CDRI
Coalition for Disaster Resilient Infrastructure

A CDRI WHITE PAPER

PATHWAYS FOR GLOBAL INFRASTRUCTURE RESILIENCE

JULY 2023

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Introduction

Strengthening infrastructure resilience is a major global contemporary challenge. Recent estimates of the annual investment required by 2050 to address the infrastructure deficit, achieve the SDGs, build net-zero economies, and strengthen resilience in low- and middle-income countries (LMIC), amount USD 2.84 - 2.90 trillion (Chavarot, 2023). Current infrastructure investment in LMIC is at least an order of magnitude lower than the projected needs.

LMICs, in particular, face a multidimensional challenge of a large infrastructure deficit that constrains social and economic development; precarious and poor-quality infrastructure due to deficiencies in infrastructure governance, rising disaster related asset loss and damage, leading to more frequent service disruption, and a stock of existing infrastructure increasingly ill-suited to address the challenges posed a rapid transition from carbon-locked-in infrastructure to low, zero or negative emission infrastructure (Seto et al., 2016).

A significant proportion of existing infrastructure investment is eroded by rising asset loss and service disruption associated with disaster and climate risk. Given an estimated global Average Annual Loss of USD 732 – 845 billion in infrastructure and buildings (CDRI, 2023), representing around one-seventh of GDP growth, new infrastructure investments without strengthened resilience are analogous to pouring water into a bamboo basket.

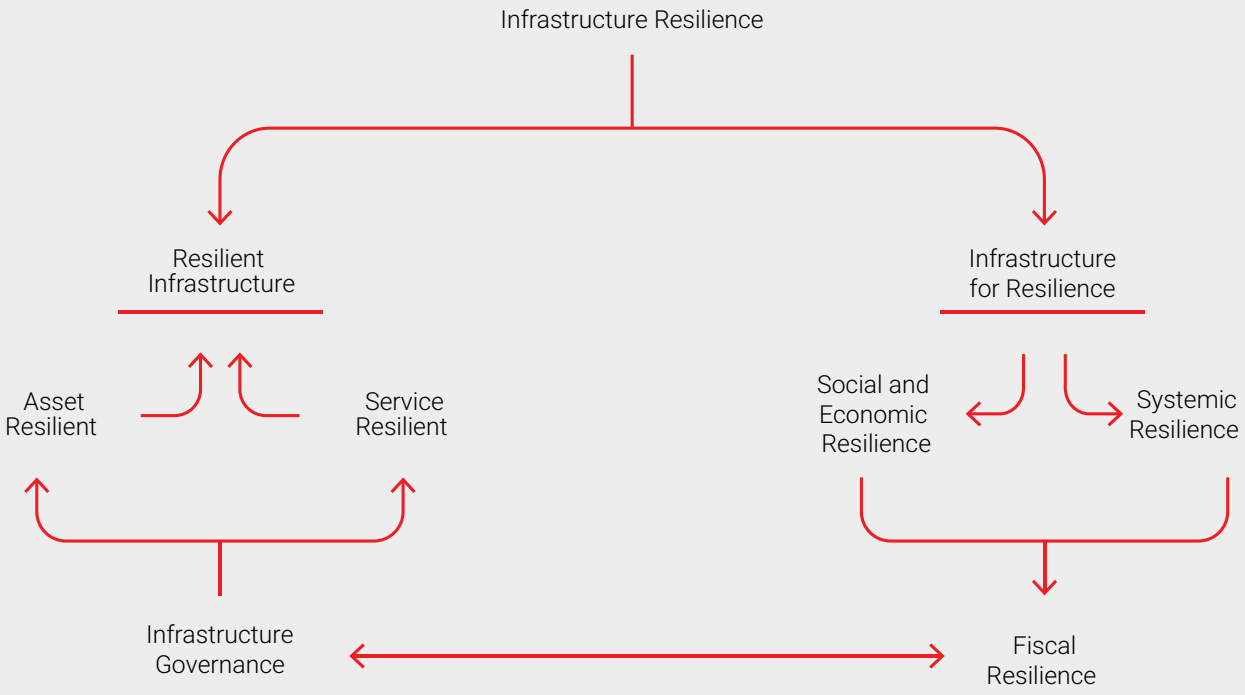
Most of the infrastructure required by 2050 in LMIC has yet to be built. This represents both a challenge as well as an opportunity. The challenge is to identify a compelling political and economic imperative to upscale investment in infrastructure resilience. The opportunity is that the dividend that can be obtained from investing in infrastructure resilience, including avoided loss and damage, reduced service disruption, wider social, economic, and environmental co-benefits, and reduced systemic risk, often represents several times the additional cost over the asset lifecycle. Identifying and estimating this dividend is essential to change the perception of resilience from a cost to an opportunity; to increase the economic and financial value of projects; and demonstrate that the risk-adjusted returns of resilient investments can be attractive to capital providers.

