastructure systems and services. The Ministry of Environment, Science, Technology, and Innovation in Ghana, infrastructure ministries and departments, and the GCA are working with the UN Office for Project Services, UN Environment Programme, and Oxford University to develop tools and methodologies that can be used for upstream planning. These will be scaled up to inform adaptation investments across Africa through the flagship Africa Adaptation Accelerator Program (AAAP), launched by the GCA and the African Development Bank.


Photo: Tetyana Dotsenko/Shutterstock

Box 3: Systemic risk and resilience assessment of Ghana's transport networks

Ghana is taking the lead in using geospatial infrastructure modelling and rigorous quantitative and qualitative assessment tools to pinpoint areas of vulnerability in the transport, energy, and water sectors.

In the transport sector, upstream assessments reveal an increasing risk of damage from direct and indirect climate impacts, including sea level rise, inland flooding, and landslides. Current flooding probability and geospatial hazard maps were created based on a methodology provided by the National Disaster Management Organisation, which involves geospatial analysis of physical parameters within catchments, including upstream areas and height and distance from drainage systems. The A1B scenario from the IPCC's 2000 Special Report on Emissions Scenarios (SRES) was selected for future climate projections up to 2050, as it uses a regional climate model and therefore provides more detailed spatial information for Ghana, as well as more realistic future projections based on a business-as-usual scenario. This scenario projects a balanced energy mix, consistent with Ghana's aim to move towards renewable energy, and includes projected socio-economic changes, including rapid economic growth and the quick spreading of new and efficient technologies. The analysis of flood hazards is based on an understanding of flood extent, with the assumption that a flooded area of road is no longer usable but does not include an assessment of flood depth or further nuance on flood characteristics beyond area extent.

Flooding is found to pose a significant hazard to the country's transport assets. By overlaying transport asset data with climate hazard data in the form of flood maps, the study found that 19 percent of Ghana's roads, 54 percent of railway assets, 27 percent of the railway network, 20 percent of port assets, and 44 percent of airport assets are exposed to flooding in a high hazard scenario by 2050. In the capital city of Accra, 27 percent of the road length (600 kilometers) is exposed to flooding, with potential damage costs of US$ 130 million.

The impact of flooding on access to health care was also calculated by intersecting flood and road data with routing to health care facilities, and the vulnerability index of districts derived from measures of adaptive capacity included in the country's Fourth National Assessment. Across all flood scenarios, the GCA finds that 12-14 million people in the country will need to travel more than 100 km to access basic health services because of damage to roads. Similarly, Ghana's supply chains are at risk from flood impacts. Flood exposure is concentrated in the Greater Accra area, which is likely to impact the movement of freight to the capital.

Table 1: Property Ownership in Sub-Saharan Africa

Sub-sectors	Hazard	National-scale exposure to hazard, including service disruptions	Population affected
Roads	Flood	**19 percent** of Ghana's 137,000 km of roads exposed	Access to healthcare for approximately **13 million** people affected
Rail	Flood	**27 percent** of total rail network length exposed	**44,700** customers face potential disruptions per day (Eastern and Western line only)
Rail	Landslide	**1 percent** of total rail network length exposed	**39,700** customers on the Eastern line face potential disruptions per day
Airports	Flood	**44 percent** of all airports potentially exposed	Approximately **460,000** passengers could face travel disruptions annually
Ports	Flood	**25 percent** of the main cargo ports are potentially exposed to flood scenarios	

As the existing problems of increased demand for roads and traffic congestion are exacerbated due to the increased number of automobile users, the existing road and railway networks across the country will need to be expanded while both existing and future transport networks are made more resilient. Ghana plans to scale up railway infrastructure by 2050 and increase the current stock of 1128 km to 4,000 km to enable cross-country freight movement across the North and South. Flooding poses high risk to future railway investments, with GCA analysis suggesting 22 percent of proposed future network will be exposed to high floods.

Ghana already pays a high economic cost for flooding. Following the 2015 flooding, the Government of Ghana had to secure funding of US$ 6.4 million for emergency repairs. Without proactive adaptation, it is estimated that maintenance and repair costs following road damage during the 2020-2100 period will amount to US$ 473 million.

