CDRI
Coalition for Disaster Resilient Infrastructure

Global Infrastructure Resilience Working Paper

Infrastructure Resilience in Africa

GIR AFRICA
2025 WORKING PAPER

This Work is a product of the Coalition for Disaster Resilient Infrastructure (CDRI) as part of a working paper series linked to the second *Global Infrastructure Resilience (GIR)* report. It presents regional analysis for Africa leveraging the results from the Global Infrastructure Risk Model and Resilience Index (GIRI) developed by CDRI. It can be downloaded from the CDRI website https://cdri.world/

Further, the online data platform enabling visualization, analysis, and downloading provisions for the results of the Global Infrastructure Risk Model and Resilience Index (GIRI), is available at https://cdri.world/giri

This Work may go further changes subject to refinement of the analysis.

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Acronyms

AAL	average annual loss
ARC	African Risk Capacity
CDRI	Coalition for Disaster Resilient Infrastructure
CoP	Community of Practice
CPI	Climate Policy Initiative
DRC	Democratic Republic of the Congo
DRI	disaster resilient infrastructure
DRR	disaster risk reduction
EWS	early warning system
GCA	Global Center on Adaptation
GDP	gross domestic product
GIR	Global Infrastructure Resilience
GIRI	Global Infrastructure Risk Model and Resilience Index
GRMA	Global Risk Modelling Alliance
ICT	information and communications technology
LEC	loss exceedance curve
LNG	liquefied natural gas
MHEWS	multi-hazard early warning system
MW	megawatts
NAPs	National Adaptation Plans
NbS	nature-based solutions
NDRR	National Disaster Risk Reduction
PIDA	Programme for Infrastructure Development in Africa
PML	probable maximum loss
PPP	public-private partnership
RCBA	Resilience Cost-Benefit Analysis
SDG	Sustainable Development Goal
SIDS	Small Island Developing States
UN	United Nations
UNDRR	United Nations Office for Disaster Risk Reduction
UNICEF	United Nations Children's Fund
WHO	World Health Organization
WMO	World Meteorological Organization

Key Messages

First comprehensive review of infrastructure risks in Africa

For the first time, CDRI's Global Infrastructure Risk and Resilience Index (GIRI) model has been used to conduct a comprehensive review of infrastructure risks in the Africa region due to disasters and climate change. GIRI is a fully probabilistic model that draws on leading global databases to assess risks from seven geological and climate-related hazards across nine key infrastructure sectors. It provides a globally comparable set of financial risk metrics, including average annual loss (AAL), relative AAL, and probable maximum loss (PML) for infrastructure assets.

Multi-hazard AAL for infrastructure and buildings in Africa is $12.7 billion

GIRI results indicate that the AAL of infrastructure and buildings damaged by disasters in Africa is $12.7 billion[1]. Looking at infrastructure assets alone, Africa is estimated to lose, on average, $1.8 billion every year. The majority of damages are caused by floods (approximately 70 percent) and earthquakes (roughly 28 percent). Earthquakes are much less frequent than floods, but can be far more catastrophic.

Impact of climate change will further exacerbate the AAL

Climate change is expected to increase the impact of disasters on infrastructure by as much as 27 percent, resulting in AAL of $2.4 billion.

[1] Dollar symbols in this working paper indicate the use of US dollars

Eastern Africa bears the highest AAL

At a regional level, the largest AAL for infrastructure and buildings is in Eastern Africa ($5.1 billion or 43 percent), followed by Northern Africa ($2.3 billion or 18 percent) and Southern Africa ($2.3 billion or 18 percent). At a country level, the nations with the largest AAL for infrastructure and buildings are South Africa ($1.7 billion), Nigeria ($1.1 billion), and Algeria ($1 billion). These are large amounts for African governments to pay each year for repair and reconstruction of damaged infrastructure. Africa cannot afford these losses.

Losses borne by smaller nations are significant to their economies

Smaller nations with fewer infrastructure assets tend to have smaller average annual losses, but these losses are more significant to their economies. For example, AAL represents 1.5 percent of Lesotho's GDP, 1.25 percent of Mauritius' GDP, and 1 percent of Comoros' GDP.

African governments are taking the lead in adaptation and resilience

African governments are taking the lead in building resilience and adaptation in their economies. Their national budgets contribute 26 percent of total adaptation financing, and they are taking loans to channel an additional 54 percent. Alongside this, the world must increase support for Africa to address the consequences of a changing climate that it did not contribute significantly to.

Maintenance, preparedness, early warnings, and alliances drive resilience action

Resilience is not only about making new assets stronger to withstand climate-related and geological disasters. Infrastructure agencies should also prepare ahead of time for disasters through regular maintenance, preparedness planning, early warning systems, and alliances with the populations and businesses they serve.

Financing resilience is a balancing act

The limited funds available should be used to: expand infrastructure services with more resilient standards; maintain and repair existing infrastructure; retrofit the most critical infrastructure and buildings; and keep reserves for future damages caused by disasters.

1. Overview

This working paper is part of a series presenting regional and thematic analyses that leverage the results of the Global Infrastructure Risk Model and Resilience Index (GIRI), developed by the Coalition for Disaster Resilient Infrastructure (CDRI), in the run-up to CDRI's second *Global Infrastructure Resilience (GIR)* report. It presents, for the first time, the detailed results of the GIRI model applied to the Africa region.

Africa is one of the most vulnerable regions to climate-related disasters. Some regions of the continent also face substantial earthquake risks. Decision makers do not have access to information that would enable them to understand the potential financial consequences of these risks in their jurisdictions. For the first time, this paper presents the results of a risk assessment for the region and individual countries. It also demonstrates its application in analyses at the subnational level, with examples of three countries. The risk assessment, categorised by type of hazard and infrastructure sector, can help decision makers, financiers, and donors identify priority areas for action.

The benefits of resilience programmes in Africa are enormous. This paper proposes specific actions to organize the financing needed for resilience and to strengthen African institutions responsible for infrastructure management to be better prepared to absorb the shock of disasters, to respond faster and more effectively once catastrophes occur, and to repair and restore services as quickly as possible to minimize the negative impact on the economy, businesses, and livelihoods. The *GIR 2025* report will elaborate further on these recommendations.

This paper is organized into seven sections. After this overview, Section 2 presents the definitions of risk, resilience, and related key concepts. Section 3 provides a summary of the GIRI model and its key findings. Section 4 summarizes the global results of the GIRI model at the regional, national, and subnational levels. Section 5 provides a detailed examination of GIRI model results for Africa. Section 6 reviews the challenges of disasters and examples of resilience solutions in the transport, energy, and urban infrastructure sectors. Section 7 discusses key elements of infrastructure resilience in Africa, focusing on ways to strengthen the capacities to absorb, respond to, and recover from disasters. This section also reviews options for financial instruments and institutional strengthening measures to enhance the resilience of infrastructure systems in Africa.

2. Risk and Resilience

Governments, businesses, homeowners, and infrastructure asset owners and operators must understand the risks their infrastructure and building assets face. Assessing disaster and climate risks for these assets allows owners to identify their contingent liabilities or financial exposure if disasters damage or destroy those assets. This section presents foundational concepts of risks used throughout this paper.

Disaster risk refers to the probability of disasters of a given intensity occurring in a given period of time. It is not an independent variable but is a function of three other variables: hazard, exposure, and vulnerability. Annex 2 presents a glossary of these terms and others related to resilient infrastructure.

Hazard refers to the probability and intensity of an occurrence of a damaging event, such as an earthquake, tsunami, flood, or tropical cyclone, and is expressed in terms of frequency and severity. Exposure refers to the number, kinds, and value of assets in areas exposed to the hazard. Vulnerability refers to the susceptibility of those assets to suffer loss or damage (UN, 2017).

The disaster and climate change risks that infrastructure assets face can be calculated based on the combination of geological and climate-related hazards, the exposure of those assets, and their vulnerability to damage when disasters strike (USFS, 2023). **Figure 1** presents the relationships between these four concepts.

The first step towards estimating infrastructure asset risk is identifying and mapping hazards in the areas where those assets are located. Tectonic faults, cyclone tracks, and floodplains define hazards. Climate change, environmental degradation, and land use changes modify hazards such as floods, landslides, cyclonic winds, storm surges, and droughts.

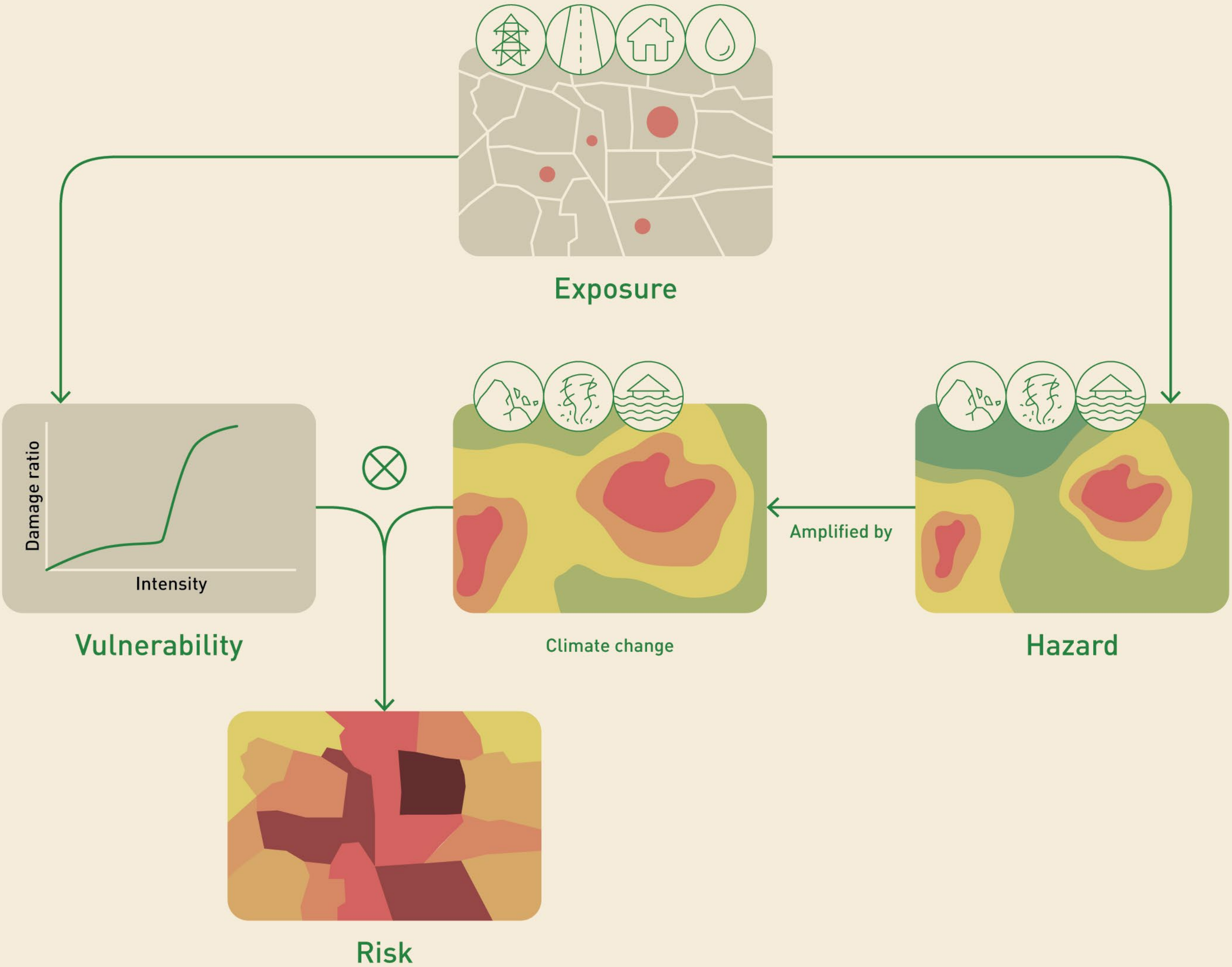


Figure 1

Exposure, hazard, vulnerability, and risk

Source: CDRI (2023b)

Climate change is projected to increase hazards that can damage infrastructure assets. It will also impact the capacity of those assets to provide the infrastructure for which they were designed. For example, droughts will reduce the capacity of hydroelectric power plants to generate energy.

The second step is identifying each infrastructure asset's location and calculating its economic value. This information allows for the calculation of the asset's exposure.

Finally, vulnerability functions are applied to each type of infrastructure asset and for hazards of different intensities to determine the level of damage that the assets will suffer. These functions are generated from the statistical analysis of loss values over a range of hazard severities, derived from field observations, analytical studies, or expert judgment.

Vulnerability generally depends on the quality of construction and adherence to resilience standards. If standards are higher and they are enforced during construction and maintenance, the risk of an infrastructure asset may be lower even in locations with high levels of hazard exposure.

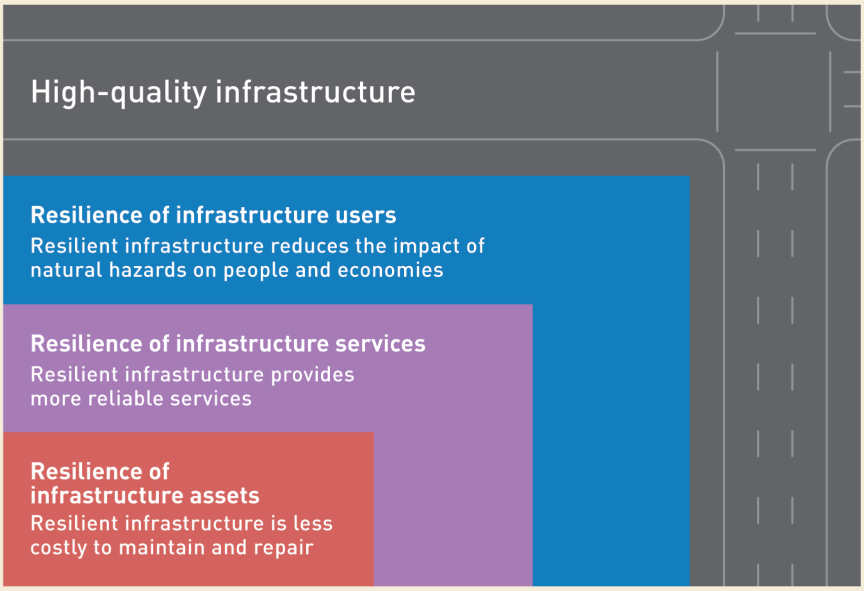


Figure 2

Three levels of resilience in infrastructure

Source: Hallegatte et al. (2019)

2.1 Disaster Resilient Infrastructure

The traditional view of infrastructure resilience has focused on engineering designs, namely, how to make infrastructure assets able to resist and absorb the impact of geological or climatic hazards. Under this view, the emphasis has been on stronger design standards, new materials, and advanced technologies. However, this is a narrow perspective. Resilient infrastructure assets are those that can not only absorb the impact of hazards, but also respond to and recover from hazard events and shocks, as defined by CDRI.

CDRI defines disaster resilient infrastructure as "infrastructure systems and networks, the components, and assets thereof, and the services they provide, that are able to resist and absorb disaster impacts, maintain adequate levels of service continuity during crises, and swiftly recover in such a manner that future risks are reduced or prevented" (CDRI, 2023a).

Furthermore, infrastructure for resilience refers to infrastructure assets that reduce the impact of hazards. Examples include flood protection infrastructure, or air conditioning systems to deal with heatwave impacts—and the energy infrastructure that supports them.

In addition to the concepts of resilient infrastructure and infrastructure for resilience, it is important to consider three levels of infrastructure resilience (Hallegatte et al., 2019) as shown in **Figure 2**.

1. **Resilience of infrastructure assets:** In the narrowest sense, resilience focuses only on the capacity of those assets to absorb, respond to, and recover from hazard events. The primary benefits of greater resilience of infrastructure assets are linked to the reduction of their life-cycle costs.

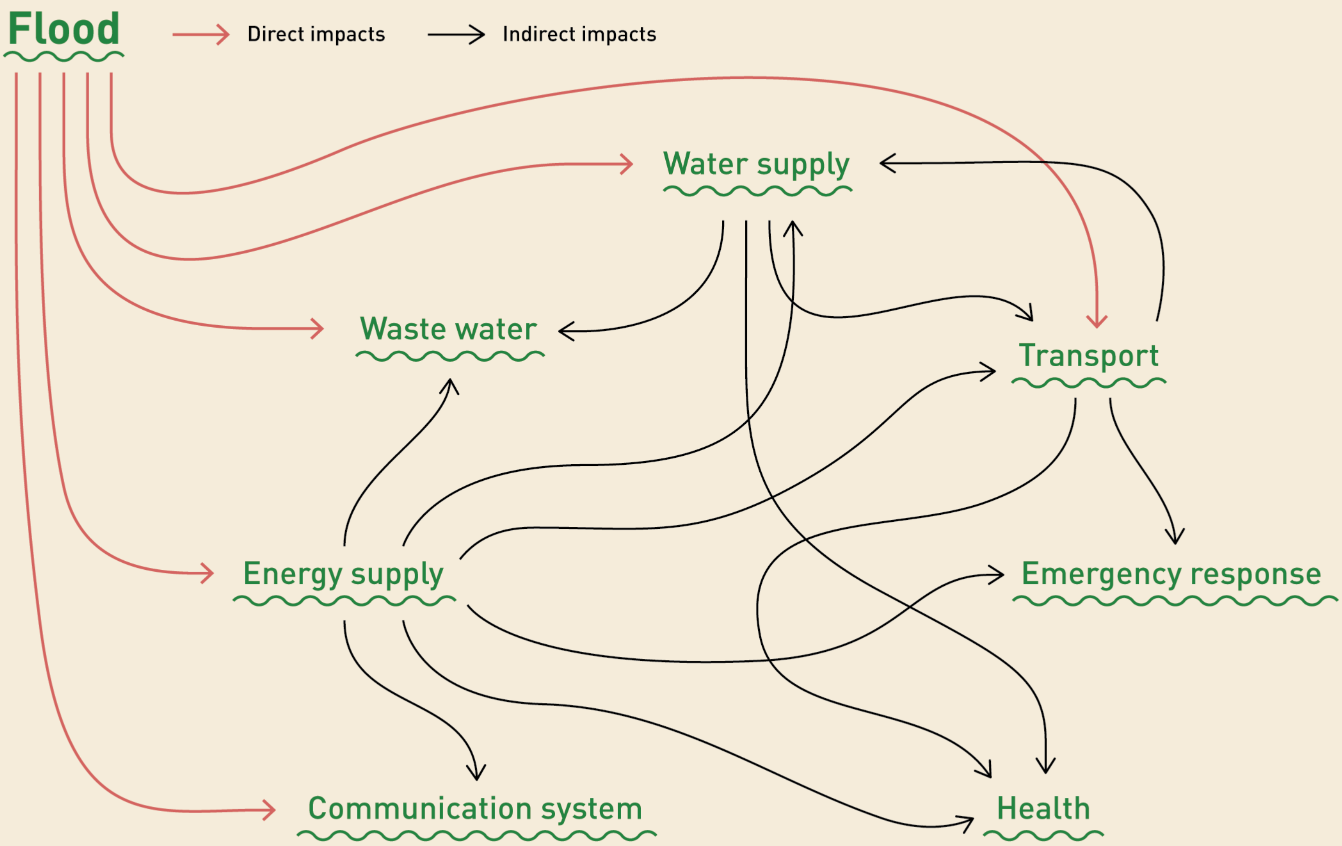


Figure 3

Direct and indirect impact of a hazard on different infrastructure assets and services

Source: Arrighi et al. (2021)

2. **Resilience of infrastructure services:** Most infrastructure systems are interconnected networks of individual assets (for example, power distribution networks that provide electricity services consist of numerous links and components). While an individual infrastructure asset may be less resilient, the network's density and the ability to reroute electricity or traffic means the overall system can be more resilient than the individual links. A more systematic approach to resilient services is preferable and potentially more cost-effective than a narrow view of assets.

3. **Resilience of infrastructure users:** For livelihoods and economies, what matters is the resilience of users. If people and supply chains can cope better with infrastructure service failures due to disasters, the impacts on lives and economies will be less severe. For example, users who are informed of potential bus route or power service interruptions due to a storm can make alternative arrangements (if they have adequate information and choices). The benefit of more resilient users is a reduced economic and livelihood impact on communities, businesses, and households.

