CDRI

Coalition for Disaster Resilient Infrastructure

Global Infrastructure Resilience Working Paper

Infrastructure Resilience in Small Island Developing States

CONFERENCE EDITION

GIR SIDS

2025 WORKING PAPER

This Work is a product of the Coalition for Disaster Resilient Infrastructure (CDRI) as part of a working paper series in the run up to the Second Global Infrastructure Resilience (GIR) Report. It presents regional analysis for the Small Island Developing States (SIDS) and other ocean states leveraging the results from the Global Infrastructure Risk Model and Resilience Index (GIRI) developed by CDRI. It can be downloaded from the CDRI website at: https://www.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 and discussions with key stakeholders.

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Acronyms

AAL	Average Annual Loss
AI	Artificial Intelligence
AIMS	Africa, Indian Ocean, Mediterranean and South China Sea
CDRI	Coalition for Disaster Resilient Infrastructure
CNBH	Haitian National Building Code
CRED	Centre for Research on the Epidemiology of Disasters
D&I	drainage and irrigation
GDP	Gross Domestic Product
GIR	Global Infrastructure Resilience
GIRI	Global Infrastructure Risk Model and Resilience Index
IRIS	Infrastructure for Resilient Island States
ISDI	Integrated Strategy for Drainage and Irrigation
NbS	Nature-based Solutions
NDIA	National Drainage and Irrigation Authority
PNG	Papua New Guinea
SIAM	Small Island Associate Members
SIDS	Small Island Developing States
SOEs	state-owned enterprises

GIR SIDS

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1. Overview

This working paper is part of a series presenting regional and thematic analyses leveraging 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, 2025) report. It presents the results of the GIRI model applied to Small Island Developing States (SIDS) and Small Island Associate Members (SIAM) of the United Nations Regional Commissions. See Annex 1 for a list and grouping of countries.

Island states are particularly susceptible to disasters, both geological and climate-related, including sea level rise and temperature variations. Their small land size and economies make them vulnerable to very large livelihood and economic impacts from disasters. This working paper, part of the Global Infrastructure Resilience (GIR) series, provides policymakers with multi-hazard risks and average expected losses to critical infrastructure. It also proposes a framework for analyzing and strengthening resilience across infrastructure sectors in these countries.

The working paper is organized into seven sections. After this overview, Section 2 presents the definitions of risk, resilience, and related key concepts used in the working paper. Section 3 describes, in summary form, the GIRI model and its basic functions. Section 4 summarizes the global results of the GIRI model, followed by the specific results for SIDS and SIAM in Section 5. Section 6 reviews the challenges of disasters and examples of resilience solutions in the transport, energy, water, and wastewater sectors. Section 7 discusses key elements of infrastructure resilience in SIDS and SIAM, 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 linked to the three capacities and then presents CDRI's Call to Action with ten specific proposals to strengthen the resilience of infrastructure systems in SIDS.

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 working 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 a function of three variables: hazard, exposure, and vulnerability. Annex 2 present 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 determine the location and nature of hazards. Climate change, environmental degradation, and land use changes modify the range of hazards such as floods, landslides, cyclonic winds, storm surges, and droughts.

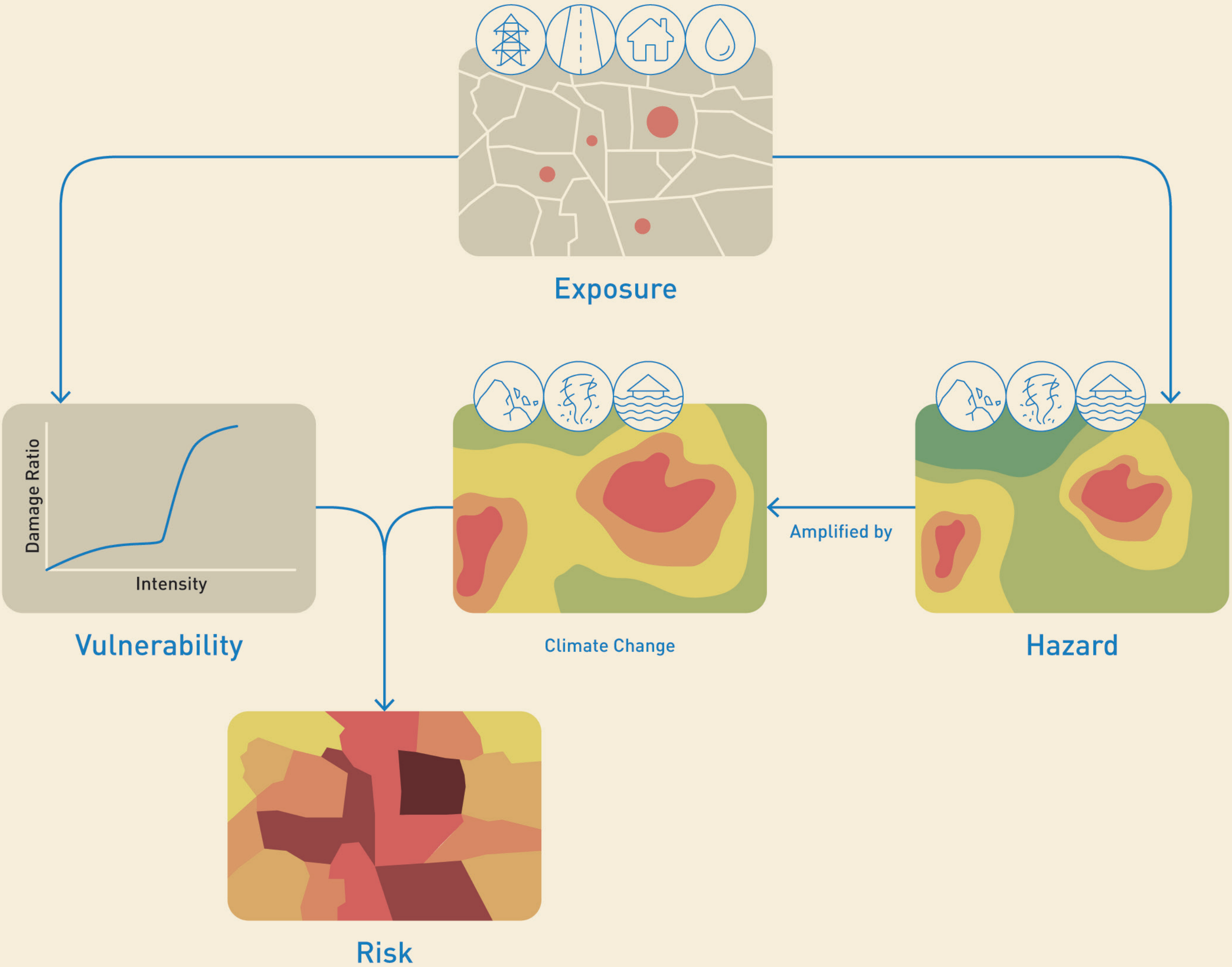


Figure 1

Exposure, hazard, vulnerability, and risk

Source: CDRI (2023b)

Climate change is projected to increase hazards that can damage infrastructure assets. Climate change will also impact the capacity of those assets to provide the services 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 effectively enforced during construction and maintenance, the risk of an infrastructure asset may be lower even in locations with high levels of hazard exposure.

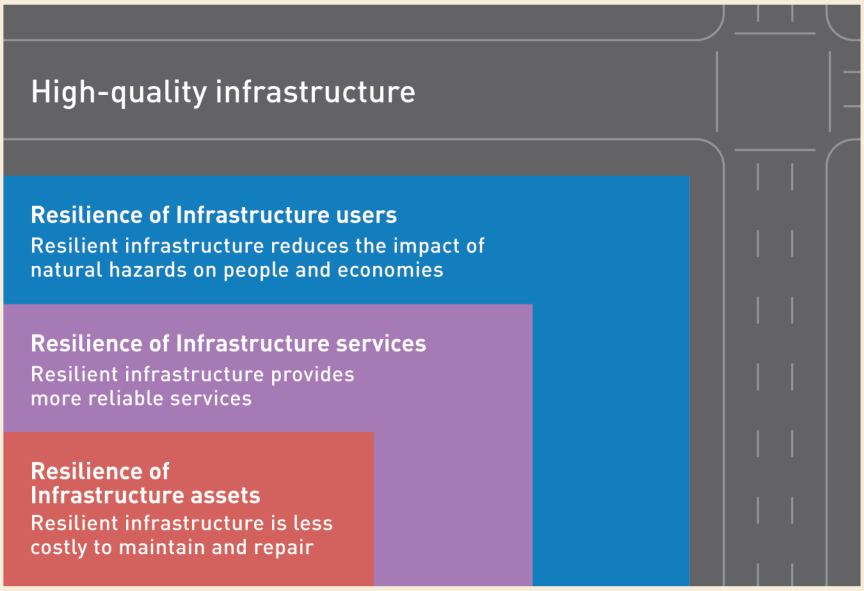


Figure 2

Three levels of resilience in infrastructure

Source: Hallegatte et al. (2019)

2.1. What is 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 highlighted in the CDRI definition.

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.

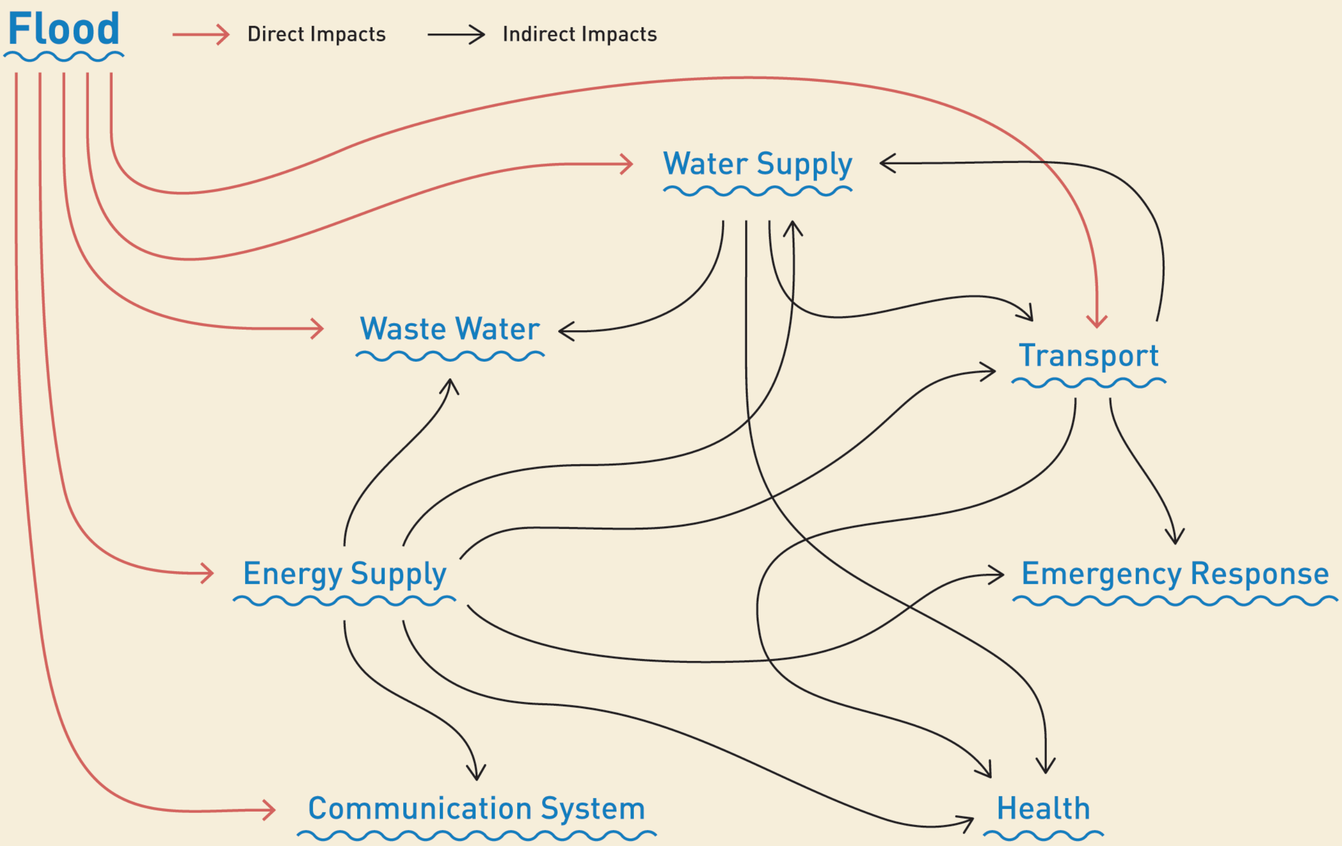


Figure 3

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 greater 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 (GIRI)

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)

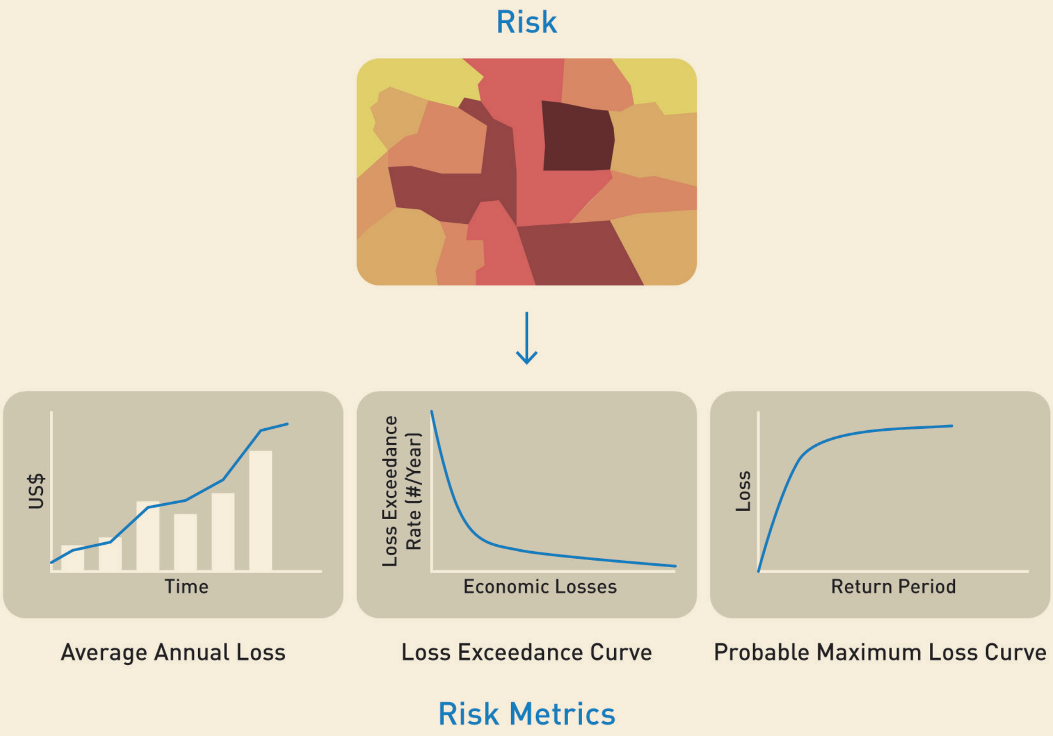


Figure 5

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. The simulations 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-localising 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 Losses (AAL) and the Probable Maximum Losses (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 as the attribution science progresses, more precise data on hydro-meteorological hazards will also become available, and GIRI results will improve simultaneously. 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 of 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 Small Island Developing States.