Integrate 'green' with 'grey'

The integration of nature-based solutions (NbS) in infrastructure planning and decision-making – including the restoration, protection, management, or creation of natural and semi-natural terrestrial and marine ecosystems – can make infrastructure more sustainable and resilient.[38] For example, coastal ecosystems such as salt marshes, coral reefs, and mangroves can help protect coastal roads and ports by reducing wave height and the extent of flooding, and by buffering winds.[39] Salt marshes can reduce non-storm wave heights by an average of 72 percent, coral reefs by 70 percent, seagrass beds by 36 percent, and mangroves by 31 percent.[40]

In the energy sector, NbS can safeguard the storage capacity of hydropower reservoirs during droughts or high temperatures by regulating and storing water, recharging groundwater supplies, and reducing sedimentation. The degradation of catchments in Kenya, for instance, has already led to high sedimentation of two hydropower reservoirs along the Tana River, and reduced total reservoir storage capacity by as much as 10-15 percent within the last three decades. NbS can also help regulate water flow to reservoirs during high rainfall events and reduce the frequency at which dams need to be discharged. In Ghana, for instance, the Atewa Forest regulates water flow to the Weija Dam, reducing the need for discharge, and preserving downstream infrastructure and communities.[41]

In the transport sector, NbS can increase the resilience of assets by shading and cooling. This slows the deterioration of streets and pavements, decreases maintenance, and provides additional benefits such as improved water management and more productive use of land. Green spaces, green roofs, and green walls can safeguard roads in African cities by improving stormwater management, and at the same time reduce the need and costs of engineered solutions such as stormwater drains.

There are significant opportunities to enhance NbS across Africa. East and southern Africa, including Tanzania, Kenya, Madagascar and Mozambique, have a total restorable area of mangroves of 41,200 hectares, with the Mozambique coast showing highest potential.[42] West and central Africa have 44,000 hectares of restorable mangroves, with the highest opportunities found in Senegal, Nigeria, Cameroon, and Gabon. To attract investments, however, this added value of restoring these ecosystems will need to be quantified.

At the same time, integrating NbS into infrastructure sectors can benefit 14 of the 17 SDGs, and impact all 17 SDGs through the delivery of wider economic, social, and environmental co-benefits.[43] Integrating NbS in the energy and transport sectors can benefit more than 40 of the 169 SDG targets, and can have co-benefits for approximately 90 SDG targets.

"The shock that the pandemic and climate change have in common is that they affect particularly the more fragile and vulnerable communities."

H.E. President Condé of Guinea, Champion of Africa Renewable Energy
Leader's Dialogue on the Africa Covid-Climate Emergency, April, 2021


Photo: Dennis Diatel/Shutterstock

Box 4: The economic benefits of Nature-based Solutions in the Weija Dam catchment in Ghana

Photo: Nature, Parks/Outdoor/Shutterstock

NbS can help countries adapt to climate change, and at the same time offer multiple benefits to stakeholders, including tangible financial returns. The Weija Dam in Ghana, for instance, currently supplies drinking water to one million citizens of Accra. This number can be doubled, and an additional one million thirsty citizens of Accra can potentially gain access to drinking water through NbS.

Using the GIS-based Revised Universal Soil Loss Equation (RUSLE) modelling approach, the GCA estimates that a 15 percent increase in erosion due to rainfall in the Dam's catchment area will increase sedimentation by 15 percent under business-as-usual (BAU) climate projections.[44] This will reduce reservoir storage capacity and increase the cost of water production. Assuming a linear cost increase for water production due to increased sediment loads caused due to climate change, the GCA estimates that the net present values for Ghana Water Company will decrease by up to 9 percent by 2050, compared to BAU.

However, a combination of forest conservation in Atewa Forest and agroforestry systems that provide overhead canopy shade for cocoa trees can reduce this sedimentation. The Economics of Ecosystems and Biodiversity (TEEB), a global initiative focused on "making nature's values visible", estimates that these NbS measures can boost the economic benefits for farmers by 32 percent and for the Ghana Water Company by up to 97 percent. Across all sectors, the potential returns can be as much as US$ 315 million. Potentially, therefore, NbS can more than offset the costs induced by climate change.

Leverage public-private partnerships

Leveraging public-private partnerships (PPPs) for climate-resilient infrastructure can help countries in Africa to mobilize funds to bridge the existing infrastructure gap, while accounting for climate change. The incentive structure of PPPs provides opportunity to establish project requirements that include resilient and adaptive assets or services. The focus on outputs and performance, meanwhile, can stimulate innovations in the integration of resilient design and NbS, to reduce costs over the lifecycle of the infrastructure. PPPs also enable the allocation of risk between public and private partners in ways that best manage uncertain climatic conditions and achieve resilience benefits.

