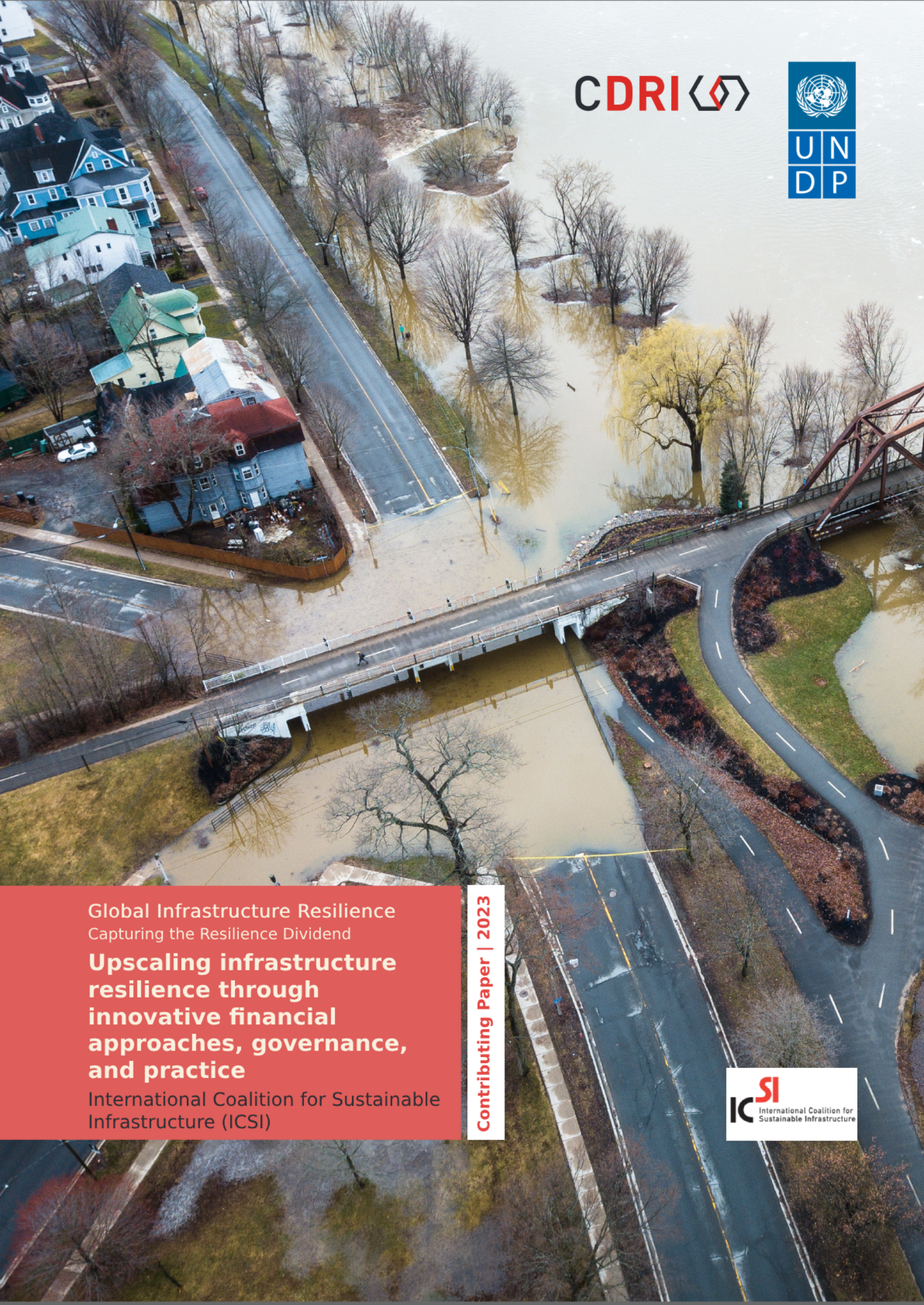

Global Infrastructure Resilience

Capturing the Resilience Dividend

Upscaling infrastructure resilience through innovative financial approaches, governance, and practice

International Coalition for Sustainable Infrastructure (ICSI)

Contributing Paper | 2023

Upscaling infrastructure resilience through innovative financial approaches, governance, and practice

Position Paper for CDRI Biennial Report of Global Infrastructure Resilience

International Coalition for Sustainable Infrastructure

GLOBAL COVENANT of MAYORS for CLIMATE & ENERGY

October 2023

ABOUT ICSI

The International Coalition for Sustainable Infrastructure (ICSI) was founded in 2019 by Resilience Rising, the American Society of Civil Engineers (ASCE) and its ASCE Foundation, the Institution of Civil Engineers (ICE), the Global Covenant of Mayors for Climate & Energy (GCoM), WSP and LA Metro, among others.

We bring together a global coalition of change agents from across the engineering, investment, city, and philanthropic communities committed to bold action to solve the systemic problems that exist at the intersection of climate change, ecosystem degradation, ageing infrastructure, and underinvestment.

ICSI is the global movement for engineering action on infrastructure sustainability, resilience, and climate change. We place engineers at the forefront of climate action, harnessing their ability to provide solutions and matching it with urgent demand. The solutions we develop and promote will deliver impact on the ground, where it is needed most. ICSI was created to bring the practical, science-based, and solution-oriented perspective for which engineers are known to solve the systems-level problems surrounding infrastructure underinvestment, climate change, and resilience.

From its origin, ICSI has been committed to driving action towards instilling sustainability and resilience as the corners11:42 AMtone of every decision in the infrastructure lifecycle. Built upon a commitment to tangible and collaborative action, ICSI continues to broaden participation across other stakeholder communities to accelerate the innovation, adoption and scaling of people-centred, sustainable, and resilient infrastructure solutions that support sustainable development for all.

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EXECUTIVE SUMMARY

Increasing pressure on infrastructure systems has been compounded by fragmented governance and a lack of investment, pushing many of these systems toward an uncertain future. Climate change is expected to exacerbate adverse impacts caused by multiple hazards and compounding threats, prompting an even greater need to strengthen infrastructure capabilities that can address known and unknown threats. Infrastructure systems with low resilience are disrupted with greater frequency, higher intensity, on a larger scale, and for longer durations than more resilient systems. The impacts on infrastructure disruption can cascade across cities, regions, and nations, causing society-wide disruption to essential services and threatening the realization of other infrastructure-enabled outcomes.

Several recent studies find that investing in resilient infrastructure provides economic benefits that far outweigh its costs. In addition to generating better economic and social outcomes, integrating resilience into infrastructure can unlock new financing strategies and potential funding streams. Despite this, investment in both infrastructure and resilience remains chronically limited compared to need. According to the OECD, infrastructure investments of approximately $6.3 trillion annually are needed to meet the UN Sustainable Development Goals (SDGs) and almost $7 trillion in aggregate is needed to meet the Paris Agreement Goals by 2030. Furthermore, the infrastructure spending gap requires urgent consideration of the existing 'resilience gap'.

Shovel-worthy projects that aim to create long-term positive outcomes for communities are being identified, and funding for resilient infrastructure is being pledged. However, investors still require some convincing to unlock finance flows, particularly in low- to middle-income countries where this investment is most urgently needed.

Pathways to investment in resilient infrastructure are part of complex institutional and organizational decision-making systems and therefore can be difficult to navigate. Although no standardized template for financing resilient infrastructure exists, these pathways to investment share commonalities and success factors. Innovative financial approaches, good governance, and systems thinking have been identified as key factors to accelerate and scale up investment in resilient infrastructure.

Building on existing concepts and published references, this paper highlights and frames key aspects that have significant potential to upscale and accelerate resilient infrastructure finance. These include bringing a sharper focus to the value case and desired outcomes for resilient infrastructure; being intentional about utilizing ongoing global initiatives as 'levers of change' for resilience and drivers for systemic change; ensuring that success-enabling factors are included in the process; and learning from practice to implement at scale and at pace.