The failure of infrastructure services, combined with weak resilience of infrastructure users, leads to indirect losses in economic activity, negative health and education outcomes, and cascading impacts on other infrastructure services (**Figure 3**). These indirect losses are often orders of magnitude larger than the value of infrastructure asset damages due to disasters.

3. Assessing Infrastructure Risks

3.1 Probabilistic Risk Assessment

In the 1990s, the insurance industry adopted probabilistic risk modelling as the best approach to estimating the full spectrum of risk and generating financial risk metrics to calibrate insurance premiums and risk financing mechanisms such as catastrophe bonds.

Probabilistic models simulate future disasters that could occur based on scientific evidence, reproducing the physics of the phenomena, and recreating the intensity of a large number of synthetic hazard events. In doing so, they provide a more complete picture of risk than is possible using historical data alone.

Insurance industry catastrophe models typically estimate risk for specific insurance markets or bundles of assets and are rarely available to governments or infrastructure investors or fully understood by insurance policy purchasers.

Open-source global risk assessments such as the Global Risk Model have partially addressed this gap (UNDRR, 2017). Open risk modelling platforms and initiatives such as the OASIS Loss Modelling Framework and the Global Risk Modelling Alliance (GRMA) have also emerged (Oasis LMF, 2023; V20 Members, 2023).

CDRI has developed the first publicly available and fully probabilistic risk model to estimate risk for infrastructure assets regarding most major geological and climate-related hazards: the GIRI.

3.2 The Global Infrastructure Risk Model and Resilience Index

The GIRI model is designed for several hazards and infrastructure sectors (**Figure 4**).

Figure 4

Hazards and infrastructure sectors in GIRI model

Source: CDRI (2023b)

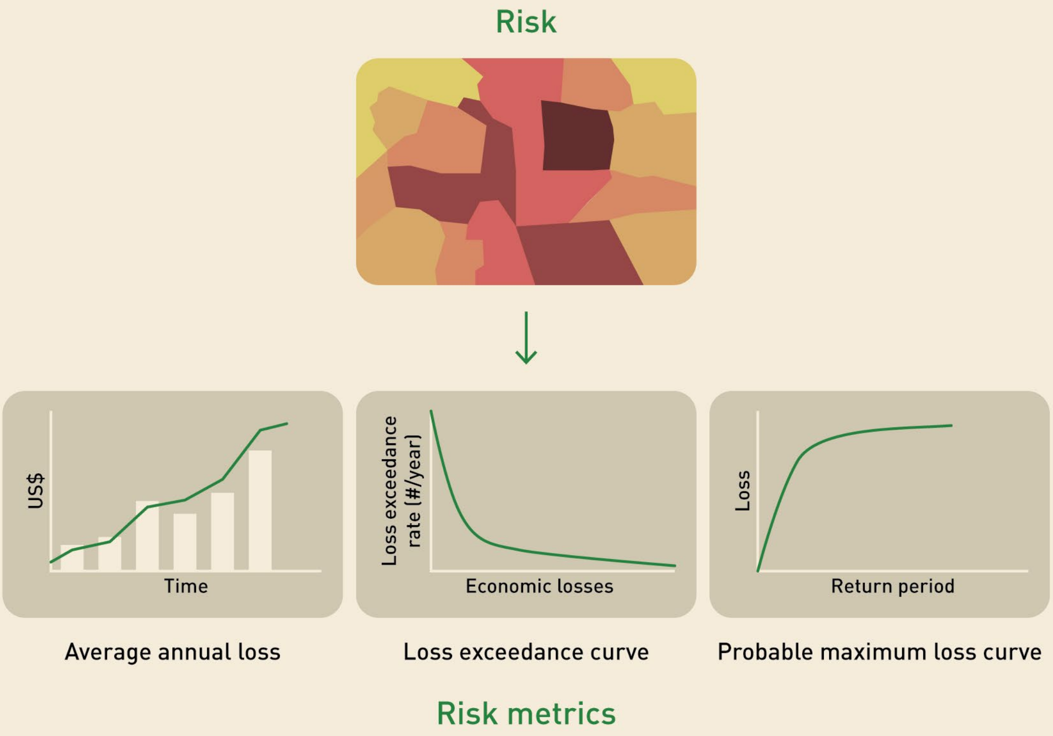


Figure 5

GIRI risk assessment model

Source: CDRI (2023b)

The GIRI model generates a series of financial risk metrics (**Figure 5**). It is built on the following six steps (for further technical details see CDRI 2023b).

1. Hazard input data was obtained by developing comprehensive sets of simulated events that account for all the possible manifestations of each hazard and provide information about the geographical distribution of the hazard intensities and their frequency of occurrence.

2. The intensities and frequency of the hydrometeorological hazards were modified to account for two future climate change scenarios, reflecting a lower and upper bound of global warming levels.

3. The exposure database was assembled by geo-localizing exposed assets and networks in each infrastructure sector from available public data sources. Public and private buildings were also included.

4. Economic values were assigned to each exposed asset using a bottom-up procedure (Marulanda, 2023). The total value of the infrastructure assets in each country was then scaled to reflect the value of the capital stock relative to other countries.

5. Vulnerability functions, relating the hazard intensities-to-expected asset losses in a continuous, qualitative, and probabilistic manner for all hazards, were developed for over 50 infrastructure archetypes. These archetypes, such as a power station or an airport, are assemblies of different infrastructure elements, each of which has a specific vulnerability signature.

6. Each asset's associated damage and loss in the exposure database was then calculated for each stochastic hazard event. The distribution of probable future losses was generated from the exceedance rates for each

loss value and presented for each sector as a loss exceedance curve (LEC). Other financial risk metrics calculated by the model include the average annual loss (AAL) and the probable maximum loss (PML).

The AAL is a commonly used measure in the insurance industry. The AAL estimates the contingent liabilities for each infrastructure sector in each country or territory. It is a practical and compact metric that presents the expected or average loss that may be experienced in the long run. The AAL is not to be confused with the annual average historical loss, or the future losses experienced yearly. The AAL is known as the pure risk premium in the insurance industry when normalized by the exposed values. The AAL for any given infrastructure sector and country measures the resources that governments would need to set aside, on average, each year to cover future asset loss and damage.

3.2.1 Limitations of the GIRI Model

The GIRI model is based on well-established risk modelling methodologies. However, the quality of GIRI's results depends on the hazard and exposure data quality. The first iteration of the GIRI model was built using global datasets (see CDRI 2023b for more details). As new hazard and exposure data become available, the quality of GIRI results will continue to improve. While the financial risk metrics presented are in the correct order of magnitude, the specific AAL values will likely evolve as the model is further calibrated and developed.

Furthermore, as climate change models become more robust, downscaling to local levels becomes more advanced, and the attribution science progresses, more precise data on hydro-meteorological hazards will also become available, and the GIRI results will improve. Vulnerability functions will also likely improve over time as they are used and tested in different applications.

The GIRI model focuses on the direct impacts on infrastructure assets caused by disasters. It does not calculate the indirect costs associated with the disruption of infrastructure services, such as economic, health and education outcomes, livelihoods, employment, and many others.

Finally, the current version of the GIRI model does not yet include important hazards such as heatwaves, wildfires, permafrost melting, or sea-level rise. Future iterations will address these.

4. An Overview of Global Results from the GIRI Model

The first *Global Infrastructure Resilience* report by CDRI (CDRI, 2023b) presents the results of the GIRI model applied to every nation and territory in the world. This section presents a summary of the global results before the following section zooms into the analysis for Africa.

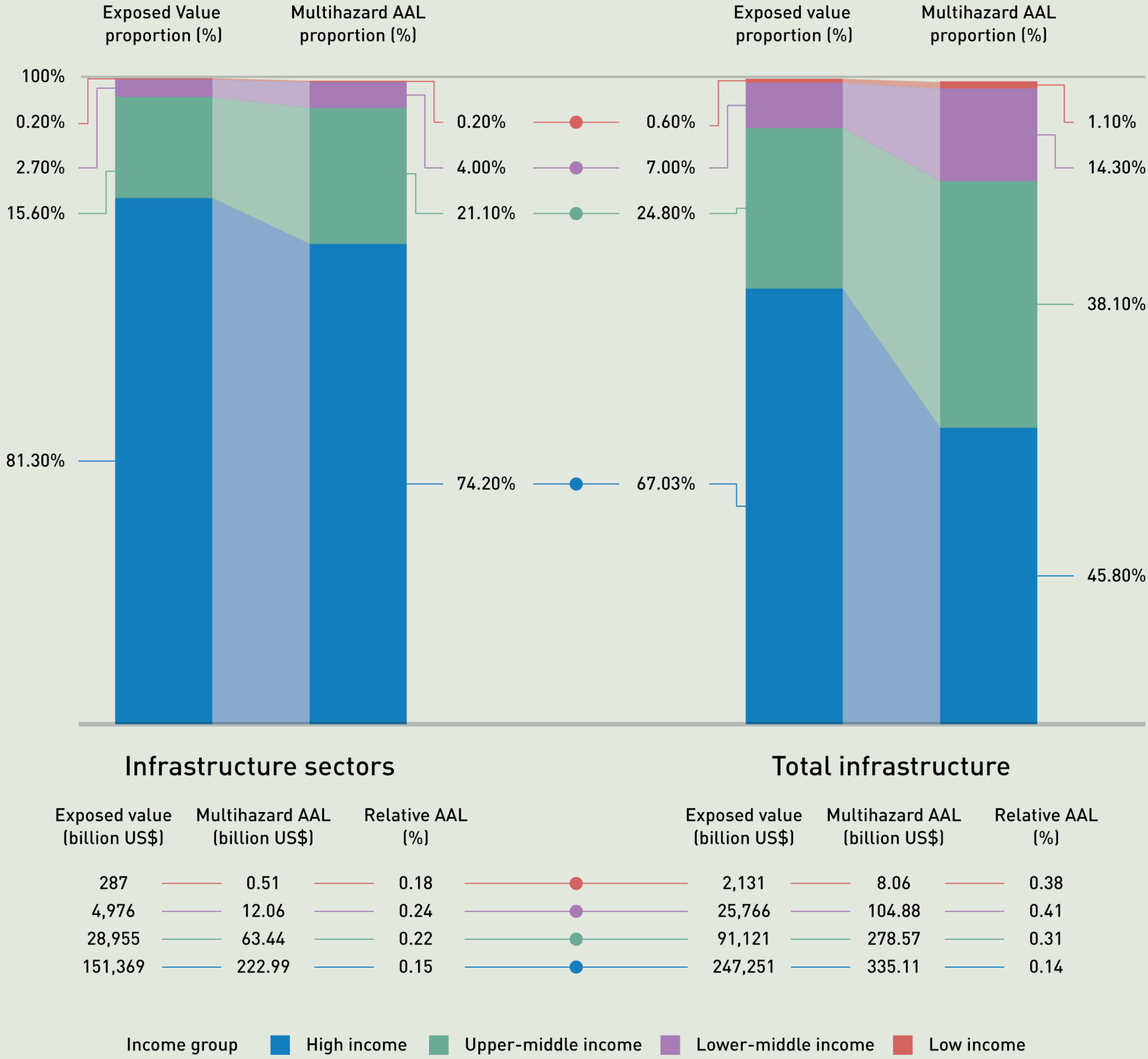
4.1 Average Annual Losses Across Income Levels

Under the present climate, the GIRI model estimates that the value of the global multi-hazard AAL caused by key disaster hazards (earthquake, tsunamis, landslides, floods, and cyclonic storms) in the principal infrastructure sectors (transport, energy, water, telecommunications, and oil) is $301 billion as of 2023.

The GIRI model was also used to calculate the average annual losses for buildings, including health and education infrastructure. The total infrastructure (infrastructure sectors plus buildings) multi-hazard AAL increases to about $732 billion when these are included. This amount represents approximately 14 percent of global 2021-2022 GDP growth.

Figure 6 shows the total value of infrastructure (including buildings) and the multi-hazard AAL (both in $ billions) divided by groups according to economic level (high income, upper-middle income, lower- middle income, and low income). The figure also shows the relative AAL calculated as the ratio between the AAL and the country's total value of infrastructure assets.

Figure 6 shows that a large portion of global infrastructure assets is located in high-income countries, with 67 percent of the global exposed value. This percentage increases to 81 percent if buildings are considered. Low-income countries only have 0.6 percent of infrastructure and building assets.



Infrastructure sectors = Power; Roads and railways; Ports and airports; Water and wastewater; Telecommunications; Oil and gas.
Total infrastructure = Infrastructure sectors plus buildings, including health and education infrastructure.

Figure 6

Exposed value of buildings and infrastructure assets and AAL by income region

Source: CDRI (2023b)

When disaster risk is considered, the situation looks different. Upper-middle-income and middle- income countries account for 53 percent of the global AAL for infrastructure and buildings, or $383 billion. On the other hand, high-income countries account for a lower percentage of global AAL, or 46 percent, despite having a much larger portion of infrastructure assets. This reflects the much higher capacity of infrastructure and buildings in high-income countries to absorb the shock and damages of disasters, compared to middle-income countries.

Furthermore, if we look at the value of AAL divided by the total value of infrastructure and buildings, in high-income countries this ratio is only 0.14

percent. In contrast, this figure stands at 0.38 percent in low-income countries, 0.41 percent in lower-middle-income countries, and 0.31 percent in upper-middle-income countries.

In summary, low- and middle-income countries have less infrastructure, lower investment, and higher risk than high-income countries.

4.2 Absolute and Relative Average Annual Losses

Another way to compare countries and their capacity to deal with the impact of disasters on infrastructure is to look at the absolute AAL[2] (in $ billions) and the relative AAL (the ratio of AAL divided by total infrastructure assets' value). **Figure 7** plots these values for a selected group of countries.

In the left-hand top quadrant, a group of mainly high-income countries and some middle-income countries with large economies have high absolute but low relative risk. Countries in this quadrant include Organisation for Economic Co-operation and Development countries such as India, China, and Mexico, and are highlighted in blue. These countries are normally able to absorb their large absolute AAL values, as they represent only a small proportion of their capital stock, given the size of their economies.

In the right-hand lower quadrant, a group of countries highlighted in red have low levels of absolute AAL (measured in $ billions) but very high levels of relative risk. These countries are mostly Small Island Developing States (SIDS). Even if the total stock of infrastructure is small, when compared to larger countries, the resources required to repair and rehabilitate damaged infrastructure annually, on average, often exceed the capacity of their small economies.

What this means is that making infrastructure assets in SIDS more resistant to disasters will require investments that are unlikely to be considered large or significant on a global scale, but that will make a critical difference to SIDS' sustainable social and economic development.

4.3 Average Annual Losses Across Infrastructure Sectors

The way the GIRI model is constructed—from the bottom up, asset by asset—allows for different ways to aggregate the results. The previous section showed the results by geographical regions and by countries. It is also possible to aggregate the results by sector.

Figure 8 shows how the exposed value and AAL are distributed globally and by geographical region across infrastructure sectors. Roads, railways, power, and energy account for around 71 percent of the total AAL of infrastructure sectors (about $213 billion), followed by telecommunications, ports, airports, water, and sanitation.

The regional breakdown is also shown in Figure 8. It is interesting to note that East Asia and the Pacific is the region with the highest AAL for all sectors (except oil and gas), followed by North America. This reflects the recent growth in

[2] In this report we use the term absolute AAL to differentiate from the relative AAL. When the word absolute is not indicated, AAL refers to absolute AAL.

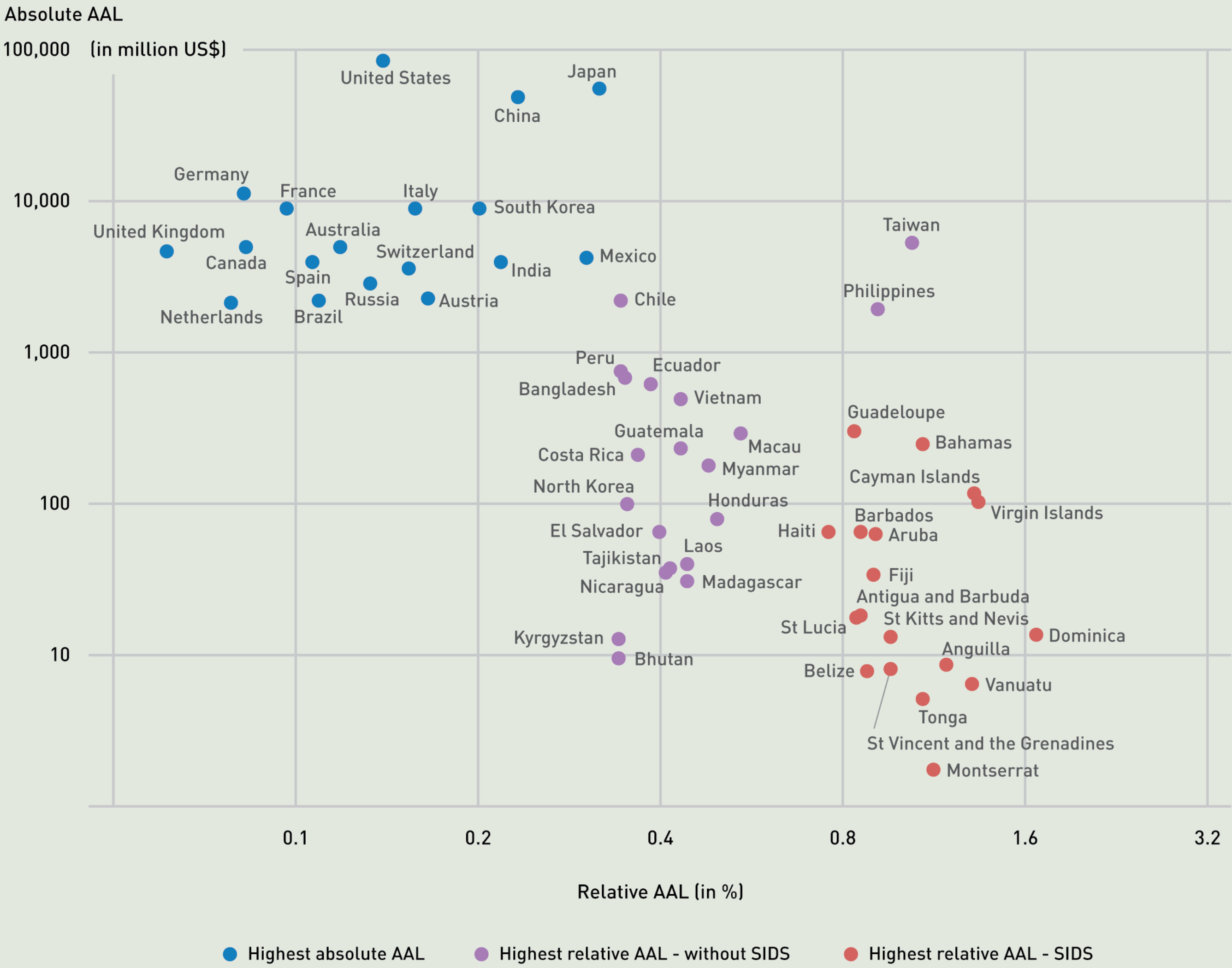


Figure 7

Absolute and relative AAL for infrastructure sectors

Source: CDRI (2023b)

infrastructure in East Asian countries, the high level of hazards in the region, and the lower resilience standards applied in past decades to infrastructure construction.

Each hazard also has an impact on infrastructure sectors in different ways. Floods and wind are associated with around two-thirds of the power sector's AAL. Wind is associated with about two-thirds of the telecommunications sector's AAL, and over half the oil and gas, and ports and airports' AAL. In contrast, landslides and earthquakes are associated with over three-quarters of the road and rail AAL, and earthquakes with around two-thirds of the water and wastewater AAL (CDRI, 2023b).