While African governments are increasingly turning to PPPs to attract private capital for infrastructure projects, the World Bank's Private Participation in Infrastructure (PPI) database shows that Africa has secured less than 7 percent, or only US$ 74.8 billion, of global PPP investments over the last decade. In Sub-Saharan Africa, PPP investments between 2010 and 2020 amount to US$ 59.3 billion, directed to 275 projects mainly related to electricity, ports, and information and communications technology. Only seven of these PPPs were for road networks. If the PPPs integrate climate resilience and adaptation considerations, they could contribute to bridging the existing infrastructure gap in Africa.

According to the Infrastructure Consortium for Africa (ICA), uncertainty and the lack of political commitment are key barriers for infrastructure PPPs.[45] Although 35 out of 54 African countries have PPP legislation and units, most African countries have not yet incorporated resilience and adaptation into their PPP frameworks.[46] More work is therefore needed in updating regulatory frameworks to provide a strong enabling environment for climate-resilient PPPs; accounting for climate risks, to ensure an acceptable level of risk in projects; incorporating adaptation interventions from the outset to deliver efficient services and provide resilience co-benefits; and ensuring adequate project preparation to make projects commercially attractive. However, while there are strong bodies of knowledge on PPPs and on climate-proofing infrastructure, information on how to bring those two fields together is lacking.[47] The GCA has developed guidance and training for PPP practitioners across Africa to fill this gap, in partnership with the World Bank, the Ministry of Infrastructure of the Netherlands, and other multilateral development banks (MDBs).

Optimize lifecycle costs

Investments with lower up-front costs are attractive for countries that need to bridge infrastructure access gaps within significant financial constraints. However, this can result in higher lifecycle costs due to climate change, where countries must spend large amounts to repair and maintain infrastructure. The chronic lack of investment in downstream operations and maintenance carries additional risks, as countries cannot benefit from the full value of assets.


Photo: Belen B Massieu/Shutterstock

In the transport sector, proactive 'upstream' investments to increase the adaptive capacity and resilience of assets can have additional up-front investment costs but reduce 'downstream' operations and maintenance costs. Studies in Malawi, Mozambique, and Zambia have revealed, for instance, that investments in proactive adaptation of road networks can reduce maintenance costs by as much as 90 percent in some cases. Adapting unpaved roads to increased precipitation in Zambia can save, on average, US$ 177-193 million annually on maintenance.

At the same time, increasing the resilience and adaptive capacity of all infrastructure assets is not feasible or optimal. There will always be a residual risk of a climatic extreme that exceeds the design condition of any asset, especially as future climatic conditions are highly uncertain. In Ghana, for example, the GCA estimates that while 19 percent of the country's 137,000 km of existing roads and highways will be exposed to flooding by 2050 in a high hazard scenario. Retrofitting adaptation options into these assets will not be affordable. While 27 percent of the country's railway network will be exposed to flooding by 2050 in a high hazard scenario, this only represents 890 km of track. Roads as an asset are therefore more exposed.

Mainstream adaptation in infrastructure networks

Infrastructure networks can be characterized as a "system of systems" that cuts across government structures, institutional coordination, political commitment, regulations, enforcement, technical and human resource capacity, funding and financing of adaptation activities, and climate hazard and infrastructure-related data management and sharing.

Various agencies hold different responsibilities across the infrastructure lifecycle for data collection, sharing and management resulting in disconnected solutions across the sectors. The technical nature of climate change impacts requires specialized knowledge, understanding, and skills in developing targeted solutions for infrastructure resilience development and management. There is increasing


Photo: KRISS75/Shutterstock

recognition of the need for long-term infrastructure planning that adopts an integrated systems approach across infrastructure sectors, including energy, mobility, digital connectivity, water, and sanitation.

While climate adaptation for infrastructure in Africa is often reflected in policy and legal frameworks, the translation of high-level policy objectives into design, construction, and management processes remains a challenge in most countries and across all infrastructure sectors.

A growing number of countries around the world are adopting National Infrastructure Plans that are based on systematic analyses of future needs for infrastructure and exploration of options for meeting those needs through portfolios of investments and policies. These plans provide the opportunity to explore future climate risks to infrastructure and to embed adaptation in the infrastructure planning process, as a necessary component of an integrated, systems-level approach. They also provide an opportunity for innovation and new technologies – for example, for integrating nature-based solutions where possible to reduce costs, yield benefits for nature, and enhance resilience.