The following recommendations have been identified to promote and embed the financing of resilient infrastructure into practice:

1. Embed systemic resilience in every investment decision
Resilience should be viewed systemically and should be embedded in every decision in the development of infrastructure, including investment decisions. A shift to outcome-based approaches for infrastructure development might present a more accessible avenue for policymakers and investors, and can encourage a deeper consideration of adaptive, resilient, and multi-purpose infrastructure solutions.

2. Promote use of 'levers of change' and enablers as factors with significant potential to deliver, upscale and accelerate resilient infrastructure finance
Linking resilience to other global drivers and objectives, or 'levers of change' (e.g. decarbonization efforts or green infrastructure), would allow resilient infrastructure projects to enhance visibility, and attract funding. Enablers (e.g., multi-level governance, public-private sector collaboration, and standards and certification) need to be in place from early stages to create a successful environment for investing in resilience.

3. Address the capacity gap for assessing broader benefits delivered by resilient infrastructure
Good examples of co-benefits assessments exist, but they are often *ad hoc* and remain heavily impacted by gaps in data and technical capacity. Additional research is urgently needed to support the development of robust cost-benefit appraisals, methodologies, and indicators to assess and allocate co-benefits delivered by resilient infrastructure.

4. Encourage cross-sectoral knowledge transfer and adaptation of existing financial approaches and mechanisms
Adapting existing financing approaches or products can offer a more viable, faster, and cheaper solution than developing an entirely new financial instrument or mechanism. This approach can be enhanced through knowledge transfer and collaboration between experts and project stakeholders.

5. Make better use of technical assistance to ensure that investment decisions take account of resilience features
The availability of predevelopment funding for technical assistance in the early stages of development plays a key role in ensuring that shovel-worthy projects receive investment. Technical assistance initiatives globally would benefit from increased coordination and from ensuring that resilience is adequately considered in investment decisions.

6. Develop a repository of case studies on investing in resilient infrastructure, based on a set of agreed criteria and principles
Learning from practice can illuminate existing pathways to investment in resilience or create new ones to educate and inspire others to find their own ways and act. Think tanks

with practical expertise across a range of contexts should spearhead the development of these knowledge resource

7. Ensure that the right experts are consulted at appropriate points in the project development

Because of the nature of the complex, systemic challenges inherent in the development of resilient infrastructure, technical-expert input should be multidisciplinary and include system thinking capabilities, which can be drawn from international best practices and adapted to the local context.

1. Introduction

Well-established research and industry knowledge have highlighted the ways that infrastructure systems serve as lifelines in the delivery of essential services, which are increasingly exposed to risks. Existing infrastructure systems have become increasingly complex and interdependent, as they have spread across national borders and have become reliant on sophisticated digital technology.[1] These systems also face pressures from population growth, accelerating urbanization, and climate change.

Increasing pressure on infrastructure systems has been compounded by fragmented governance and a lack of investment, pushing many of these systems toward an uncertain future.[2] In addition to these pressures, lifeline infrastructure systems are increasingly impacted by hazards with human-induced and natural origins.[3] Climate change is expected to exacerbate adverse impacts caused by multiple hazards and compounding threats, prompting an even greater need to strengthen infrastructure capabilities that can address known and unknown threats.

Infrastructure systems with low resilience are disrupted with greater frequency, higher intensity, on a larger scale, and for longer durations than more resilient systems. The impacts on infrastructure disruption can cascade across cities, regions, and nations, causing society-wide disruption to essential services and threatening the realization of other infrastructure-enabled outcomes.[4] Infrastructure disruptions have secondary impacts affecting public health and social functioning. Most low- to middle-income countries (LMICs) disproportionately suffer from the effects of infrastructure failure in terms of relative costs and other impacts, such as weakened public health.[5] In the long term, low resilience can create a downward spiral in which more frequent disruptions undermine the quality of life, reduce productivity and Gross Domestic Product (GDP), damage businesses and investor confidence, reduce business rates, and channel resources into reactionary expenditures and away from other strategic priorities.

Box 1 2022 Pakistan floods

In July 2022, melting glaciers following an intense heatwave and atypically intense monsoon rains triggered unprecedented floods in Pakistan. Floods and landslides affected all four of the country's provinces and approximately 15% of its population, displacing 33 million people and killing more than 1,600. The floods impacted 5,000 kilometers of road infrastructure, destroyed 240 bridges and 1.2 million houses, disrupted energy and telecommunications networks, and caused extensive damage to crops. Economic losses have been estimated at 40 billion USD. As a result, Pakistan's GDP growth is expected to slow down from 5% in the fiscal year 2022 to around 2% in the fiscal year 2023 and the national poverty rate may increase by 2.5 to 4 percentage points, pushing between 5.8 and 9 million more people into poverty.[6]

Several recent studies find that investing in resilient infrastructure provides economic benefits that far outweigh its costs. On average, investing in resilience increases project costs by 3%, which equates to approximately 0.1% of GDP for most LMICs. According to some estimates, resilience measures for infrastructure projects produce an average of $4 in benefits for every $1 dollar spent.[7] Bangladesh, for instance, has avoided $1.6 billion in damages to power systems as the result of resilience measures that equate to less than 1/3 of the damages avoided.[8] Resilience measures can generate co-benefits, such as reducing the incidence of unsafe sanitation or providing new jobs.[9] In addition to generating better economic and social outcomes, integrating resilience into infrastructure can unlock new financing strategies and potential funding streams, which is discussed in Section 2.

Despite the importance of infrastructure in providing for basic functions and an urgent need to enhance its resilience, investment in both infrastructure and resilience remains chronically limited compared to need. According to the OECD, infrastructure investments of approximately $6.3 trillion annually are needed to meet the UN Sustainable Development Goals (SDGs) and almost $7 trillion in aggregate is needed to meet the Paris Agreement Goals by 2030.[10] Other estimates conclude that addressing the impacts of climate change alone will require $200 billion annually by 2040.[11] Despite an uptick in investment, current investment levels for most countries are not on track to close this gap. Many of these countries are LMICs. Some LMICs have increased investment relative to GDP (3-5%), but financing and funding continues to fall short of investment targets in absolute terms.[12] Furthermore, the infrastructure spending gap requires urgent consideration of the existing 'resilience gap'. Embedding resilience is not routinely accounted for in investment planning or incorporated into 'build back better' efforts after the Covid-19 pandemic, for example.[13]

Private and public investment needs to be urgently unlocked and upscaled, especially in LMICs, to meet an increase in demands, risks, and opportunities for resilient infrastructure and to deliver on global commitments, such as the SDGs. Private savings with institutional investors recently reached an all-time high at $80 trillion.[14] Although traditional channels for financing infrastructure development remain relevant, it is evident that innovative mechanisms need to be explored to encourage private investment.

Good governance approaches can play a key role in enhancing an enabling environment for infrastructure resilience and can facilitate effective engagement and investment through governmental and non-governmental stakeholders to increase infrastructure resilience.[15] To this end, a G20 report asserts that infrastructure governance over a project's lifecycle is key to ensuring long-term cost-effectiveness, accountability, transparency, and integrity of infrastructure investments.[16]

2.1 Scope of the Position Paper

Innovative financial approaches, good governance and systems thinking have been identified as key factors to accelerate and scale up investment in resilient infrastructure.[17] Nonetheless, pathways to invest in resilient infrastructure are part of complex institutional and organizational decision-making systems and therefore difficult to navigate. Challenges exist for resilient infrastructure finance, such as fiscal constraints, weak and fragmented governance, conflicting funding priorities, capacity gaps, difficulty quantifying risk and returns, systemic undervaluation of resilient infrastructure, short-term funding cycles, and difficulties translating international and national guidance into projects.[18]

Despite the pressing need to close the infrastructure spending gap, along with a growing amount of pledged funding, many projects continue to struggle to secure financing. The volume of projects that are sustainable and resilient often becomes lost between the project pipeline and project funding (see Figure 1).