This White Paper summarizes some of the key challenges that need to be addressed to strengthen global infrastructure resilience (See Box 1 and Figure 1.) It draws on evidence from the new Global Infrastructure Risk Model and Resilience Index (GIRI, 2023) to highlight how these challenges manifest in different income and regional geographies and infrastructure sectors. It then focuses on a range of opportunities and pathways to strengthen infrastructure resilience, including through the upscaling of Nature based Infrastructure Solutions (NbIS), the strengthening of infrastructure governance and the mobilization of private capital.

Box 1: What is infrastructure resilience

The concept of *infrastructure resilience* includes *resilient infrastructure* as well as *infrastructure for resilience*. *Resilient infrastructure* refers to infrastructure assets that can absorb, bounce back from, and adapt to hazard events and shocks, and ensure service continuity. *Infrastructure for resilience* refers to infrastructure as a core driver of and support to broader social and economic or systemic resilience. For both to be achieved, infrastructure governance and fiscal resilience are critical enablers (Figure 1).

Figure 1: Dimensions of Infrastructure Resilience



Source: CDRI, 2023, Global Infrastructure Resilience: Capturing the Resilience Dividend, a Biennial Report from the Coalition for Disaster Resilient Infrastructure.

The challenges

Infrastructure for social and economic resilience

Infrastructure is the engine of economic growth and social development. Infrastructure investment (using Gross Fixed Capital Formation or GFCF as a proxy) has steadily increased annually, from just over US$ 742 billion in 1970 to more than USD 25 trillion today. More than 90 percent of today's infrastructure has been built in the last 50 years, underpinning the 'urbanization of society' in all regions.

Infrastructure is critical to the achievement of the Sustainable Development Goals (SDG) Infrastructure is fundamental to achieving Goal 9 of the SDGs (industry, innovation, and infrastructure) but also contributes to good health and well-being (Goal 3), quality education (Goal 4), clean water and sanitation (Goal 6), affordable clean energy (Goal 7) and urban resilience (Goal 11) (UN, 2015). Dependable essential services support multiple welfare benefits such as sustained employment (Goal8), poverty reduction (Goal1), and gender equality (Goal5).