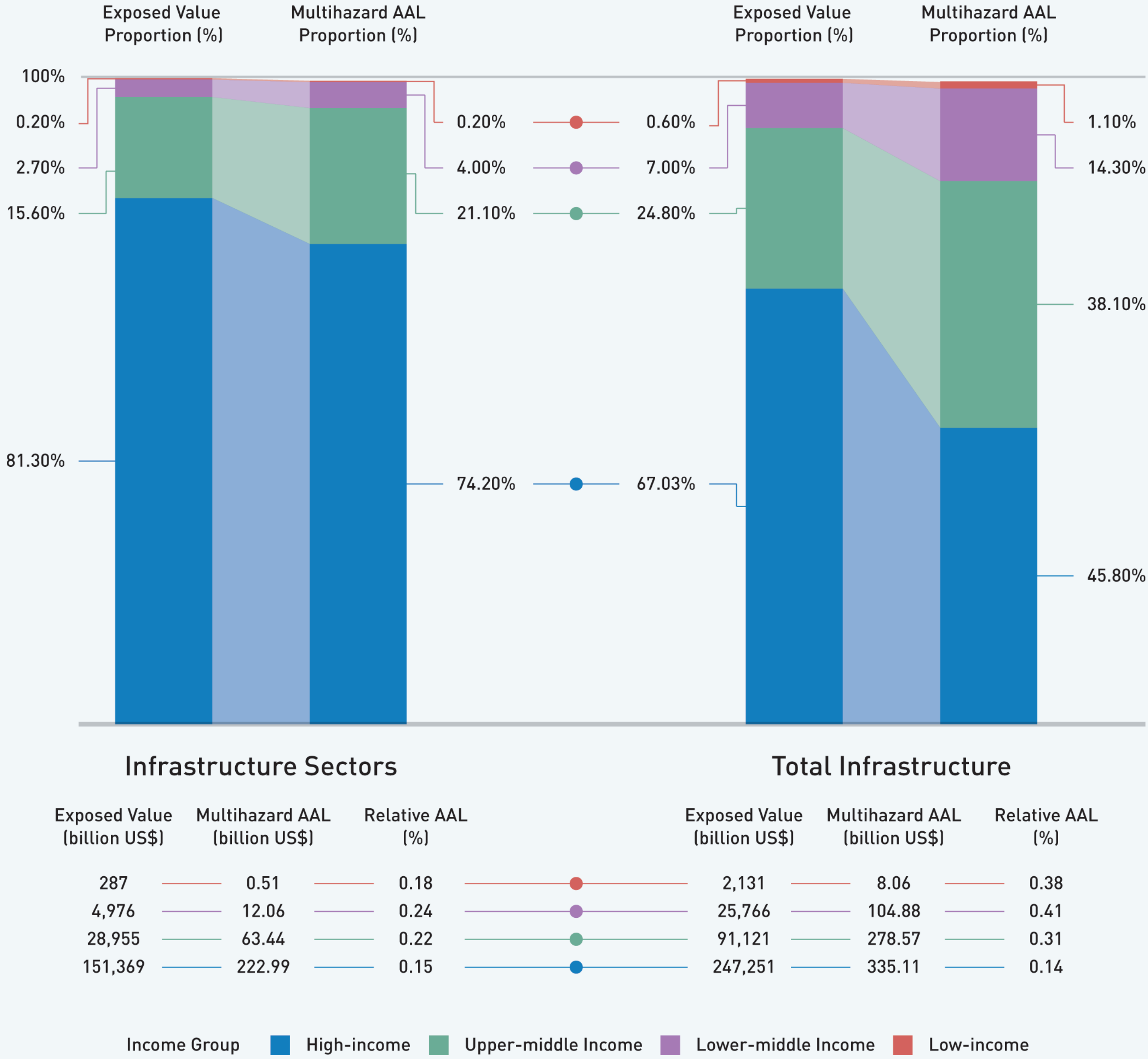
4.1. Annual Average Losses across income levels

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 US$ 301 billion as of 2023.

The GIRI model was also used to calculate the AAL for buildings, including health and education infrastructure. The total infrastructure (infrastructure sectors plus buildings) multi-hazard AAL increases to about US$ 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 US$ 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

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 US$ 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. Annual 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[1] (in billions US$) 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 US$ billions) but very high levels of relative risk. These countries are mostly Small Island Developing States. 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 resilient 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.

[1] 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.

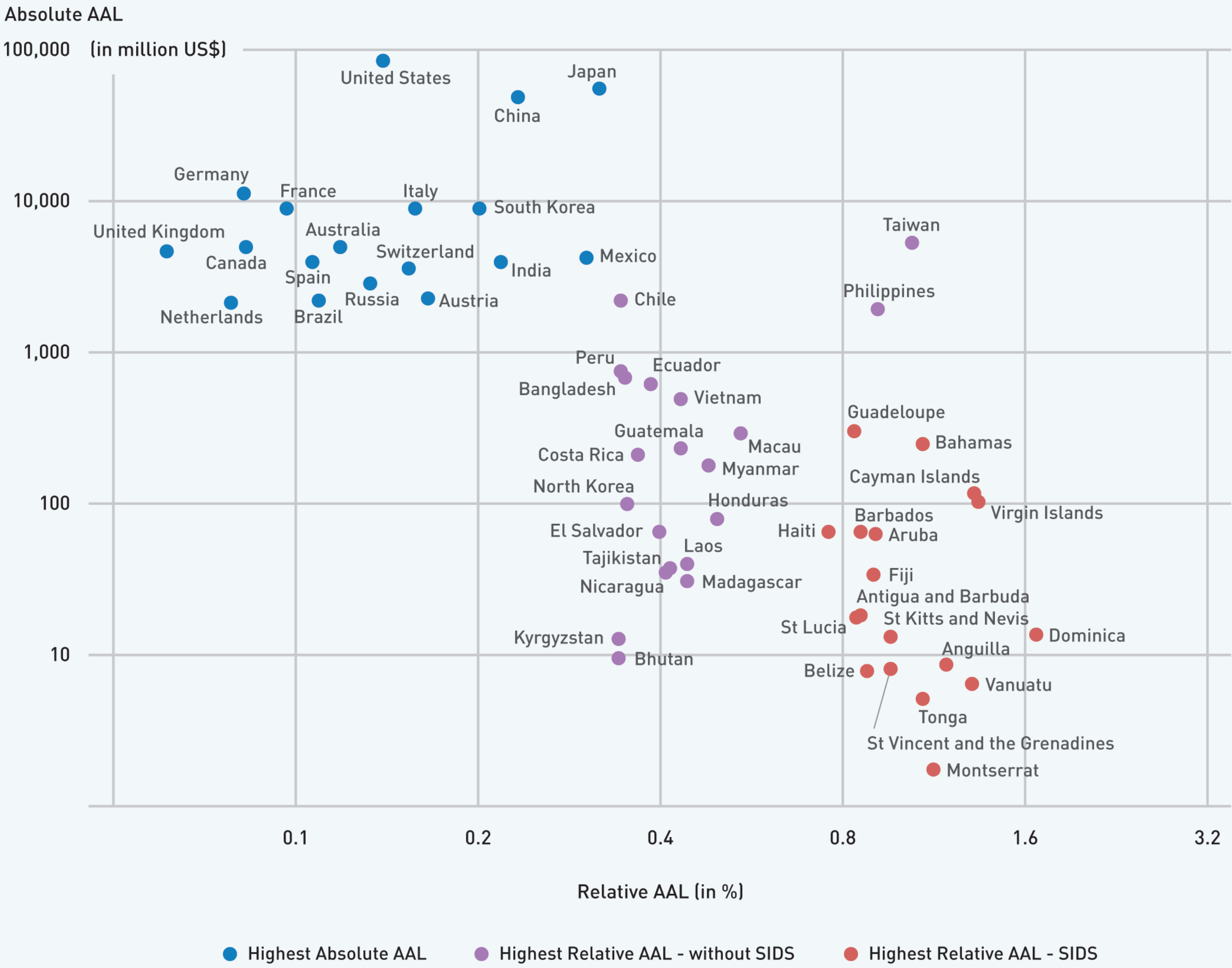


Figure 7

Absolute and relative AAL for infrastructure sectors

Source: CDRI (2023b)

4.3. Annual Average 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 US$ 213 billion), followed by telecommunications, ports, airports, water, and sanitation.

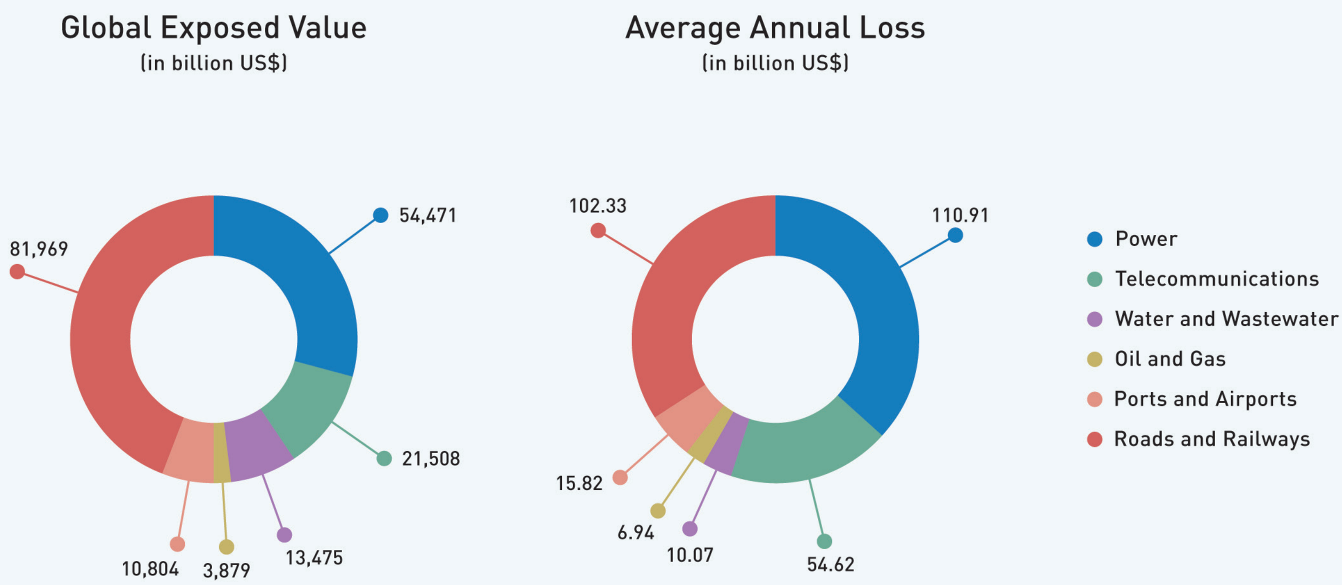
The regional breakdown is also shown in Figure 8. It is interesting to note that East Asia and the Pacific is the region with the highest AAL for all sectors (except oil and gas), followed by North America. This reflects the recent growth in infrastructure in East Asian countries, the high level of hazards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

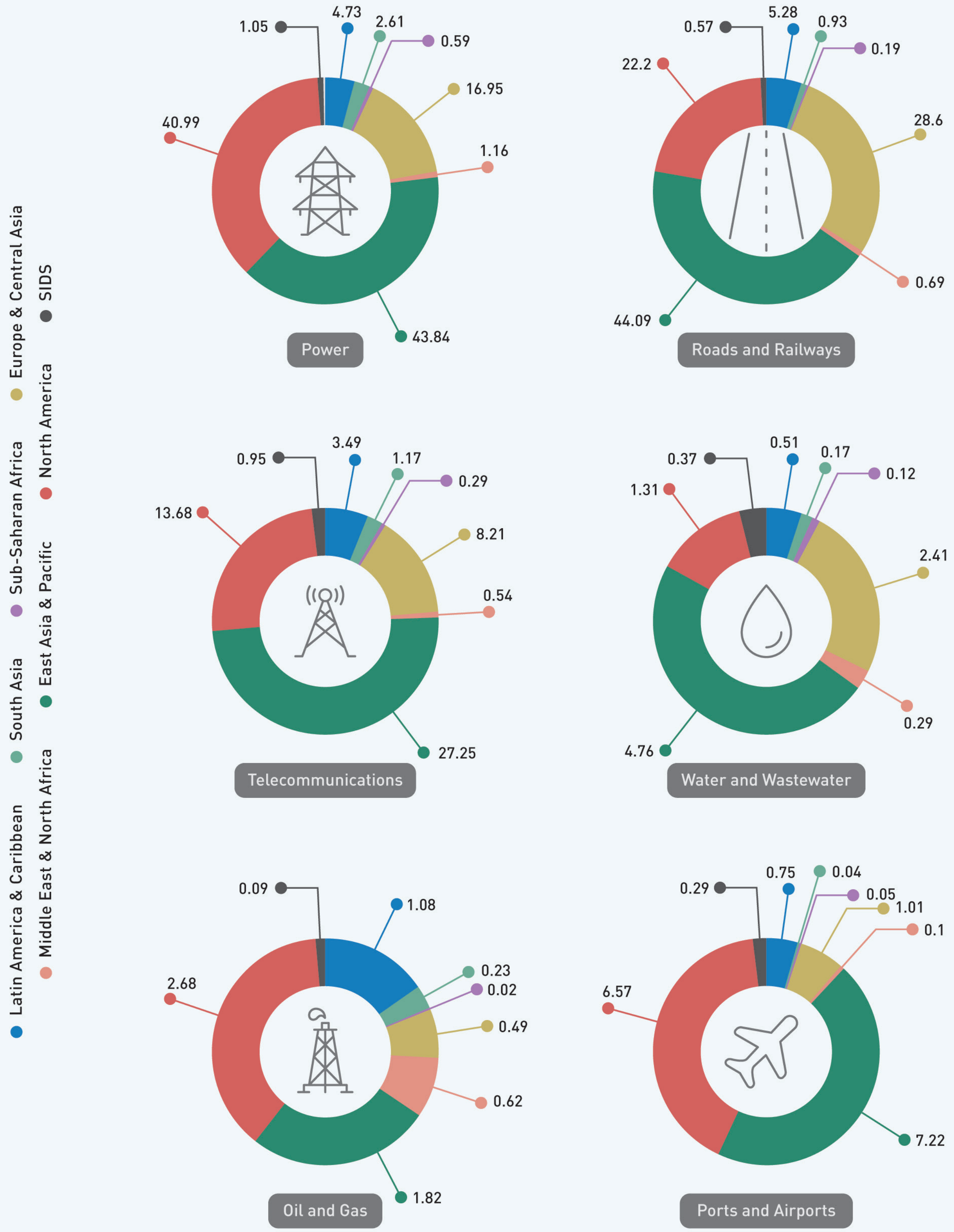
Exposed value and AAL by sector and by geographical region