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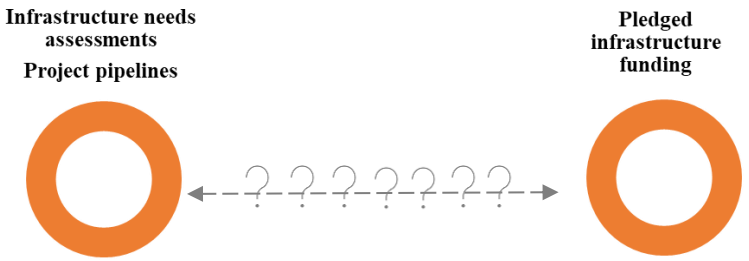

Figure 1 - The "Valley of Death" of project financing for resilient infrastructure

This paper focuses on pathways to get from 'A to B' for financing resilient infrastructure projects. Building on established key concepts and published research, it emphasizes some essential components of a successful path to investment, especially those related to good governance and innovative financing. Lessons learned from real world examples are translated into tangible and scalable actions for stakeholders across a range of sectors, contexts, and scenarios.

Although financing for resilient infrastructure is the focus of this paper, it is important to note that prioritized investments should enhance both the resilience and sustainability of wider infrastructure systems. In this vein, sustainability and resilience should be explicitly integrated into infrastructure objectives from needs assessment to planning, delivery, and operation of new builds or retrofitting of existing infrastructure.

2.2 Definitions

Governance of infrastructure for resilience	
Definition	**Source(s)**
Resilience of infrastructure focuses on the ability of infrastructure systems to absorb, adapt, and transform in response to threats (see Section 2.1 for resilience). Governance of infrastructure comprises the processes, tools, and norms of interaction, decision-making and monitoring used by governmental organizations and their counterparts with respect to making infrastructure services available to the public and the public sector. Good governance facilitates collaboration across sectors and levels (multi-level governance), allows for transparency and public engagement, and spans the entire lifecycle of infrastructure projects. Governance of infrastructure for resilience is additionally characterized by an ethos of transformation and adaptation to new challenges and threats, consideration of complementary risk and resilience-based thinking and approaches in all decision-making across the lifecycle of infrastructure and an impetus to catalyze multi-stakeholder collective action to maximize the economic, social, environmental, and development impact of infrastructure.	Akshaya Kannan, Oliver Pritchard, Chris Freakes, Savina Carluccio, and Nikita Chauhan, 2021. *Governance of Infrastructure for Resilience*.[19] OECD, 2017. *Getting Infrastructure Right: A framework for better governance*.[20]

Investment in resilient infrastructure	
Definition	**Source(s)**
Resilience of infrastructure focuses on the ability of infrastructure systems to absorb, adapt, and transform in response to threats. An investment in resilient infrastructure can increase the robustness of an asset or group of assets (e.g., flood barrier), it can improve safety, continuity and reliability of the services provided by the infrastructure (e.g., early warning system) but can also adopt a systemic approach that delivers wider resilience outcomes such as increased wellbeing of users, economic growth, improved ecosystem health (e.g., nature-based solutions). Resilience financing should adopt a lifecycle view and be agnostic to specific threats; however, given the significant and ubiquitous impacts of climate change and its interconnectedness with other risk drivers, resilient infrastructure investments should routinely include consideration of climate-related risks.	National Infrastructure Advisory Council, 2009. *Critical Infrastructure Resilience: Final Report and Recommendations*.[21]

Systemic Resilience	
Definition	**Source(s)**
Systemic resilience can be defined as the system's ability to reduce the frequency, scale, intensity, and duration of cascade failures caused by resilience and sustainability challenges. These challenges are deeply interdependent and are best resolved synergistically through a diverse, long-term, collaborative, dynamic, multifaceted, multi-scale, cradle-to-cradle portfolio of systemically targeted interventions focused on transforming the wider system. Systemic resilience is a dynamic, emergent, and intrinsic characteristic of an infrastructure system. The need for systemically resilient infrastructure is a consequence of a combination of all three of the following: the dynamic complexity of the infrastructure system, the dynamic complexity of the external environment and the interdependencies between the two. Infrastructure governance is critical to changing the systemic conditions that cause systemic resilience to be undervalued, underprovided, and undermined, and that cause opportunities to enhance whole system resilience to be undervalued and overlooked.	Tom Dolan, 2021. *Systemic Perspectives on National Infrastructure for a Sustainable, Resilient Net Zero Future*.[22]

Infrastructure interdependencies	
Definition	**Source(s)**
The infrastructure systems which enable all aspects of our modern lifestyles, societies and economies are immensely complex. This complexity arises from four major categories of interdependencies: 1. Interdependencies within infrastructure sectors 2. Interdependencies between infrastructure sectors 3. Interdependencies between infrastructure systems and the social and economic activity they enable 4. Interdependencies between infrastructure systems and the natural systems within which they are embedded.	Rudolph Stapelberg, 2008. *Infrastructure Systems Interdependencies*.[23] Steven Rinaldi, James Peerenboom, and Terrence Kelly, 2001. *Identifying, understanding, and analyzing critical infrastructure interdependencies*.[24]

2. What is needed to scale up financing for resilient infrastructure?

This paper identifies four key themes as essential components of successful pathways to finance resilient infrastructure.[25] Key theme 1 focuses on how demonstrating the value of resilient infrastructure could be improved. Key theme 2 introduces the concept of 'levers of change' as synergistic opportunities for financing resilient infrastructure. Enablers for unlocking and scaling up finance are covered in Key theme 3. Key theme 4 comprises a selection of case studies and identifies scalable actions that could be taken by different stakeholders to unlock and/or scale up financing for resilient infrastructure.

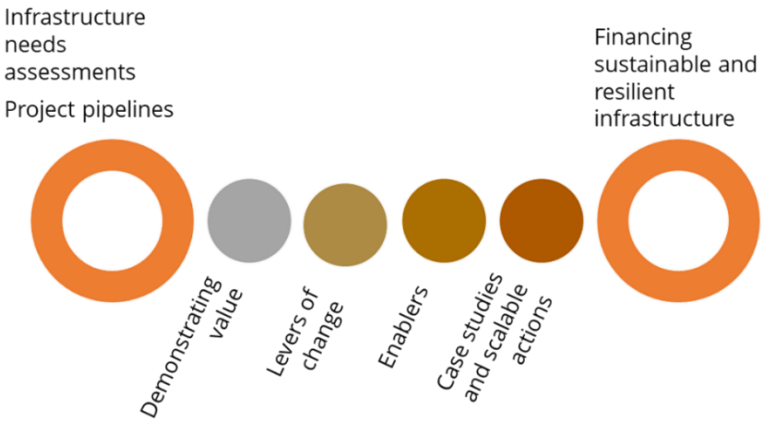

Figure 2 - Key thematic components of investment pathways for resilient infrastructure

2.1 Key Theme 1: Demonstrating the value of resilient infrastructure

Infrastructure underpins and enables all sectors of society. However, the value of infrastructure to economic and social functioning is often underestimated. This underestimation leads to a secondary underestimation of the impact of an increase in resilience. The value of infrastructure to the economy and society is best illustrated by envisioning what would happen to human activity in the event of infrastructure failure. The value of a resilience-enhancing intervention is linked to the avoided costs of reducing the likely scale, intensity and duration of disruption caused by any given scale of hazard. Identifying and demonstrating the value of resilience from past projects can help to build a stronger case for unlocking and scaling up financing for similar projects.