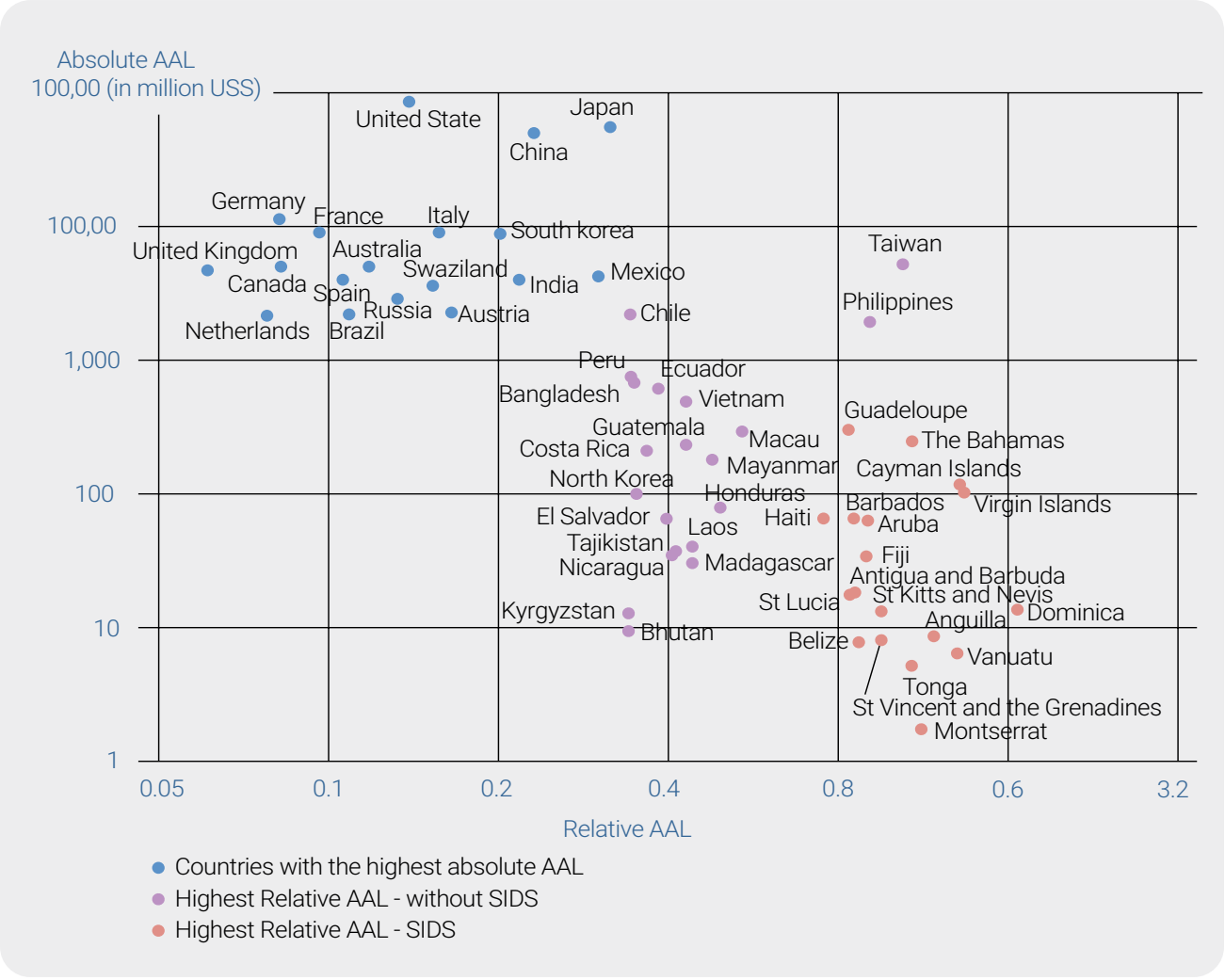
The gap in infrastructure investment between lower and higher-income countries is widening, constraining social and economic development in the former. In high-income countries, the per capita value of infrastructure is USD 200,000 compared to USD 37,000 in upper-middle-income countries, USD 8,000 in lower-middle-income countries, and USD 3,000 in low-income countries (GIRI, 2023). In low-

income countries, capital investment, as a proportion of GDP, has consistently lagged behind that of middle or higher-income countries. For example, annual capital investment in Africa has historically averaged around 13 – 14 percent of GDP compared to26 – 31 percent of GDP in Asia, nearly double that rate. The COVID-19 pandemic has further aggravated the gap: since 2020 progress against some SDGs, such as water, has stalled or in some cases, reversed. In Sub-Saharan Africa, the proportion of the population without access to electricity rose to 77 percent, compared to 74 percent before the pandemic (IEA, 2022).

Increasing asset loss and damage and service disruption

High levels of disaster-related asset loss and damage, erode the capacity of LMIC to make new capital investments, as budgets (including for operations and maintenance) are diverted to repair, rehabilitate, and reconstruct damaged infrastructure. Considering the effect of climate change, the global Average Annual Loss (AAL)[1] for infrastructure, including buildings, is in the range of USD 732 – 845 billion, representing about 14 percent of 2021 - 2022 GDP growth. Around USD 280 billions of this contingent liability is held by LMIC. The AAL

Figure 2: Absolute and relative AAL for infrastructure sectors across countries



Source: CDRI, 2023, Global Infrastructure Resilience: Capturing the Resilience Dividend, a Biennial Report from the Coalition for Disaster Resilient Infrastructure.