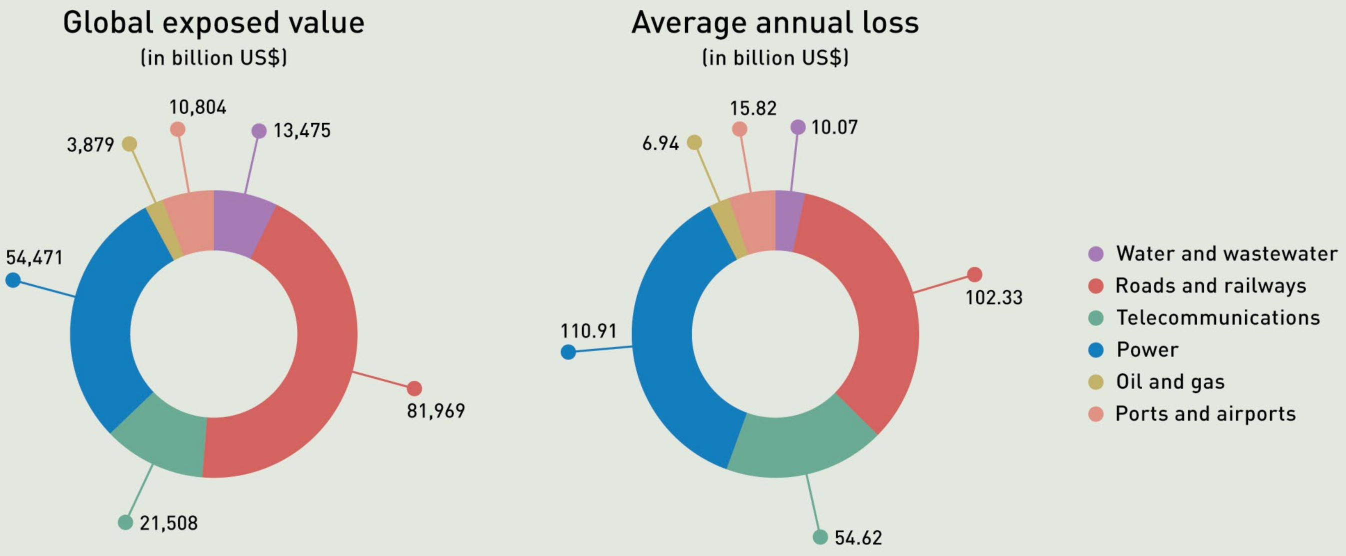


Figure 8 (top and right)

Exposed value and AAL by sector and by geographical region

Source: CDRI (2023b)

4.4 The Projected Impacts of Climate Change on Infrastructure

The GIRI model can be used to understand the impact of climate change on disaster risks. Two future climate change scenarios for 2100, one based on a lower bound of greenhouse gas emission trajectory and the other on a more carbon-intensive pathway, were used. To make the comparisons consistent, the GIRI model was run with the updated hazards for these two climate scenarios, assuming the existing stock of infrastructure (without changes to resilience or location).

Globally, 30 percent of the AAL is associated with geological hazards such as earthquakes, tsunamis, and earthquake-induced landslides, and 70 percent with climate-related hazards such as cyclonic winds, storm surges, floods, and rainfall-induced landslides, using today's conditions. While climate change is an increasing threat, geological risk cannot be ignored in many countries.

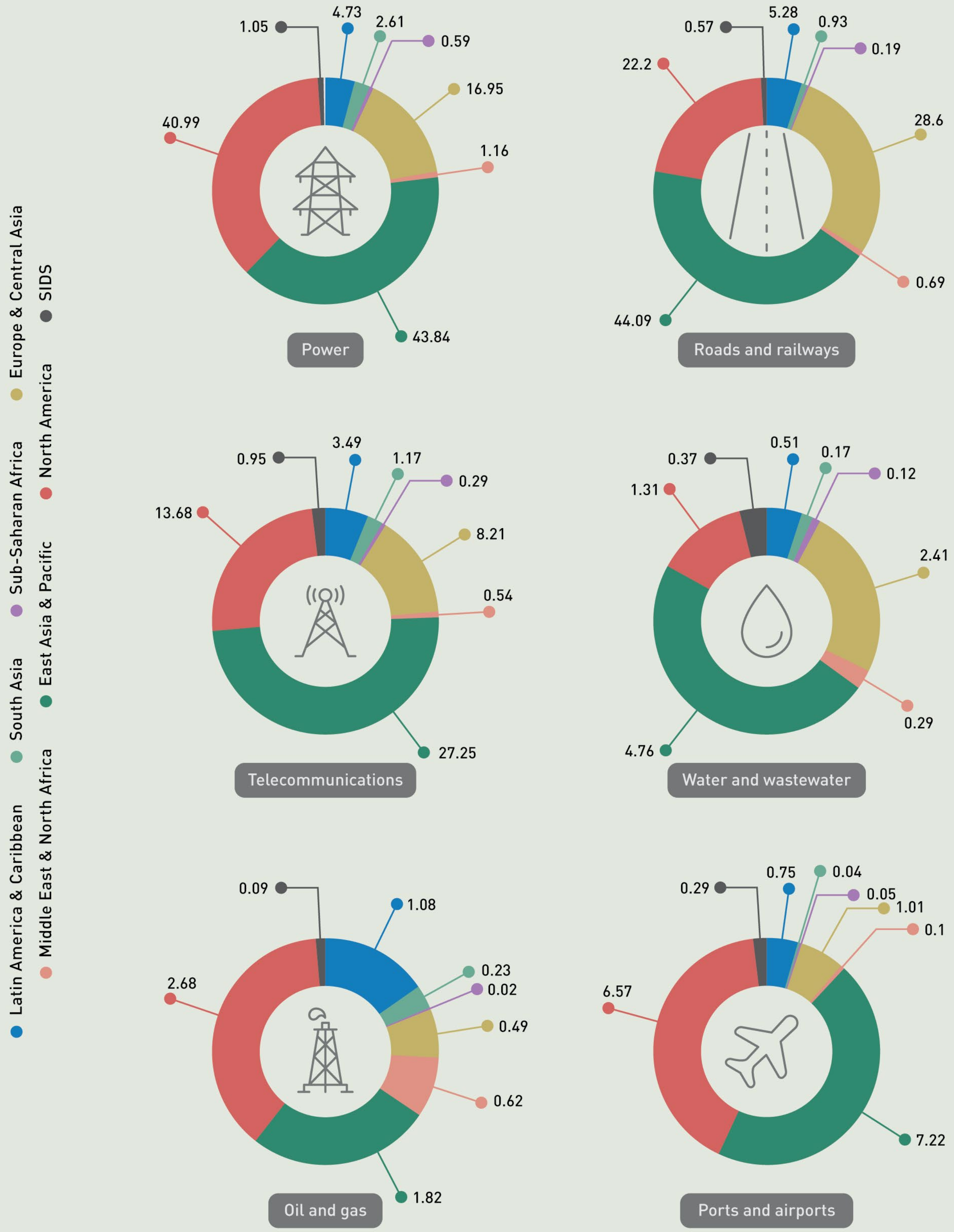
Figure 9 shows the difference between the global multi-hazard AAL for all infrastructure sectors, including buildings, by region.

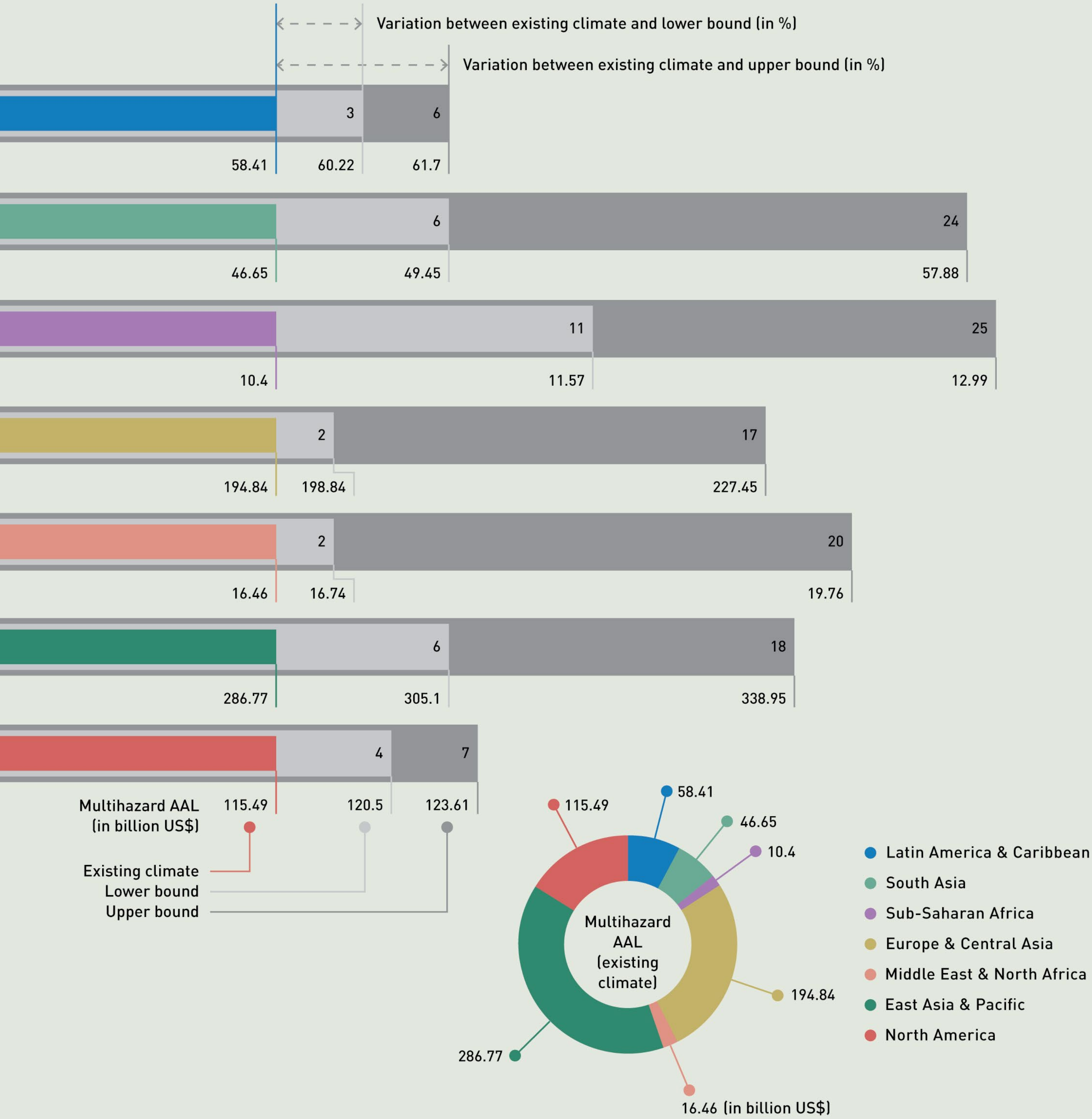
The global total infrastructure AAL, including buildings and the health and education sectors, today is about $732 billion. With climate change, this amount would increase to a range between $762-$842 billion, depending on the warming trajectory.

The regions that would see the highest increase of AAL due to climate change are Sub-Saharan Africa (11-25 percent) and South Asia (6-24 percent, depending on the climate scenario).

Absolute AAL by infrastructure sectors

(in billion US$)





Total infrastructure

Infrastructure sectors = Power; Roads and railways; Ports and airports; Water and wastewater; Telecommunications; Oil and gas.
Total infrastructure = Infrastructure sectors plus buildings, including health and education infrastructure.

Figure 9

The impact of climate change on buildings and infrastructure

Source: CDRI (2023b)

5. Infrastructure Risk Assessment in Africa

5.1 Hazards and Disasters in Africa

In addition to geological risks, such as earthquakes (for example, where the Eurasian and Nubian plates converge, or in the East African Rift System) (Global Earthquake Model, 2018) and volcanoes, Africa is subject to many climate-related hazards, including floods, cyclones, droughts, and heatwaves.

Africa today, and historically, has contributed very little to global greenhouse gas emissions. However, it is one of the most vulnerable regions to the impacts of climate change and is already suffering enormous loss and damage. Africa's economy is highly dependent on climate-sensitive sectors (e.g., agriculture, tourism, the blue economy) which all rely on infrastructure services (e.g., transport, energy, water, and sanitation) that are highly vulnerable to geological and climate-related hazards (African Union, 2022).

The Centre for Research on the Epidemiology of Disasters maintains the most comprehensive record of disasters—the EM-DAT database. The analysis of the African Risk Capacity (ARC) of this data from 2000 to 2023 shows that the central, eastern, and southern regions of Africa have seen the most disasters over this period (African Risk Capacity, 2024). The number of disasters has increased over the last decade, particularly floods, which have been amplified not only by climate change but also by an increase in exposure, with the rapid growth of urban centres, and vulnerability due to deforestation and land use change.

The last decade has seen numerous large-scale disasters with significant impacts on infrastructure and buildings, including the 2017 mudslides in Sierra Leone; cyclones Ida and Kenneth (2019) impacting Mozambique, Zimbabwe, Malawi, and Comoros; cyclones Batsirai and Emnati (2022) causing massive damage in Madagascar and Mozambique; major floods in East Africa (2018), Sudan and Sahel (2020), and Libya (2023); and the earthquake in Morocco (2022) (EM-DAT, 2025).

According to Munich Re, the total economic losses in Africa in 2023 reached $14.6 billion, with a significant portion linked to the earthquake in Morocco. In 2022, the economic losses were $10.5 billion, with the leading damages caused by floods in South Africa and Nigeria (Munich Re, 2024). ARC reviewed the government expenditures and annual budget plans for 29 African countries in 2023 and found that they spent $2.2 billion on the response and recovery of weather-related disasters. Furthermore, Burundi spent about 10 percent of its GDP responding to disasters, and Libya, Rwanda, and Mauritius spent more than 0.5 percent of their GDP in 2023. This level of expenditure sets back the development trajectory of African countries year after year (African Risk Capacity, 2024).

Climate change will exacerbate the impact of climate-related hazards in Africa. The intensity and frequency of high-precipitation rains are projected to increase almost everywhere in the region, especially in coastal areas, where a current 1-in-100-year flood will have return periods of 10-20 years by 2050, and a return period of 1-5 years by 2100, even under moderate warming (Trisos et al., 2022). The future floods will be more frequent and intense than those Africa sees today.

According to the Global Center on Adaptation (GCA), most economic analyses show that the climate change costs for Africa over the next few decades will be as high as several percent of GDP per year. These costs can rise to more than 5 percent and plausibly more than 10 percent for some countries in the longer term. Furthermore, the level of climate change and its expected impacts in Africa are locked in for the next 20 years regardless of action on greenhouse gas emissions today. Therefore, decisive action on resilience to today's climate-related disasters and adaptation to tomorrow's damages is an imperative for the region (GCA, 2021).

One of the most important actions that can be taken to strengthen the resilience and adaptation of African countries is the development and implementation of early warning systems. The UN defines an early warning system (EWS) as: "An integrated system of hazard monitoring, forecasting and prediction, disaster risk assessment, communication and preparedness activities systems and processes that enables individuals, communities, governments, businesses and others to take timely action to reduce disaster risks in advance of hazardous events." (Sendai Framework Terminology).

A multi-hazard early warning system (MHEWS) is designed to address several hazards at the same time, taking into account potential interrelated effects among them. According to the UNDRR and WMO, in Africa in 2022, only 20 countries (or 45 percent of countries reporting on the status of an MHEWS) had an MHEWS. This is substantial progress compared to 2015, when only nine countries (20 percent) had an MHEWS in place (UNDRR and WMO, 2023). Timely dissemination of early warnings followed by prompt decision making by infrastructure agencies can help reduce the damage to infrastructure assets and losses incurred by disruption of services.

In 2022, the UN Secretary-General launched the EW4All Initiative to develop and implement multi-hazard early warning systems worldwide by the end of 2027. The Action Plan for Africa (2023-2027) was developed to support the achievement of full EWS coverage for the region. The plan builds upon existing regional EWS efforts and provides a platform for countries and stakeholders to address weather, water, and climate service-related opportunities (WMO, UNDRR, African Union, ITU, IFRC, 2023).

5.2 Infrastructure Risks in Africa

Although historical data on the impact of disasters is very important for planning and improvement processes to enhance resilience—governments and other stakeholders need better information on the average expected losses they will incur due to damage and destruction of infrastructure assets.

CDRI's GIRI model is a probabilistic model that uses global databases of hazards, exposure, and vulnerability of infrastructure assets and buildings to estimate key financial indicators such as the average annual loss (AAL) and the probable maximum loss (PML) that are invaluable in evaluating the contingent liabilities that African countries may face year after year due to impact of disasters and climate change.

This section presents the results of the GIRI model described in Section 3 when applied to the Africa region. See Annex 1 for a list of the subregional groupings used in the analysis.

Considering current climate conditions, the present quantity and location of infrastructure assets, and their associated hazards, exposure, and vulnerability, the GIRI model calculates the multi-hazard AAL value. The model considers the key hazards that impact African nations: earthquakes, floods, cyclonic storms, storm surges, landslides, and tsunamis. The model also considers the main infrastructure sectors, grouped in the following categories: water and wastewater; telecommunications; roads and railways; power; ports and airports; and oil and gas. In addition, the model considers risks to buildings (residential and commercial) as well as health and educational facilities.

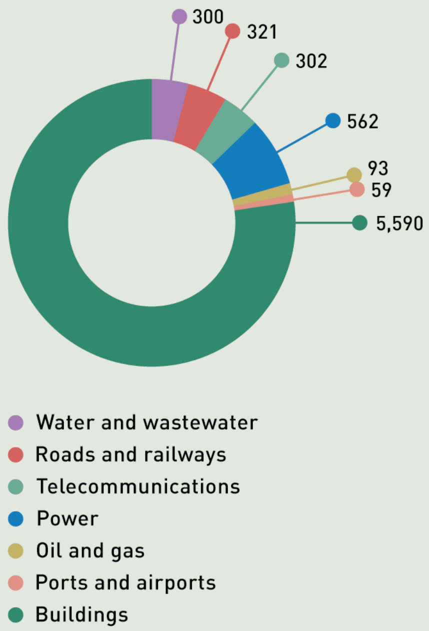


Figure 10

Total exposed value of infrastructure sectors and buildings in Africa ($ billion)

5.2.1 Average Annual Losses of Infrastructure Assets in Africa

The first step in the GIRI model calculation is to understand the value of exposed assets in the African region. **Figure 10** presents the total exposed value of infrastructure assets grouped by the sectors described above, plus buildings.

In Africa, the highest estimated total value of infrastructure assets corresponds to the energy sector at $562 billion, followed by roads and railways at $321 billion, telecommunications at $302 billion, and water and wastewater at $300 billion.

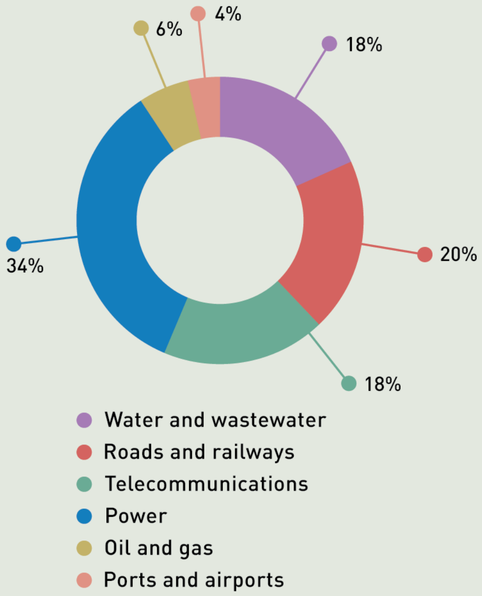


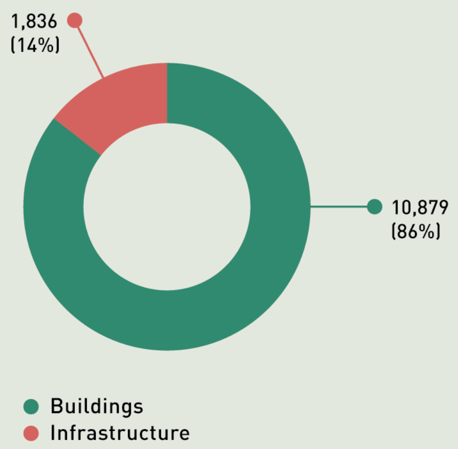
Figure 11

Exposed value of infrastructure sectors in Africa (%)

Figure 11 presents the relative importance of infrastructure sectors based on their asset value, with energy at the top (including generation, transmission, and distribution assets) with 34 percent of total infrastructure assets, followed by roads and railways, telecommunications, and water and wastewater, each with around 20 percent of the total regional assets.

The next step in the GIRI model is to use probabilistic calculations to combine the hazard information in the region, the asset location and value, and the vulnerability curves (connecting hazard intensity with asset damage) to calculate AAL (see Section 3 for a description of how the GIRI model does the estimations). **Figures 12 and 13** present the AAL for Africa for all infrastructure sectors and buildings, and the percentage values of AAL only for infrastructure sectors. The AAL is a useful general indicator that can inform decision makers at the Ministry of Finance and the respective infrastructure agencies of what they can expect to see, on average, as direct losses due to damage to infrastructure assets from all types of hazards.