The lack of clear definition, measurement, and communication of the value of resilient infrastructure presents a challenge to securing financing for resilience. Demonstrating the value of resilient infrastructure would benefit from expanding the scope and capture of benefits delivered, improving the understanding and communication of systemic risk, complexity, and deep uncertainty and how they can be managed, and presenting resilience in projects as a sensible economic decision for the long-term. This would help to highlight

the importance of resilient infrastructure to different stakeholder groups across the lifecycle of infrastructure.

Recognizing, managing, and communicating systemic risk, complexity, and deep uncertainties

Building resilience into infrastructure systems can address the systemic nature of risk, deep uncertainties, and the interdependent complexity of the infrastructure systems that enable all aspects of modern life, societies, and economies. Enhancing understanding of risk could support investment decisions and unlock funding for resilient infrastructure.[26] Given the long lifecycle of most infrastructure projects, which can be extended through retrofitting, projects should consider ways to anticipate future conditions and remain adaptable to meet both known and unforeseen challenges. It is important to recognize that infrastructure needs to deal with systemic and interconnected risks (i.e., those associated with cascading impacts that spread within and across systems and sectors and across boundaries).[27]

Climate-related risks have gained increased attention because they not only introduce greater levels of uncertainty but also have the potential to substantially amplify the negative consequences of disasters and other underlying risk drivers. Climate change impacts such as more extreme temperatures and heavier, more prolonged rainfall are already impacting some areas across the world. Climate change also will involve greater frequency and intensity of extreme weather events, increased risk of surface water flooding as well as rising sea levels, and damaged ecosystems and environmental changes, which are all adversely impacting people's lives with the potential to cause massive upheaval on a global scale. According to the United Nations High Commissioner for Refugees (UNHCR), an average of 21.5 million people have been forcibly displaced by weather-related events annually – such as floods, storms, wildfires, and extreme temperatures – since 2008, which is expected to increase. By 2050, 1.2 billion people globally could be displaced due to climate change and disasters.[28] These displacements are not only transboundary. The Internal Displacement Monitoring Centre (IDMC) estimates that 23.7 million people were displaced internally in 2021 due to disasters. In addition to the physical risks from climate change, transitioning to a lower-carbon economy may entail extensive political, legal, technological, and market changes to address mitigation and adaptation requirements related to climate change, which may pose varying levels of financial and reputational risk to organizations.[29]

Increasingly, traditional risk management tools and assessments cannot encapsulate the increasing complexity and interconnectedness of threats that infrastructure systems and the wider system they sit within will face in the future. Uncertainty, ambiguity, volatility, and complexity are inherent characteristics of the environment where infrastructure needs to exist and operate.[30] Dealing with deep uncertainty underpins the move from traditional risk management to resilience. Although risk assessment quantifies both the potential vulnerability and threat associated with specific scenarios to estimate risk and direct efforts

to prevent its realization, resilience emphasizes response and recovery from known and unknown risks alongside adaptation.

The concepts presented in this section are often difficult to articulate clearly to and be acted upon by practitioners across the lifecycle of infrastructure, from government to finance to design, operation, and management. Using case studies that explain how uncertainty can be managed over the lifecycle of infrastructure can help to transfer some of the theory into practice.[31] The DC Water (Case Study #1 included in Annex 1) demonstrates how allowing for iterative processes to incorporate better data can help manage uncertainty over the infrastructure lifespan.

Making the case of economic viability for embedding and enhancing infrastructure resilience

Developing approaches, products and solutions that successfully demonstrate that investment in resilience is not only the right thing to do but also makes good financial sense is key to facilitate the financing of resilient infrastructure. Building the economic case for resilience should take a lifecycle approach. OPEX and other lifetime costs, such as damage repairs following adverse events, often are underestimated compared to CAPEX costs, due to uncertainties and insufficient available information. In the case of existing infrastructure, aging and faster deterioration resulting from changes in use or environmental conditions are straining operation and performance and can lead to increased vulnerability and slower recovery in case of failure. Infrastructure maintenance has been recognized as an urgent priority, not just as the cost of keeping assets in good order, but also as an investment yielding significant benefits both in the short and long term.[32] Advancements in digital technologies and innovative tools provide an opportunity to improve the data and information used in the early-stage project assessments and analyses that are used to develop the economic case for resilience.

Expanding traditional understanding of benefits

Resilient infrastructure should consider reframing common understandings of value by emphasizing long-term implications and including other non-economic benefits whenever possible. Although bankability (i.e., the acceptability to the lenders of a project's overall structure as a basis for raising finance) should not be the governing factor in deciding which projects get financed, co-benefits can be difficult to quantify in a way that can attract investors.

Recognizing the difference between the resilience ***of*** infrastructure and the resilience ***through*** infrastructure and considering the multi-dimensional qualities of resilient infrastructure (e.g., resilience of individual assets, services provided, and infrastructure users) can be a helpful framing to articulate the broader benefits delivered by the infrastructure, see Figure 3 below.[33]

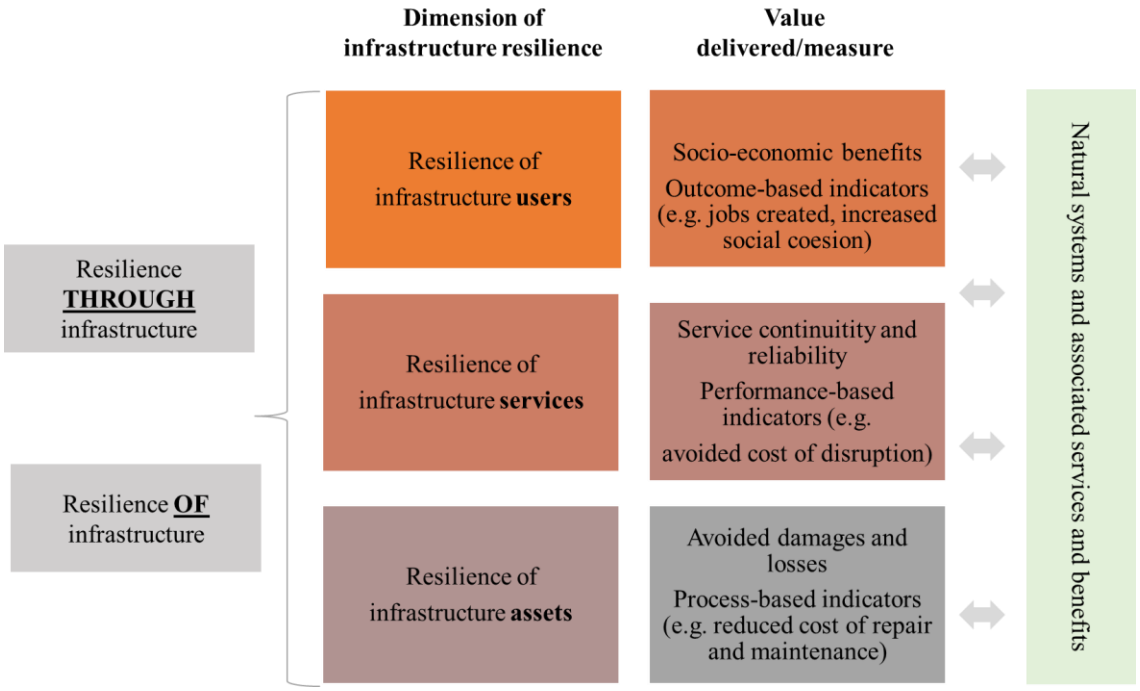

Figure 3 - Multi-dimensional resilience of infrastructure and value delivered, adapted from Hallegatte et. al[34]

Broader benefits delivered by infrastructure include:

- Maximizing social benefits and enhancing equity and minimizing negative social consequences to support broader societal resilience to disasters and climate change, particularly for those who are most vulnerable.
- Minimizing negative environmental impacts and contributions to climate change.
- Protecting and leveraging natural ecosystems.