[1] The Average Annual Loss or AAL is a measure of annualized future losses over the long term, derived from probabilistic risk models.

should be understood as an opportunity cost, given that the financial resources required to cover for loss and damage could have been used for new capital investment.

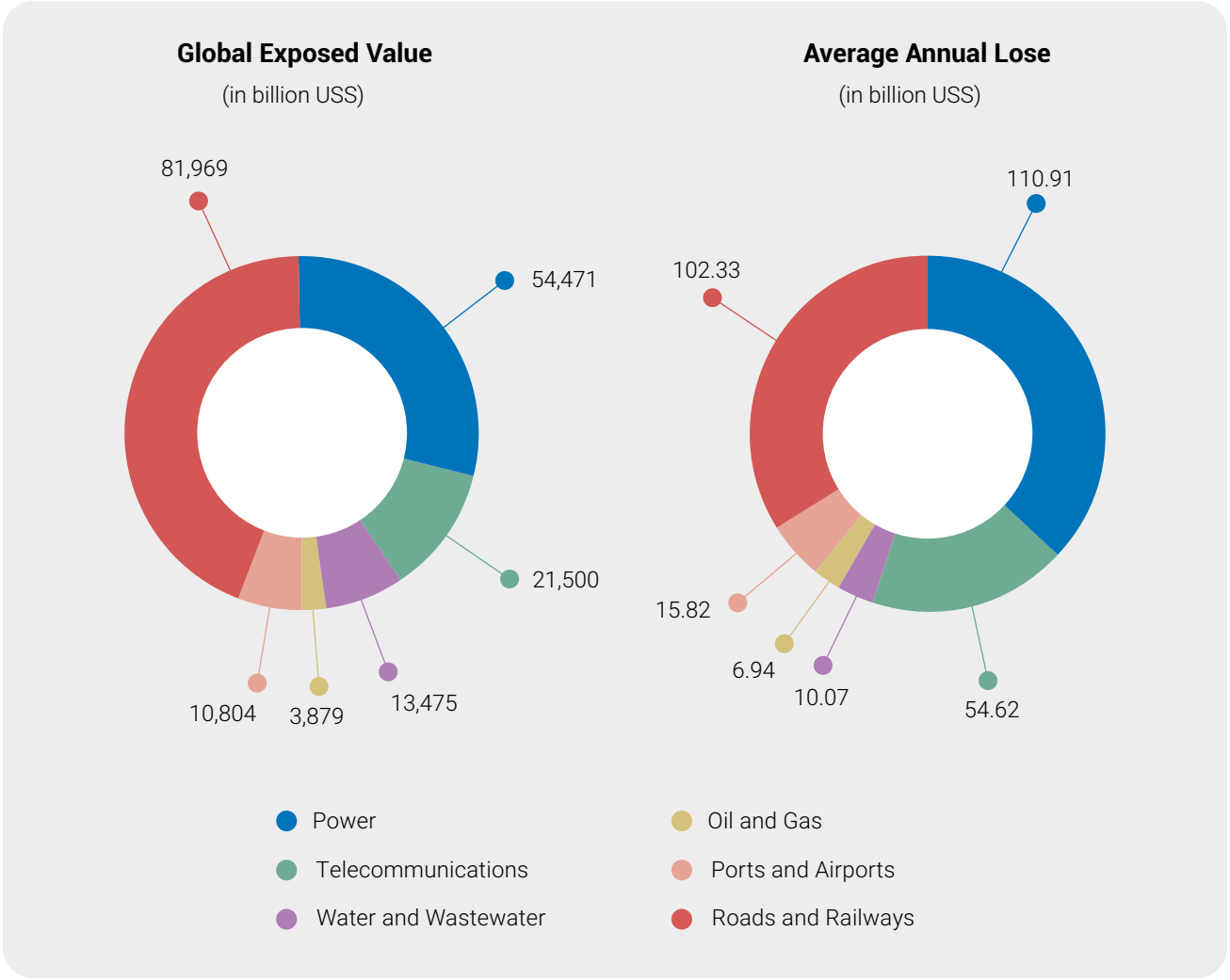
Compared to high-income countries, LMIC have less infrastructure, less investment and higher risk. High-income countries concentrate 67 percent of the global exposed value of infrastructure assets, with a relative AAL that represents 0.14 percent of that value. LMIC account for only 33 percent of the exposed value but their relative AAL is 0.31 - 0.41 percent.