Source: CDRI (2023b)



Absolute AAL by Infrastructure Sectors

(in billion US$)



4.4. The projected impact of climate change on Annual Average Losses of infrastructure assets

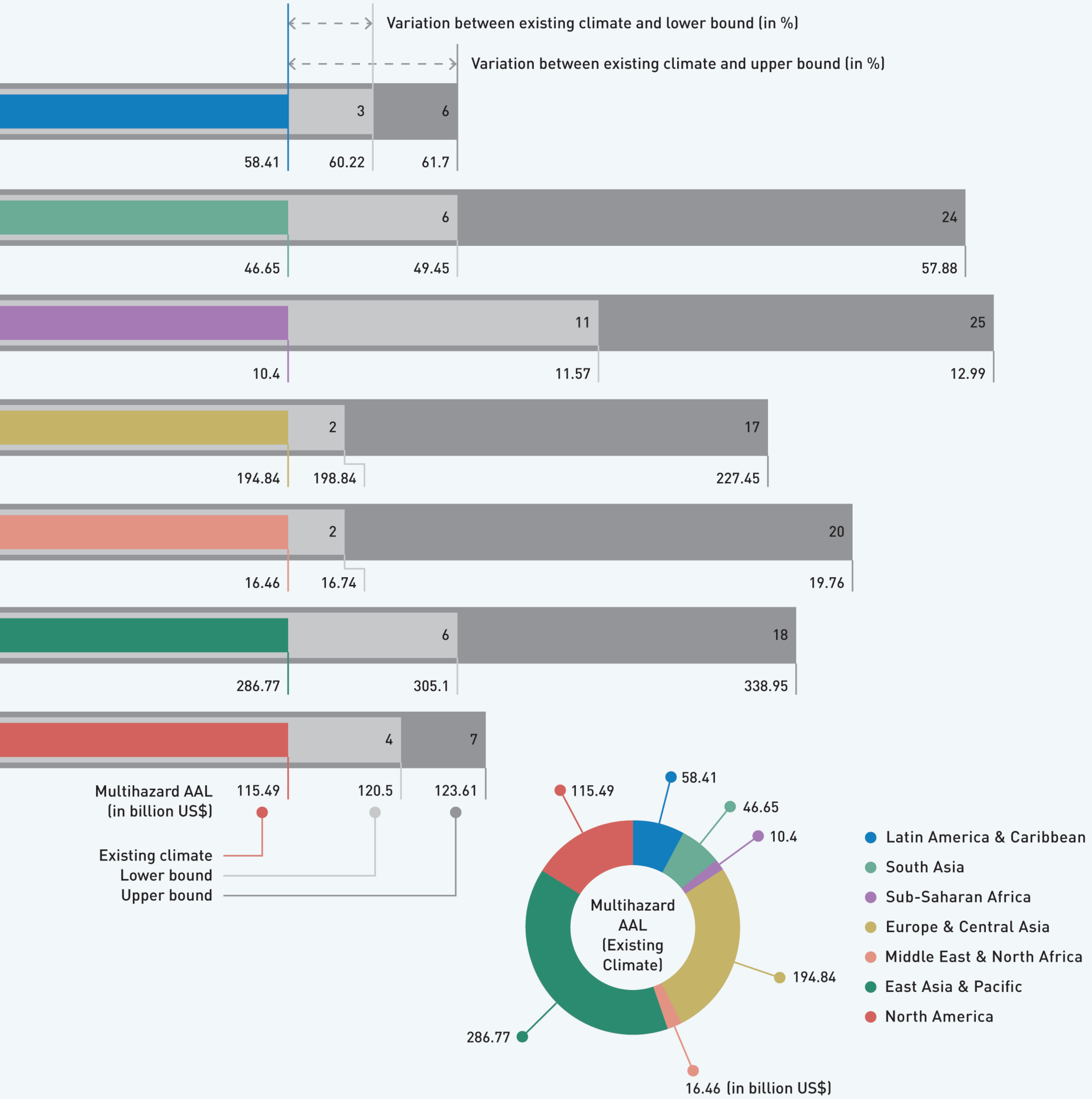
The GIRI model can be used to understand the impact of climate change on disaster risks. Two future climate change scenarios for 2100, one based on a lower bound of greenhouse gas emission trajectory and the other on a more carbon-intensive pathway, were used. To make the comparisons consistent, the 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 a mounting 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 US$ 732 billion. With climate change, this amount would increase to a range between US$ 762-US$ 842 billion, depending on the warming trajectory.

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



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. Disaster challenges to infrastructure in Small Island Developing States (SIDS)

5.1. Hazards and disasters in SIDS

In addition to geological risks, such as earthquakes and volcanoes, SIDS are subject to many climate-related disasters, like tropical cyclones, storm surges, and floods. Slow-onset climate impacts such as rising sea levels and increasing temperatures amplify hazard risks to SIDS (UNFCC, 2005). The small land area of these nations implies that many of these disasters affect the whole country, often devastating their entire economy and the livelihoods of a large portion of their population. In recent decades, the North Atlantic and South Pacific have seen, on average, an increase in the intensity of tropical cyclones. Sea level rise for most of the Caribbean, Western Tropical Pacific, and the Indian Ocean has exceeded global averages (Climate Studies Group Mona, 2020). Projections of climate-affected hazards are limited due to insufficient baseline data, downscaled climate modelling, and the diversity of geographical conditions with small land masses.

According to the EM-DAT32 database of the Centre for Research on the Epidemiology of Disasters (CRED), between 2014 and 2024, storm-related disasters impacted close to 22 million people. Floods impacted about 4.4 million people during the same period (EM-DAT. n.d.). Geological hazards (earthquakes, landslides, and volcanic eruptions) also impact SIDS. The most notable geological disaster was the 2010 earthquake in Haiti that caused the death of 220,000 people (UN DESA and UNDRR, 2022).

Some of these tropical cyclones can affect entire economies. For example, Hurricane Irma impacted 10 million people in Cuba, Cyclone Kenneth affected 345,000 people in Comoros, and Hurricane Fiona impacted 1.4 million people in the Dominican Republic, among many others. Many of these islands can be affected by more than one extreme climate-related disaster in a single year. For example, Vanuatu was hit by tropical cyclones Judy and Kevin in 2023, while Fiji suffered damage from cyclones Josie and Keni in 2018 (EM-DAT. n.d.).

In addition to the growing hazards due to climate change, the vulnerability of infrastructure and housing is high in SIDS, as many settlements are located along the coast, particularly in low-elevation coastal zones (LECZ), defined as coastal areas below 10 m elevation (above sea level). Specifically, about 22 million people in the Caribbean live in areas below 6 m elevation (Cashman and Nagdee, 2017) and about 90 percent of the Pacific Islands' population are located within 5 km of the coastline (not including Papua New Guinea (PNG)). Furthermore, most Pacific SIDS have more than half of their infrastructure located within half a kilometre of the coastline (Andrew et al., 2019).

The hazards, exposure, and vulnerability factors described above mean that SIDS are subject to substantial disaster risks. As a group, they are, proportional to the size of their economies, the most disaster-prone countries. On average, SIDS lose about 2.1 percent of their GDP annually due to disasters (UNCTAD, 2020).

5.2. Infrastructure risks in SIDS and SIAM

This section presents the results of the GIRI model described in Section 3 to SIDS and Small Island Associate Members (SIAM). See Annex 1 for a list of each country grouping. The risk calculations presented in this paper exclude Singapore from the SIDS grouping to minimize biases resulting from the country's significantly higher level of infrastructure and economic development compared to other SIDS.

Considering present climate conditions, the current quantity and location of infrastructure assets, and their hazards, exposure, and vulnerability, the GIRI model calculates the multi-hazard AAL value. The model considers the key hazards that impact SIDS and SIAM nations: earthquakes, tsunamis, landslides, floods, storm surges, and cyclonic storms (hurricanes and typhoons).

Figures 10 and 11 show the global value of all infrastructure assets in SIDS and SIAM nations in the transport, energy, water, wastewater, telecommunications, oil and gas sectors. For SIDS, the highest estimated total values of infrastructure assets correspond to the energy sector at US$ 89 billion, telecommunications at US$ 57 billion, and roads at US$ 52 billion.

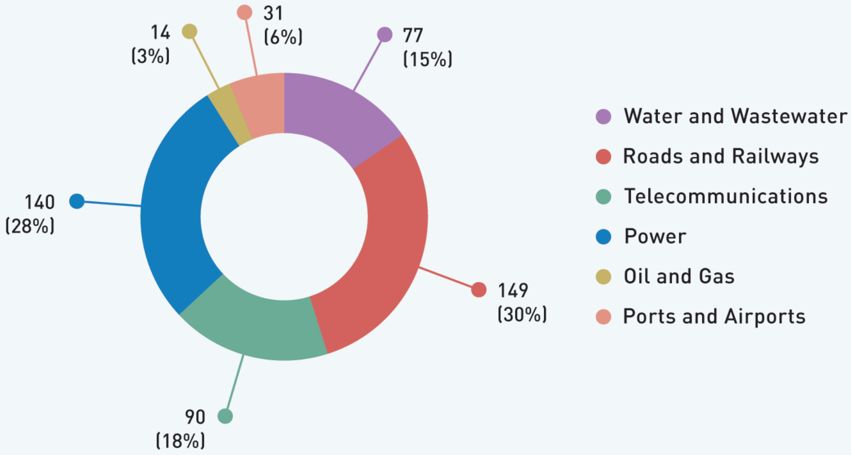
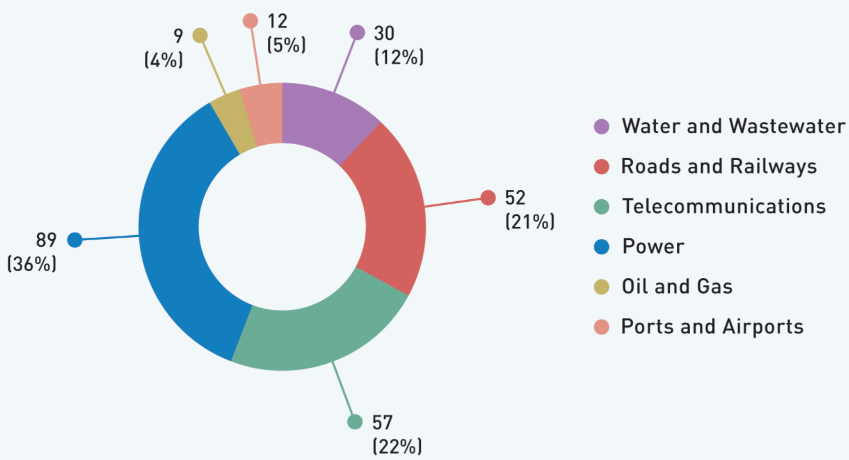


Figure 10

Global exposed value of infrastructure sectors for SIDS and SIAM (in billion US$)

Figure 11

Global exposed value of infrastructure sectors for SIDS (in billion US$)



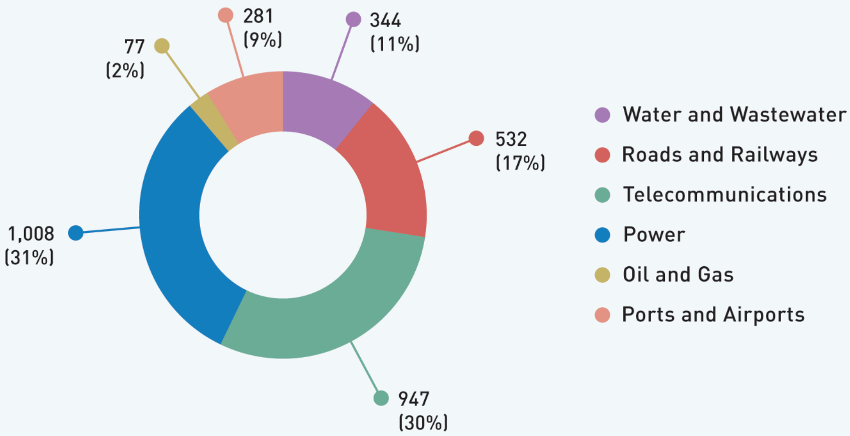


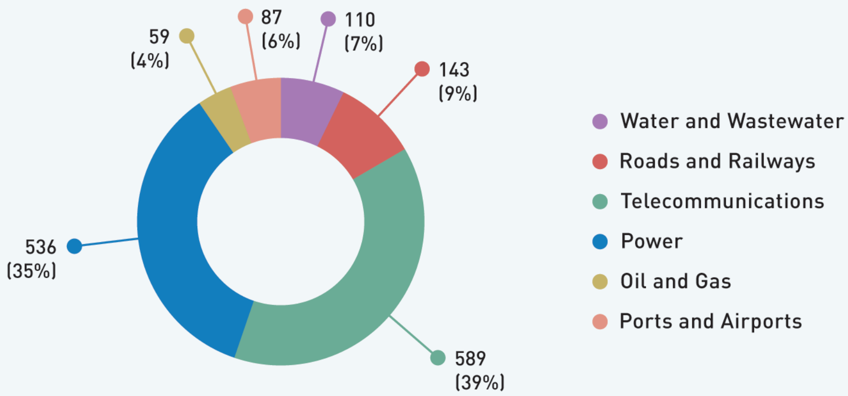
Figure 12

Average Annual Loss of infrastructure sectors for SIDS and SIAM (in million US$)

The GIRI model uses probabilistic calculations (see Section 3 for a description) to estimate the AAL. **Figures 12 and 13** present the AAL for SIDS and SIAM nations by infrastructure sector. This number is a useful general indicator that can inform decision-makers at the Ministry of Finance and the respective infrastructure agencies of what can they expect to see, on average, as direct losses due to damages to infrastructure assets.