These benefits and co-benefits should be identified as early as possible in a project's development. Pre-development finance plays a key role in allowing quantification and capture where possible, for example see Case Study #5 in Annex 1.[35] However, the case for investing in resilience involves an ability to assess costs and benefits that exceeds most standard analyses. Some of these benefits are more easily quantifiable and measurable, such as the creation of new jobs. Other benefits, especially when compared to a loss avoidance scenario, can be more difficult to demonstrate. Good examples of co-benefits assessments exist but they are done *ad hoc,* and they are heavily impacted by gaps in data and technical capacity.[36]

Outcome-based approaches for infrastructure development can encourage deeper consideration of adaptive, resilient and multi-purpose infrastructure solutions. Adopting outcomes can have an impact on how infrastructure decisions are made, what business model is developed and how the value of resilient infrastructure is perceived.[37] If the

objectives of the investment are framed incorrectly or too narrowly, e.g., greenhouse gas (GHG) emissions are treated as externalities, resilience is not prioritized, or projects are conceived and implemented independently of the context into which they are introduced, these investments will reinforce undesirable outcomes.

Allocating benefits, costs, and risks

Resilience is important to everyone in the value chain of infrastructure but can be valued differently by different stakeholders. For example, infrastructure owner-operators value resilience for an increased ability to continue providing services through the infrastructure system in which they operate. Even though the ultimate beneficiaries of resilient infrastructure are communities and the society at large, multiple parties have a direct stake in infrastructure resilience investment, including national governments, sub-national governments, private asset owners and landowners.

Box 2 - Infrastructure value chain and resilience

One of the biggest challenges for critical infrastructure is breaking down the silos within and between infrastructure developers, providers, and customers along the supply chain so that everyone is focused on delivering resilience value where they can. The infrastructure value chain is extremely useful for connecting the concepts of resilience and value in the context of the infrastructure lifecycle that will be familiar to everyone. This concept of 'connecting the dots' helps articulate the contribution of all parties in delivering the overall function and value of infrastructure systems and helps align stakeholders behind a common outcome.

Value chains integrate more social and information networks with all their complexity, interconnectedness, and interdependencies across multiple stakeholders. Nonetheless, most stakeholders oversee only specific domains or activities within a larger value chain, but their decisions on value production should not seek to maximize their own benefits without examining other impacts on the system.[38]

Identifying the benefits, costs, and risks of a resilient investment can help lead decision-makers to the most appropriate funding and financing mechanisms. This can be done through robust project appraisal methodologies that appropriately acknowledge investment in resilience. Considerations that can aid decision-making include, but are not limited to:

- **Identification of key beneficiaries:** If parties, such as property owners or private infrastructure providers, stand to benefit from public investment in resilience, it may be appropriate for them to contribute a financial share (through development contributions, land value capture instruments, taxation, etc.)
- **Share of cross-subsidization:** National governments need to establish the extent to which they want to subsidize sub-national governments. Some parties simply will not be

able to fund their share of investment in resilience, so some cross-subsidization will be inevitable. This will particularly be the case for communities in developing countries.

- **Equity**: Some stakeholders will be better placed to finance resilient infrastructure than others. Vulnerable communities may need additional financial support from central governments or third parties to meet an acceptable level of resilient infrastructure. For example, where it is deemed appropriate that private parties contribute to their community's resilience, it could be feasible to use cost-sharing mechanisms, such as pay-as-you-go schemes. In other cases where there are significant inequities, such as sub-national governments being unable to raise the funding needed from their constituents, centrally raised debt may be the most suitable approach.
- **Incentives and disincentives:** Disincentivize asset owners and landowners from building infrastructure in high-risk places in the future. One effective way to do this is to transfer a reasonable and proportionate share of financial risk to them. It is also reasonable that private asset owners and property owners pay for some of the resilience costs, given they are the direct beneficiaries of the investment.
- **Compensation and liability:** This is essential to resilience funding and financing. Understanding who is financially liable if land is deemed no longer habitable is an important step in determining who the financial contributors ought to be and therefore, what the appropriate funding and financing mechanisms are. Insurance can provide a buffer in case of a disaster, although the limitations of this approach should be acknowledged (Case Study #2 in Annex 1).

2.2 Key Theme 2: Levers of change

A lever of change can be understood as an area of work that has the potential to deliver wide-ranging positive change beyond its immediate focus.[39] In the context of this paper, levers of change are defined as areas that have the potential to enhance the systemic resilience, or tackle the causes of low systemic resilience, while synergistically addressing other grand challenges or societal priorities that seek to solve or mitigate problems on a global scale.

Examples of levers of change include, but are not limited to:

- Decarbonization efforts
- Green infrastructure initiatives e.g., integration of nature-based solutions
- Energy efficiency
- Waste minimization
- Sustainable urban drainage, and flood risk management
- Preventative maintenance
- Estate management
- Ecosystem regeneration and restoration efforts
- 'Build back better' initiatives
- Local policies (e.g., improvements to infrastructure, equity and access for underrepresented groups)

Levers of change can act as 'force multipliers' in scaling up resilience due to their ubiquity and scale and, in some cases, greater maturity in securing financing for infrastructure projects. Attracting investors who are interested in the lever of change can create opportunities to systematically include and embed resilience, even if resilience is not the main or only driver for the project.

Awareness of the value of the resilience gain that can be generated, and losses avoided by incorporating resilience into levers of change can be increased and enhanced. Resilience should be incorporated in the governance structures and decision-making processes associated with these levers. In a similar vein to the concepts of complexity and deep uncertainty explored in Section 2.1, understanding and acting on systemic resilience might be challenging for policymakers and investors lacking sufficient technical capacity.[40] Practical guidance, examples and collaboration with experts can help bridge this capacity gap. Where possible, the case studies presented in Annex 1 indicate how exploiting synergies with levers of change has added value and contributed to creating a stronger benefits case.

'Levers of change' as drivers of positive system-level impacts

The integration of levers of change supports the identification of the infrastructure projects with greatest potential for a net positive impact on the wider system. For example, a project that has resilience as one of its key objectives could be integrated with decarbonization or ecosystem regeneration efforts to achieve an 'overall net gain' across systems rather than limiting it to a "resilience net gain." If an investment can deliver multiple synergistic purposes, the business case should account for the total value of the benefits for all objectives. Equally, if an investment would result in dis-synergistic outcomes (i.e., benefits for one objective, but negative impacts on another) this must be accounted for in the decision-making process (also see Section 2.1). This is true for other societal priorities, not just resilience. If systemic resilience is treated as a priority by all other decision-making processes, the cost of enhancing resilience can be shared across the cost of other societal objectives.

This whole-system approach is best suited for national-level needs assessments and investment planning, which relies on a good understanding of the different component systems and their interdependencies and leverage points, capacity of stakeholders involved, and data availability.[41] Similar system-level assessments are supported by incorporating approaches from other fields, like stress testing (see Box 3) or the use of modelling tools, as outlined in the Ghana resilience roadmap (Case Study #6 in Annex 1).[42]

Box 3 - Stress-testing the resilience of infrastructure

The Resilient Infrastructure Stress Test methodology is being developed by the United Nations Office for Disaster Risk Reduction (UNDRR) to support national partners and decision-makers in identifying vulnerabilities, bottlenecks and inter-dependencies between sectors and services. Stress testing is also a key action of the UNDRR's Principles for Resilient Infrastructure.[43] The methodology is an agile mechanism that allows decision-makers to engage infrastructure stakeholders, take into consideration the changing risk scenario, identify inter-dependencies, provide an overview of risks and vulnerabilities, and test the level of resilience of infrastructure in multiple and complex scenarios. A tiered approach for stress testing infrastructure was developed, which includes three levels. Tier 1 analysis provides policymakers and senior stakeholders with a general understanding of what the most important critical infrastructure domains are and how cascading failure can affect their performance. Tier 2 provides system-level improvements through an understanding of a system's structure and dynamics. The completion of a Tier 2 analysis allows policymakers to consider how changes in policy may impact critical infrastructure systems, providing specific policy recommendations, which feed into the Principles for Resilient Infrastructure. Tier 3 includes complex data analysis and scenario modeling and is meant to operate at the asset level.