Roads and railways, telecommunications, and power and energy account for around 80 percent of the total AAL (see Figure 4). Flood and wind are associated with around two-thirds of the power sector AAL. Wind is associated with about two-thirds of the telecommunications sector AAL and over half the oil, gas, 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.

The distribution of risk is more skewed for social infrastructure than for other infrastructure sectors, presenting a grave challenge to the SDGs. The relative risk in low-income countries in the education and health sectors is over three times greater than in high-income countries. The relative AAL of South Asia in the education and health sector is 0.51 and 0.47 percent respectively and in Latin America and the Caribbean 0.35 and 0.31 percent. In North America it is only 0.09 percent in both sectors.

Around 30 percent of infrastructure risk is associated

Figure 3: Global infrastructure risk by sector



Source: CDRI, 2023, Global Infrastructure Resilience: Capturing the Resilience Dividend, a Biennial Report from the Coalition for Disaster Resilient Infrastructure.

with geological hazards, such as earthquakes or tsunamis, that are not climate conditioned. However, across all regional geographies, the relative AAL associated with climate-related hazards is higher than that associated with geological hazards. The two regions where the climate related relative AAL is highest are South Asia with 0.42 percent and Latin America and the Caribbean with 0.22 percent.

In low-income countries, climate change will have a significantly greater impact. At the upper bound of climate change, while the total AAL may increase by 11 percent in high-income countries, in LMIC the increase could be in a range of 12 – 33 percent The regional geographies where climate change will significantly increase the AAL are South Asia and sub-Saharan Africa, where, risk to infrastructure assets from climate related hazards could increase by around 24 per cent.

The indirect losses associated with service disruption are often greater than the value of asset loss and damage. With an AAL in the principal infrastructure sectors in a range of USD 301 - 330 billion, the real cost of disrupted services could be as high as USD 700 billion per year, without considering the negative impacts on sustainable social and economic development.

Weak infrastructure governance

The infrastructure deficit in LMIC is aggravated by weak infrastructure governance, characterized by deficient planning and design, inadequate standards, ineffective systems for regulation and compliance, corruption, and low levels of investment in maintenance and operation. Capital investment in an infrastructure asset only accounts for 15–30 percent of overall expenditure, over the design life cycle, while 70–85 percent of the expenditure is attributable to operations and maintenance (UN, 2021). Therefore, even if infrastructure is built to a high standard initially, inadequate operations and maintenance budgets can lead to premature obsolescence and increased service disruption.

Increasing systemic risk

While massive new infrastructure investment is required to accelerate development, that investment may be counterproductive unless it strengthens systemic resilience. Climate change, biodiversity loss, growing social and economic inequality, and unplanned urban development are endogenous attributes of the 'urbanization of society', underpinned by massive infrastructure investments (Lavell & Maskrey, 2014; Maskrey et al., 2023). Infrastructure investment itself, therefore, has been a major driver of systemic risk, which then feeds back into increasing asset loss and damage and service disruption. New investment that addresses the infrastructure deficit but increases systemic risk is ultimately self-defeating. Infrastructure resilience, therefore, is contingent on investments that strengthen systemic resilience.

Protect ecosystems and their services. Ecosystem degradation and depletion, undermine systemic resilience. Across LMICs environmental policy and regulation is often poorly enforced, leading to the degradation of the ecosystem services on which NbIS can potentially be based. Effective legislation to protect and enhance ecosystems is necessary to affirm a longer-term commitment to NbIS, providing infrastructure investors with greater confidence and reduced risk.

Low fiscal resilience

Few low-income countries have the fiscal capacity to address the infrastructure deficit, maintain existing infrastructure, invest in the transition to net zero and strengthen asset and service resilience. LMICs debt burdens have increased since the pandemic, as spending increased while revenues fell due to lower growth and trade. The total external debt of LMIC rose by 5.3 percent in 2020 to US$ 8.7 trillion. In low-income countries, the total public and publicly guaranteed debt service to export ratio rose from an average of 3.1 percent in 2011 to 8.8 percent in 2020. Around 60 percent of low-income countries are now at high risk of debt distress.