Figure 13

Average Annual Loss of infrastructure sectors for SIDS (in million US$)



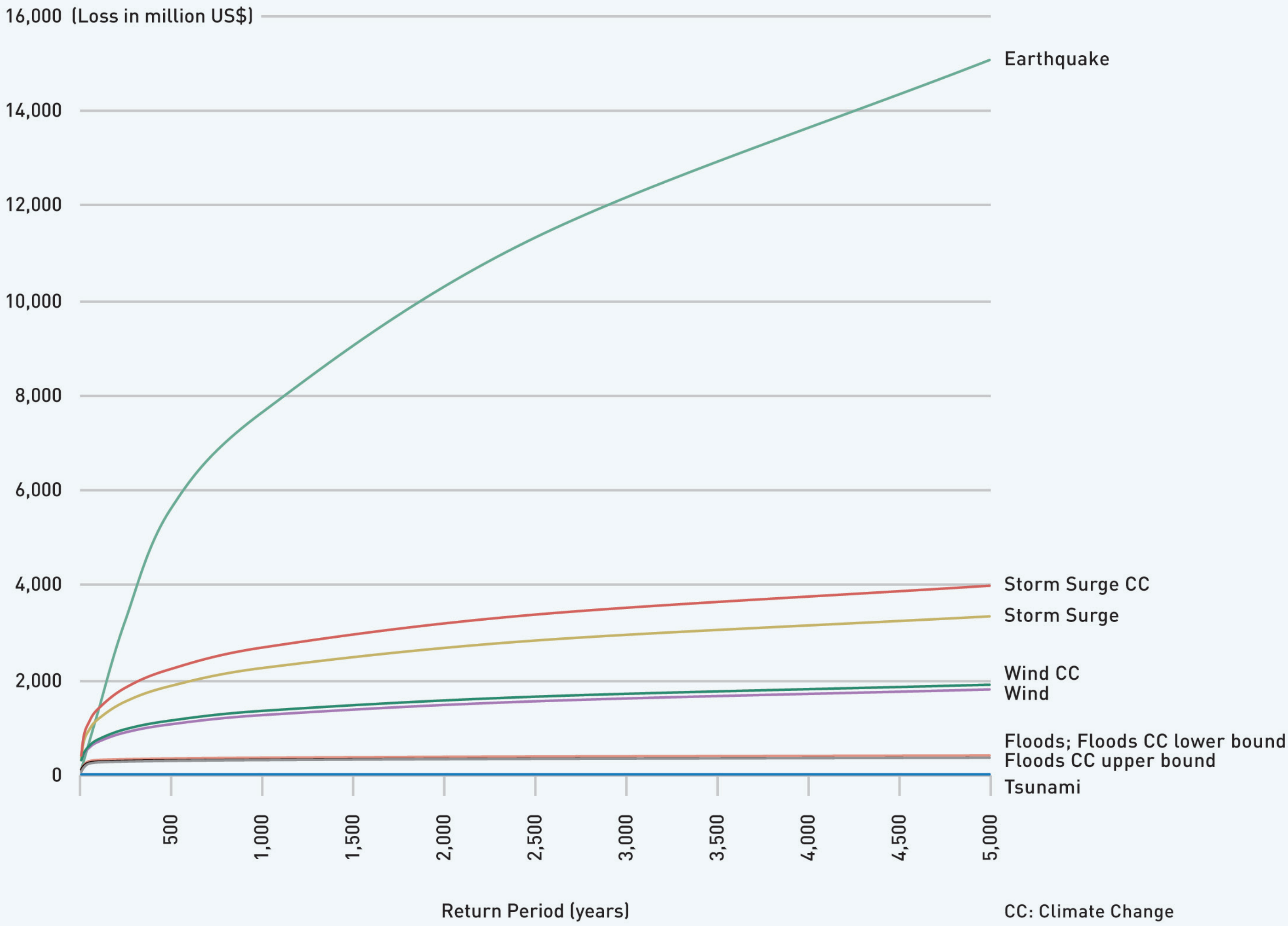


Figure 14

Expected Probable Maximum Losses (in US$) by return period (in years) in Jamaica

Source: CDRI, (2023b)

In SIDS, the telecommunications sector has the highest AAL with US$ 589 million, followed by the energy sector with US$ 536 million. These two sectors have widely distributed assets (towers and power cables). The roads sector and the water and wastewater sector follow in terms of AAL with US$ 143 million and US$ 110 million, respectively. These assets also have extensive networks across islands. Ports and airports are not far behind with US$ 87 million in AAL. Their smaller footprint and generally higher resilience measures mean lower losses.

It is important to note that AAL are different from worst-case disasters. Many cyclones can destroy large portions of the entire infrastructure asset of an island nation. There are many years when a specific island does not suffer disasters and the AAL considers such probabilistic distribution.

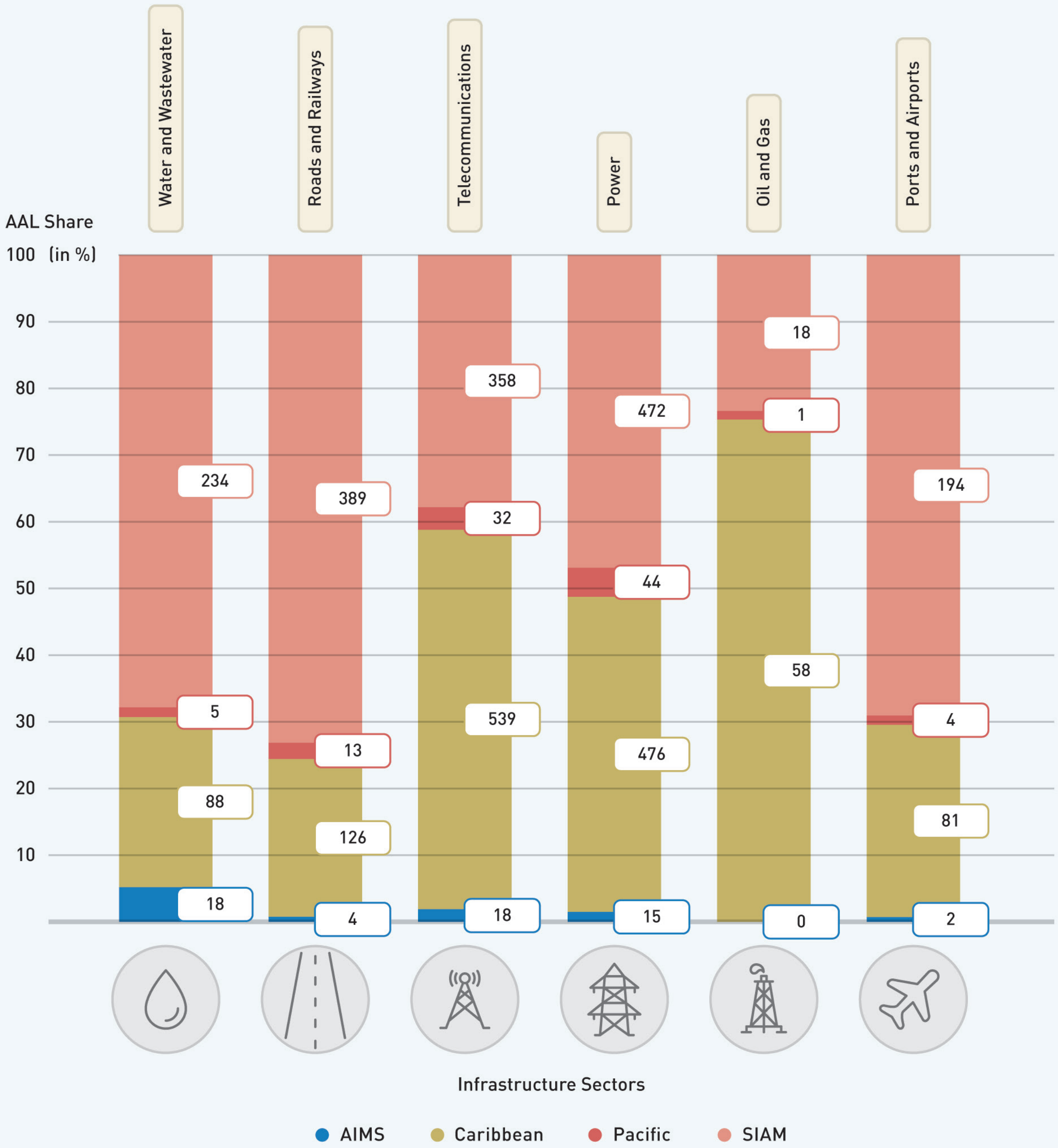
Resilience challenges in each sector are associated with specific hazards that have different periods of recurrence. As **Figure 14** highlights, earthquake risk in the case of Jamaica is associated with longer periods of recurrence compared to wind and floods. The Probable

Maximum Losses vary with the recurrence period considered. Countries, therefore, need to adopt hazard and sector-specific resilience policies, tailored to maximize the resilience dividend.

Figures 15 and 16 break down the AAL by regional country groupings (Caribbean islands, Pacific islands, Africa, Indian Ocean, Mediterranean and South China Sea (AIMS), and Small Island Associate Members (SIAM)). As the GIRI model is built from the bottom up considering every individual infrastructure asset, it is possible to aggregate in different ways, making it a flexible model to analyze at the country, regional, and sectoral level, along with many other combinations.

Figure 15

AAL by infrastructure sectors in SIDS and SIAM (in million US$)



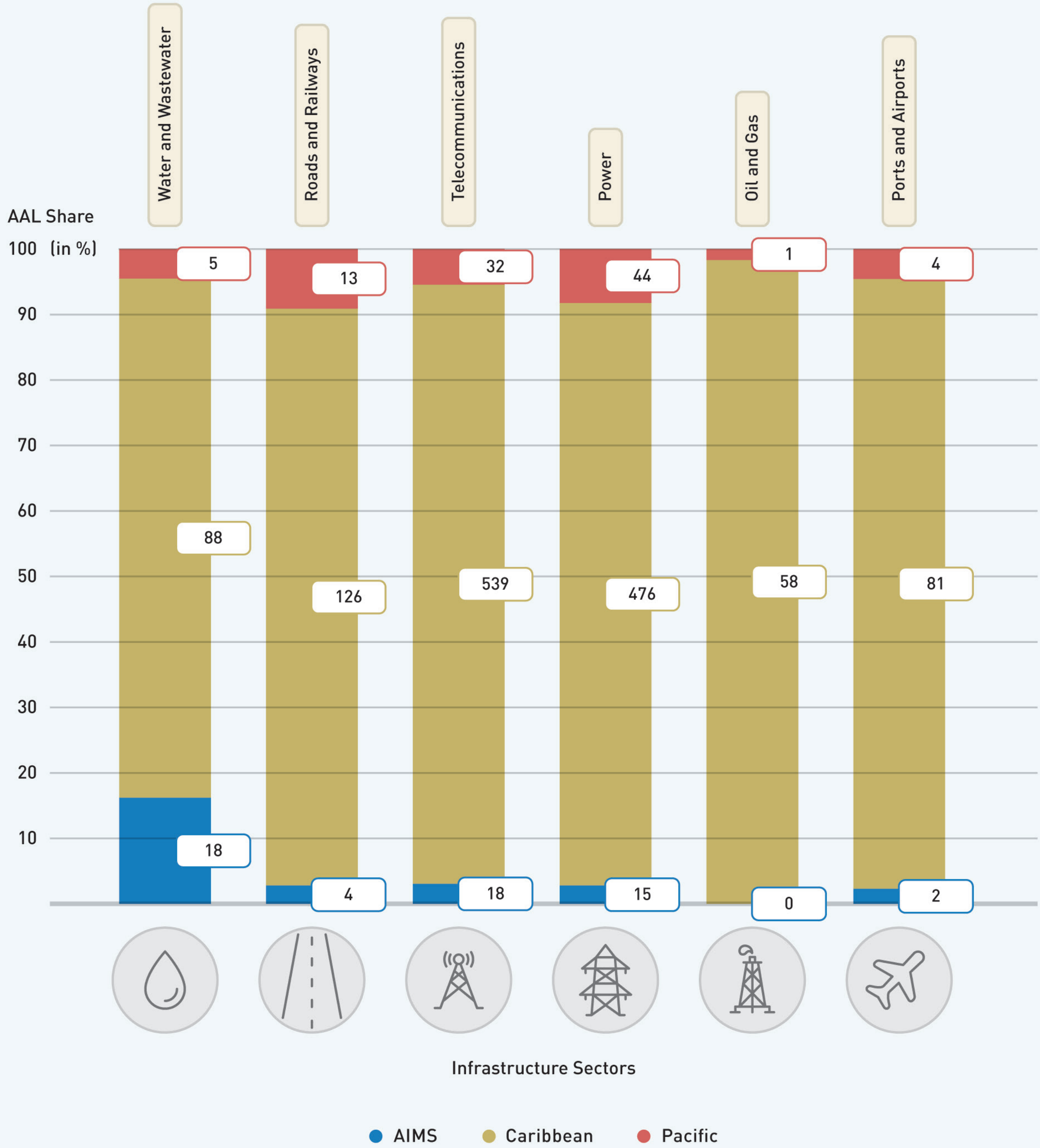


Figure 16

AAL by infrastructure sectors in SIDS (in million US$)

Figure 15 shows that the AAL values for all sectors are generally greater for SIAM nations, as they have larger infrastructure stocks and relatively similar risk profiles. The Caribbean islands have the second largest AAL as they have larger infrastructure stocks (generally linked to their size, economic development, and populations). For example, the telecommunications sector has AAL of US$ 539 million in the Caribbean and US$ 358 million in SIAM nations. The Pacific Islands and AIMS nations have much smaller values at US$ 32 million and US$ 18 million, respectively. The power sector has AAL of US$ 476 million in the Caribbean and US$ 472 million in SIAM nations.