Knowledge transfer across sectors and contexts

Integrating levers of change and resilience in the development of infrastructure projects requires and benefits from knowledge transfer across sectors and contexts. Engaging with technical experts is key to knowledge transfer. Adapting ideas, processes, and products from a lever of change can reduce development or other project costs, such as the development of a new analytical technique or financial instrument. Moreover, building on or adapting existing processes might encounter less resistance when seeking to increase resilience. Case #2 (CCRIF) demonstrates how parametric insurance models can be adapted to cover specific disaster risks for sovereign states and private utilities.

2.3 Key Theme 3: Enablers

Enablers refer to global factors that can facilitate or unlock infrastructure finance, including finance for resilient infrastructure. Enablers are crucial to create an environment for infrastructure finance, as they are needed to build a strong business case and unlock finance flows. Combinations of enablers will differ across contexts, and no specific combination is needed to create a successful environment for infrastructure finance. Adapted from published research, the list below provides a general overview of enablers that are particularly relevant to financing infrastructure projects.[44]

Table 1 List of Enablers for Resilient Investment

Enabler	How it helps
Policy and regulatory frameworks	Policies and regulations can encourage finance in resilient infrastructure. For instance, a governmental body could mandate that projects consider the most current data, as in Case Study #1. Other policies may provide incentives to incorporate resilience, such as concessional funding and tax incentives. Some policy and regulatory frameworks can hinder resilient infrastructure projects by imposing regulatory constraints or project selection criteria that eliminate many of the benefits of resilient infrastructure. Case Study #1 shows how projects developed an innovative financing approach to surmount existing parameters or negotiated with a regulatory agency to incorporate new targets. Case Studies #5 and #6 highlight the importance of developing policy as a pre-condition for resilient finance.
Multi-level governance	Institutions, especially public institutions, cannot enact changes or execute projects in a vacuum. Multi-level governance is a process that encourages collaboration across two planes, vertical (local, regional, national, etc.) and horizontal (departments at a similar governance level). Several case studies, including Case Study #3, demonstrate how multi-level governance can improve design aspects related to a project's resilience and facilitate project development.
Capacity and resourcing	Technical experts such as engineers, urban planners, climate scientists, and owner-operators play a key role across a project's lifecycle in ensuring that investment decisions are driven by the right set of priorities, evidence -based, grounded in deep domain knowledge and good practice. Studies have shown that predevelopment funding is an estimated 3%-10% of total project costs yet remains chronically underfunded.[45] This can be attributed in part to fiscal constraints or risk aversion for both private and public investors. Lack of predevelopment funding can prevent projects from reaching fruition. Case studies #5 and #6 demonstrate the important role of multinational technical assistance in reducing predevelopment costs for national and city governments. Additionally, beginning with a base plan and incorporating new information over the project's development also can help projects overcome capacity and resourcing challenges

Enabler	How it helps
Public-private sector collaboration	Reports and case studies, such as Case Study #6, have demonstrated how private-public collaboration can provide opportunities to develop and finance infrastructure projects. Private-public partnerships (PPPs) can help to limit risk exposure and boost private sector confidence as well as offer flexibility in funding and financing to cover the lifetime of an asset, from predevelopment to maintenance and end-of-life. Nonetheless, PPPs are not a one-size-fits-all solution; other mechanisms might be more appropriate.[46] Public investment can play a useful role in crowding in private finance to fund high-impact projects with higher risk.
Standards and certifications	Standards and certifications provide a common language to understand and compare different infrastructure projects, which could aid in scaling projects and prioritizing project benefits. In particular, standards and certifications can help lower perceived risks for private investors by providing additional clarity, therefore unlocking additional financing and funding streams. As of this writing, two prominent global standards are being spearheaded by the public sector (Blue Dot Network[47]) and the private sector (FAST-infra Sustainable Infrastructure label[48]).
Data, information, and technology	Data, information, and technology can be enhanced by the development of policies and standards around their control, along with the development of instruments, models, and collection methods to improve data availability and accessibility.[49] This is easier said than done, however. Resilience thinking helps to surmount a lack of data or standards through selective modeling, incorporating methods from other fields, and remaining open to incorporating new data throughout the project.

2.4 Key Theme 4: Case studies and scalable actions

Six case studies were selected to outline how innovative financing approaches and/or good governance practices have resulted in the development of resilient infrastructure programs and projects. The case studies were developed with a focus on learning from their successes and failures and an emphasis on how these examples could be scaled up and transferred to different sectors and contexts. They represent a broad range of financial approaches, country income levels, geographical contexts, and levers of change (as defined in Section 2.2). Case studies and key takeaways from each are summarized in Table 2 and shown on Figure 4. Full case studies are included in Annex 1.

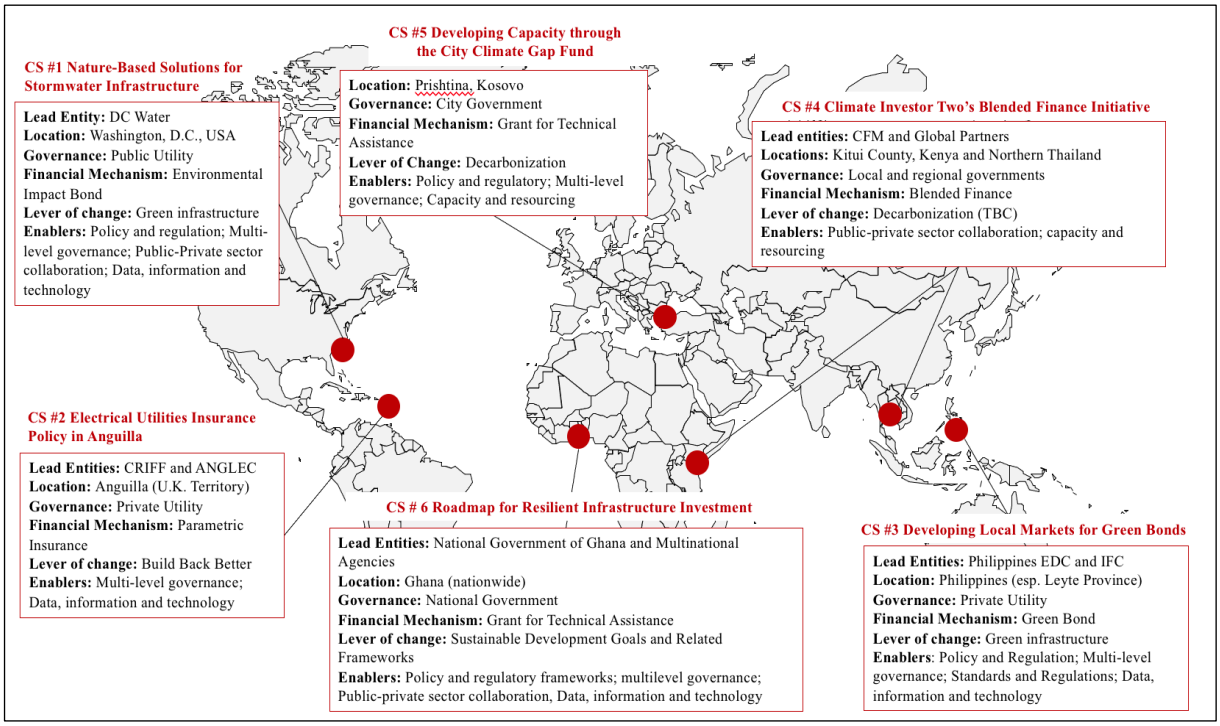

Figure 4 - Map view of the best practice case studies

Table 2 - List of Case Studies and Key Takeaways

Case Study	Key Takeaways
Case Study #1: Nature-Based Solutions for Stormwater Infrastructure	- DC Water altered the project several times to increase resilience, based on new information and new standards, and to reduce costs - Green infrastructure served as a lever of change by presenting an economically viable alternative to grey infrastructure's high capital costs and by generating sufficient interest to finance an experimental project