While there is an estimated USD 106 trillion of untapped private institutional capital worldwide, **which would be more than sufficient to close the current infrastructure resilience investment gap.** (World Bank Group, 2016). Only 1.6 percent of this available capital is currently invested in infrastructure, Around, three-quarters has been concentrated in high-income countries, half of which has flowed into renewable energy generation. LMICs only attracted a quarter of global private infrastructure investment mainly in the non-renewable energy and transport sectors (Global Infrastructure Hub, 2021). Infrastructure investment

grew by 8.3 percent in high-income countries in 2021 but fell by 8.8 percent in LMICs.

Annual infrastructure investment in LMICs will have to increase to USD 2.84 - 2.90 trillion through to 2050, to finance the achievement of the SDGs the transition to net-zero economies and the infrastructure resilience. Current levels of public and private investment and climate finance represent are around an order of magnitude lower. While climate adaptation finance is one of the few new sources of funding that LMIC can access to strengthen infrastructure resilience, in 2021 multilateral development banks (MDB) only provided USD 19 billion in climate adaptation financing of which 92 percent went to LMICs (African Development Bank (AfDB) et al., 2021).

Opportunities to strengthen infrastructure resilience

Most of the infrastructure that will be required by 2050 has yet to be built. Given the long design life cycles of many infrastructure assets, success, or otherwise, in integrating resilience into this massive investment will configure development trajectories for decades to come. Investing to strengthen infrastructure resilience can set countries on a development trajectory characterized by quality and dependable essential services, reduced damage to infrastructure assets, lowered systemic risk and sustainable social and economic development. If this opportunity is not seized, the alternative is stagnant social and economic development, stranded infrastructure assets, increasing contingent liabilities, unreliable and inferior services, and growing systemic risk.

Identifying the resilience dividend. There are a broad range of benefits that can accrue from investing in infrastructure resilience. These include avoided asset loss and damage, reduced service disruption, better quality, and reliable public services, accelerated economic growth and social development, reduced carbon emissions, enhanced biodiversity, improved air and water quality, more efficient land-use, and others. When this dividend is identified and estimated it normally several times greater than the additional capital expenditure required to strengthen resilience**.**

Strengthening systemic resilience. New ways of delivering infrastructure are becoming available which not only strengthen asset resilience but also contribute to strengthened systemic resilience. Nature-based Infrastructure Systems (NbIS) often maximize the resilience dividend at the same time as strengthening systemic resilience, through reduced carbon emissions, strengthened biodiversity benefits, better water availability and quality and other benefits. NbIS can be used to *complement, substitute for or safeguard* traditional 'grey' infrastructure, particularly in the water and hazard mitigation sectors. It is estimated that NbIS cost on average only 51 percent of grey infrastructure projects and that 11 percent of all grey infrastructure could be replaced by NbIS (Bassi et al., 2021). Unfortunately, despite this potential, current investment in NbIS represents only 0.3 percent of overall infrastructure investment (WEF, 2022).

NbIS can accelerate the achievement of the SDG (IISD, 2021). Because NbIS provide social, environmental, and economic co-benefits, their upscaling and widespread adoption would influence the achievement of 115 of the 169 targets across all 17 SDGs. In specific infrastructure sectors, such as water, the adoption of NbIS would influence up to 25 to 44 percent more SDG targets compared to the use of *grey* infrastructure alone (UNEP, 2023). It is critical to strengthen access to knowledge on NbIS by fully integrating NbIS concepts in curricula spanning engineering, urban planning, and architecture as well as introducing capacity-building programs for planners and managers in infrastructure-related functions. Countries may also consider national centres of excellence in NbIS to document and research best practices, disseminate knowledge, provide outreach to practitioners, and share information with other countries.

Estimating, monetizing, and distributing the resilience dividend can provide the missing financial imperative to mobilise the capital that LMIC require. A more complete estimation and visualisation of the *resilience dividend* can provide a solid economic imperative for investing in infrastructure resilience. Financial risk metrics can help to quantify the resilience dividend and optimize the most cost-effective strategies to strengthen resilience. If the *resilience dividend* is captured, monetized and distributed in a way that benefits governments,

investors, and other stakeholders, it may provide the missing financial imperative to invest.