In Africa, as buildings correspond to a larger proportion of assets at the regional level, and given their higher vulnerability to disasters, the estimated AAL is about $11 billion or 86 percent of total infrastructure losses. As residential buildings, both formal and informal, are one of the most important assets of families, these losses have a significant impact on livelihoods. It is important to note that these losses are not only caused by floods and cyclones but also by earthquakes, that are less frequent but far more devastating.



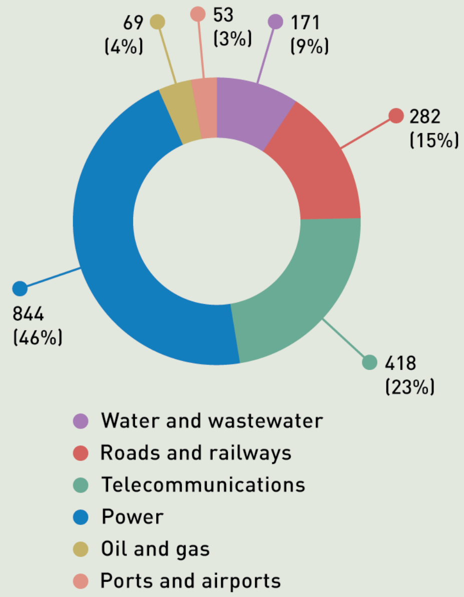


Figure 12

AAL for infrastructure and buildings in Africa ($ million)

Figure 13

AAL of infrastructure sectors for Africa ($ million)

Among the infrastructure sectors, the estimated AAL of the power sector is the largest at 46 percent ($844 million), followed by telecommunications at 23 percent ($418 million) and roads and railways at 15 percent ($282 million). The respective infrastructure agencies should consider these amounts as contingent liabilities that will occur, on average, every year, and consider the necessary financial and insurance measures to absorb them. In addition, resilience building measures and retrofitting programmes will reduce these annual estimated losses.

It is important to note that AAL is different from worst-case disasters. In any given year in a country, extensive floods can cause losses that are several times larger than the AAL. Conversely, there are many years when a specific country does not suffer disasters, and the AAL considers such a probabilistic distribution.

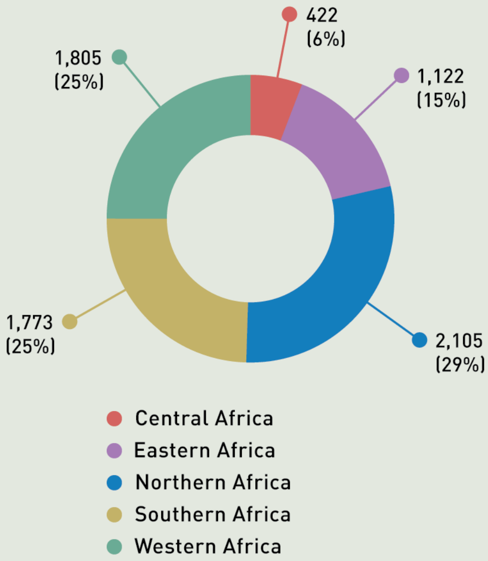


Figure 14

Regional exposed value of total infrastructure in Africa ($ billion)

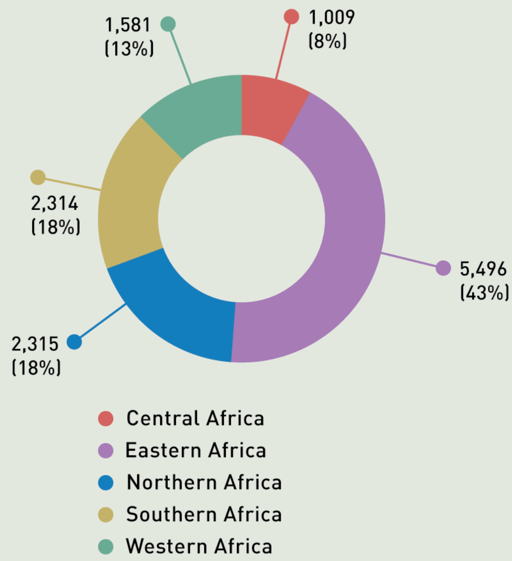


Figure 15

AAL of infrastructure sectors in Africa, by region ($ million)

5.2.2 Regional Distribution of Disaster Impacts

One of the advantages of the GIRI model is that it is built from the bottom up, considering individual infrastructure assets. This approach allows results to be aggregated by sector, subregion, hazard, and many other criteria.

Figures 14 and 15 break down the regional exposed value of total infrastructure assets (infrastructure sectors and buildings) and the AAL by regional country groupings (Northern, Western, Central, Eastern, and Southern Africa—see Annex 1 for country lists).

Northern Africa, with large economies, has the largest total infrastructure values, with 29 percent of the region, followed by Southern and Western Africa, with about 25 percent each. Correspondingly, the largest calculated AAL by region is in Eastern Africa at 43 percent of the Africa region ($5.5 billion) due to higher exposure and vulnerability. Southern and Northern Africa follow with about 18 percent of regional values, and then Western and Central Africa, with 13 and 8 percent of regional AAL, respectively.

It is also possible to study the subregional distribution of AAL values for each infrastructure sector, as shown in **Figure 16**. For example, the AAL for ports and airports in Western Africa is much higher than in other regions, as is the AAL for oil and gas infrastructure in Northern Africa. Generally, Northern and Southern Africa, with their larger stock of infrastructure have higher levels of AAL for most sectors.

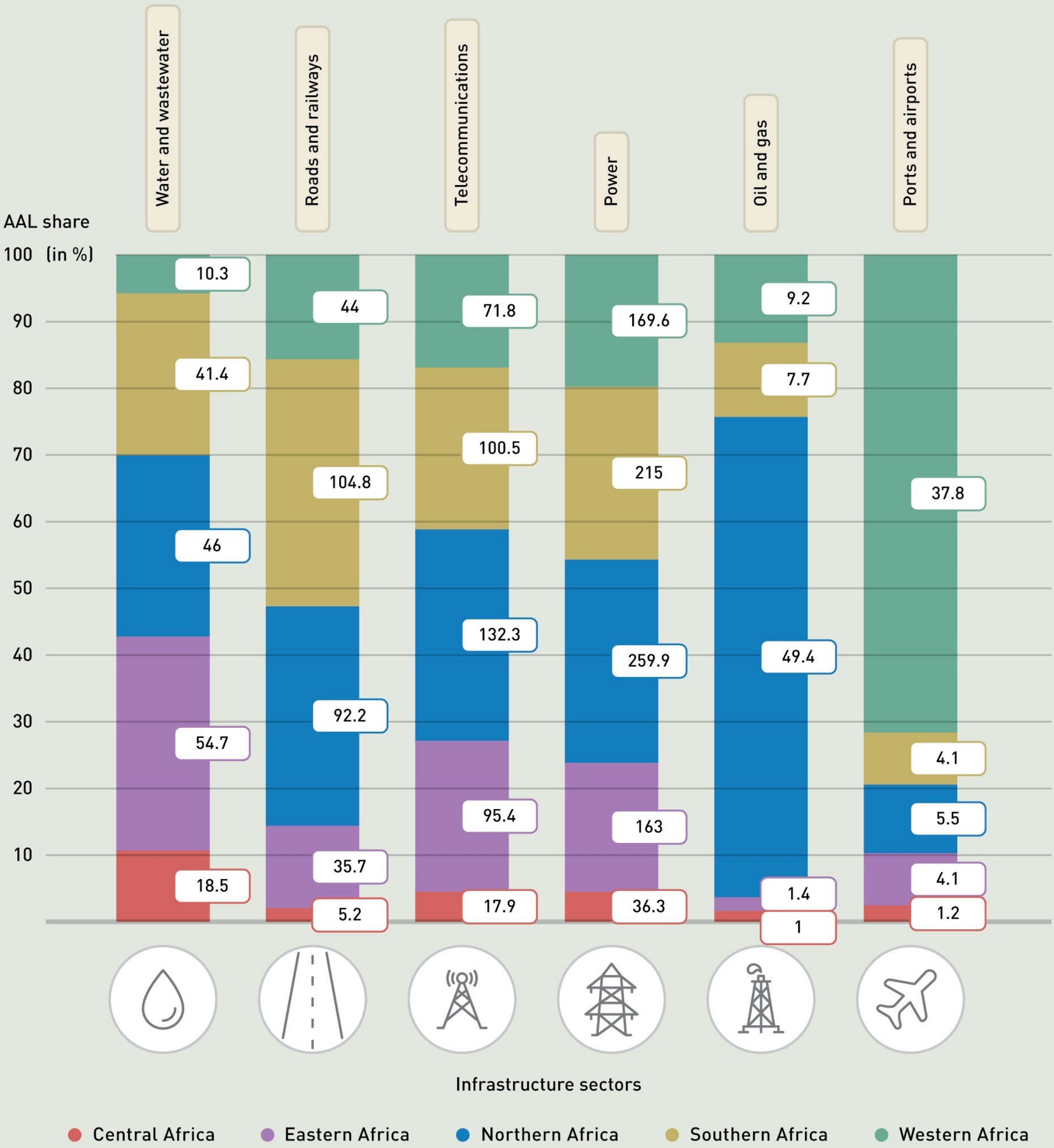
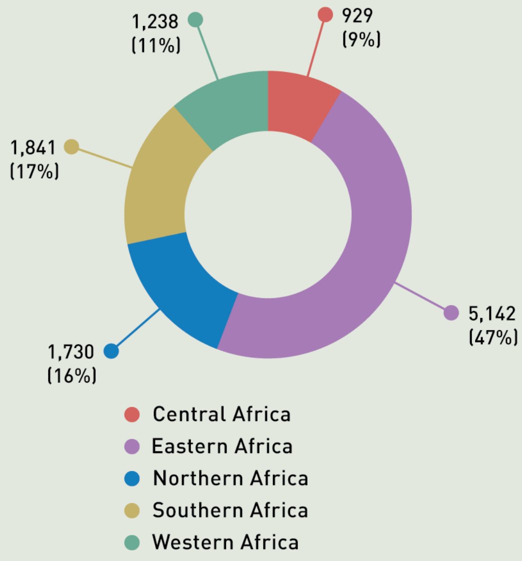


Figure 16

AAL by infrastructure sectors in Africa, disaggregated by region ($ million)



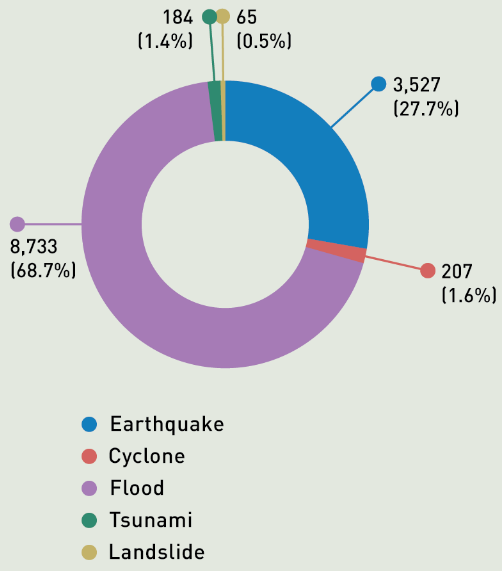


Figure 17

AAL for buildings in African regions ($ million)

Figure 18

AAL of infrastructure sectors and buildings in Africa, by hazard type ($ million)

A similar subregional analysis can be done for the AAL of buildings (residential, commercial, health, and education). **Figure 17** shows the AAL for each subregion. Eastern Africa has the largest share of regional AAL due to the much higher earthquake risk and the consequences on buildings with subpar construction quality and standards. Southern and Northern Africa follow with about 17 percent and 16 percent of the regional AAL, corresponding to approximately $1.8 billion and $1.7 billion, respectively.

The GIRI model results can also be aggregated by hazard type for all infrastructure sectors in Africa. **Figure 18** presents the AAL by hazard type for all infrastructure sectors plus buildings. Floods are the most dangerous hazard for infrastructure and buildings in Africa, with close to 69 percent of AAL, followed by earthquakes with about 28 percent. Unfortunately, the low frequency of earthquakes sometimes leads governments and residents to forget about them and pay less attention to the resilience of infrastructure and residential resilience standards. Figure 18 shows regional averages. Every country will have a different distribution with some countries being more affected by cyclones and others having higher AAL values associated with earthquakes.

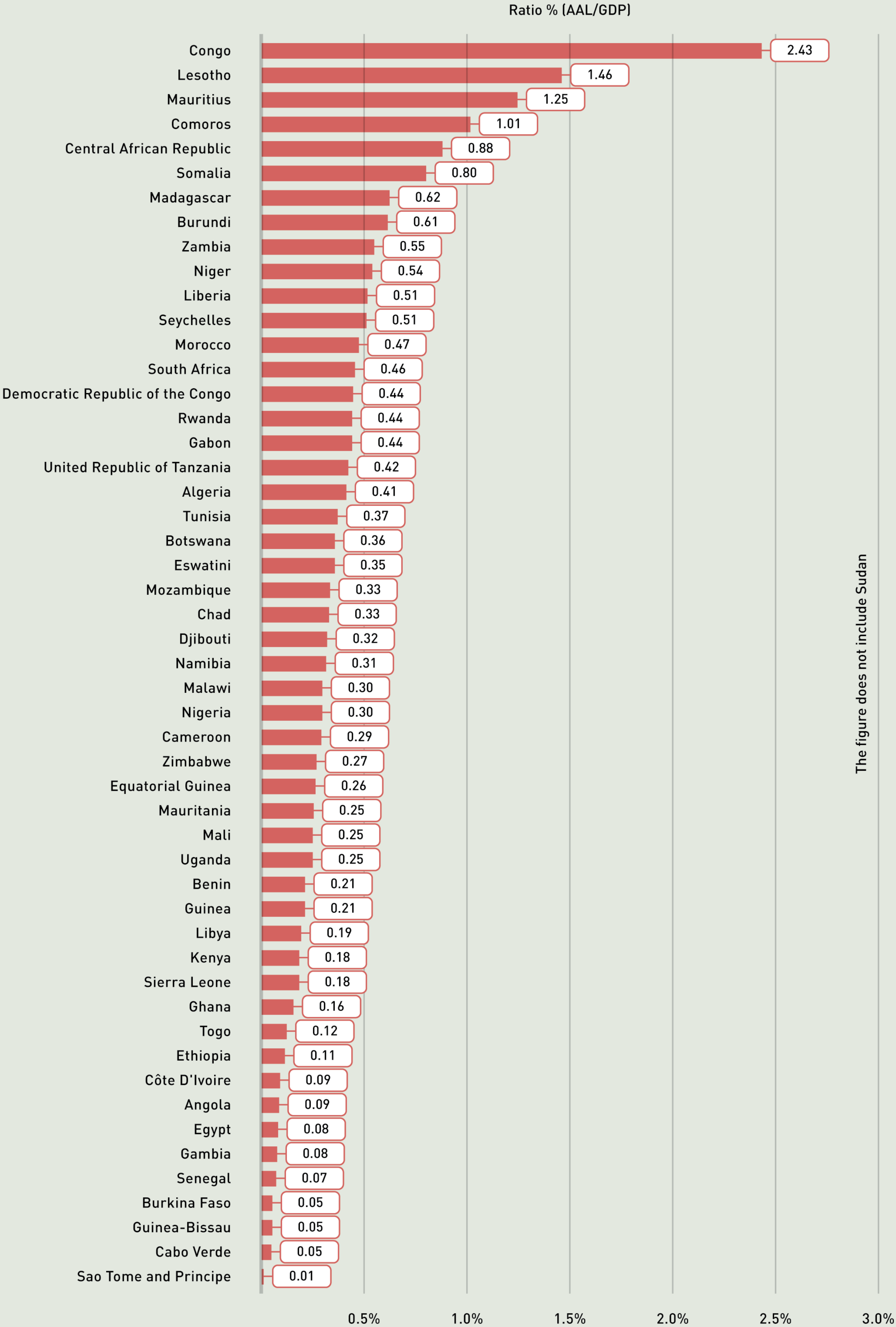
5.2.3 Impact on African Economies

In addition to the absolute value of AAL, it is helpful to analyse the relative AAL. The relative AAL is defined as the ratio between the absolute AAL and the total value of assets. Countries with a lot of infrastructure assets (e.g., extensive road and power distribution networks, numerous airports and ports, and full coverage of water and wastewater networks) tend to have high values of AAL (if they face significant hazards). Many countries with fewer infrastructure assets and high exposure to hazards may have smaller values of absolute AAL but very high values of relative AAL. This means that when disasters occur, a higher proportion of their infrastructure assets are damaged, and the relative impact to the economy is much larger.

Figure 19 shows the plot distribution (in log-log axes) of absolute AAL and relative AAL. Figure 7 in Section 4.2 shows the global plot.

Figure 19

Plot distribution (in log-log axes) of absolute AAL ($ million)



Ratio % (AAL/GDP)
Congo 2.43
Lesotho 1.46
Mauritius 1.25
Comoros 1.01
Central African Republic 0.88
Somalia 0.80
Madagascar 0.62
Burundi 0.61
Zambia 0.55
Niger 0.54
Liberia 0.51
Seychelles 0.51
Morocco 0.47
South Africa 0.46
Democratic Republic of the Congo 0.44
Rwanda 0.44
Gabon 0.44
United Republic of Tanzania 0.42
Algeria 0.41
Tunisia 0.37
Botswana 0.36
Eswatini 0.35
Mozambique 0.33
Chad 0.33
Djibouti 0.32
Namibia 0.31
Malawi 0.30
Nigeria 0.30
Cameroon 0.29
Zimbabwe 0.27
Equatorial Guinea 0.26
Mauritania 0.25
Mali 0.25
Uganda 0.25
Benin 0.21
Guinea 0.21
Libya 0.19
Kenya 0.18
Sierra Leone 0.18
Ghana 0.16
Togo 0.12
Ethiopia 0.11
Côte D'Ivoire 0.09
Angola 0.09
Egypt 0.08
Gambia 0.08
Senegal 0.07
Burkina Faso 0.05
Guinea-Bissau 0.05
Cabo Verde 0.05
Sao Tome and Principe 0.01
0.5%
1.0%
1.5%
2.0%
2.5%
3.0%
The figure does not include Sudan

Figure 20 (left)

AAL as percentage of GDP in Africa (2023)

This figure shows that small island nations in Africa, such as São Tomé and Príncipe and Cabo Verde, have lower values of absolute AAL but much higher values of relative AAL. This means that the impact of disasters on their infrastructure systems and the economy in general is much higher, even if the total average losses are relatively small when compared to other countries. On the other side of the spectrum, large countries with higher GDP per capita, like Egypt, South Africa, or Nigeria have much larger values of absolute AAL, but smaller values of relative AAL, meaning that the impacts of individual average disasters are not as large on the system and the economy compared to smaller countries with less extensive infrastructure assets and networks.

Another way to look at the significance of AAL values for different countries is to compare AAL against the country's GDP, as shown in **Figure 20**. Countries such as Congo, Mauritius, the Central African Republic, and Madagascar have calculated AAL on their infrastructure and buildings above 0.8 percent of their GDP. Enhancing the resilience and climate adaptation of infrastructure assets and buildings in these countries would reduce the very large contingent risk their economies face from potential disasters. It is important to emphasize that these values are averages over a probabilistic distribution. In a given year, a large disaster can overwhelm the economy, and other financial indicators calculated by GIRI, like the probable maximum loss, can complement the analysis of risks to the economy.

Finally, the GIRI model has been used to calculate the AAL for groups of countries with varying income levels, utilizing the World Bank's categorization. **Figure 21** shows the total AAL for countries ranging from high income to low income. Low-income countries account for approximately 58 percent of the total regional AAL, while lower-middle-income countries comprise about 38 percent of the AAL for the African region. The economic burden on low-income countries in these areas due to the impacts of disasters on infrastructure with insufficient resilience is enormous.