Case Study	Key Takeaways
	- The Environmental Impact Bond (EIB) was not a "brand-new" financial product, but rather a product adapted from a different sector
Case Study #2: Electrical Utilities Insurance in Anguilla	- The Caribbean Credit Risk Insurance Facility (CCRIF) used its original parametric insurance policies as templates to innovate new solutions, like the electrical utility policy, or update legacy solutions with relative ease - Multi-national organizations like CCRIF can fill a need by developing economically viable solutions that are difficult for infrastructure owners and operators to outsource to the private market or develop in-house - Rapid liquidity can help utilities avoid transferring significant repair costs on their consumers, which is particularly important during times of recession or economic vulnerability
Case Study #3: Developing Local Market for Green Bonds	- Developing a robust governance structure that incorporates risk reduction during non-disaster periods and having a partnership mindset with local stakeholders that exceeds a service provider mindset - Using a financing mechanism to encourage the development of a new local market, as in the case of The International Finance Corporation (IFC)'s peso-backed green bond
Case Study #4: Climate Investor Two's (CI2) Blended Finance Initiative	- CI2 closed its first round at $675 million in November 2021 with an innovative financing structure composed of three stages: a development fund, a construction equity fund, and a climate credit fund - Blended finance was an enabler to accelerate the development of, and subsequent investment in, resilience solutions like solar-powered desalination units in Kenya and two waste-to-energy facilities in Thailand - The fund's management and advisory boards guide the investment strategy providing independent governance, which optimizes the capital allocation framework
Case Study #5: Developing Capability through the City Climate Gap Fund	- The Gap Fund is a unique collaboration between implementing agencies (the World Bank and the European Investment Bank), donors, and city networks (GCoM, C40, ICLEI, and CCFLA)50 - Since its inception, the Gap Fund has supported 80+ cities worldwide by mobilizing more than 7M euros in early-stage project preparation

Case Study	Key Takeaways
Case Study #6: Ghana's Roadmap for Resilient Infrastructure Investment	- Decision-makers need better tools and data to provide actionable information on how to identify adaptation needs in the country and to prioritize infrastructure investments that will address the existing and future risk of climate impacts, needs and gaps through informed investments that are more cost-effective in the long-term, including through nature-based solutions - Adaptation investment options need to be based on the country's needs and backed by robust research and analysis to provide the evidence-based, impactful adaptation projects and enabling environment interventions for funders and financiers to invest - Ghana is committed to implementing the roadmap of 35 adaptation investment options and to build a more sustainable, resilient, inclusive, and prosperous society. However, the government cannot do this alone and requires additional financial resources from development partners and private sector

Identification of scalable actions

The selected case studies blend standardized approaches and contextual nuances to illustrate how different projects share key actions or enablers but enact them in different ways. An initial set of actions related to innovative finance and good governance practice across the case studies are highlighted below. Additional details about the case studies, enablers, participants, and context of each action can be found in Annex 1.

Table 3 Actions Identified from the Case Studies

Innovative finance	Governance
- Make use of levers of change to increase access to financing and create wider system change. - Adapt financial approaches created for other levers and/or used by other sectors. - Use a "simple" financial solution as a baseline to meet a range of more complex scenarios. - Develop a rapid payout mechanism to support 'build back better' efforts. - Leverage innovative financing to develop new financial markets/additional investment for resilient infrastructure. - Focus investment on distinct risk periods in a project's lifecycle to spread the cost of capital and accelerate a project's execution.	- Invest in planning and other strategic pre-development activities. - Develop review mechanisms to incorporate new data/new transaction approaches to secure regulatory approval and attract investor interest. - Leverage access to technical assistance by using a lever of change. - Collaborate with expert entities to reduce the burden on modeling or project execution. - Include local communities and other local stakeholders. - Include training and implementation sessions with key personnel to increase the likelihood of project implementation.

3. Learning from practice

Learning from practice can illuminate existing pathways to financing resilient infrastructure or create new ones to educate and inspire others to find their own ways and take action. Key themes presented throughout Section 2 were used to frame and analyze the case studies in Annex 1. Emerging common themes for pathways to investment in resilient infrastructure are highlighted below.

Demonstrating the value of resilience

An analysis of the case studies showed that demonstrating the value of resilience depends on input from three kinds of actors: public officials or other designated decision-makers, technical subject matter experts, and the interested and affected parties to the decision. Public officials and some technical experts are usually included in the process that leads to decision-making, but the interested and affected parties are sometimes overlooked. Their inclusion is critical to ensure that all relevant information is included, leading to better deliberation. DC Water considered the input from interested and affected parties to decide on the implementation of nature-based solutions in Case Study #1.

As the case studies indicate, stakeholders from the government and infrastructure owner-operator groups possess varying levels of awareness of available financing mechanisms and capacity to drive the process. Awareness, education, and receptivity will influence the selection of the most appropriate investment pathway alongside the mix of partners involved in the early stages of project development.

Results from the case studies suggest that demonstrating the value of resilience includes a risk assessment that considers qualitative and quantitative data to highlight future scenarios with and without resilient interventions. It could be as technical and narrow as stormwater runoff modeling, such as Case Study #1, or as broad and qualitative as the impact of urban planning on transportation exposure to hazards, as in Case Study #5. Despite variations in scope and data, this assessment implies or demonstrates the undesirability of a scenario without resilient interventions. Physical climate risk assessments are key instruments for financing resilient infrastructure.[51]

Good governance and innovative finance approaches

Good governance practices or innovative financing mechanisms identified in this paper are not uniquely applicable to infrastructure resilience. Good governance practices exhibited in many of the case studies included strong cross-sectoral collaboration, multi-level governance, mechanisms for review, and engagement with the public. Similarly, innovative financing mechanisms borrowed models from other sectors or iterated from pre-existing finance mechanisms, such as a Case Studies #1 and #2 respectively. Section 2.2 highlighted that resilience should produce net benefits to a system. An examination of good governance practices and innovative financing demonstrates this assertion. Pathways to achieving resilience benefits to infrastructure and organizations extend beyond the benefits of resilience. Strengthening collaborative efforts to improve resilience can improve an organization at large. Determining creative ways to adapt and create new financial mechanisms can be used for other aspects of infrastructure projects.

The role of private finance

The level of finance required to deliver on the Paris Agreement and other global agendas cannot be met by public finance alone. In addition to the role of technical assistance in developing resilient projects, other elements can lay the groundwork for private finance such as early-stage risk capital and guarantees. Additionally, concessional and blended finance can help to reduce risk and increase private sector confidence where there is not a clear picture of creditworthiness.

Public finance can provide an environment to encourage private investment through the creation of new markets and as an augment to public finance. Case study #3 demonstrates how a major development finance institution (DFI) issued the first peso-backed green bond, which led to the creation of a green bond market for infrastructure in the Philippines. Case study #4 used blended finance to attract investors to LMIC projects.

Projects can also use explicit means to improve private investors' confidence. Private investment can also be unlocked through the adoption of an international standard or third-party review, as in Case Study #3, or through attracting investors' interest to a specific 'lever of change' (see Section 2.2). The use of a nature-based solution in Case Study #1 seems to have encouraged investment from major players in the United States, for instance.