National Infrastructure Plans also need to be integrated into other ongoing and existing policy and planning processes, such as the Nationally Determined Contributions (NDCs) and National Adaptation Plans. The African Development Bank's review of the 44 NDCs submitted by African countries indicate that while all governments considered adaptation as a priority to some extent in vision statements, outcomes, or processes and actions, only 18 NDCs specifically mentioned adaptation priorities in the energy sector, and eight NDCs in the transport sector.[48]

Building resilience in the transport and energy sectors will require new tools and approaches that allow climate and disaster risks to be systematically identified, prioritized, and built into investment planning and decision-making processes. These range from upstream sectoral assessment and spatial planning to post disaster risk and recovery support; and from infrastructure system solutions and support, to building an enabling environment.

Act now

Transformation is urgent and necessary because climate change will fundamentally alter the context in which infrastructure is financed and delivered in Africa over the next few decades. Events that were rare will become much more common. As investors are now aware, these changes are an economic and financial risk for infrastructure. African governments and private infrastructure providers will need to prepare for increased risks of asset-value losses, increases in capital and operating costs, and/or a decline in the economic benefits or revenues that infrastructure assets generate. Acting now is much cheaper than deferring action to the future and will generate greater economic benefits. The magnitude of the costs of inaction – versus the benefits of proactive action – are large. Delaying action will make it much harder to tackle the climate risks and could make large future costs inevitable. Moreover, the opportunities for building resilience into the planning stages for infrastructure will decline over time.

Adapting infrastructure to climate change in Africa will have implications for the entire (systems-level) approach to planning, delivering, financing, and managing infrastructure in a country, and thus on the national public finances. This is generally due to four key issues:[49]

1. The increased chance of cascading risks, as damage to critical infrastructure leads to knock-on impacts in other sectors and geographies, will magnify the economic damage and fiscal impact of climate-related disasters.
2. As credit rating agencies factor climate change risks into sovereign creditworthiness, this could result in higher risk premiums, and increase borrowing costs – diverting government spending on debt servicing rather than development.
3. Contingent liabilities due to climate change could have potential implications for financing models. For instance, difficulties in allocating climate risks could make PPPs increasingly unattractive for infrastructure financing.
4. Rising climate extremes could reduce the availability of insurance or result in higher prices for insurance, increasing the risk of financial instability.

POLICY RECOMMENDATIONS

The scale and multi-sectoral scope of interventions to increase infrastructure adaptation and resilience creates a complexity that is difficult to navigate. Together with African governments, many private and public investors are already exploring – or have committed to – major new infrastructure projects over the next decade. Africa's current pipeline of infrastructure projects includes US$ 2.5 trillion worth of projects estimated to be completed by 2025, across all asset classes. Over 50 percent of these projects are still in the early feasibility stages, and while not all of them are expected to succeed, will a critical mass of the projects that move from feasibility to completion be resilient to climate change? The answer to this question will determine whether Africa will progress in closing its infrastructure gap, and climate-proof these investments to make them sustainable and resilient.

The following recommendations help chart the way forward:

- **A transformational shift is necessary in how infrastructure is planned and designed, with systemic climate risks and resilience integrated upstream.** While infrastructure development in energy and transport sector is vital to Africa's growth, there is a high potential that climate change will offset or reduce the benefits of such infrastructure. Adaptation has great potential to reduce the negative impacts of climate change, but the planning and design of infrastructure in Africa is still conducted largely without taking climate change into account. Failing to adjust designs ex ante to improve infrastructure performance over a range of climate futures may be an economic loss for the economy and the society in the long term. Proactive adaptation in the energy and transport sectors, meanwhile, is a no-regret option. There is momentum building for national governments, development partners, and the private sector to integrate climate change into asset design. Development partners such as the World Bank and the African Development Bank, for example, already screen projects for adaptation. However, there needs to be a fundamental shift further upstream to integrate climate resilience into how country and sector projects pipelines are planned, financed, and developed. Ghana's ongoing efforts to implement a national risk and resilience assessment provides a roadmap for other countries. While this shift needs to be country-led, MDBs can rapidly catalyze this change by integrating national and regional systemic risk and resilience assessments into their country strategies.