Strengthening the resilience of small countries with high risk may not require globally significant investments but can make a critical difference to their sustainable social and economic development. Fiscal resilience is severely challenged in countries with low absolute but very high relative risk, such as Small Island Developing States (SIDS). The upside of this picture, however, is that the investments required to strengthen infrastructure resilience in these countries are a very small proportion of the estimated global requirements, and can be easily achievable.

Pathways to infrastructure resilience

Strengthen infrastructure governance through the development of national infrastructure resilience policies, strategies, and plans. National infrastructure resilience policies are essential to determine country-specific resilience objectives, including. upscaling the application of NbIS. The development of national resilience policies, strategies and plans send positive signals to capital markets that a country is serious about strengthening resilience: improving potential returns, and reducing risks for investors. An essential first step towards the development of national infrastructure policies, strategies and plans is to develop and maintain national audits of all infrastructure assets.

Identify and estimate disaster and climate risks. Once the assets have been clearly identified, financial risk metrics, such as those produced by the GIRI, can then allow risk and resilience to be layered, identifying the contingent liabilities held by public and private infrastructure providers in each sector and territory. Mapping ecosystems and their services, geological and climate-related hazards, exposed infrastructure, buildings and agriculture, at an appropriate scale and obtaining data on vulnerability and economic values is a critical first step.

Accounting for the resilience dividend: Conventional methods for accounting for costs and benefits and rates of return often fail to include the systemic risks posed by infrastructure investments. Similarly, the long-term benefits of protecting, supporting, or supplementing infrastructure with NbIS are not accounted for in a way that could encourage investment. For example, net present value calculations do not account for the potential appreciation of the performance of NbIS over time compared to the depreciation of traditional infrastructure. To account for the resilience dividend, risk identification and estimation should be integrated into the budgets and feasibility studies of all new infrastructure projects.

Maximizing the resilience dividend: By layering risk, national resilience strategies can then identify the most cost-effective approaches to maximize the resilience dividend. Highlighting the positive social, economic, and environmental benefits that can accrue from NbIS are critical to strengthening their political attractiveness. The inclusion of metrics that account for disaster and climate risks in financial models and asset balance sheets can then help investors to fully understand their portfolio risks and shift investments towards strengthened resilience. Financial risk metrics are also used to price risks and underpin risk transfer mechanisms such as insurance, which should form an integral part of a national infrastructure resilience policy and strategy and infrastructure financing.

Resilience standards and certifications. The development of resilience standards based on the integration and enhancement of existing meta-standards could provide a common language to understand and compare different infrastructure projects, from a resilience perspective. Resilience standards could then inform national and sector policies for infrastructure development. Standards, validated by third party certification, can help lower perceived risks for private investors by providing additional clarity, therefore unlocking additional finance and funding streams and encouraging the emergence of a resilient infrastructure asset class. Nationally developed and adopted performance-based standards for NbIS based on best practices may provide a flexible route that can allow project designs to be approved without potential issues of professional liability.

Project pipelines. Small projects do not have the scale to attract private investment and increase risk for investors. However, if they are aggregated and bundled together in a project pipeline, they become more attractive for investors as the risk is distributed and mutualized across the range of projects. In the

context of national resilience plans, project pipelines can facilitate the bundling and aggregation of smaller projects, in a way that optimises the allocation of funding sources across projects into a predictable medium-term flow.

National resilience funds. National resilience funds can provide a new mechanism to finance project pipelines and implement national resilience strategies and plans. A national resilience fund could allow the blending of public resources, climate finance, loans from MDB, private capital, risk financing and other sources in a way that allows governments to de-risk infrastructure investment for private capital, while at the same time optimising the use of different resources.

Capturing the resilience dividend: National resilience funds would feature mechanisms to monetise the resilience dividend, based on the full range of benefits that could accrue over the life cycle of the asset, a clear identification of all the relevant stakeholders, and transparent and efficient procedures to distribute the monetised resilience dividend. Monetising the resilience dividend would enable private capital to view infrastructure resilience as an opportunity rather than as an additional cost or an obligation imposed by regulators. Different conservation finance instruments such as PES (Payment for Ecosystem Services) provide examples of how the resilience dividend can be monetized and can help to secure the protection and management of land in ways that protect ecosystem services.

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