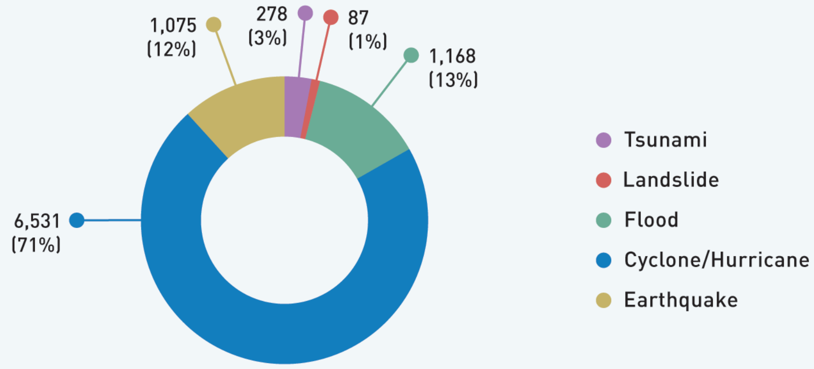


Figure 17

AAL by hazard type in SIDS and SIAM (in million US$)

The roads and the water and wastewater sectors show much higher AAL in SIAM nations compared to the Caribbean, with US$ 389 and US$ 234 million, respectively.

The GIRI model results can also be aggregated by hazard type for all infrastructure sectors. **Figures 17 and 18** present the AAL by hazard type.

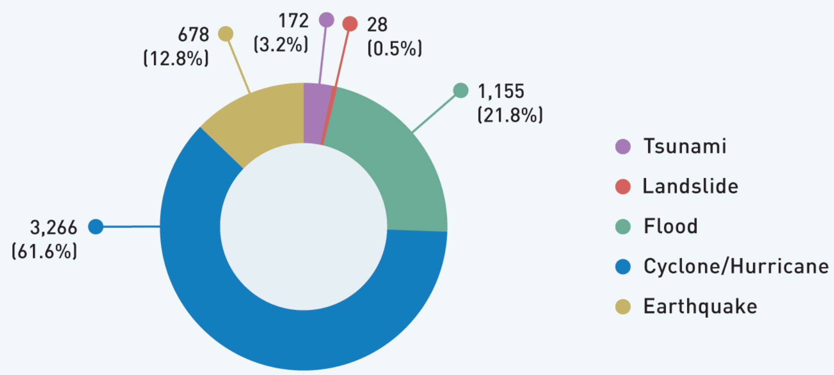
For SIDS, cyclones and floods are the main hazards for all infrastructure sectors. They are responsible for US$ 3.2 billion and US$ 1.1 billion AAL, or 62 and 22 percent of AAL, respectively. The third most damaging hazard is earthquakes with AAL of US$ 678 million.

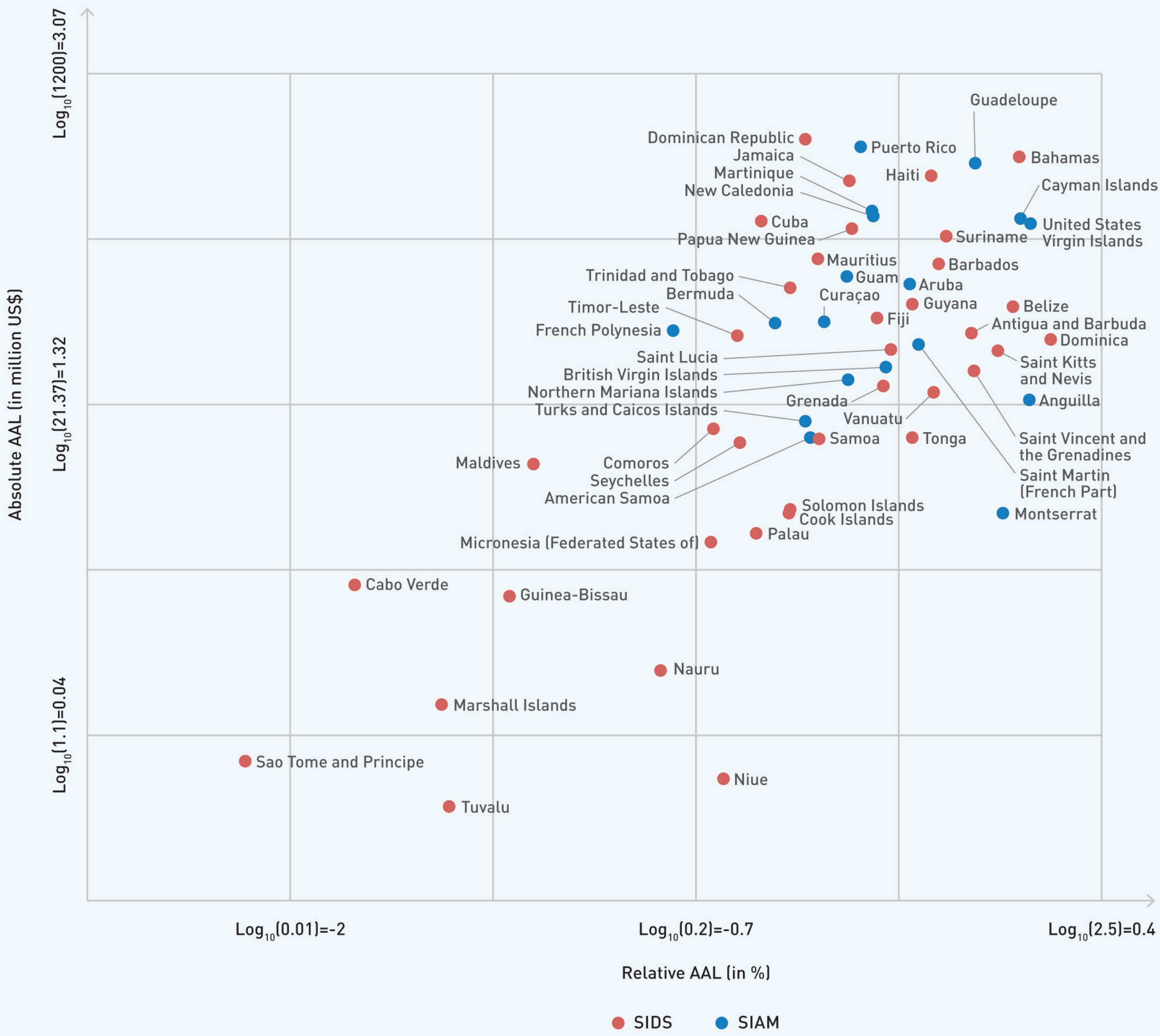
For SIDS and SIAM nations together, the AAL of cyclones is US$ 6.5 billion (US$ 3.2 billion for SIDS and US$ 3.3 billion for SIAM).

Another important variable to analyze is the relative AAL, which is the ratio between the absolute AAL and the value of assets. **Figure 19** shows the plot distribution (in log-log axes) of absolute AAL (measured in US$ millions) and the relative AAL.

Figure 18

AAL by hazard type in SIDS (in million US$)





All values represented in this scatter plot are equivalent logarithmic values.

Figure 19

Absolute AAL and relative AAL

Figure 7 in Section 4.2 shows the global plot. This figure shows that SIDS generally have a higher relative AAL compared to high-income nations because the hazards in SIDS are more significant, and the AAL are high compared to the infrastructure asset stock.

Figure 19 shows that SIAM nations and Caribbean nations, with their larger economies, infrastructure stocks, and geographical sizes have higher AAL and relative AAL thereby falling in the right-top quadrant, while Pacific Islands tend to be located in the lower-left quadrant.

Figure 20 shows the values of absolute and relative AAL by geographical groupings. SIAM and Caribbean nations have higher values, compared to Pacific Islands and AIMS nations.

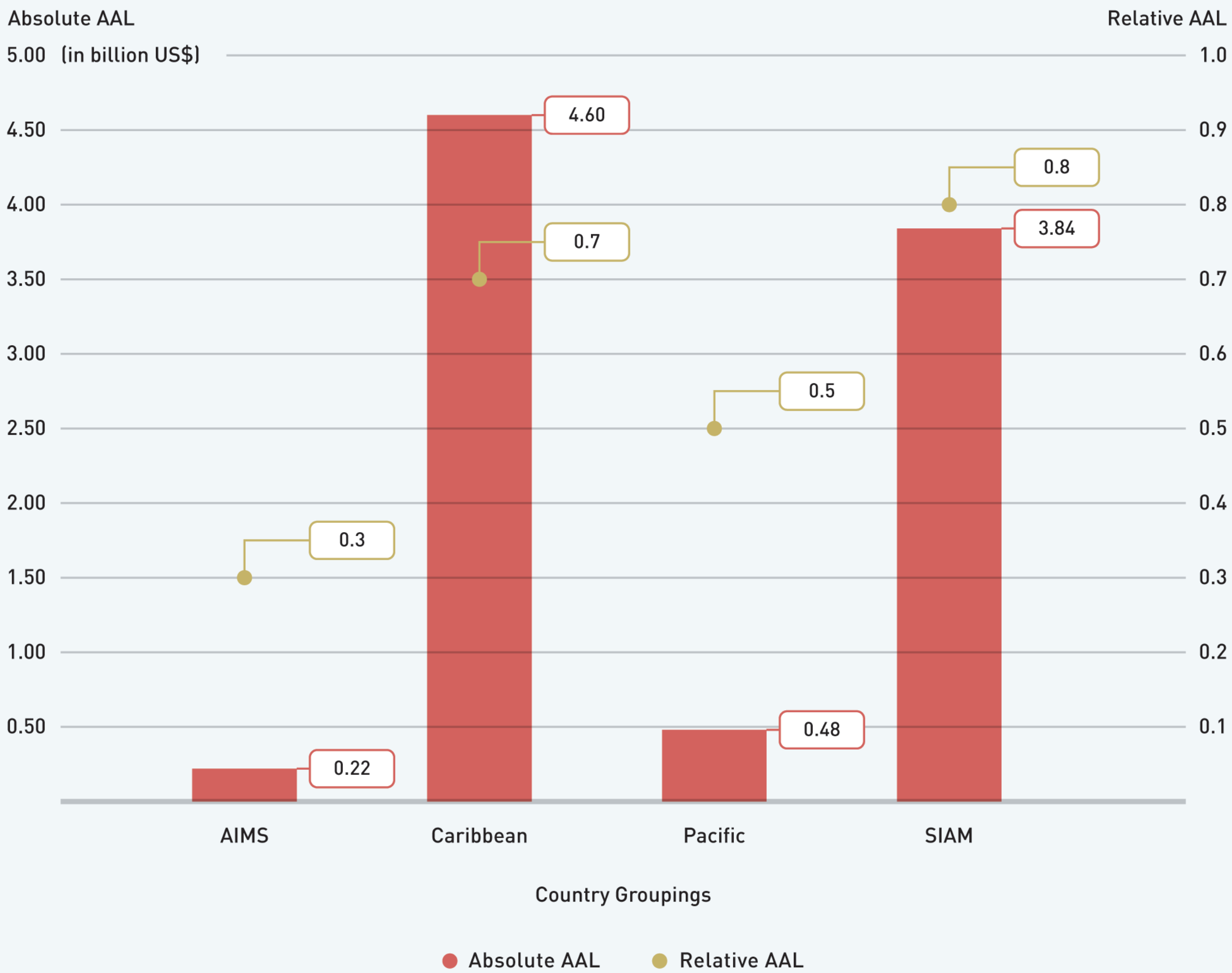
The GIRI model can also be applied to buildings (residential, commercial, public health and education facilities). The data for this infrastructure tends to be a little less reliable than for other infrastructure sectors. However, the order of magnitude calculations are reasonable to provide a sense of AAL.

Figures 21 and 22 show the global value of total infrastructure assets (infrastructure sectors discussed earlier in this section plus buildings) and the corresponding AAL. The values of AAL for the country groupings are higher than in Figure 20, as these do not include buildings. The total AAL for the Caribbean islands is US$ 4.6 billion, followed by SIAM nations with US$ 3.8 billion. The Pacific Islands and AIMS nations have total AAL of US$ 483 and US$ 217 million, respectively. **Figure 23** shows the distribution of AAL for infrastructure sectors (US$ 1.5 billion) and for buildings (US$ 3.8 billion).

Finally, the GIRI model can be used to estimate the increase in AAL when the hazards change due to climate change. **Figure 24** shows the difference between the AAL for current climate conditions and for a future high-warming scenario. The total AAL for the Caribbean islands increases from US$ 3.9 billion to US$ 4.3 billion, and for SIAM nations it changes from US$ 3.3 billion to US$ 3.6 billion.

Figure 20

Absolute and relative AAL by country groupings



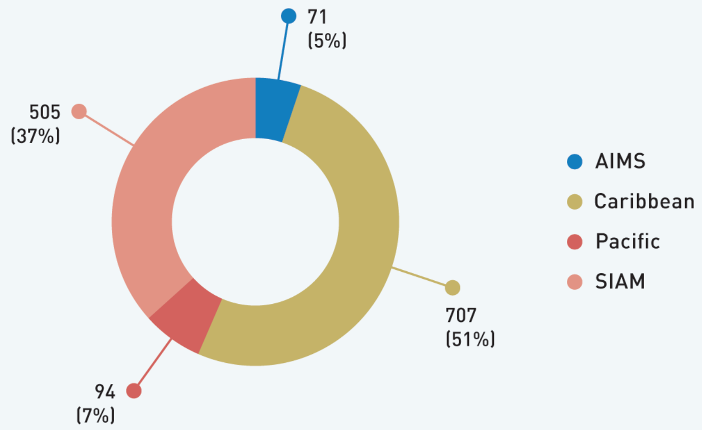
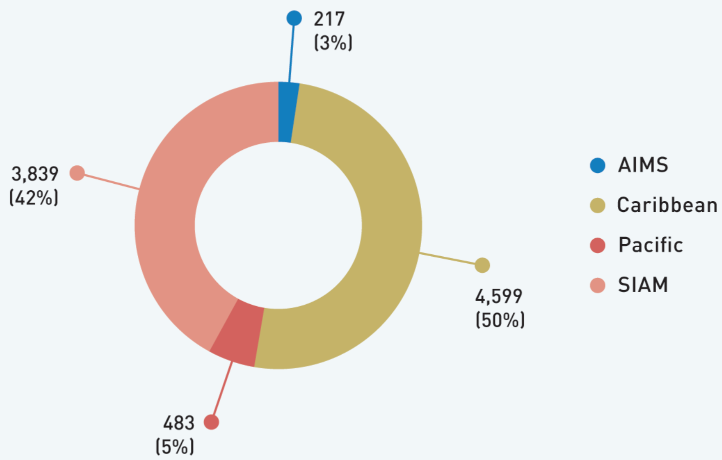


Figure 21

Global exposed value of total infrastructure (in billion US$)

Figure 22

Total infrastructure AAL (in million US$)