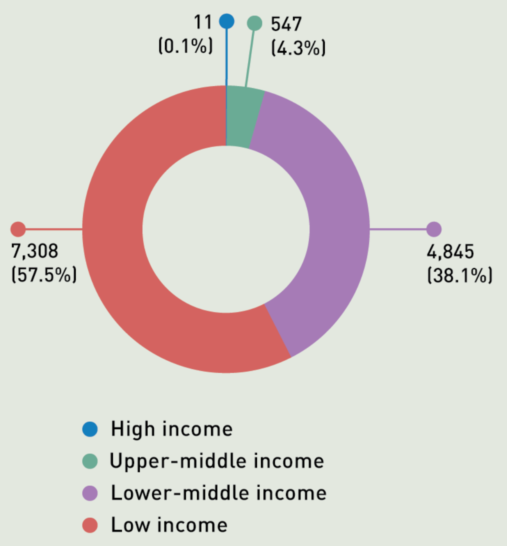


Figure 21

AAL for infrastructure sectors and buildings for high- to low-income countries in Africa ($ million)

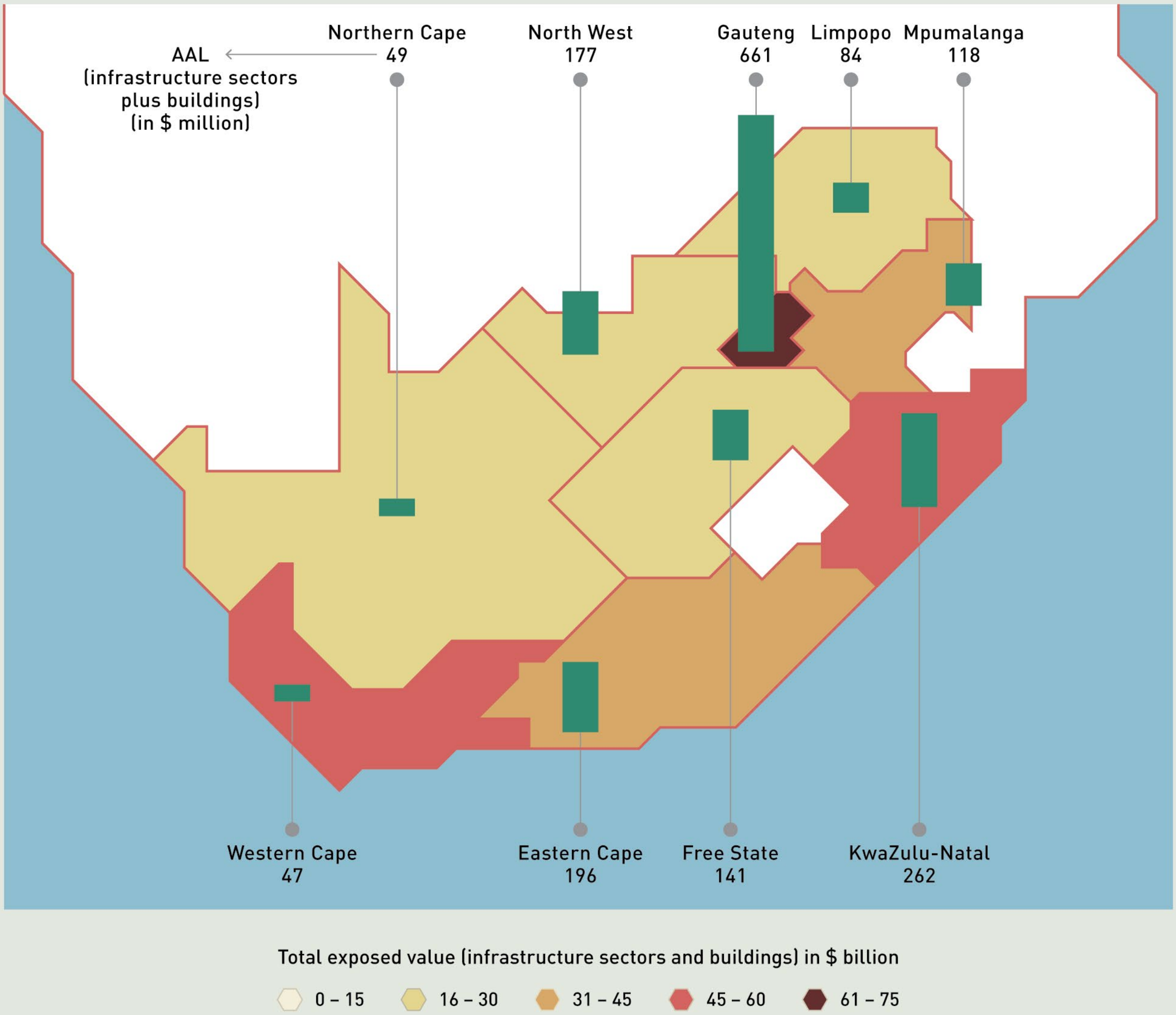


Figure 22

Total exposed value of infrastructure and buildings for provinces in South Africa ($ billion)

5.2.4 Infrastructure Losses Due to Disasters at the Subnational Level

The modelling approach of GIRI enables the disaggregation of results at the subnational level (provinces or states) to understand variations in parameters, such as average annual losses, across infrastructure sectors or caused by different hazards. The results are helpful in understanding the disaster risk characteristics and variations across subnational entities. This information can be used, as a first-order overview, in the following ways:

- Ministries of finance can understand the regional variations in the level of contingent liabilities linked to disasters impacting existing infrastructure in subnational entities.
- Infrastructure agencies can use this information to complement the inputs for their preparedness plans and retrofit programmes.
- Disaster risk management agencies can incorporate these results to plan, in targeted ways, the response to disasters and their damage to infrastructure, as provinces have different levels of AAL in absolute and relative terms.

Many countries have more detailed data than that available in global databases used in the GIRI model. Local practitioners and researchers have a deeper understanding of the vulnerability of infrastructure and building assets in various subnational areas, encompassing factors such as construction quality and age distribution. This information can be used in the GIRI model to provide more refined estimates of financial parameters. The upcoming *GIR 2025* report presents examples of these refined modelling exercises in several countries.

In Africa, for this working paper, CDRI has calculated the impact of infrastructure damage caused by disasters at the subnational level in Egypt, Nigeria, and South Africa. This section provides highlights of this analysis.

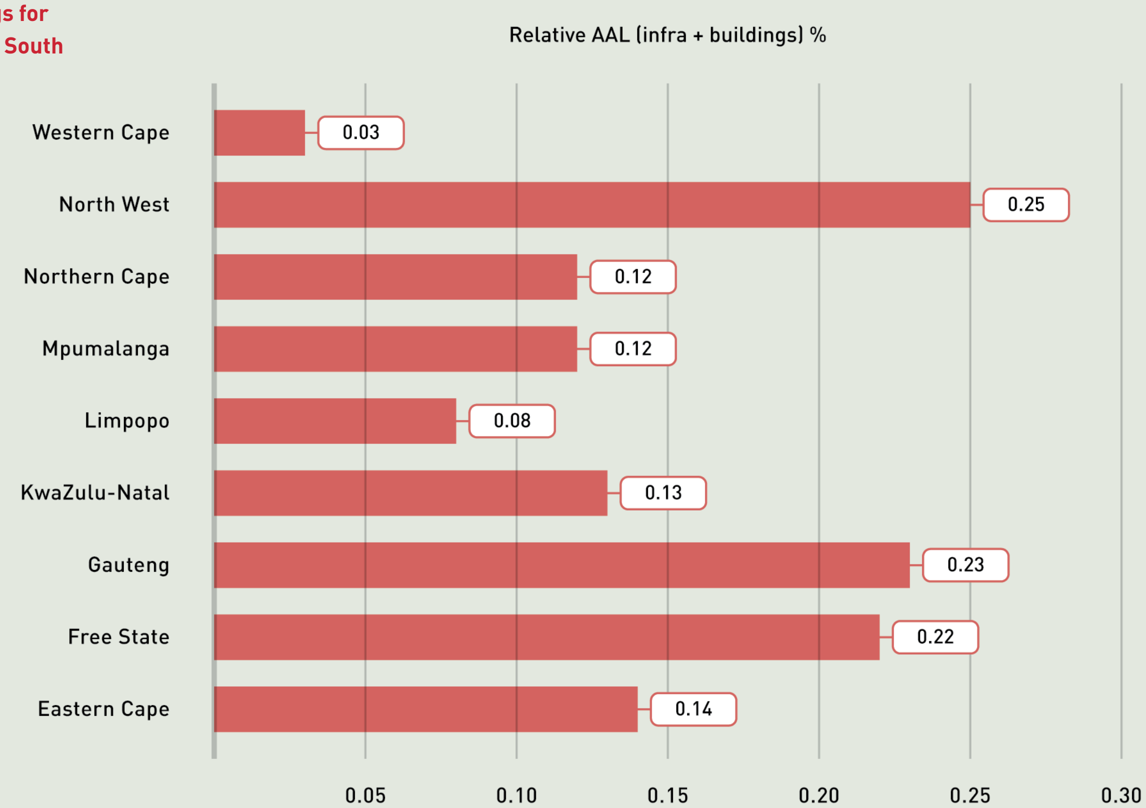
As discussed earlier in this working paper, the GIRI model is used to calculate the value of infrastructure assets for each subnational entity, estimate the AAL, and compute the relative AAL (as the ratio of AAL over the value of assets). **Figure 22** shows the results of these calculations for the provinces of South Africa.

The colour scheme in Figure 22 represents the total exposed value of infrastructure assets for the sectors analysed, plus buildings. This value ranges from $25 billion for Northern Cape Province to more than $72 billion for Gauteng. The bars in Figure 22 represent the AAL calculated for each province, considering all infrastructure sectors and buildings. The AAL values range from $47 million in Western Cape to $661 million in Gauteng. The total AAL for the country comes to about $1.7 billion. This is an important contingent liability for the country and represents the approximate amount that, on average, South Africa would see in damage to its infrastructure and buildings from disasters on an annual basis.

Figure 23 shows the relative AAL for each province in South Africa for all infrastructure sectors plus buildings. Provinces with higher relative AAL (like North West, Gauteng, and Free State) would see, on average, proportionally higher impacts on their infrastructure and building stock from disasters.

Figure 23

Relative AAL for infrastructure and buildings for provinces in South Africa (%)



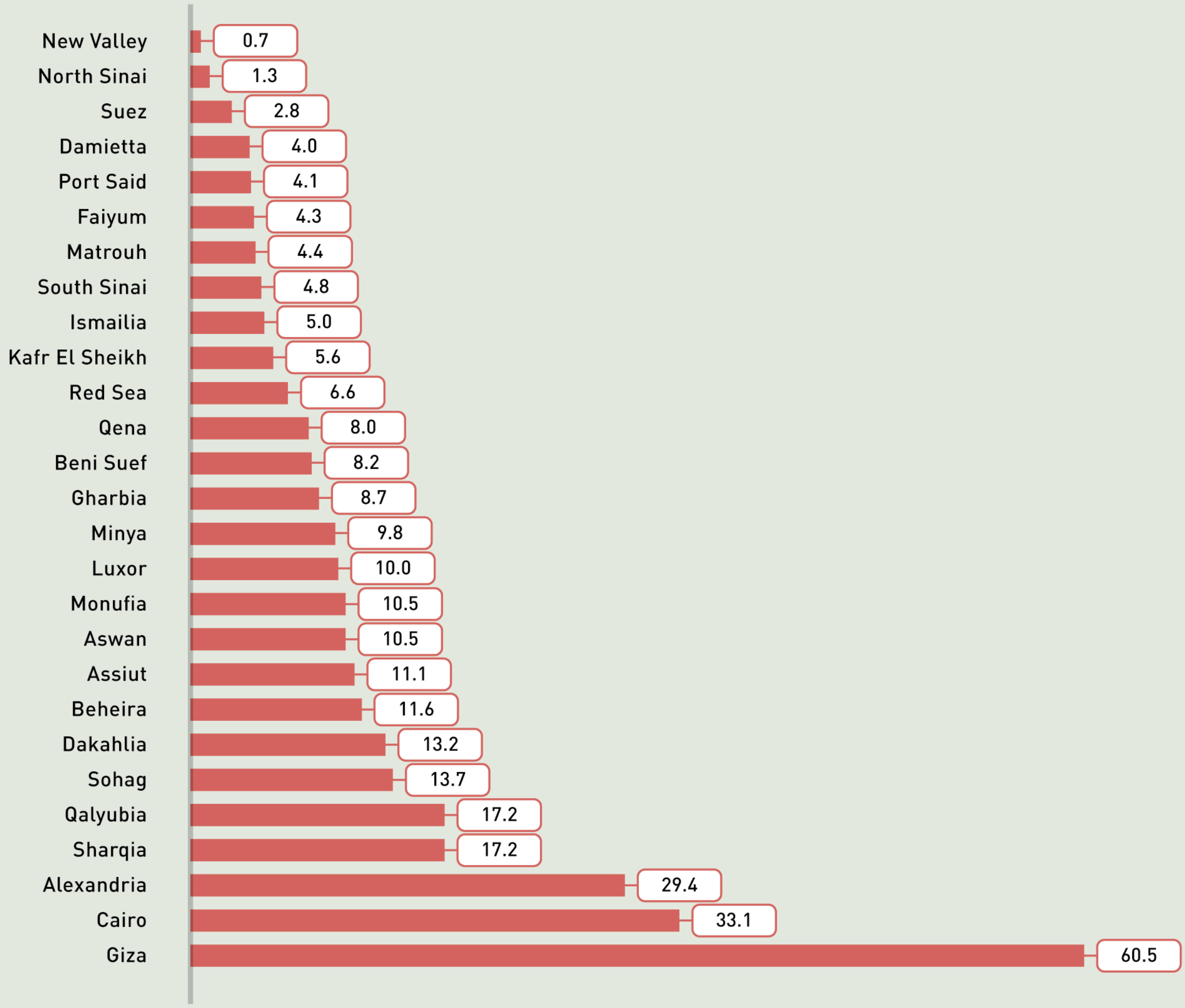


Figure 24

AAL for infrastructure and buildings for governorates in Egypt ($ million)

Similar analyses were conducted at the subnational level for governorates in Egypt and provinces in Nigeria. **Figures 24 and 25** show the distribution of AAL for all infrastructure sectors and buildings for subnational divisions (governorates and provinces) in Egypt and Nigeria, respectively. In Figure 24, the length of the horizontal bars for each province represents the individual AAL for Egyptian governorates. In Figure 25, the area of the rectangle represents the individual AAL for each Nigerian province. These calculations provide estimates of what each subnational government level may face, on an average basis, due to damage to infrastructure and buildings by disasters.

As the GIRI model calculates the AAL from the bottom up, it is possible to estimate the AAL for each infrastructure sector by province. **Figure 26** illustrates the AAL for each infrastructure sector, broken down by province in South Africa. **Figure 27** shows the same AAL for each province divided by infrastructure sectors.

Note: The area of each rectangle represents the AAL of the province; larger rectangles indicate higher AAL values.

Figure 25

AAL for infrastructure and buildings for provinces in Nigeria (area represents $ million)

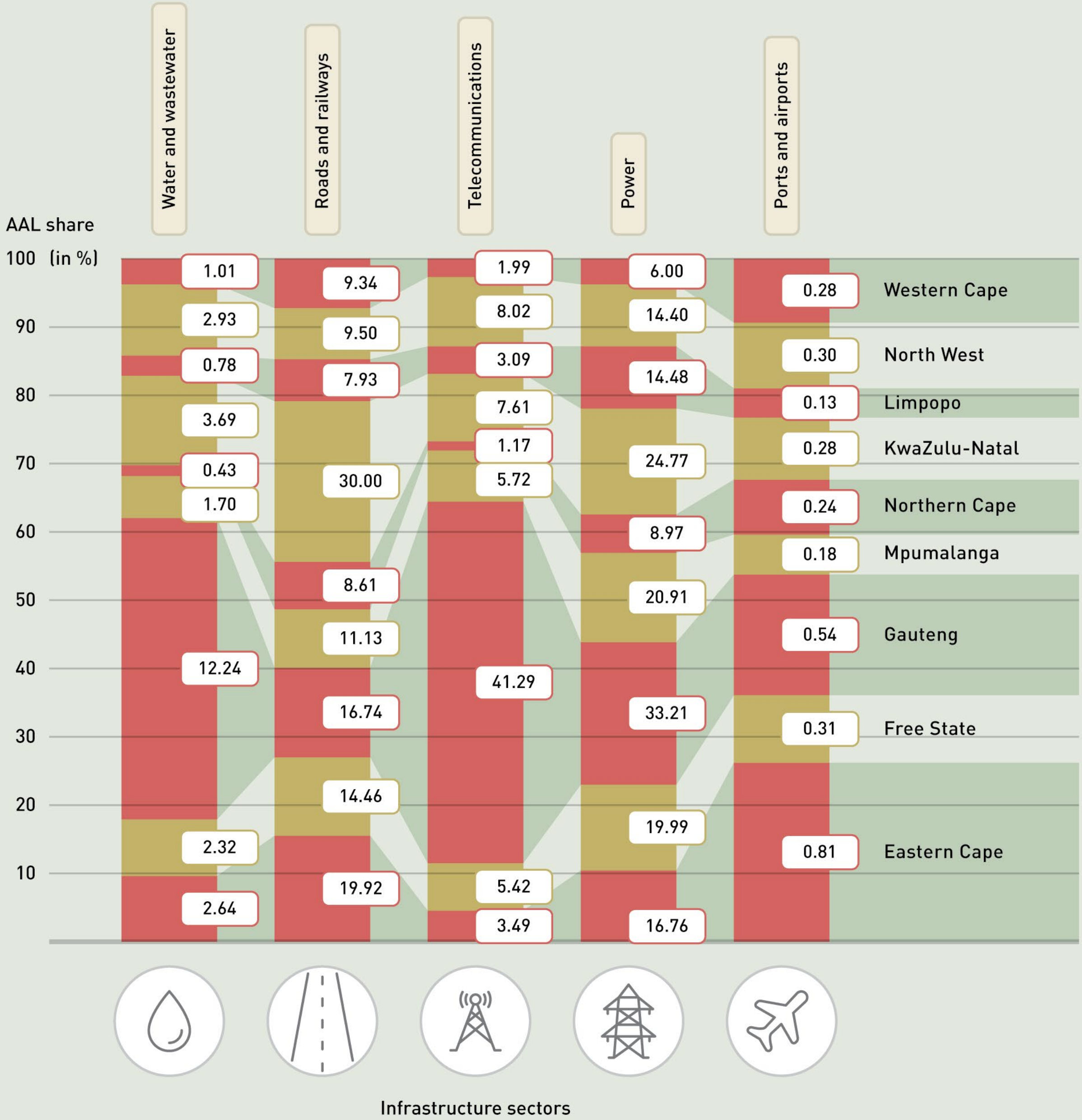


Figure 26

AAL for each infrastructure sector by province in South Africa ($ million)

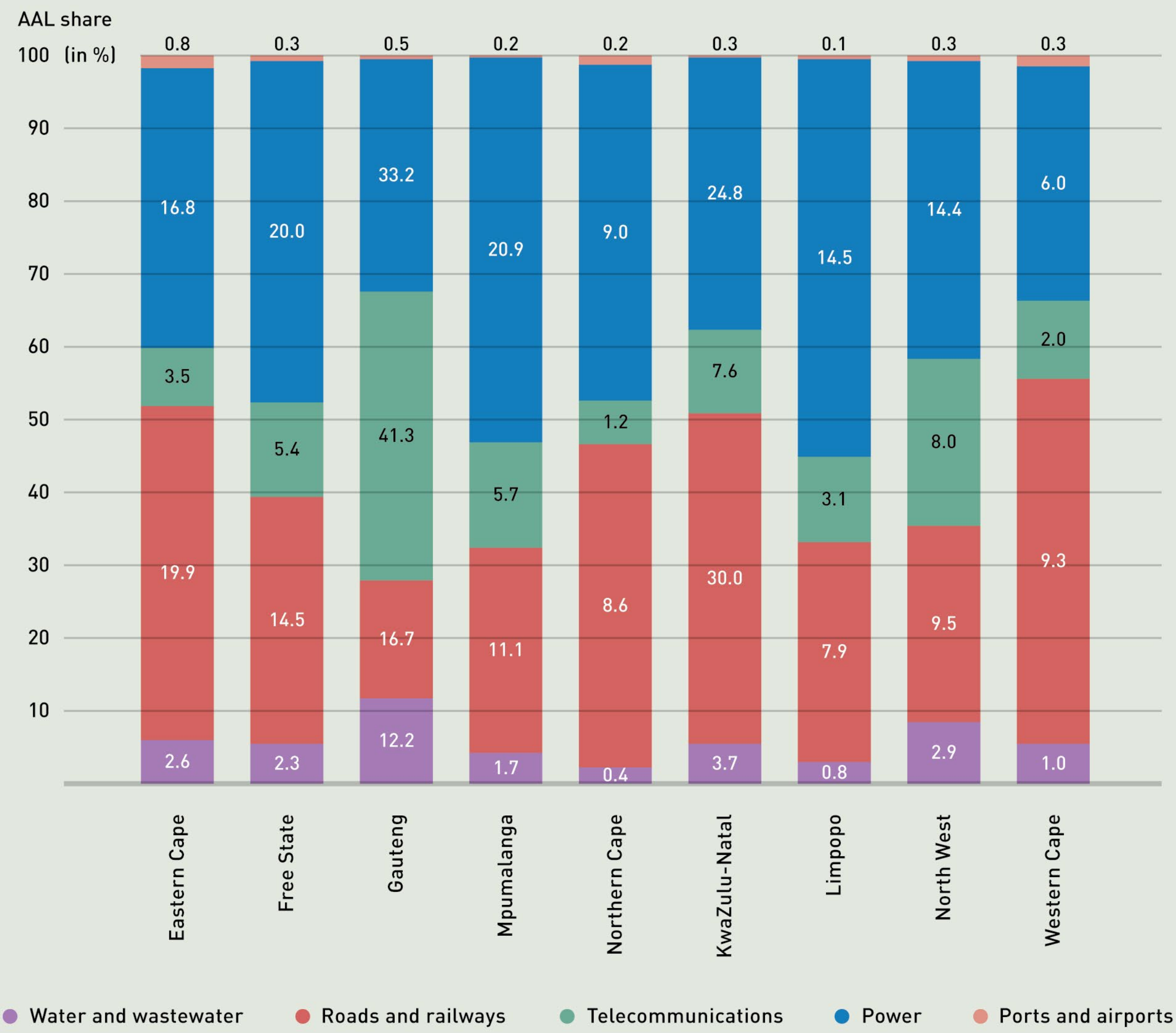


Figure 27

AAL for each province by infrastructure sector in South Africa ($ million)