- **Invest in integrated systems to generate data for investment planning.** To bring down the cost of the analysis needed to integrate climate considerations into energy and transport development, and to mainstream systemic risk and resilience, significant amounts of data on climate, infrastructure assets, supply chains, the environment, economic activities, and other socio-economic aspects is needed. Most African countries and their development partners already have existing systems and projects that generate the required data, but these systems are siloed and mostly disconnected from decision-making processes. Data on climate change and hazard projections, for example, is often held within environment departments and MDBs. Similarly, data on supply chains and economic output may not be readily available or used for planning investments in transport and energy infrastructure. While data alone will not increase infrastructure adaptation and resilience, it is a vital entry point for putting in place the building blocks for climate-smart investments in infrastructure. African countries should focus on two priorities:
  - Climate data needs to be ubiquitous and tailored for actionable decisions. While countries and cities increasingly have climate risk projections, the data is difficult to comprehend and typically focused on longer-term projections that are not helpful for short-term planning.
  - Infrastructure asset data needs to include spatial markers and be integrated, or at least available, across sectors. This will also improve assessments of key vulnerabilities of infrastructure when used with the climate data and help to prioritize investments.
- **Transport assets tend to be long-lived and adaptation to new norms takes time.** Adequate road maintenance is the most critical and efficient way of reducing the impacts of a changing climate on the road system in Africa. However, adaptation often requires technological changes (such as the use of innovative materials that can withstand long periods of flooding); and involves transitional phases (such as ensuring redundancy in the connectivity of rural and urban areas).


Photo: Vadim Petrakov/Shutterstock

- **Invest in tools and methodologies to quantify energy, transport, and infrastructure related ecosystem services provided through natural assets.** NbS, implemented on a large scale, could reduce costs by 90 percent for the same level of adaptation benefits. With the increased urgency to protect 30 percent of land by 2030, as proposed under the UN Convention on Biodiversity, it is essential to find opportunities for investment programs to achieve multiple objectives. Quantifying these benefits will provide the data required to structure NbS investment models. It will also provide the adaptation link with carbon markets and could help reduce speculative pricing of carbon. This in turn can also derive additional revenue streams for NbS and climate-resilient infrastructure. There is a need to ensure sharing of research within and across sectors and to standardize methodologies and approaches for integrating NbS in infrastructure planning and implementation where appropriate, while recognizing the context-specificity of NbS projects.
- **Leverage PPP frameworks that promote incentives for climate resilience and adaptation of infrastructure projects.** While PPPs represent a relatively small proportion of infrastructure

investments in Africa, they provide a clear entry point for integrating adaptation and resilience into infrastructure design and asset management. A robust PPP framework is imperative to attract private capital for infrastructure, particularly in Africa where market conditions are more sensitive, given the complexity of PPP projects, contract size, and risk exposure.[50] Four key aspects need to be considered to integrate climate adaptation and resilience into PPPs in Africa:

- Accept uncertainty of climate risks and account for future climate scenarios in the decision-making process. Managing climate risks can be translated into improvements during the design and operations of infrastructure, as well as the use of innovative financing mechanisms to transfer those risks. This can also be reflected in "force majeure" clauses or relief and compensation events in the PPP contract.
- Enhance capacity of practitioners to understand and integrate climate resilience into infrastructure PPPs. Besides the legal, financial, and public knowledge required to structure PPPs, there are other skills that can support the development of climate-resilient PPPs, such as climate change policy, environmental engineers and economists, and stakeholder engagement experts. These capabilities should be readily available for collaboration across PPP units, line Ministries and government agencies, and the private partners.
- Develop innovative financing and funding instruments to support resilient investments and facilitate the allocation of climate-related risks between the public and private partners. This includes insurances, guarantees and green bonds, and alignment of investments with green finance measures and standards.
- Integrate NbS into PPP design and tender documents. PPPs can provide a vehicle to finance and scale up the implementation of NbS. However, NbS should be mainstreamed from project identification and considered as a key solution in the resilience options appraisal, along with grey infrastructure solutions, to adapt and mitigate identified climate risks.