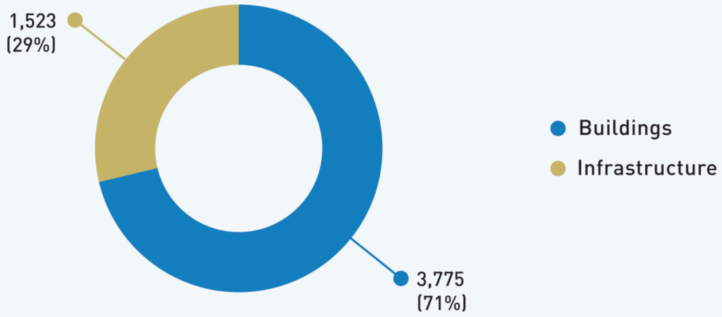
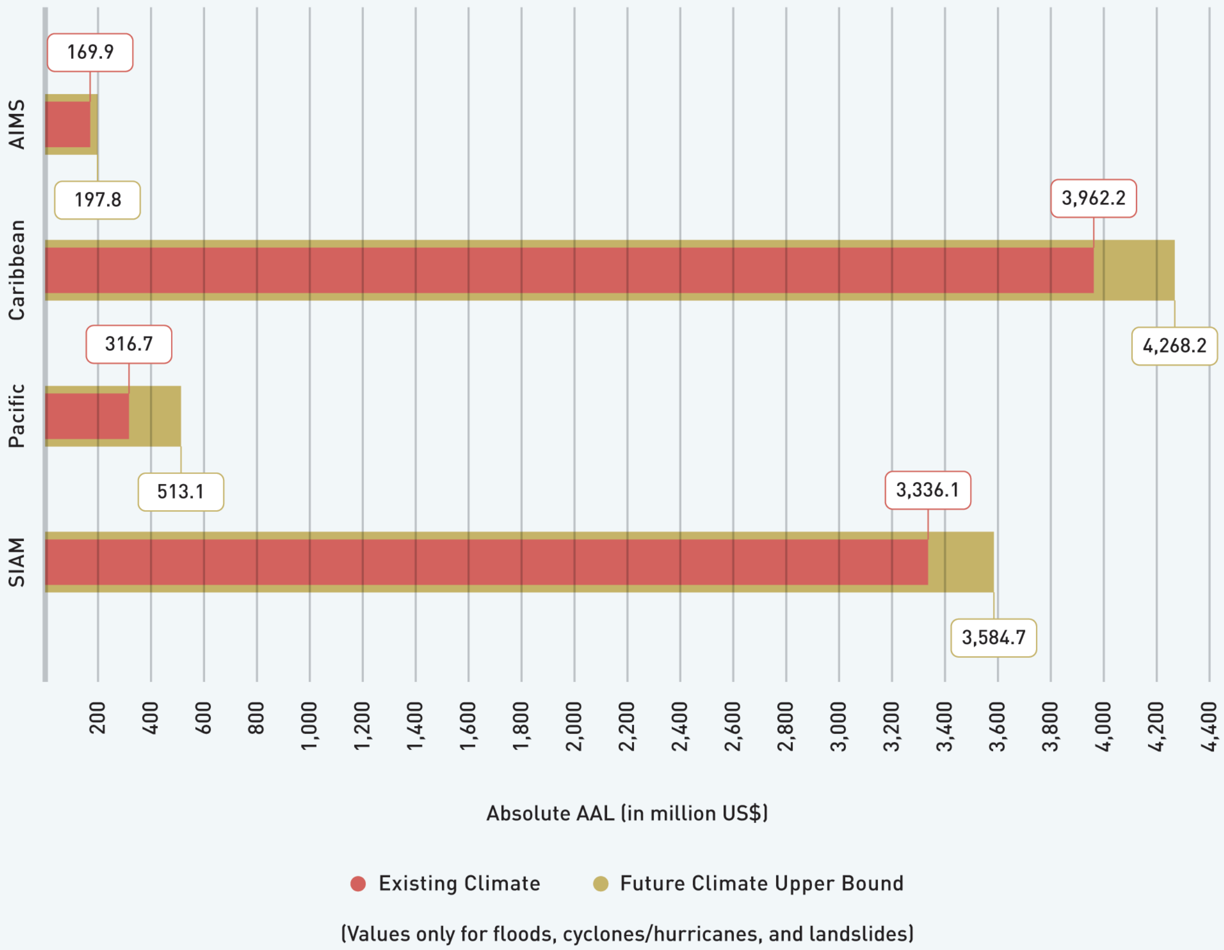


Figure 23

AAL for infrastructure sectors and buildings in SIDS (in million US$)

Figure 24

The impact of future climate in infrastructure sectors AAL (in million US$)



6. Challenges posed by disasters and climate change on infrastructure sectors and resilience solutions

This section presents examples of the enormous challenges that disasters are causing to the infrastructure of small islands. It also discusses the growing impacts of more frequent and intense climate-related disasters on infrastructure assets and services. The section reviews the transport (including ports and airports), energy, and water sectors.

6.1. Transport

Transport assets in island states are among the most affected infrastructure sectors, especially by tropical storms and storm surges. For example, Cyclone Maria caused US$ 182 million in damages to the transport assets of Dominica in 2018, and Cyclone Winston was responsible for US$ 63 million in damages in Fiji in 2016. These damages were, respectively, 60 and 61 percent of the total destruction to infrastructure assets (GFDRR, 2024).

These damages result from the growing intensity of tropical storm hazards and the vulnerability of transport assets due to insufficient resilience measures incorporated in their design and maintenance. In addition, these assets are exposed to a growing frequency of inundation caused by sea level rise, as most of these assets are located in low-elevation coastal zones due to the geography of islands. For example, in the Pacific SIDS, transport assets located within 500 meters of the coastline account for more than 50 percent of the total inventory.

In addition to the vulnerability of individual transport assets, the networks are generally weak due to low redundancy. For example, many islands depend on a circuit of roads around the island, or a single international port or airport. Consequently, when a single network link fails, the entire system fails. For example, according to World Bank calculations, a 100-year flood would damage about 30 percent of SIDS' road networks, but it would reduce road transport services by 65 percent (World Bank, 2017). When ports or airports fail due to disasters, the ability to receive essential goods for recovery and reconstruction, such as food, medicine, and construction materials, is severely constrained, thereby amplifying the disaster's impact on the economy.

Maritime transport assets are particularly vulnerable due to their coastal location. For example, Cyclone Evan caused US$ 26 million to maritime transport assets in Samoa in 2012 or about 4.6 percent of GDP (World Bank, 2023b). Even when maritime transport assets are not affected significantly, their financial performance drops after disasters, as they become the single point of entry for disaster relief and materials for reconstruction (docking fees are not charged in many of these crises). Retrofit programmes are needed in many ports serving SIDS. It is important to note, however, that disasters will cause damage to ports, so a preparedness and repair or reconstruction plan is also needed for each facility.

The vulnerability of transport assets is directly linked to their construction using outdated standards that are not ready for the changing risk profile of climate-related hazards. SIDS also lack sufficient funds for using updated construction standards as part of retrofit and rapid post-disaster reconstruction of transport assets. Finally, the limited fiscal capacity of SIDS to implement enhanced preventive maintenance programmes designed to strengthen the resilience of transport assets contributes to the sector's vulnerability.

On the institutional front, the transport sector needs strong strengthening measures. For example, transport agencies need specialized units to strengthen the resilience of assets and networks. Improved coordination with disaster management agencies to strengthen preparedness and enable rapid response after disasters would reduce the time to full recovery. Transport agencies can benefit from tools for disaster planning, asset management, new standards, and SIDS-specific design codes. Easy access and integration of assets, hazards, exposure, and vulnerability data would help transport agencies design retrofit, preparedness, and post-disaster recovery programmes.

SIDS' transport agencies are taking action to enhance the resilience of their assets and services. For example, the Pacific Islands, with the support of the World Bank, are implementing the successful Pacific Climate Resilient Transport Program. The programme supports deploying spatial and sector planning tools, such as a climate vulnerability assessment at the asset and network levels, and climate-informed asset and safety management systems. The programme finances the rehabilitation and construction of transport assets using climate-resilient design standards, including nature-based solutions (NbS). The programme also provides technical assistance to develop new climate-resilient standards, and systems to collect and analyze data and information on hazard risks (World Bank, 2022).

Another example is the Caribbean Regional Air Transport Connectivity Project (CATCOP), an initiative led by Grenada, Haiti, and Saint Lucia and supported by a US$ 159 million World Bank project. The initiative used a participatory design process involving experts in civil aviation, airport infrastructure, and resilience. The programme supports resilience-building investments, strengthens the airport sector's financial performance, enhances the airport management structure, embeds resilience in the respective organizations, and delivers a resilience enhancement implementation plan with hard and soft investments (World Bank, 2023a).

6.2. Energy

Energy systems in SIDS are characterized by high electricity costs, higher than in the US or Europe. This results from systems that work on imported fossil fuels and the high logistical costs of delivering this fuel in remote locations with small markets.

The typical electricity system in small islands is characterized by a central generation installation and distribution by overhead cables. This design is quite vulnerable to disasters such as tropical storms. The insufficient redundancy in the generation and distribution components adds to the vulnerability of the overall system. Cyclones have caused havoc to energy systems in small islands with multi-million-dollar damages and enormous economic impacts. For example, Hurricane Maria in 2017 caused more than US$ 350 million in damages to the electricity system of Puerto Rico (Rand Corporation, 2020). It took almost a year to restore power to some parts of the island, with enormous negative impacts on small businesses and households. Hurricane Dorian in 2019 caused more than US$ 130 million in damages to the energy sector (Doespersad et al., 2020).

The resilience of electricity systems in small islands should be considered at the asset and system levels. At the asset level, project siting is critical to enhance resilience by selecting sites that bring together hazard maps with the requirements of the energy system. The incorporation of resilience features in the design of systems is equally important. For example, solar photovoltaic installations can be designed to withstand Category 5 hurricanes with winds over 250 km/h. In the British Virgin Islands and Puerto Rico, solar photovoltaic systems survived hurricanes Irma and Maria with minimal damage (RMI, 2020). Practical measures such as adequate drainage for hurricane conditions, mounting structures designed for high wind conditions and low tilt angles are helpful.

Resilience at the system level means incorporating resilience throughout planning processes and, when needed, involves diversifying locations and energy resources to increase the system's capacity to withstand disasters and reduce the cost of electricity. The consideration of decentralized renewable energy solutions that can complement the system and be built to absorb disaster shocks is increasingly important in the planning processes of energy systems in SIDS. For example, Barbados used feed-in tariff policies and tax incentives to expand the use of distributed renewable energy resources, reaching an installed capacity of about 100 megawatts. The country is now working towards extending its storage capacity as a prerequisite to expanding its renewable resources further.

Investments in resilience are paying off. For example, Tonga Power Limited, the state-owned enterprise responsible for electricity in the country, launched a programme to strengthen the resilience of its network—the Tonga Village Network Upgrade Project. In 2018, when Cyclone Gita hit the country, only 10 percent of electricity distribution infrastructure was damaged in project areas, compared to 80 percent outside project areas.

However, physical resilience investments are only part of the solution. Institutional strengthening activities to support the many state-owned enterprises (SOEs) providing electricity in SIDS are also required (Darcy et al., 2023). These SOEs need stronger capacity for resilient energy system planning—hazard data and analysis combined with energy expansion plans, upgraded standards and enforcement capacity, and financial planning for resilient investments. The private sector can be a useful partner in these endeavours.

6.3. Water and wastewater

SIDS suffer from multiple water challenges. Not only are their infrastructure assets vulnerable to a wide range of hazards, but climate change impacts such as droughts and sea level rise affect water availability for multiple uses—households, tourism, and agriculture. Almost all SIDS face situations of water stress. For example, Trinidad and Tobago have had a water deficit since 2000, and Barbados uses nearly all its available renewable water resources (GWP, 2014).

Rapid-onset disasters, such as hurricanes, can cause substantial damage to the water and wastewater systems of SIDS. For example, Hurricane Maria left Barbuda, Dominica, and Puerto Rico without piped water services for several months. Slow-onset disasters such as droughts have caused havoc in the Caribbean. The major droughts of 2009-2010, 2014-2016, and 2018-2019 caused substantial service interruptions on several islands.

The vulnerability of water and wastewater systems is linked to the inability of infrastructure assets to withstand rapid-onset disasters, and to the insufficient capacity to store water and avoid water wastage in the distribution network. A combination of inadequate maintenance and limited financial capacity is behind these weaknesses in water systems in SIDS.

Water utilities need stronger financial and institutional capacity to tackle the resilience challenges of water and wastewater systems. At the planning level, integrated water resources management is needed which embeds resilience in all its stages—from planning to execution. Retrofit investments that protect infrastructure assets against disasters and reduce water losses and inefficiencies in systems are integral to resilience plans. Better data and early warning systems—both for rapid-onset hazards such as cyclones and slow-onset disasters such as droughts, sea level rise, and groundwater intrusion—should be embedded in water utilities. Finally, greater access is urgently needed to finance resources for resilience in new systems, retrofit programmes, and post-disaster reconstruction activities.

7. Elements of infrastructure resilience in SIDS and SIAM

This section proposes a framework for analyzing resilience across infrastructure sectors. This framework is then used to examine finance and institutional arrangements for resilient infrastructure. Finally, the section presents the CDRI Call to Action 2025-2034 towards resilient infrastructure for SIDS and coastal regions.

7.1. Three capacities for resilient infrastructure

Building resilience in infrastructure assets and systems requires a comprehensive view of the resilience cycle. **Figure 25** 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 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).