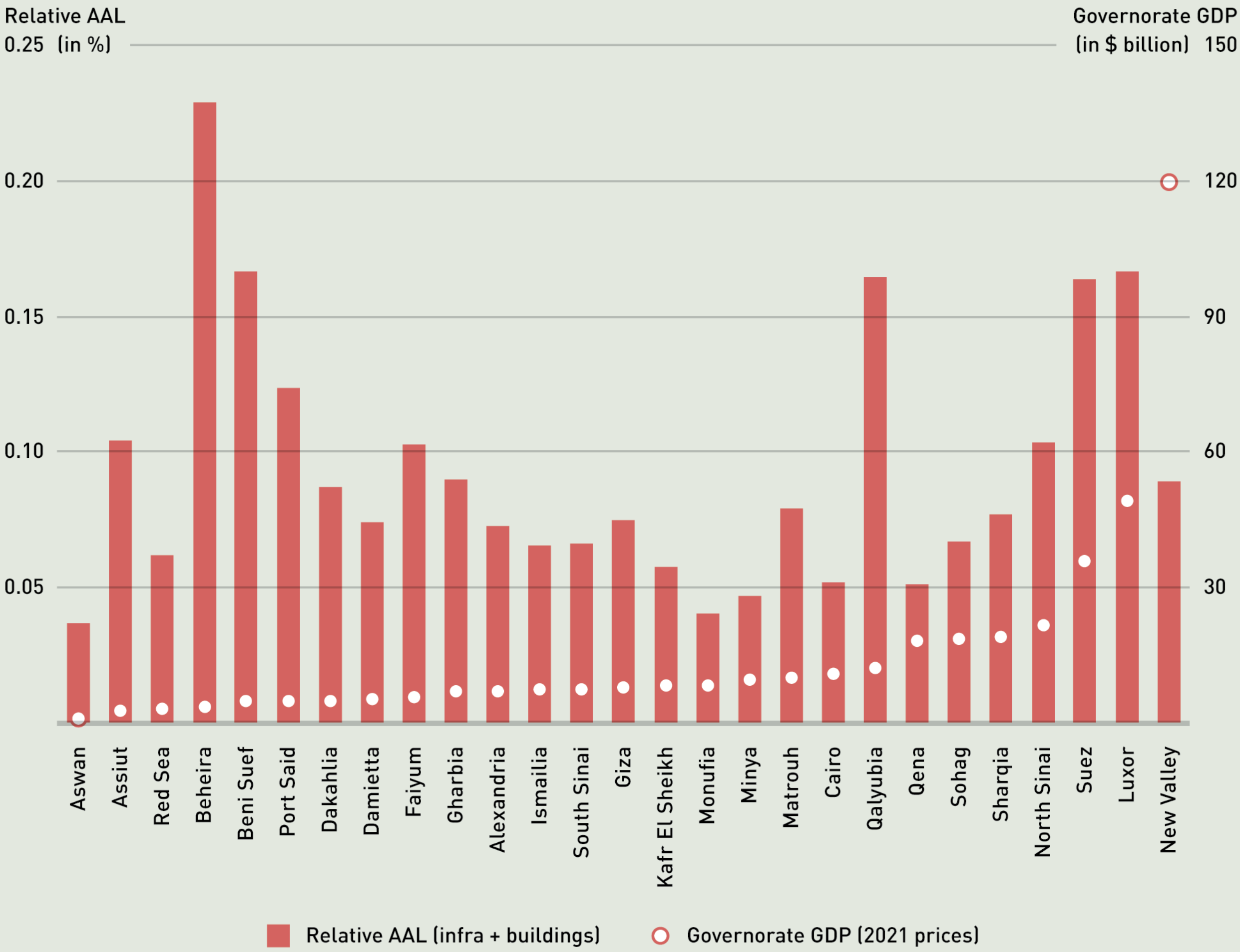


Figure 28

Relative AAL and GDP for governorates in Egypt

The GIRI model results also allow for a comparison of relative AAL (the ratio of absolute AAL for infrastructure sectors and buildings divided by the value of infrastructure and building assets) by province. **Figure 28** shows the distribution for Egypt. Provinces with lower GDP (on the left-hand side) have a generally higher relative AAL because they have less infrastructure coverage, and disasters proportionally impact them more. Provinces with higher GDP (on the right-hand side) also have higher relative AAL because they face more coastal flooding risks in urban areas.

6. Infrastructure Sector Challenges and Solutions

This section presents examples of the enormous challenges that disasters pose to Africa's infrastructure. It also discusses the growing impacts of more frequent and intense climate-related disasters on infrastructure assets and services. The section reviews the transport, energy, and urban sectors. It concludes with a review of financial flows for climate adaptation.

6.1 Infrastructure in Africa

Infrastructure is a key factor in the economic development and well-being of Africa. The Sustainable Development Goal (SDG) 9 addresses infrastructure specifically, but infrastructure services are indispensable to make progress in all 17 SDGs and 121 of the 169 SDG targets (72 percent) (Thacker et al., 2019).

African governments are making substantial efforts to expand infrastructure services. Approximately $80 billion is invested in infrastructure every year. However, the needs are enormous, and the gap, according to the Africa-Europe Foundation, could be as much as $90 billion per year (Africa Europe Foundation, 2025).

The infrastructure gaps in Africa are substantial. Approximately 660 million people lack access to electricity, with the majority residing in rural areas. Some countries, such as Egypt and Tunisia, have near-universal access. Others, such as the Democratic Republic of the Congo (DRC) and Burundi, have electricity access rates below 25 percent (IEA, 2025).

About 300 million people live more than two kilometres away from an all-season road (Briceno-Garmendia and Foster, 2010). In Sub-Saharan Africa, only 43 percent of roads are paved, and a little less than one-third of these paved roads are in South Africa (CGDEV, 2024).

Less than 30 percent of the population in Sub-Saharan Africa has access to safely managed drinking water, according to WHO and UNICEF. Over 354 million people in the region still practice open defecation due to insufficient sanitation infrastructure (WHO and UNICEF, 2024).

The commitment of African governments to expand infrastructure services and support the investments needed is attracting the private sector. According to the World Bank's most recent figures, in 2023, Africa saw $3.5 billion in infrastructure investment deals involving the private sector. This portfolio included 66 new projects across the continent (World Bank, 2024).

According to McKinsey, this level of private sector investment in infrastructure could be even more substantial with larger deal pipelines, higher-quality long-term master plans, stronger feasibility studies, and faster approval of licenses and permits (McKinsey, 2020).

6.2 Transport

Transport in Africa is one of the most affected infrastructure sectors by disasters—both geological and climate-related.

Roads (paved and unpaved) are affected by: washaways and overtopping due to floods; increased roughness of the road surface caused by large precipitation in unpaved roads; and high moisture content in subgrade layers affecting the stability of paved roads; blockages and damage by landslides; and, in some countries, cyclonic storms and storm surges (World Bank, 2017).

According to GCA, based on estimates from the Programme for Infrastructure Development in Africa (PIDA), Sub-Saharan Africa needs approximately $2 billion per year to repair the damage caused by weather-related disasters to roads and bridges, even without considering the impacts of climate change. If these are added, under a high-warming scenario, the cost will increase to approximately $7.4 billion per year (GCA, 2021).

Furthermore, weather-related disasters exacerbated by climate change will lead to shorter life cycles for road rehabilitation. In high-warming scenarios, the additional stress caused by larger precipitation could increase rehabilitation costs by up to 10 times. Larger floods could increase these costs by 17 times in the coming decades (World Bank, 2017).

The impact of disasters on roads goes beyond the direct damage to transport assets. For example, according to studies by the World Bank, one-third of residents in Kampala will not be able to reach a health facility within 60 minutes (the critical timeframe to increase their chance of survival) in the event of a major flood. These results were similar to those of Bamako, Kigali, and Dar es Salaam (Rentschler et al., 2019).

The roads, border crossing points, and ports of Africa—vital for access to food and basic supplies—are highly vulnerable to climate-related disasters. The sparsity of the road network means that in the event of a disruption caused by a disaster, the detour costs in several countries would be very high and slow. The DRC and Nigeria are the most vulnerable in terms of absolute costs. The Republic of Congo and Somalia have a combination of challenges, including high transport cost and poor local access to surplus food production (World Bank, 2025).

Countries such as Somalia, Nigeria, and Gabon rely disproportionately for their imports on their maritime ports (Verschuur et al., 2022). The risk of closure and interruptions of these ports due to disasters is a severe risk for their economies and populations.

6.3 Energy

The centralized distribution of electricity in African countries is vulnerable to a wide range of disaster risks, from earthquakes and landslides to cyclones, floods, and droughts. According to the International Energy Agency, water stress risks affect over 60 percent of thermal power plants in Africa, and about one-sixth of liquefied natural gas (LNG) plant capacity is vulnerable to floods. Storm surges as sea level rise amplify those risks (IEA, 2023).

The impact of droughts on hydropower generation is well known and documented in Africa. In addition, cyclones can have large-scale impacts on energy systems. In Malawi, Cyclone Anna in 2022 caused 130 MW (about 23 percent of the country's capacity) to be taken off the grid for over 13 months due to damages to the Kapichira Power Station (Egenco, 2023). Cyclone Idai in Mozambique in 2019 caused a total blackout in the city of Beira, and across 64 districts, leading to power outages for over a million people after the disaster (GoM, 2019). Full electricity service was restored only five months after the cyclone hit (World Bank, 2019a).

Hydropower dams like the Gilgel Gibe III in Ethiopia, located near the Main Ethiopian Rift, which is part of the East African Rift System, are subject to significant earthquake and landslide risks (Carr, 2017). An analysis of dams in West Africa, a region considered generally stable, found that 59 percent of the dams reviewed were identified as high risk to earthquakes (Irinyemi et al., 2022).

Mini-grids are considered to be the cheapest solution for more than 60 percent of the population who are not connected to electricity services in Sub-Saharan Africa (ESMAP, 2022). However, these systems are also prone to damage by disasters. Heatwaves can reduce electricity generated by as much as a quarter if the solar panels are too hot; degraded battery performance and lifespan; and lead to more frequent maintenance and unstable service. Flooding can impact panel and battery performance. Poles and power lines can be impacted by high winds. These risks require careful design and maintenance of mini-grids for resilience (Rocky Mountain Institute, 2025).

The costs of disasters on the energy sector go beyond direct damage to infrastructure assets and extend towards businesses. Apart from the impacts of interrupted production, reduced use of company assets, and lower sales—businesses are also forced to absorb coping costs, including purchase and operation of generators. This leads to higher operational costs and reduced competitiveness. In a review of 25 African countries, self-generation was found to be, on average, three times more expensive than regular electricity tariffs (World Bank, 2019b).

6.4 Urban Infrastructure

A defining characteristic of Sub-Saharan Africa is its low level of urbanization and the very rapid growth of cities. Only 40 percent of the African population lives in cities. At the same time, Sub-Saharan Africa is urbanizing at 4.4 percent every year, the fastest rate worldwide. This rate, combined with insufficient planning and capacity, means that about 60 percent of urban residents live in unplanned urban settlements or slums (UN-Habitat, 2020). By 2050, the urban population of Sub-Saharan Africa is projected to triple, reaching 1.3 billion (Mo Ibrahim Foundation, 2015). Most of the infrastructure to serve this growing urban population is yet to be built.

Flooding is a common disaster in many African cities. In 2024, 27 countries in the region saw unusually heavy rainfall that impacted about 11 million people, of which about 3 million were urban residents (Africa Center for Strategic Studies, 2024). The situation is worse in low-lying coastal areas which have higher population densities than inland. About half of African cities with a population between 1 and 5 million are located in low elevation coastal areas. About 30 million Africans today live in the flood hazard zone in coastal areas of the Indian and Atlantic oceans. The combination of sea level rise and more intense precipitation events will increase flood risks to these populations and the infrastructure that provides services to them (Mbaye, 2020).

Droughts are a major risk for African urban residents. The combination of poor water provision, the large population served by informal providers, insufficient water storage and distribution infrastructure, and a rapidly changing hydrologic regime all work against the resilience of the population when facing periods of low rain. Cape Town is the first major city in the world that faced the possibility of running out of water, or ‘Day Zero’ as it was called. A massive programme of rapid response, behavioural change, and investments averted a crisis that may be repeated in the future in other urban agglomerations in Africa (Taing at al., 2019).

Heatwaves are a hazard of increasing importance in Africa. A study reviewed projections for temperature and population growth for the largest 150 African cities. The number of people that will be subject to dangerous heat conditions will be as much as 50 times higher than today’s risk levels (Harrington and Otto, 2020). Heat-related deaths in Nigeria could be as high as 43,000 per year by the end of this century (Vishal Bobde et al., 2025).

Informal settlements in high-risk areas are prone to large-scale landslides. A tragic example was the devastating landslide disaster in Freetown, Sierra Leone, in 2017. Rapid housing development and deforestation, combined with steep slopes and geological risks, led to weakened soil integrity and low rainfall absorption (Bruce, 2019). The disaster caused the loss of more than 1,000 lives and millions of dollars of damage to infrastructure and buildings.

Earthquakes are a hazard that is less discussed in the African region, but it is nonetheless important. Cities like Algiers, Tangier, and Tunis are located near the Nubian-Eurasian plate boundary, and cities like Addis, Nairobi, and Kampala sit near the East African Rift System. The 2023 earthquake in Morocco killed close to 3,000 people and left many thousands homeless (Voice of America, 2023). The Addis Abeba city resilience strategy indicates that a 6.5 magnitude earthquake, like the one that hit the capital city in 1906, could lead to as many as 4,000-5,000 people being killed and damages above $80 million (City of Addis Ababa, 2020).

7. Elements of Infrastructure Resilience in Africa

Africa faces a triple challenge in infrastructure services: insufficient coverage of these services to the population and businesses, variable quality of construction of existing infrastructure assets (with many lacking adequate resilience standards), and enormous reconstruction needs after disasters that damage or destroy assets and interrupt infrastructure services.

At the same time, Africa has several key advantages in enhancing the resilience of its infrastructure services. First, the majority of infrastructure assets in the region have yet to be built, and it is more cost-effective to construct them with resilient standards than to retrofit or reconstruct them, as is the case in other regions.

Second, Africa has a unique opportunity to leverage its natural resources for nature-based resilience solutions that protect existing and future infrastructure. Other countries have consumed green resources or built on areas that are needed for nature-based tools, making them a lot more expensive to implement.

Third, African policymakers understand the consequences of disasters on their economy to a greater degree. With fewer infrastructure assets and less redundancy, disasters have a disproportionately higher impact on citizens and businesses. The political will to take action is clear. The African Union Climate Change and Resilient Development Strategy and Action Plan (2022-2032) is a demonstration of this commitment. In addition, African countries invest more from their own budgets and loans into climate adaptation than all the external grants received for that purpose, even though they did not cause the climate change that is amplifying disasters on their infrastructure.

This section proposes a framework for analysing resilience across infrastructure sectors. This framework is then used to examine finance and institutional arrangements for resilient infrastructure.

7.1 Three Capacities for Resilient Infrastructure

Building resilience in infrastructure assets and systems requires a comprehensive view of the resilience cycle. **Figure 29** illustrates this cycle. When a disaster occurs, the operating performance of an asset is reduced. For example, a four-lane highway can end up having only two operational lanes after a landslide, or an electricity distribution line could collapse completely after a cyclone. The drop in performance is related to the capacity of that asset to absorb the disaster shock.

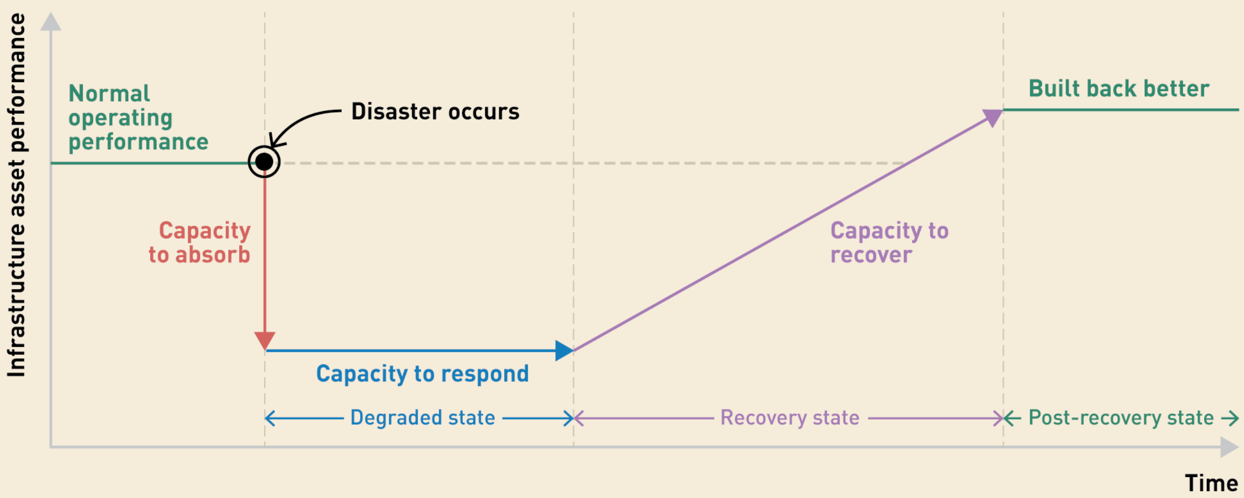
After the rapid-onset disaster hits, the infrastructure asset enters a degraded state of performance. Those responsible for the asset (and related agencies responsible for finance and disaster management) respond to the disaster, including cleaning up debris, damage assessment, and bidding for repair or reconstruction works. Once these works start, the asset enters a state of recovery that brings its performance to its normal level or, ideally, a strong performance level after the asset is 'built back better'.

Many infrastructure agencies pay particular attention to the capacity to absorb by strengthening standards and regulations, implementing retrofit programmes for existing assets, and enhancing construction supervision for new, more resilient assets. They also expand maintenance and repair programmes to make assets stronger and ready for future disasters (like the cyclone season).

However, focusing only on the capacity to absorb is insufficient. The economic and livelihood impacts linked to interruptions of infrastructure services are directly related to the time it takes for the asset to be back to full or enhanced operation. The longer it takes for the infrastructure asset manager to respond and recover, the larger the impact on households, businesses, and communities.