- **Governments must drive reforms for improved operations and maintenance asset management.** Planning, designing, and financing climate-smart infrastructure represents only one portion of the infrastructure lifecycle. Asset management is often ignored or de-prioritized in the drive to finance and increase infrastructure capacity in Africa. Countries must enhance fundamentals of climate-smart infrastructure governance by reflecting climate change in asset management practices through clearly defined system performance metrics and levels of service. Specific recommendations to integrate climate change into asset management practices include:
  - Define requirements: Asset lifecycles and management timelines should reflect climate change and projections. Resilience measures that define how quickly services need to be restored should include projected climate hazards.
  - Assess climate impacts on the asset base: Detailed spatial climate hazard data should be used to assess vulnerabilities across all assets; and asset management plans should identify climate risk and key performance thresholds that place people and services at risk.
  - Develop climate-smart capital works strategies: Risk analysis should inform operational expenditures and procedures; and capital expenditures should address key asset vulnerabilities including through retrofitting infrastructure where required.
  - Integrate climate risk in financial plans: Financial models should integrate climate risk in cash flow projections through climate-sensitive demand and supply assessments and projected asset maintenance costs. Asset managers should run climate-risk scenarios to stress test systems.
  - Integrate climate change and hazard data in management information systems (MIS): Managing climate risk is a data-intensive process, but climate hazard data needs to be integrated into decision-making. MIS offer a viable entry point to mainstream climate risk into asset management.

> **"Climate change would lead to 55 million people who are undernourished in 2050, but without adaptation through trade, the impact of global climate change would increase to 70 million, an increase of 33%."**
>
> **Jamal Saghir, GCA Board Member and Professor of Practice, McGill University**
> High-Level Dialogue "An adaptation acceleration imperative for COP26", September, 2021

Bamboo bikes: A small innovation with big wins

Ghana Bamboo Bikes Initiative

The transport sector is a major driver of development in Ghana, playing a fundamental role in key sectors such as agriculture, trade, education, and health. As in other parts of the world, however, it is heavily reliant on fossil fuel-powered motorized vehicles, and is therefore a major contributor of greenhouse gas emissions, and of other pollutants with significant impacts on human health and the environment.

Motorized transport is also infrastructure intensive and needs extensive and expensive road networks that require regular upkeep. Low farm productivity, due to unpredictable weather among other things, has driven populations further into the hinterlands of the country in search of better farming conditions and other livelihoods, but the road infrastructure has not been able to keep up. Roads, where they exist in these remote regions, are in poor condition and unfit for most motorized form of transport, particularly during and after torrential rainfall. Most people have to rely on bicycles as a more reliable and affordable means of transport – even so, bicycles are a privilege that only a few can afford.

Over the past few years, a novel initiative to overcome these transport challenges in remote areas has been trialed in the Ashanti, Eastern, and Northern Regions,

A group of students at Nabdam Girls Model School in the north ready to head home after class hours during a field visit

Source: Authors

"I love to be in school, but sometimes I had to absent myself twice a week because my mother could not afford to pay the fare for transport," says 15-year-old Adwoa Kra Veronica, from Amasu. "Each day, I had to travel over 10 kilometers through a bushy foot path to get to school, and my mother was very concerned about the risks involved. After I was gifted this bamboo bicycle in 2017, I have consistently performed well in class since I am among the few students who come to school early for morning studies."

where livelihoods are primarily agrarian, and rely on the ability to transport perishable agricultural commodities from aggregation centers to markets in time. The Ghana Bamboo Bike Initiative (GBBI), a social enterprise, has distributed over 500 bamboo bicycles to select members of the community in these regions, including farmers, students, teachers, and social workers. GBBI developed the bicycles as a means of addressing, among other things, challenges related to climate change, poverty, unemployment, and education; and trains rural women and youth in bamboo bicycle building to enable them to earn a sustainable income.

The bikes have had a transformational impact on the lives of the recipients. "A major problem of farming in the Northern Region is the dry, hot climate," says Tembire Yensomre, a farmer in Kong-Daborin. "The farms are very far because that is where we can find some spots of water to grow crops. Transportation has been a great challenge for me for quite a long time. The day I received this bicycle, I wondered if it could last long on our very poor roads. As you can see, it is very strong – I have only had a flat tire once. Now, I farm yam in addition to millet because I can spend more time on the farm, and expect to produce 500 kilograms of yam this year!"

Built from a native bamboo species, local fiber materials, and plant-based resin, the bicycles have proven their potential to bolster the adaptive capacity and resilience of communities that are outside the mainstream transport system in Ghana. Encouraging their use through subsidies, and providing climate-resilient infrastructure necessary to increase user safety and extend the product life of the bicycles, will go a long way towards meeting the goals of existing national and regional policies and strategies that seek to promote non-motorized transport, and ensure better transport accessibility in the face of climate change, economic growth, clean air, and reduced emissions. These include the National Transport Policy, Non-Motorized Transport Strategy, Nationally Determined Contribution, Growth and Poverty Reduction Strategy, and the Action Framework of the Africa Sustainable Transport Forum.