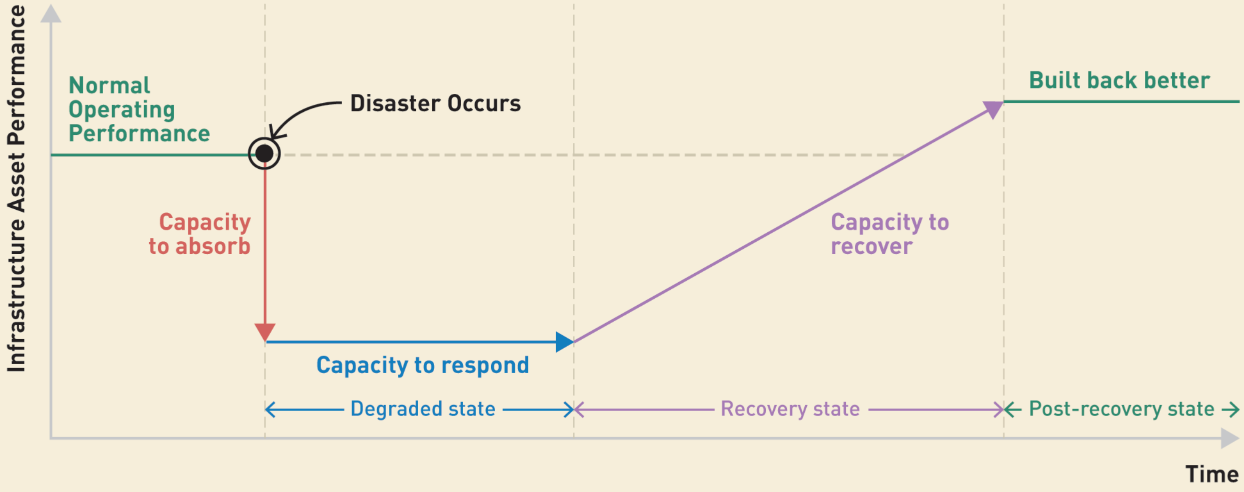


Figure 25

Three capacities for resilient infrastructure

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.

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 26** 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.

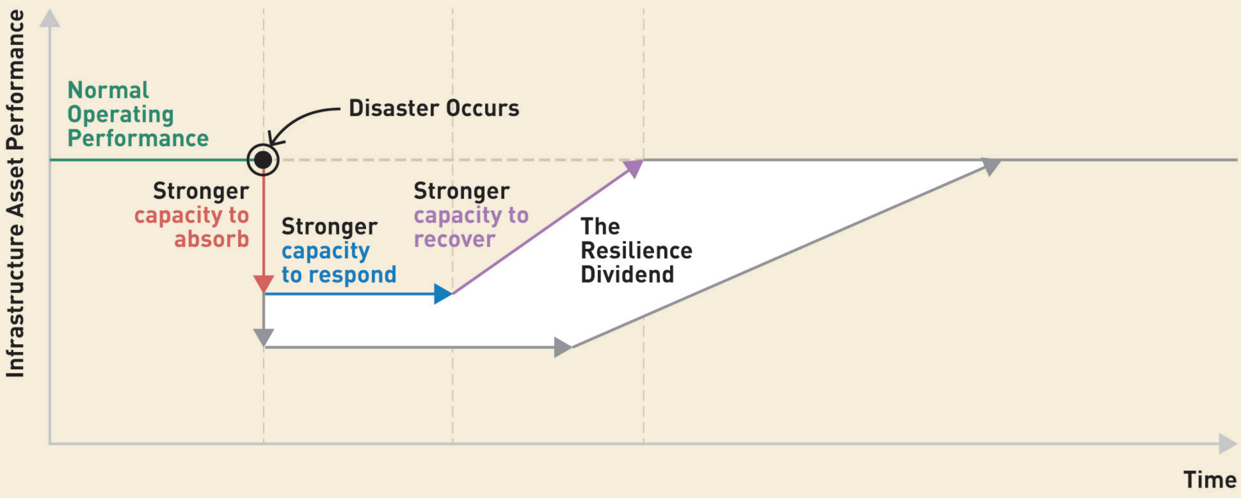


Figure 26

The resilience dividend

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 allow infrastructure agencies to strengthen the capacity of assets and systems to absorb, respond, and recover from disasters.

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

Strengthening the capacity of infrastructure assets and systems requires:

- Transparent financial allocations from the Ministry of Finance to infrastructure agencies are needed to retrofit existing assets. These allocations require a cost-benefit analysis of different levels of resilience. Introducing NbS as part of integrated grey-green infrastructure schemes can reduce up-front costs but may increase the maintenance costs—although they generally lead to lower life-cycle costs.
- Additional resources should be included 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 allow decisionmakers to allocate a reasonable level of resources commensurate with the fiscal capacity of the country, and the benefits (direct and indirect) that those resilience measures can achieve.

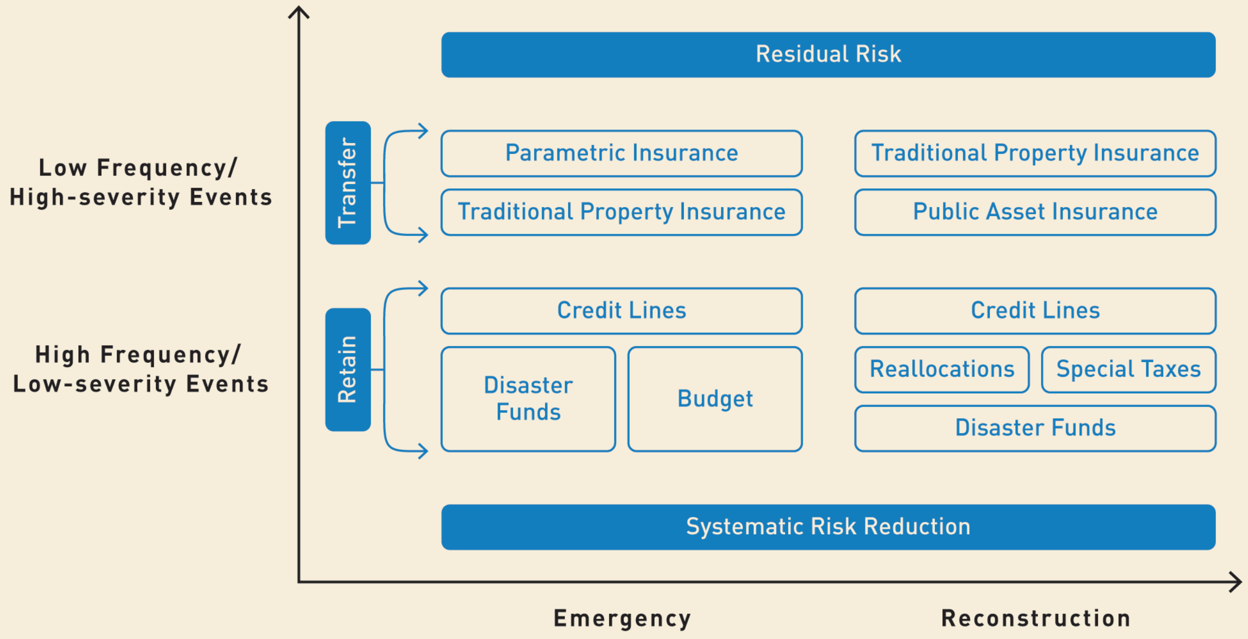


Figure 27

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

Source: Adapted from Toro et al. (2023)

- Clear and transparent resilience criteria should be incorporated in the bidding documents of infrastructure assets to be built and/or operated by private partners under a public-private partnership 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 the infrastructure users.

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 resources needed for repair and reconstruction as fast as possible can help reduce the recovery time. **Figure 27** shows a range of financing instruments for the recovery and reconstruction phases after disasters of different frequency and severity.

For low-severity disasters, the country 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 at either level—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. Speed in accessing these resources is critical to reduce the indirect economic and livelihood impacts.

For high-severity disasters, it is advisable to consider transferring the risk to entities that are better prepared to handle it: private or public insurance companies. The country can consider traditional infrastructure asset or property insurance or parametric insurance. SIDS in the Caribbean and the Pacific have effectively used multi-country parametric insurance that provides coverage for the initial emergency phase.

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

7.3. Institutional arrangements for disaster resilient infrastructure

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

At the institutional level, four important 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 expertize 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 expertize in design, construction, retrofit, preparedness, post-disaster response, and reconstruction.
- **Strengthen the private sector's technical capacity for resilience.** Private companies play a critical role in the construction, retrofit, repair, reconstruction, and construction supervision of infrastructure assets.
- **Define agile and effective inter-institutional mechanisms to prepare, respond, 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.
- **Develop the capacity for data collection and management.** Collection of data related to hazard, asset, vulnerability, and loss, to serve all infrastructure agencies in their resilience functions is critical.

Key areas commonly requiring strengthening in roles and responsibilities include:

- Upgrade standards with up-to-date data and resilience analysis in a manner that is appropriate for local SIDS' environments.
- Clarify the roles of disaster management and infrastructure agencies so that both can cooperate and leverage their strengths for faster recovery and reconstruction phases after disasters.
- Establish a cross-ministerial committee, chaired by the Ministry of Finance or the Office of the Prime Minister/President, to coordinate resilience actions that balance the needs of multiple sectors in a fiscally constrained environment.

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 SIDS include:

- Expand 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.).
- Provide 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.).
- Engage 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 Global Infrastructure Report 2025 from CDRI will analyze developing countries' institutional and governance experiences in their journey to strengthen the resilience of their infrastructure assets, systems, and users.

7.4. A Call to Action: Resilient infrastructure for SIDS and coastal regions

Recognizing the urgency of making infrastructure more resilient in SIDS, CDRI convened three expert working groups between March and April 2025 to interrogate barriers and identify solutions, which include: Access to Finance; Standards and Codes; and Data, Technology and Early-Warning systems. Annex 3 presents the members of these working groups.

The Call to Action is based on the following vision crafted by the working groups: "By 2034, all SIDS can build and maintain disaster resilient infrastructure, guided by localized codes, open risk data, and a mix of concessional, domestic, and private finance".

The expert groups had three main conclusions as a result of their deliberations:

1. Fragmented funding streams and complex fiduciary and reporting requirements, income-based eligibility, rigid timelines and thin project pipelines keep development and climate finance from reaching SIDS when and how they need it. The finance architecture needs reshaping so resources flow into resilient infrastructure investment programmes in small islands, at scale.
2. Foreign design codes and standards are misaligned with island hazards and limited human capacities, documents are difficult to access, and enforcement is challenging. Construction regulations need to be fit-for-purpose for SIDS, adapted to their size and capacities, encouraging 'minimum' requirements through incentives (as well as penalties) and the use of local materials.
3. Lack of baseline information, dispersed data across portals and behind paywalls, and gaps in communications networks, all pose severe challenges for building, maintaining and operating resilient infrastructure and early warning systems, and reaching vulnerable communities and people with disabilities. Unified, trusted data ecosystems and inclusive, tech-enabled alert systems can overcome these challenges.

This Call to Action proposes practical steps to close the resilience gap and protect hard-won development gains in some of the world's most vulnerable nations.

1. **Launch the SIDS Global Data Hub 2.0.** Consolidate hazard, asset and loss data for SIDS into an open, cloud platform with gender and disability disaggregated layers and a live interface for policy-makers, planners and investors.
2. **Ensure 100 percent multi-hazard early-warning coverage in SIDS by 2030.** Fund sensors, satellite links and low-cost, last-mile messaging (radio, cell-broadcast, vibro-alerts, sirens) so warnings reach every person, including remote atolls and persons with disabilities.

3. **Build permanent data-tech cadres.** Geospatial/physical planning units in SIDS receive long-term (9-year) capacity strengthening and knowledge exchange with university partners and budgets to maintain systems, audit data quality and translate analytics into investment-ready resilient projects.
4. **Develop SIDS-specific design codes.** CDRI and regional bodies develop a set of modular, hazard-appropriate minimum building and infrastructure design standards for SIDS that recognize vernacular methods, nature-based solutions and locally available materials.
5. **Tie finance to resilience compliance.** Normalize practice of providing higher concessional lending, conditional on resilience standards, insurance-premium discounts and tax rebates on certified resilient designs, retrofit and maintenance plans.
6. **Digitize standards enforcement and access.** Publish free, translated standards online; establish national or regional mechanisms, equip construction inspectors in SIDS with checklists and access to monitoring technologies, and fund vocational training programmes for contractors and communities to monitor compliance.
7. **Create a one-stop accreditation process for SIDS.** Establish a 'SIDS accreditation passport' across the climate funds and with MDBs, using AI to update information (for reaccreditation), to reduce duplicative application processes and capacity pressures on SIDS.
8. **Establish resilience units within ministries of finance.** Support SIDS to consolidate climate-finance, engineering and legal expertise in one unit and embed long-term climate finance/project finance technical advisers in these units.
9. **Generate resilient infrastructure pipelines and country investment platforms.** Develop resilient infrastructure pipelines in all SIDS covering both new builds and retrofits, and country investment platforms through which donors coordinate, pool resources and expertise, and give private financiers a clear entry point for blended finance.
10. **Launch a SIDS capacity accelerator for resilient infrastructure.** Establishing regionally coordinated training, diploma, apprenticeship, and micro-credential programmes that upskill SIDS engineers, data specialists and procurement officers to plan, finance and maintain resilient infrastructure.

7.5. CDRI's Infrastructure for Resilient Island States (IRIS) programme: Action on the ground

Infrastructure for Resilient Island States (IRIS) is CDRI's flagship programme offering financial and technical assistance, capacity building, and partnership support to all 57 SIDS. Launched at COP26, IRIS supports SIDS in achieving sustainable development through a systematic approach to resilient and inclusive infrastructure. The initiative is funded by Australia, India, the European Union, and the United Kingdom through donations totalling US$ 40 million.

CDRI is committed to assisting SIDS to develop resilient infrastructure through technical support, interventions in policy and regulatory frameworks, project proposal development, resource mobilization, enhancing capacities for project management and implementation, and strengthening data systems. IRIS aspires to equip SIDS with the knowledge and support needed to achieve disaster and climate resilient infrastructure and hence, sustainable and resilient prosperity.

Focus areas for IRIS include financing risk-informed and inclusive pipelines of infrastructure projects, facilitating uptake of tangible and locally relevant solutions for infrastructure resilience, and promoting locally available technical expertise and know-how.

Anchored on the key guiding principles of 'co-creation' and 'complementarity', IRIS is co-curated by SIDS and CDRI partners and proactively builds complementarity with past and ongoing initiatives that support disaster and climate resilient infrastructure development in SIDS. IRIS interventions are designed considering the demands and absorptive capacity of SIDS and strive to foster SIDS' ownership and leadership without unduly burdening SIDS' institutions.

Through IRIS, SIDS are supported to upgrade their capacities to mainstream resilience in the planning, operation, maintenance, or rehabilitation of their key infrastructure sectors. Beyond direct spending, IRIS aims to leverage its policy, planning, and project design support to prepare realistic 'bankable' infrastructure resilience project pipelines to unlock additional financing streams for SIDS. The IRIS advocacy strategy focuses on amplifying the voice of SIDS in demanding increased climate change adaptation funds and multilateral development bank reforms to allow smaller countries to access the investment they need.