Figure 29

Three capacities for resilient infrastructure



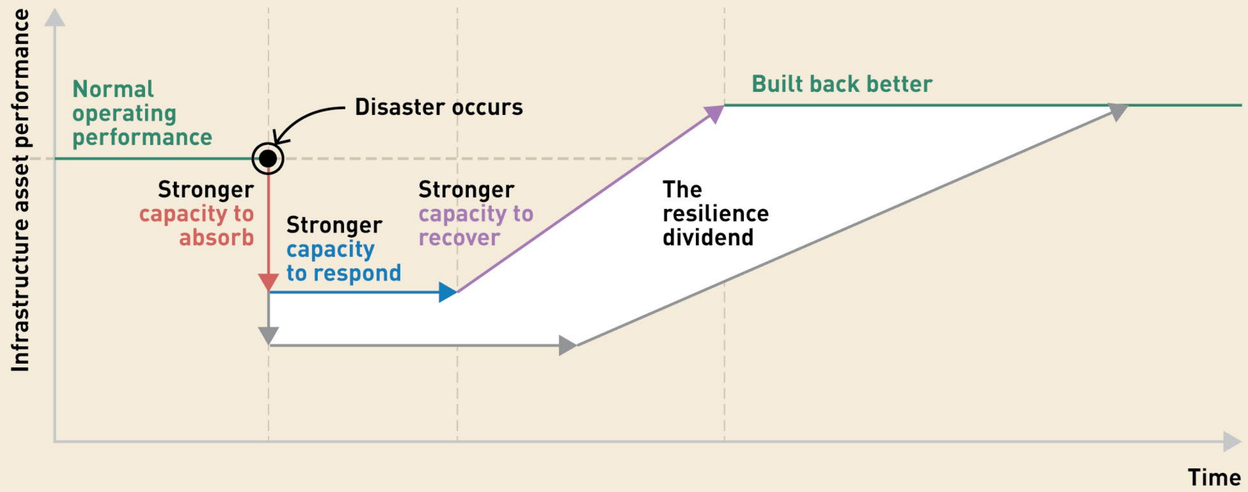


Figure 30

The resilience dividend

Building resilience of infrastructure systems requires agencies and asset managers to strengthen not only the capacity to absorb disasters, but also to respond to those shocks and recover from them quickly. **Figure 30** shows the resilience building process that strengthens the three capacities. The shaded area represents the 'resilience dividend' of those efforts.

This resilience building process is not a 'one-off' effort. Continuous investments in capacities, financial instruments, inter-agency coordination, and work with communities and businesses are part of the improvement processes leading to stronger resilience. Countries with limited financial resources will only be able to invest in small improvements of resilience. As economic conditions improve and the resilience investments generate significant economic returns, greater investments can be made in a continuous improvement process.

7.2 Financial Instruments to Support Resilient Infrastructure

Capturing the resilience dividend, as described in Section 7.1, requires a series of financial instruments that enable infrastructure agencies to enhance the capacity of their assets and systems to absorb, respond to, and recover from disasters.

These financial instruments are required at multiple levels, including the Ministry of Finance, infrastructure agencies, and asset managers (for example, the Ministry of Transport, a port authority, or an electricity utility), and, where appropriate, disaster risk management or disaster reconstruction agencies.

Strengthening the capacity of infrastructure assets and systems requires:

- **Transparent financial allocations from the Ministry of Finance to infrastructure agencies that are retrofitting existing assets.** These allocations require a cost-benefit analysis of different levels of resilience. Introducing nature-based solutions (NbS) as part of integrated grey-green infrastructure schemes can reduce up-front costs but may increase maintenance costs, although they generally lead to lower life-cycle costs.

- **Additional resources as part of allocations to new projects to ensure that hard resilience measures are incorporated in the design.** Again, a transparent cost-benefit analysis of different measures is required to enable decision makers to allocate a reasonable level of resources commensurate with the country's fiscal capacity and the benefits (direct and indirect) that those resilience measures can achieve. CDRI has developed a Resilience Cost-Benefit Analysis tool and toolkit that can be helpful to conduct analysis of best resilience measures for new infrastructure assets (See Box 1).
- **Clear and transparent resilience criteria to be incorporated in the bidding documents of infrastructure assets to be built and/or operated by private partners under a public-private partnership (PPP) contract.** These criteria will allow the private sector to cost out the expected resilience levels. The competition among bidders will lead to an efficient price for the public agency and infrastructure users.

African governments are already investing substantial amounts in resilience and adaptation of their economies. An analysis by Climate Policy Initiative (CPI) and Global Center on Adaptation (GCA) reveals that Africa invested $11.4 billion in adaptation across all sectors in the 2019-2020 period. More than half (53 percent) came from multilateral development finance institutions. African governments invest directly from their budgets about 26 percent of total adaptation financing (or about $2.2 billion), which is larger than the funds provided by bilateral development financiers at 16 percent. Commercial banks, philanthropies, and corporations only invest about 6 percent.

A remarkable fact in adaptation finance is that African governments are taking loans to channel more than half (54 percent or $6.2 billion) of these investments. Between loans and government budgets, Africa is investing about 80 percent of total adaptation finance to tackle a

Box 1

Resilience Cost-Benefit Analysis (RCBA) tool and toolkit

CDRI has developed a Resilience Cost-Benefit Analysis (RCBA) tool and a toolkit to support the government and line ministries to analyze the benefits of investing in resilience and incorporate disaster resilience considerations into infrastructure projects. The tool is currently being piloted in India.

The RCBA tool comprises an interactive spreadsheet-based application and a user guide. It utilizes project-level data as inputs and uses hazard data as available from various public sources to help stakeholders make informed decisions about investing in resilience measures during the initial phases of a project. The toolkit for disaster resilience comprises four components: i) a list of resilience measures for bidding and contractual documents; ii) a list of design options for asset resilience; iii) a guidance document for line ministries on incorporating disaster resilience aspects during the project identification and appraisal phases; and iv) a guidance document for potential bidders to help them prepare project proposals that include disaster resilience considerations.

The RCBA tool and the toolkit are intended to support the infrastructure ministries in integrating disaster resilience into the project identification and appraisal stages, while also enabling private sector bidders to effectively plan and budget for disaster resilience measures in their project proposals.

climate crisis that it did not cause. The grant component for adaptation finance in sectors such as energy and transport is less than 15 percent (GCA, 2023).

Governments in Africa face significant challenges in allocating funding to support their infrastructure sectors, particularly in terms of enhancing resilience against disasters. These challenges can be described in four questions (See Box 2).

Each of the four funding allocation questions below requires different financial instruments for effective delivery and use of resources. For the financing of new resilient infrastructure, the usual government allocation from the Ministry of Finance to infrastructure agencies, or regular financing of infrastructure agencies through tariffs, fees, and loans, or engagement with the private sector through PPPs, can make new assets more resilient.

Box 2

Four questions on resilience financing of infrastructure

1. What level of resilience standard to use for new infrastructure assets, and what is the additional cost per unit of new assets? Every new kilometre of road or power distribution line that is built can withstand different intensities of disaster shocks. The higher the intensity that new assets can withstand, the more funding they will require for their construction. Furthermore, the resilience level of a railway line or a highway differs from that of a tertiary rural road. With limited funding for infrastructure expansion and the enormous needs, this first question about resilience funding is very important.

2. How much to allocate for enhanced maintenance and repairs? This is one of the most cost-effective ways to increase the resilience of existing infrastructure assets. Fixing drainage ditches before the rainy season or maintaining transformers before high-temperature months can prevent partial or total failures and enhance the asset's capacity to absorb shocks. Worldwide, infrastructure maintenance receives insufficient attention and funds. Enhanced resilience begins with good maintenance and preventive repairs.

3. How much to allocate for retrofitting programmes of existing infrastructure assets so that they can be better prepared to withstand future disasters? Many existing assets may have been constructed with low standards or inadequate quality, rendering them vulnerable to disasters. Retrofit programmes are expensive but are essential for critical assets (e.g., schools, hospitals, primary infrastructure links for exports). Again, the number of assets to be retrofitted, the level of resilience for the retrofit programmes, and the funding allocations go hand-in-hand with the answer to this question.

4. How much to reserve for repairs and reconstruction of infrastructure assets after disasters? No matter the level of resilience of new assets, there will always be disasters with an intensity large enough to overwhelm the system. The time that it takes to repair or reconstruct these assets and restore services has a direct impact on businesses, households, and the economy. The longer the repairs take, the higher the impact on livelihoods and economic growth. Access to funds through various financial mechanisms is a crucial component of the system's resilience. The capacity of infrastructure agencies to respond and recover from disasters as efficiently as possible is proportional to the funding available, among other factors.

For enhanced maintenance and repairs that strengthen the resilience of existing assets, mechanisms such as road funds or contractual requirements with the private sector can mainstream the resilience dimension.

Retrofit programmes typically have separate funding streams, and many countries are developing programmes, such as Global Program for Safer Schools which is currently being implemented in Mozambique, Tanzania, Ghana, and Rwanda (GFDRR, 2025).

For the fourth funding question, strengthening the capacity to respond and recover requires different financial instruments. As discussed in Section 7.1, the magnitude of the economic and livelihood impacts caused by the interruption of infrastructure services depends on timing. Financial instruments that can provide the necessary resources for repair and reconstruction as quickly as possible can help reduce the recovery time. **Figure 31** illustrates a range of financing instruments for the recovery and reconstruction phases following disasters of varying frequency and severity.

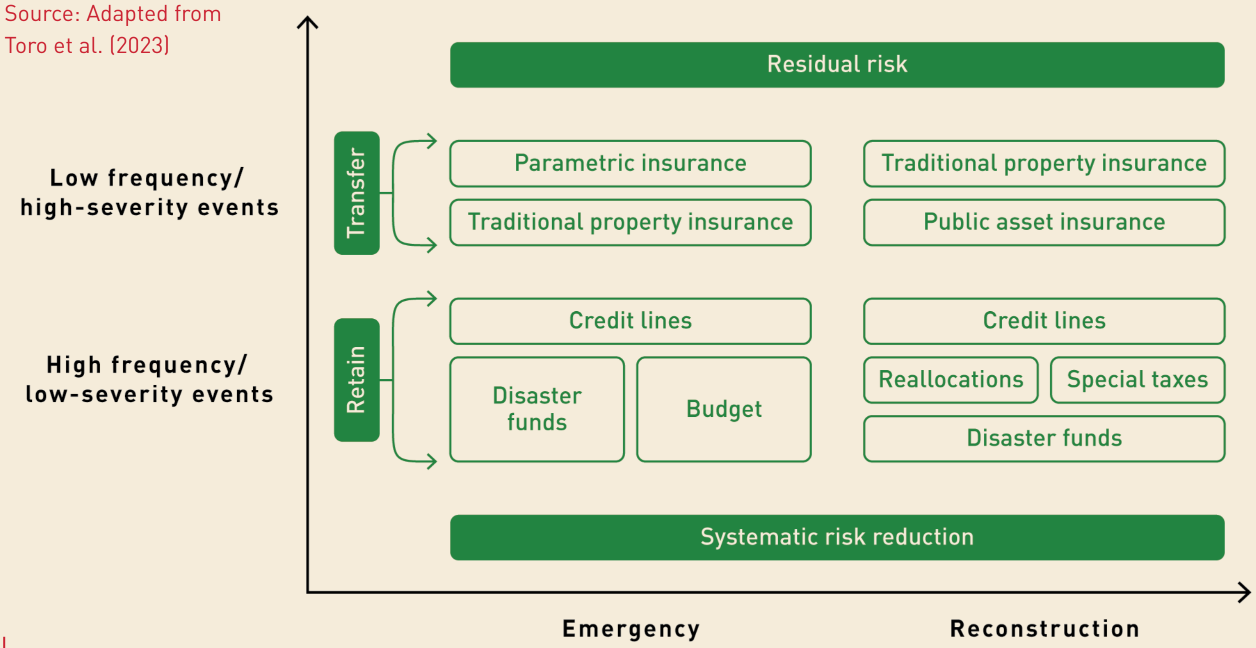
For low-severity disasters, countries and infrastructure agencies can be ready for rapid repair and reconstruction of assets by retaining the costs within the budget. This requires the establishment of credit lines, specific contingent budget lines, or disaster funds. These financial instruments can be established with the Ministry of Finance or the infrastructure agency. When these instruments are not available, then budget reallocations will be needed. However, these are usually difficult to implement and often slow down the process. Speed in accessing these resources is critical to reducing the indirect economic and livelihood impacts.

For high-severity disasters, it is advisable to consider transferring the risk to entities that are better equipped to handle it, such as private or public insurance companies. The country can consider traditional infrastructure assets, property insurance, or parametric insurance as options.

Figure 31

Risk layering and financial instruments to strengthen the capacity to respond and recover

Source: Adapted from Toro et al. (2023)



The limited funds available for infrastructure in Africa, particularly when the enormous needs of expanding services to the population and businesses are considered, do not allow for all four areas of resilience described above (new resilient assets, maintenance, retrofit, response, and recovery funds) to be fully covered. Therefore, decision makers in Africa need to consider a prioritization process based on risks and cost-benefit analyses.

For risk, methodologies such as GIRI, applied at the national or subnational level as described earlier in this report, can help identify which critical areas of the country, links in the transport or electricity network, or assets in the inventory (such as specific schools or hospitals) represent priority areas for action.

For cost-benefit comparisons, it is essential to consider that: (i) lower-cost items sometimes yield the highest benefits (maintenance, targeted repairs of high-value infrastructure assets, NbS for resilience); (ii) some assets are more closely linked to economic activities and their protection and enhanced resilience brings substantial indirect benefits and they need to receive priority (e.g., a road to a port that support exports, a bridge that connects valuable agriculture production areas with markets, or a power plant that is critical for production of high-value goods or exports); and (iii) some assets are more critical due to substantial indirect benefits to the population (e.g., schools and hospitals that are required for education and health outcomes) (Hallegatte et al., 2020).

Building disaster risk financial architecture with complementary instruments targeted at different layers of risk is an effective way to leverage limited funding and address growing climate risks. The upcoming *GIR 2025* report from CDRI will provide more details on the financial instruments described in this section, including global examples and lessons learned from their implementation.

7.3 Institutional Arrangements for Disaster Resilient Infrastructure

A common challenge in African countries is the need to strengthen institutional capacity. Infrastructure agencies were initially designed to provide and expand infrastructure services to citizens and businesses. Strengthening the capacity to absorb, respond to, and recover from disasters requires modified institutional arrangements and the development of new skills for staff working in these agencies.

At the inter-institutional level, five necessary upgrades are commonly required:

- **Develop the capacity for resilient infrastructure in ministries of finance and planning.** For countries with limited technical human resources, units that aggregate this expertise and provide support to all infrastructure agencies may be required. As this capacity gradually grows, the key ministries and agencies can develop their own technical resilience capacity with expertise in design, construction, retrofit, preparedness, post-disaster response, and reconstruction.

- **Strengthen the private sector's technical capacity for resilience.** Private companies play a crucial role in the construction, retrofitting, repair, reconstruction, and construction supervision of infrastructure assets. For PPP infrastructure projects, establish clear contractual clauses that distribute the responsibility to handle different layers of risk between the public and private parties (including minimum resilience standards expected from new and retrofitted assets, levels of disasters below which the private party is responsible for insurance and repairs, and levels above which force majeure can be declared and the government gets involved using its funds or catastrophic bonds).

- **Define agile and effective inter-institutional mechanisms to prepare for, respond to, and recover from disasters.** Failure of critical infrastructure services has cascading impacts that negatively affect other infrastructure services and the economy. For example, failure of electricity services can lead to failure of telecommunications, making the work of disaster relief actors more difficult. These inter-institutional mechanisms can be particularly important at the subnational level (e.g., provinces/states, and cities) for planning regional, multisectoral infrastructure resilience.

- **Develop the capacity for data collection and management.** Collecting data related to hazards, assets, vulnerabilities, and losses to support all infrastructure agencies in their resilience functions is critical. Without this data, it is challenging to prioritize and assign limited funds across different areas of infrastructure resilience.

- **Strengthen the regulatory framework and compliance for resilient buildings,** given the significant proportion of risk they carry in Africa. The total building stock (household, commercial, and government) has an AAL of $10.9 billion, that is larger than that of the infrastructure sectors.

- **Build the capacities, standards, and systems for nature-based solutions to enhance the resilience of infrastructure assets.** Africa can leverage its abundant natural resources and work with nature to strengthen the resilience of infrastructure assets. Forests, mangroves, wetlands, and other ecosystems can be protected and enhanced to provide resilience services that will reduce the costs of safeguarding infrastructure assets. This will require collaboration among infrastructure agencies, other government agencies responsible for environmental and land management, and local communities.

At the individual infrastructure agency level, some common recommendations for African countries include:

- **Infrastructure agencies need specialized units with the capacity to strengthen the resilience of assets and networks.** The analysis of hazards and vulnerabilities, infrastructure risk assessments, designing various resilience measures, as well as the identification of priority investments based on cost-benefit analyses, requires specialized skills. Specialized units can provide support across the agency. For example, the Ministry of Roads can have a unit that supports its rural roads, highways, urban road networks, and bridge divisions.

- **Infrastructure agencies should have clear coordination mechanisms with disaster risk management agencies, hydrometeorological agencies, and other hazard-specific scientific institutions and agencies**—for data exchange, interpretation of early warnings, disaster preparedness planning, and cascading impact analysis. Weak links with these agencies have been at the core of failures during disasters. Strong links are associated with a more efficient response to disasters and faster recovery of services. Infrastructure agencies should build their capacities to interpret early warnings for appropriate decision-making, which will help reduce damage to infrastructure assets and services.
- **Infrastructure agencies should build their capacities to respond to and recover from disasters.** Agencies can benefit from tools for disaster preparedness, response and recovery planning, asset management, new standards, and country-specific design codes. They should implement retrofit, preparedness, and post-disaster recovery programmes to enhance resilience of the overall infrastructure system.

Finally, as discussed in Section 2, in addition to strengthening the resilience of infrastructure assets and services, it is equally important to strengthen users' resilience. In this area, some common measures that can be implemented in Africa include:

- **Expanding the reach of multi-hazard early warning systems** to the entire population and enhance these systems to provide information on infrastructure service failures and alternatives (e.g., alternative transport routes, details on when electricity services will return, etc.).
- **Providing financial support to households and businesses** during the recovery and reconstruction phases so that they can, if possible, access alternative infrastructure services (e.g., support for basic energy or lighting supply, subsidies for alternative transportation modes, etc.).
- **Engaging with communities** in two-way communication and participation processes to build back the infrastructure services better by using users' perspectives on system failures and ideas for improved and more resilient services.

The upcoming *GIR 2025* from CDRI will analyse the institutional and governance experiences of developing countries in their journey to strengthen the resilience of their infrastructure assets, systems, and users.

7.4 A Call for Action: The Role of Infrastructure Agencies

Agenda 2063, Africa's blueprint for transforming the region into a global powerhouse of the future, assigns central roles to infrastructure and climate action (African Union Commission, 2015). In the area of infrastructure, Agenda 2063 envisions a "world-class, integrative infrastructure that criss-crosses the continent," serving as a key catalyst for manufacturing, trade, and regional integration. The document puts forward ambitious agendas for transport, energy, ICT, housing, and urban development.

At the same time, Agenda 2063 highlights that Africa contributes less than 5 percent of global carbon emissions but bears the brunt of climate change. It calls for the prioritization of climate adaptation in all development actions and asks for support for the development and transfer of affordable technology, capacity building, and access to financial and technical resources in this area. Infrastructure agencies play a crucial role in realizing the ambitions of Agenda 2063, which aims to expand and enhance the resilience of infrastructure services.

The African Union Climate Change and Resilient Development Strategy and Action Plan (2022-2032) is a strong political statement of support for a climate resilient and adapted development trajectory for the region. This document acknowledges the need to expand infrastructure services but highlights the high likelihood that these investments will increase exposure to extreme weather events. The strategy and action plan call for better "life cycle planning, development and management of infrastructure, rigorous mitigation and protection measures, strategic foresight, and appropriate environmental regulations, licensing, contracting and enforcement of regulations, together with well monitored and deliberate investments, and inclusion in planning with the communities which are both impacted and dependent upon them." (African Union, 2022).

Across the four Strategic Intervention Axes of the strategy and action plan, resilient infrastructure is mainstreamed as a key theme, be it in governance and policy, pathways towards transformative climate resilient development, means of implementation, or regional flagship initiatives. The strategy and action plan cannot achieve its goals without the committed engagement of Africa's infrastructure agencies.

For the first time the G20 Summit is being held in Africa in 2025. It is a historic moment and demonstrates South Africa's leadership in bringing issues affecting Africa to a global stage. It is a chance to ensure that the region's unique challenges and opportunities receive global attention and collective support. The Disaster Risk Reduction Working Group constituted under the G20 Presidency has identified resilient infrastructure as a priority area of action and emphasized the need to invest in infrastructure resilience. The working group has underscored the importance of data sharing, knowledge, technologies, risk assessments, building codes, recovery assessment frameworks, and finances to accelerate global efforts towards disaster resilient infrastructure.

At the country level, National Adaptation Plans (NAPs) and National Disaster Risk Reduction (NDRR) Strategies are key planning documents linked to the development of resilient infrastructure.

The *2025 Global Status* report of NDRR strategies conducted by the United Nations Office for Disaster Risk Reduction (UNDRR) shows that the Africa region has

55 percent of its countries reporting in the Sendai Framework Monitor that they have NDRR strategies. The global report indicates that regional collaboration is increasing, but challenges persist in mobilizing funding, building capacity for disaster risk reduction (DRR) implementation, and translating national strategies into sectoral and local action (UNDRR, 2025).

The Global Center on Adaptation conducted a review of NAPs in Africa and found that about one-third of the countries have these plans. The review found that the breadth and depth of NAPs vary across the continent, with about half of the African nations having a good or better environment for investments in climate adaptation. The review identifies seven countries in Africa that have good practices in strategic planning for adaptation investments. The review also found that fewer than 40 percent of African countries connect DRR and climate adaptation in their national strategies. While agriculture, water, and health are identified in NAPs as priority sectors for most African countries, infrastructure sectors, such as transport and energy, receive less attention. Infrastructure agencies play a critical role in national strategic planning exercises for DRR and climate adaptation. Early engagement at the strategic level will ensure policy coherence and translate regional and national goals into local action for infrastructure resilience.

In the run-up to COP30 in Belem, CDRI has established a Community of Practice (CoP), which brings together global experts, including representatives from various governments, think tanks, development banks, NGOs, and research entities, to discuss the relevance of disaster resilient infrastructure (DRI) in complementing climate adaptation strategies globally. The expert group is deliberating on opportunities for DRI as a key enabler for climate adaptation, offering actionable recommendations on how country governments can effectively integrate DRI into national adaptation strategies. The CoP discussions will culminate at COP30 with the release of an agenda on integrating DRI into adaptation strategies.

CDRI's Resilient Infrastructure, Resilient Africa progamme aims to strengthen resilience of infrastructure systems in African countries by leveraging solutions that are locally driven, context-based and inclusive. As of August 2025, nine African countries are part of the Coalition, wherein CDRI has been supporting national and regional resilience priorities through institutional training, knowledge resources, and assessments. With the African Union Commission joining CDRI in June, 2025, the impetus is on demand-driven, coordinated, and continent-wide action through a tailored technical assistance programme. The programme also aims to deepen South-South cooperation, promoting shared learning and scaling Africa's resilience leadership and innovations globally.

Annex 1. List of African Countries by Subregion

The country grouping in this paper has been created using the United Nations Standard Country or Area Codes for Statistical Use classification (https://unstats.un.org/unsd/methodology/m49/).

Central Africa (9)	Eastern Africa (14)	Northern Africa (6)	Southern Africa (10)	Western Africa (15)
Burundi	Comoros	Algeria	Angola	Benin
Cameroon	Djibouti	Egypt	Botswana	Burkina Faso
Central African Republic	Eritrea	Libya	Eswatini	Cabo Verde
Chad	Ethiopia	Mauritania	Lesotho	Côte D'Ivoire
Congo	Kenya	Morocco	Malawi	Gambia
Democratic Republic of Congo	Madagascar	Tunisia	Mozambique	Ghana
Equatorial Guinea	Mauritius		Namibia	Guinea
Gabon	Rwanda		South Africa	Guinea-Bissau
Sao Tome and Principe	Seychelles		Zambia	Liberia
	Somalia		Zimbabwe	Mali
	Sudan			Niger
	South Sudan			Nigeria
	Uganda			Senegal
	United Republic of Tanzania			Sierra Leone
				Togo

Annex 2. Glossary

All definitions are adapted from Disaster Resilient Infrastructure Lexicon (https://lexicon.cdri.world/) and the Sendai Framework Terminology on Disaster Risk Reduction (https://www.undrr.org/terminology/)[3] unless stated otherwise.

Average Annual Loss (AAL)
A measure of annualized future losses over the long term, derived from probabilistic risk models (UNISDR, 2013).

Basic infrastructure
Infrastructure that provides services considered fundamental for human development, growth, safety, and security.

Climate adaptation
Adjustments in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects. It refers to changes in processes, practices and structures to moderate potential damages or to benefit from opportunities associated with climate change (UNFCCC, n.d. a).

Climate change
A change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods (UNFCCC, 1992).

Climate finance
Local, national or transnational financing, drawn from public, private and alternative sources of financing, that seeks to support mitigation and adaptation actions that will address climate change (UNFCCC, n.d. b).

Contingent liability
Potential liability that may occur in the future depending on the disaster-related outcome of a hazard impact. In disaster risk evaluations, contingent liability refers to future projected damage and loss that must be paid for by the government, individuals, private sector, or others.

Critical infrastructure
The physical structures, facilities, networks, and other assets, which provide services that are indispensable to the social and economic functioning of society, and which are necessary for managing disaster risk.

Disaster risk management
The application of disaster risk reduction policies and strategies to prevent new disaster risk, reduce existing disaster risk and manage residual risk, contributing to the strengthening of resilience and reduction of disaster losses. Disaster risk management actions can be distinguished between prospective disaster risk management, corrective disaster risk management and compensatory disaster risk management, also called residual risk management.

- Prospective disaster risk management activities address and seek to avoid the development of new or increased disaster risks. They focus on addressing disaster risks that may develop in future if disaster risk reduction policies are not put in place. Examples are better land use planning or disaster-resistant water supply systems.

[3] United Nations General Assembly, Report of the open-ended intergovernmental expert working group on indicators and terminology relating to disaster risk reduction, which was adopted by the General Assembly on February 2nd, 2017.

- Corrective disaster risk management activities address and seek to remove or reduce disaster risks which are already present, and which need to be managed and reduced now. Examples are the retrofitting of critical infrastructure or the relocation of exposed populations or assets.
- Compensatory disaster risk management activities strengthen the social and economic resilience of individuals and societies in the face of residual risk that cannot be effectively reduced. They include preparedness, response, and recovery activities, but also a mix of different financing instruments, such as national contingency funds, contingent credit, insurance and reinsurance and social safety nets.

Disaster risk

The potential loss of life, injury, and/or destroyed and damaged assets, which could occur in a system, society, or community in a specific period, determined probabilistically as a function of hazard, exposure, vulnerability and capacity.

- Extensive risk, the risk of low-severity, high-frequency hazardous events and disasters, mainly but not exclusively associated with highly localized hazards.
- Intensive risk, the risk of high-severity, mid- to low-frequency disasters, mainly associated with major hazards.

Essential services

The services provided by infrastructure, such as water and wastewater, power and energy, transport, telecommunications, health, and education that are essential for social and economic development. (Definition adopted in this Report)

Grey infrastructure

Engineered physical structures that underpin energy, transport, communications (including wireless and digital), built form, water and sanitation, and solid waste management systems and that protect human lives and livelihood.

Infrastructure

Individual assets, networks and systems that provide specific services to support the functioning of a community or society.

Infrastructure lifecycle

The series of stages during the lifetime of an infrastructure asset, starting from planning, prioritization and funding to the design, procurement, construction, operation, maintenance, and decommissioning.

Infrastructure governance

The capacity to plan, finance, design, implement, manage, operate, and maintain infrastructure systems (Hertie School of Governance, 2016).

Infrastructure maintenance

Maintenance is a cycle of activities designed and undertaken to preserve the optimal functioning of infrastructure, including in adverse conditions. It is a necessary precondition for the preservation of its operational capability, and to guarantee service continuity.

Infrastructure systems

Arrangements of infrastructure components and linkages that provide a service or services.

Local infrastructure systems

Facilities at the local level, including water, drainage and sanitation networks, road, river and rail networks, bridges, health, and education facilities, as well as other local facilities services to individuals, households, communities, and businesses in their current locations.

Nature-based (Infrastructure) solutions (NbS/ NbIS)

Actions to protect, conserve, restore, sustainably use, and manage natural or modified terrestrial, freshwater, coastal and marine ecosystems, which address social, economic and environmental challenges effectively and adaptively, while simultaneously providing human well-being, ecosystem services, and resilience and biodiversity benefits (UNEP, 2023). NbIS is used in this report to refer to the application of nature-based solutions to address infrastructure requirements, in other words, directly connecting the natural environment with the built environment.

Project pipelines

A set of infrastructure projects and assets (accounting for the existing stock of assets), and future assets in early development and construction stages prior to project commissioning, typically presented as a sequence of proposed investment opportunities over time that align with and are supportive of long-term climate and development objectives (OECD, 2018).

Redundancy

Alternative or back-up means created within an infrastructure system to accommodate disruption, extreme pressures, or surges in demand. It includes diversity, i.e., the presence of multiple ways to achieve a given need or fulfil a particular function.

Reliability

Ability of an infrastructure asset or system to perform the desired function based on specified requirements over time without interruption or degradation.

Resilience

The ability of individuals, households, communities, cities, institutions, systems, and society to prevent, resist, absorb, adapt, respond, and recover positively, efficiently and effectively when faced with a wide range of risks, while maintaining an acceptable level of functioning and without compromising long term prospects for sustainable development, peace and security, human rights and well-being for all. (UN, 2020).

Resilience dividend

The value of reduced future asset loss and damage avoided service disruption, wider social, economic, and environmental co-benefits, and reduced systemic risk, that accrue over the lifecycle of an infrastructure system. (Definition adopted in this Report)

Resilient infrastructure

Infrastructure systems and networks, the components, and assets thereof, and the services they provide, that can resist and absorb disaster impacts, maintain adequate levels of service continuity during crises, and swiftly recover in such a manner that future risks are reduced or prevented.

Systemic resilience

The resilience of social, economic, territorial, and environmental systems at all scales, that conditions the ability of infrastructure assets and the services they provide to resist and absorb disaster impacts. (Definition adopted in this Report)

Systemic risk

In the context of infrastructure, systemic risk is a cumulative risk to a system as an outcome of physical, biological, social, environmental, or technological shocks and stresses. These may be internal or external to the system. Impact on individual components of the system (assets, networks, and subsystems) becomes systemic due to interdependence and interactions between them.

Annex 3. Exposed Value, AAL, and Relative AAL by Countries in Africa

Country	Exposed value ($ billion)	AAL ($ million)	Relative AAL%
CENTRAL AFRICA	**421**	**1009**	**0.24**
Burundi	5.76	16	0.28
Cameroon	111	144	0.13
Central African Republic	11	22	0.20
Chad	27	43	0.16
Congo	92	372	0.40
Democratic Republic of the Congo	97	294	0.30
Equatorial Guinea	29	32	0.11
Gabon	48	85	0.18
Sao Tome and Principe	0.9	84	0.08
EASTERN AFRICA	**1122**	**5496**	**0.49**
Comoros	6.06	14	0.23
Djibouti	5.60	13	0.23
Eritrea	6.30	5	0.08
Ethiopia	200	187	0.09
Kenya	183	200	0.11
Madagascar	38	98	0.26
Mauritius	40	182	0.46
Rwanda	19	62	0.32
Seychelles	4.05	11	0.27
Somalia	28	88	0.32
South Sudan	18	53	0.30
Sudan	308	4131	1.34
Uganda	78	121	0.15
United Republic of Tanzania	187	332	0.18
NORTHERN AFRICA	**2105**	**2315**	**0.11**
Algeria	957	1015	0.11
Egypt	345	316	0.09
Libya	150	87	0.06
Mauritania	27	27	0.10
Morocco	475	685	0.14
Tunisia	145	180	0.12

Country	Exposed value ($ billion)	AAL ($ million)	Relative AAL%
SOUTHERN AFRICA	**1773**	**2314**	**0.13**
Angola	249	73	0.03
Botswana	64	69	0.11
Eswatini	9.67	16	0.16
Lesotho	12	31	0.27
Malawi	15	38	0.26
Mozambique	40	69	0.17
Namibia	33	39	0.12
South Africa	1166	1735	0.15
Zambia	126	151	0.12
Zimbabwe	60	94	0.16
WESTERN AFRICA	**1805**	**1581**	**0.09**
Benin	41	42	0.10
Burkina Faso	38	11	0.03
Cabo Verde	6.35	1.25	0.02
Côte D'Ivoire	102	71	0.07
Gambia	3.69	1.85	0.05
Ghana	262	118	0.05
Guinea	32	47	0.15
Guinea-Bissau	1.86	1.05	0.06
Liberia	9.12	22	0.24
Mali	30	52	0.17
Niger	49	91	0.19
Nigeria	1129	1079	0.10
Senegal	72	21	0.03
Sierra Leone	8.55	12	0.14
Togo	21	11	0.05
GRAND TOTAL	**7226**	**12715**	**0.18**

Annex 4. AAL by Infrastructure Sectors in Africa ($ million)

Country	Oil and gas	Ports and airports	Power	Roads and railways	Telecommu-nications	Water and wastewater
CENTRAL AFRICA	**1.02**	**1.21**	**36.29**	**5.21**	**18**	**18**
Burundi	0.00	0.02	0.89	0.10	0.83	0.33
Cameroon	0.18	0.42	10.04	1.73	2.97	3.93
Central African Republic		0.00	0.74	0.03	0.46	0.22
Chad	0.05	0.00	3.53	0.10	2.46	0.51
Congo	0.10	0.01	3.55	0.79	1.28	4.24
Democratic Republic of the Congo	0.01	0.47	13.95	0.71	9.25	5.39
Equatorial Guinea	0.49	0.27	2.23	0.71	0.44	2.94
Gabon	0.19	0.01	1.35	1.02	0.24	0.92
Sao Tome and Principe	0.00	0.00	0.01	0.02	0.00	0.02
EASTERN AFRICA	**1.40**	**4.08**	**163**	**36**	**95**	**55**
Comoros		0.05	0.90	0.33	1.45	0.62
Djibouti	0.01	0.05	0.74	0.36	0.55	1.19
Eritrea	0.00	0.01	0.53	0.17	0.21	0.24
Ethiopia	0.00	0.04	18	10	1.40	10
Kenya	0.01	0.19	11	10	10	3.21
Madagascar	0.00	0.57	13	1.13	14	1.18
Mauritius	0.21	2.29	13	2.13	15	15
Rwanda		0.01	3.97	0.50	1.75	1.21
Seychelles	0.00	0.08	0.33	0.93	0.45	1.78
Somalia	0.00	0.02	4.10	0.22	1.80	0.76
South Sudan	0.84	0.08	2.76	0.12	2.38	0.72
Sudan	0.31	0.36	66	5.76	37	3.34
Uganda	0.00	0.04	13	0.82	3.00	2.17
United Republic of Tanzania	0.01	0.32	16	2.70	6.17	13
NORTHERN AFRICA	**49**	**5.51**	**260**	**92**	**132**	**46**
Algeria	37	2.80	140	65	81	35

Egypt	5.29	0.91	46	5.97	27	2.92
Libya	6.52	1.12	13	2.96	5.03	2.78
Mauritania	0.00	0.01	2.93	0.35	1.50	0.12
Morocco	0.47	0.39	52	16	14	3.73
Tunisia	0.25	0.27	6.46	2.59	4.17	1.85
SOUTHERN AFRICA	**7.69**	**4.07**	**215**	**105**	**101**	**41**
Angola	2.00	0.65	7.42	4.36	0.80	4.38
Botswana	0.00	0.06	11	2.67	6.26	1.03
Eswatini		0.00	1.54	0.52	0.88	0.08
Lesotho		0.01	1.98	0.94	1.39	0.11
Malawi	0.00	0.01	2.64	0.21	2.56	0.50
Mozambique	0.02	0.12	3.96	0.23	2.41	0.60
Namibia	0.00	0.05	7.76	1.78	3.48	0.41
South Africa	5.66	3.12	160	92	78	28
Zambia	0.01	0.04	10	1.42	3.24	3.91
Zimbabwe	0.00	0.02	8.80	0.66	1.64	2.55
WESTERN AFRICA	**9.17**	**38**	**170**	**44**	**72**	**10**
Benin	0.00	0.11	6.12	0.31	6.62	0.23
Burkina Faso		0.00	1.57	0.13	0.37	0.02
Cabo Verde		0.01	0.26	0.27	0.44	0.04
Côte D'Ivoire	0.77	0.11	14	0.95	6.83	0.42
Gambia	0.00	0.00	0.06	0.02	0.09	0.01
Ghana	0.15	0.07	30	3.33	4.30	0.99
Guinea		0.01	1.63	0.32	0.29	0.04
Guinea-Bissau	0.00	0.00	0.20	0.01	0.04	0.01
Liberia	0.00	0.01	1.56	0.12	0.86	0.07
Mali		0.24	4.13	0.21	2.27	0.07
Niger	0.05	0.00	5.39	0.29	2.43	0.11
Nigeria	8.13	37	100	37	44	7.61
Senegal	0.06	0.05	1.80	1.05	2.23	0.52
Sierra Leone		0.01	0.43	0.09	0.11	0.02
Togo	0.00	0.02	3.44	0.21	1.00	0.09
GRAND TOTAL	**69**	**53**	**844**	**282**	**418**	**171**

Annex 5. Exposed Value, AAL, and Relative AAL by Province in Egypt, Nigeria and South Africa

Province/state	Exposed value ($ billion)	AAL ($ million)	Relative AAL (%)
EGYPT			
Aswan	8.49	11	0.12
Assiut	15	11	0.07
Red Sea	3.95	6.58	0.17
Beheira	23	12	0.05
Beni Suef	11	8.16	0.07
Port Said	2.51	4.13	0.16
Dakahlia	20	13	0.07
Damietta	5.52	4.00	0.07
Faiyum	11	4.29	0.04
Gharbia	17	8.69	0.05
Alexandria	18	29.43	0.16
Ismailia	4.87	5.00	0.10
South Sinai	2.11	4.82	0.23
Giza	36	60	0.17
Kafr El Sheikh	12	5.63	0.05
Monufia	13	10	0.08
Minya	17	9.81	0.06
Matrouh	6.74	4.44	0.07
Cairo	37	33	0.09
Qalyubia	17	17	0.10
Qena	9.20	8.02	0.09
Sohag	15	14	0.09
Sharqia	22	17	0.08
North Sinai	2.05	1.27	0.06
Suez	4.28	2.83	0.07
Luxor	9.66	10	0.10
New Valley	1.79	0.66	0.04
TOTAL	**345**	**316**	**2.51**

Province/state	Exposed value ($ billion)	AAL ($ million)	Relative AAL (%)
NIGERIA			
Abia	21	6.37	0.04
Adamawa	20	24	0.14
Akwa Ibom	31	23	0.10
Anambra	25	24	0.11
Bauchi	32	16	0.06
Benue	26	21	0.09
Borno	32	32	0.13
Bayelsa	19	11	0.09
Cross River	20	54	0.35
Delta	47	95	0.32
Ebonyi	13	22	0.19
Edo	26	27	0.14
Ekiti	15	1.73	0.01
Enugu	21	6.84	0.04
Abuja Federal Capital Territory	30	23	0.10
Gombe	16	8.82	0.07
Imo	26	10	0.04
Jigawa	27	28	0.12
Kaduna	45	17	0.04
Kebbi	21	38	0.21
Kano	71	19	0.03
Kogi	26	67	0.37
Katsina	36	5.95	0.02
Kwara	17	12	0.09
Lagos	130	169	0.19
Nasarawa	13	15	0.15
Niger	36	44	0.19
Ogun	33	16	0.07

Ondo	24	35	0.18
Osun	23	15	0.08
Oyo	45	5.64	0.02
Plateau	21	3.88	0.02
Rivers	64	58	0.14
Sokoto	25	40	0.19
Taraba	15	29	0.24
Yobe	18	30	0.22
Zamfara	21	25	0.14
TOTAL	**1129**	**1079**	**0.12**

Province/state	Exposed value ($ billion)	AAL ($ million)	Relative AAL (%)
SOUTH AFRICA			
Eastern Cape	143	196	0.14
Free State	64	141	0.22
Gauteng	287	661	0.23
Mpumalanga	102	118	0.12
Northern Cape	43	49	0.12
KwaZulu-Natal	204	262	0.13
Limpopo	103	84	0.08
North West	71	177	0.25
Western Cape	148	47	0.03
TOTAL	**1166**	**1735**	**0.15**

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