At the SIDS4 conference in May 2024, IRIS focused on strengthening partnerships with organizing partners, the UN Office of the High Representative for the Least Developed Countries, Landlocked Developing Countries and Small Island Developing States (UN-OHRLLS) and the Government of Antigua and

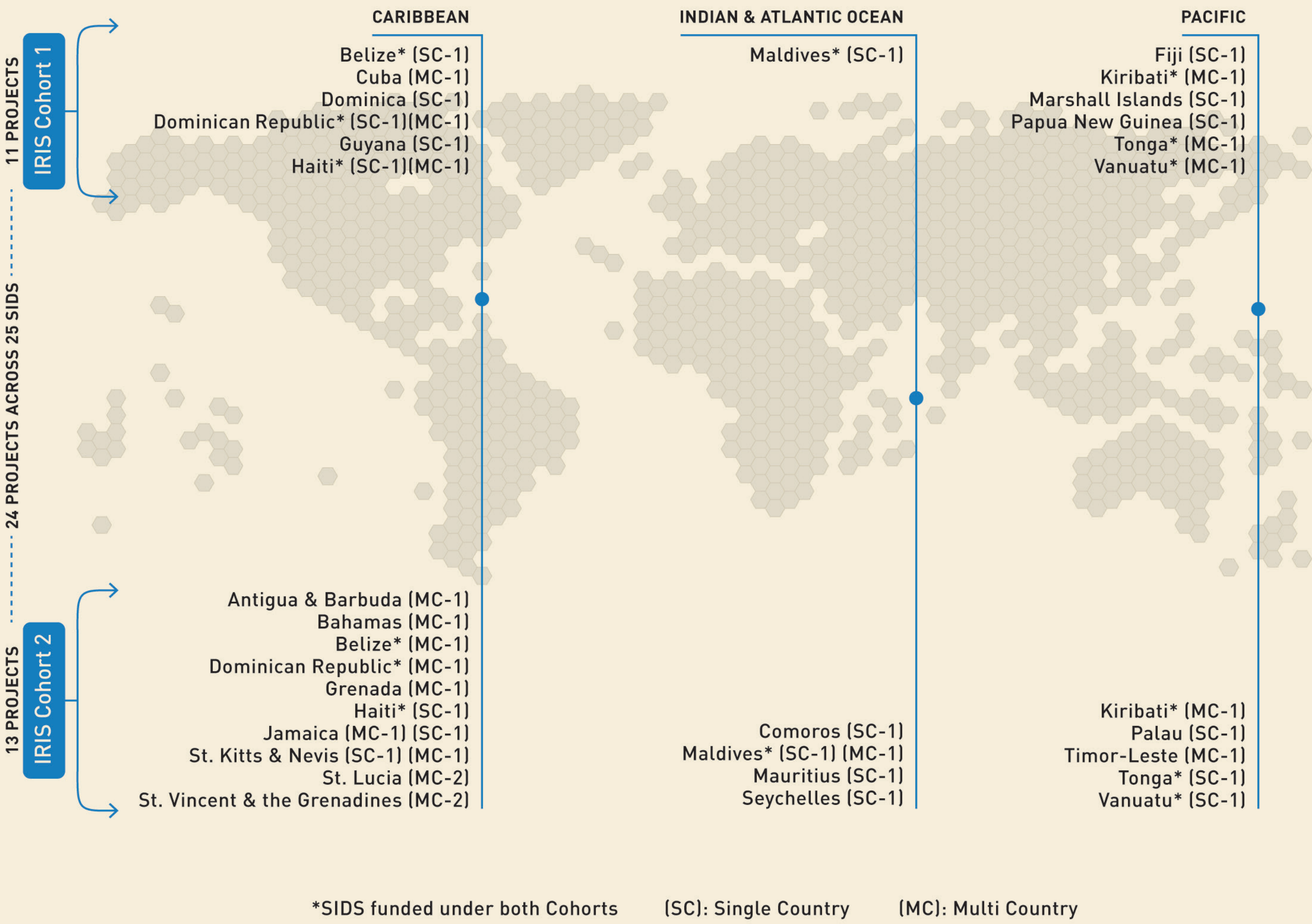


Figure 28

Projects supported by IRIS

Barbuda. As a result, CDRI was able to include disaster resilient infrastructure considerations in the draft 10-year roadmap for SIDS which was adopted in Antigua and Barbuda in May 2024. Acknowledging the participatory and inclusive approach that IRIS takes to provide technical support on multifaceted issues posed by infrastructure systems and promote disaster and climate resilience of infrastructure assets in SIDS, the initiative won the 2024 UN SIDS Partnerships Awards.

A total of 24 projects across 25 SIDS, including multi-country and regional projects, are being funded by the IRIS Programme through CDRI's Multi Partner Trust Fund (MPTF) and Infrastructure Resilience Accelerator Fund (IRAF), with an overall budget of US$ 13.8 million (**Figure 28**). The interventions target critical infrastructure sectors including housing, transport, power, telecommunications, water, health, and education. The projects focus on risk-informed policy and planning, implementation readiness, and access to finance.

Figure 29

Projects supported by CDRI in First IRIS Call for Proposals

7.5.1. First Cohort

Under the IRIS First Call for Proposals (**Figure 29**), 11 projects across 13 SIDS with a total budget of US$ 5.8 million were awarded in October 2023. The projects are currently at varying stages of implementation. They support SIDS' governments through concrete initiatives, including retrofitting of houses and hospitals, improving multi-hazard early warning systems, upgrading local building codes, and improving the resilience of renewable energy sources to strong winds and flooding.

7.5.2. Second Cohort

CDRI, in partnership with Antigua and Barbuda, announced the IRIS Second Call for Proposals—"Climate Action, Mainstreaming Resilience and Strengthening Data for Resilient and Inclusive Infrastructure" at SIDS4. The call was aligned with the Antigua and Barbuda Agenda for SIDS, adopted at SIDS4.

1. **Socially Inclusive Strengthening of Climate Resilient Infrastructure and Action in Caribbean SIDS**
   - Antigua and Barbuda
   - Dominican Republic
   - Saint Lucia
2. **Boosting the resilience of infrastructure assets and planned large-scale infrastructure investments in 4 Caribbean SIDS through risk-informed infrastructure asset management policies and practices**
   - St Vincent and the Grenadines
   - Bahamas
   - Jamaica
   - Belize
3. **Improving schools' resilience to natural disasters and climate adaptation**
   - Comoros
4. **Strengthening health facilities for disaster resilience**
   - Haiti
5. **Enhancing availability, quality, and use of risk information for critical infrastructure to reduce disaster risk, increase resilience and strengthen early warning systems**
   - Timor-Leste
   - Maldives
   - Kiribati
6. **Ensuring a sustainable and climate-resilient water supply in the Northern part of Mauritius**
   - Mauritius
7. **Guidelines and tools to enhance the resilience of schools**
   - Maldives
8. **Disaster Resilient Utility Infrastructure**
   - St. Kitts and Nevis
9. **The Blue Economy and Climate Change: Risk Assessment and Adaptive Strategies for Improved Seaport Resilience to Climate Change**
   - Seychelles
10. **Strengthening power sector resilience in Caribbean Island states**
    - St Vincent and the Grenadines
    - St. Kitts and Nevis
    - Saint Lucia
    - Grenada
11. **Enhancing resilience of critical subsea telecommunications connections for Tonga, Palau and other South Pacific Small Island Developing States (SIDS)**
    - Tonga
    - Palau
12. **Strengthening the resilience of the Vanuatu energy sector against climate-induced disasters**
    - Vanuatu
13. **Kingston Metropolitan Area (KMA) Water Utility Infrastructure Disaster Mitigation & Climate Change Resilience Programme, Kingston Jamaica**
    - Jamaica

Figure 30

Projects supported by CDRI in Second IRIS Call for Proposals

A total of 13 projects across 19 SIDS under a total budget envelope of US$ 8 million were awarded at COP29 (**Figure 30**). The projects are at varying stages of rollout and propose solutions to strengthen climate and disaster resilience of schools and health facilities, subsea telecommunications infrastructure, seaports, as well as energy and water systems.

7.5.3. Featured projects

Haiti

Revision of the National Building Code

Implementing partner: Build Change

Description: Given the need to improve the Haitian normative framework around housing resilience, the Ministry of Public Works, Transport and Communications, and Build Change are revising the Haitian National Building Code (CNBH) to incorporate best practices for building more resilient housing that can better withstand the impacts of climate change.

Key activities:

1. Revise CNBH to include detailed hurricane resilience specifications, especially for roofs and structural connections, using cost-effective, locally available materials.
2. Integrate retrofit standards into the CNBH by endorsing the existing seismic reinforcement guide and expanding it to include hurricane retrofitting for existing homes.
3. Broaden the CNBH to cover a wider range of small buildings, including timber frame houses and vernacular rural construction, which are common across Haiti.
4. Ensure the code revision process is inclusive and participatory, involving government agencies, private sector actors, and civil society stakeholders.
5. Raise awareness among stakeholders on the importance of resilient construction, improving readiness for implementing the revised code once adopted.
6. Deliver a more complete, practical, and enforceable building code that supports long-term housing resilience in the face of climate change.

Papua New Guinea

Strengthening institutional and technical capacity for climate resilient transport infrastructure development

Implementing partner: Global Green Growth Institute (GGGI)

Description: The project aims to support the government of PNG to develop risk-informed investment in the transport sector, for example, targeting vulnerable roads and bridges for reinforcement or designing new infrastructure to withstand future climate events.

Key activities:

1. Build capacity on climate resilient road infrastructure development in PNG including a south-south knowledge exchange modality to share best practices on mainstreaming climate and disaster resilience in transport infrastructure among countries facing similar climate related challenges.
2. Develop climate hazard risk and vulnerability assessment guidelines on climate-proofing road infrastructure and road design standards that will guide the Department of Works and Highways and relevant departments to systematically mainstream climate change in the entire lifecycle of current and new road infrastructure projects.
3. Develop standards and guidelines for climate resilient transport infrastructure that will govern the operationalization of the sector contributing to achieving Nationally Determined Contribution (NDC) and National Adaptation Plan (NAP) priorities.

Guyana

Towards developing strategic sustainable integrated national drainage and irrigation systems

Implementing partner: Global Green Growth Institute (GGGI)

Description: The project is designed to support the Ministry of Agriculture in developing an Integrated Strategy for Drainage and Irrigation (ISDI) for the period 2025-2030, aligning with the Low Carbon Development Strategy 2030 (LCDS 2030) and enabling inter-ministerial collaboration on drainage and irrigation (D&I) and flood management efforts.

The project's specific objectives are to reduce Guyana's vulnerability to floods through integrated planning; support institutional strengthening capacity building; and enhanced data collection and management to measure impact, with an emphasis on collaboration.

The updated ISDI will guide and augment the National Drainage and Irrigation Authority (NDIA)'s decision-making for flood management by building capacity in operations, investment prioritization, and resource allocation.

Key activities:

1. Reduce Guyana's vulnerability to floods through integrated planning and institutional capacity strengthening.
2. Enhance data collection and management to measure impact while emphasizing collaboration.
3. Conduct technical studies on the potential for integration of resilience and NbS into D&I systems in Guyana.
4. Support development of ISDI which will include strategies for resilient, effective, and inclusive flood management and agricultural development.
5. Design a data collection and prioritization system for capital works in D&I which considers the impact of investment projects on ecosystems, farmers, and communities.
6. Increase NDIA's engineering, monitoring and evaluation, and learning capacity towards the design of improved data collection systems integrating resilience and NbS approaches.

Annex 1.

List of SIDS and SIAM

This annex presents the list of Small Island Developing States (SIDS) and Small Island Associate Members (SIAM) as defined by the United Nations.[2]

Small Island Developing States

Antigua and Barbuda
Bahamas
Barbados
Belize
Cabo Verde
Comoros*
Cook Islands
Cuba
Dominica
Dominican Republic
Fiji
Grenada
Guinea-Bissau*
Guyana
Haiti*
Jamaica
Kiribati*
Maldives
Marshall Islands
Mauritius
Micronesia (Federated States of)
Nauru
Niue
Palau
Papua New Guinea
Saint Kitts and Nevis
Saint Lucia
Saint Vincent and the Grenadines
Samoa
Sao Tome and Principe
Seychelles
Singapore
Solomon Islands*
Suriname
Timor-Leste*
Tonga
Trinidad and Tobago
Tuvalu*
Vanuatu

** Also Least Developed Country*

Small Island Associate Members

American Samoa
Anguilla
Aruba
Bermuda
British Virgin Islands
Cayman Islands
Curaçao
French Polynesia
Guadeloupe
Guam
Martinique
Montserrat
New Caledonia
Northern Mariana Islands
Puerto Rico
Saint Martin (French Part)
Turks and Caicos Islands
United States Virgin Islands

The risk calculations presented in this paper do not include Singapore as part of the SIDS grouping to avoid biases due to the much higher level of infrastructure and economic development of the country compared to other SIDS.

[2] https://www.un.org/ohrlls/content/list-sids

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.

[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.

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.
- 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.

List of Working Group members for CDRI's Call to Action: Resilient infrastructure for SIDS and coastal regions

Dr. Emily Wilkinson Principal Research Fellow ODI Global, (Lead for 'Access to Finance' Working Group)	**Dr. Ravi Sinha** Professor, Department of Civil Engineering, IIT Bombay (Lead for 'Standards and Codes' Working Group)	**Ajay Lavakare** Senior Advisor, CDRI (Lead for 'Data, Technology and EWS' Working Group)
Ashaki Goodwin Director of the Development Bank for Resilient Prosperity, PVBLIC Foundation	**David Fatscher** Interim Head of Standards-Sustainability & ESG BSI Group	**Delka Espinal** Representative of the Dominican Republic, GeoHazards International
Emmanuel Escoto G Manager Global Cooperation, ASTM	**Dr. Giriraj Amarnath** Principal Researcher, CGAIR	**Dr. Greg Scott** Executive Director, SDG Data Alliance PVBLIC Foundation
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Dr. Ilan Noy Chair in the Economics of Disasters & Climate Change, Victoria University of Wellington	**Judy Zakreski** Senior Vice President, Global Operations & Solutions, International Code Council	**Dr. Karim Selouane** Co-chair of Adaptation Hub of the GlobalABC, Adaptation Mission Board Member of the European Commission, AFPCNT Board Member
Louise Foulkes Caribbean director and engineering program manager, Build Change	**Mairi Dupar** Senior Technical Advisor ODI Global	**Maria Medard** Disaster Management Coordinator CARILEC
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Dr. Sudheer Joseph Scientist-G & Division Head, ARO INCOIS	**Taneque Heslop** Senior Chief Executive, Ministry of Economic Growth and Job Creation, Jamaica	**Victor Pianet** Projects Leader, Observatoire de l'immobilier durable
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