With this said, however, some existing literature cautions that blended finance may reinforce a disparity between private and public finance by offering tax breaks or other regulatory incentives for privately financed options, but not for State-Owned Enterprises or public agencies, which can borrow on the capital market/issue bonds. This disparity might lead to bias toward private finance.[52]

Technical assistance

Highlighting the importance of technical experts throughout the phases of a project's lifecycle also demonstrates the unique importance of technical assistance, particularly in the pre-development phase. The cost-benefit analysis conducted at this stage is predicated on an understanding of the possible impacts of a range of natural and man-made hazards. In the case of climate change, impacts accounting for increased frequency and intensity of weather-related events, such as floods and storms, need to be included in the assessment. The expertise needed to do such an analysis may not be available locally, especially in LMICs. Furthermore, many countries around the world may lack the subject matter expertise and computational resources required to downscale climate change models to the regional level or below.

As discussed previously, the predevelopment phase of an infrastructure project represents a fraction of total project costs, yet it remains chronically underfunded. This is particularly the case in LMICs.[53] Case studies #5 and #6 demonstrate the critical role of technical assistance in supporting the pre-development phase. Case study #5 highlights implementation of policies at the local level, while Case Study #6 highlights the importance of prioritized projects at a national level. Both types of technical assistance play important roles. Local-level technical assistance can provide the framework to facilitate project implementation. National-level technical assistance can encapsulate broad strategies and can serve as a bridge between international frameworks, such as the Sustainable Development Goals, and local projects.

Building capacity during technical assistance increases the likelihood of implementation. Many DFIs, such as the World Bank, offer robust technical assistance programs to meet this need. With this said, an increase in effective technical assistance programs could help close the gap in resilient financing, especially for LMICs. Although determining factors that make technical assistance "effective" extends beyond the scope of this paper, Case Study #6 highlights the importance of engagement with key stakeholders, including direct knowledge transfer and training in technical assistance. Project leads engaged with

stakeholders to gather their input during the development of an investment roadmap. Following the development, project leads worked with government departments and personnel to train and develop their capacity to implement these projects, increasing the likelihood of implementation.

Praxis-based education

Praxis-based education, or learning from practice, can serve as an important tool to showcase concepts in action. Selected case studies have been used to demonstrate this framing and to identify opportunities for tangible actions to transfer lessons learned to other sectors and contexts. The case studies emphasize key actions that contributed to a project's success as different aspects of a 'playbook' that can match a solution or opportunity with a challenge that a particular stakeholder may be facing. Although the environments that enable these case studies differ (e.g., regulatory environment, partners involved, etc.), it is argued that key actions can translate across contexts with some adaptation.

Further collation of case studies would support practitioners who are trying to implement investing in infrastructure resilience. Case studies should collate data on the business case; benefits assessment and capture; transaction models, returns and pricing; and clear, tangible actions for different stakeholder groups. This would deliver multiple benefits, including raising awareness of the available financing mechanisms and technical assistance, providing benchmarking for what good looks like, and boosting investors' confidence that investing in resilience can be economically viable and meet their risk-return criteria.

Technical expertise

All case studies included collaborations with multiple experts to develop models, whether they were qualitative or quantitative. Some cases also highlighted collaborations with experts to implement a retrofit, new build, or strategy. Climate Investor 2 partnered with experts to design and implement a waste-to-energy project in Thailand in Case Study #4, while a team of technical experts assisted Prishtina, Kosovo, to implement codes and an urban planning strategy in Case Study #5. Technical experts can also help boost investor confidence. In Case Study #3, an energy corporation in the Philippines used an expert third party to validate green bonds. In all these cases, outside experts fulfilled a critical role for owners-operators or government officials by taking some of the technical burden from these stakeholders, which improved the projects' outcomes and reduced costs of hiring or developing an in-house capability.

Reliable technical and scientific input is essential to making sound decisions about resilience.

Technical experts bring indispensable substantive knowledge, methodological skills, experience, and judgment to the task of developing resilient infrastructure. Novel mechanisms should be identified to allow technical experts to be more actively involved in

discussions with policymakers and investors from the early stages of project development. For example, ANGLEC's technical experts were consulted throughout the design of the parametric insurance policy by the Caribbean Catastrophe Risk Insurance Facility in Case Study #2. The analytical work needed to support resilience decision-making requires contributions from many diverse disciplines, including economic, social and behavioral sciences in addition to engineering and natural sciences.

4. Conclusions and Recommendations

Shovel-worthy projects that aim to create long-term positive outcomes for communities are being identified, and funding for resilient infrastructure is being pledged.[54] However, investors still require some convincing to unlock finance flows, particularly in low- to middle-income countries where this investment is most urgently needed.

Building on existing concepts and published references, this paper highlights and frames key aspects that have significant potential to upscale and accelerate resilient infrastructure finance. These include bringing a sharper focus to the value case and desired outcomes for resilient infrastructure; being intentional about utilizing ongoing global initiatives as 'levers of change' for resilience and drivers for systemic change; ensuring that success-enabling factors are included in the process; and learning from practice to implement at scale and at pace.

Although no standardized template for financing resilient infrastructure exists, the pathways to reaching an investment decision share commonalities and success factors. Recommendations to promote and embed these into practice have been identified and are presented below.

Recommendation #1: Embed systemic resilience in every investment decision

Resilience should be viewed systemically and should be embedded in every decision in the development of infrastructure, including investment decisions. This is currently an aspiration, as resilience is not routinely considered and 'baked in' in the decision-making processes. The interdependent nature of these systems demands that risk assessments and resilient solutions take a systemic approach. Actions that undermine systemic resilience need to be identified and curtailed, as they can produce negative impacts across the system. Infrastructure governance will be critical to ensure the right conditions are in place for systemic resilience to thrive. Overcoming barriers to embedding systemic resilience in every investment decision will require a technical capacity that decision-makers do not usually possess. A shift to outcome-based approaches for infrastructure development might present a more accessible avenue for policymakers and investors, and can encourage a deeper consideration of adaptive, resilient, and multi-purpose infrastructure solutions.

Recommendation #2: Promote use of 'levers of change' and enablers as factors with significant potential to deliver, upscale and accelerate resilient infrastructure finance

Resilient infrastructure projects can benefit from understanding and linking to other goals and objectives, which can allow projects to enhance visibility, interest, and funding. Awareness should be raised of the value of the resilience gain that can be generated, and losses avoided by incorporating resilience into the objectives of 'levers of change', for instance. Resilience should be incorporated in the governance structures and decision-making processes associated with these levers. Integrating 'levers of change' and resilience in the development of infrastructure projects requires knowledge transfer across sectors and contexts. Partnerships, especially with regulatory bodies and DFIs, seem to aid in this practice, as Case Studies #1 and #3 suggest. In addition, all case studies highlight that project success will depend on enabling factors, such as those identified in Section 2.3. Ensuring that enablers are in place from early stages of project development will allow stakeholders to capitalize on them more effectively.

Recommendation #3: Address the capacity gap for assessing broader benefits delivered by resilient infrastructure

Difficulties with quantifying non-traditional benefits seem to be global and cross-cultural. Good examples of co-benefits assessments exist, but they are often *ad hoc* and remain heavily impacted by gaps in data and technical capacity. This emerging field would benefit from the development of methodologies and indicators for different sectors and incorporation of these into cost-benefit appraisals. Allocation of the direct and indirect benefits, costs and risks associated with the investment among all parties involved is an area that should be given more prominence and further explored. Additional research and learning from project examples where co-benefits have been successfully assessed and allocated is required to close this gap.

Recommendation #4: Encourage cross-sectoral knowledge transfer and adaptation of existing financial approaches and mechanisms

Adapting existing financing approaches or products can offer a more viable, faster, and cheaper solution than developing an entirely new financial instrument or mechanism. Moreover, building on or adapting existing processes and products might encounter less resistance when seeking to increase resilience. This approach can be enhanced through knowledge transfer and collaboration between experts and project stakeholders. As shown in Case Studies #1 and #2, large institutions, non-governmental think tanks, and private sector players should collaborate with infrastructure owners to develop mechanisms that meet a specific concern or constraint. Communicating with investors and lenders during the development of the mechanism also significantly increases the likelihood of success.

Recommendation #5: Make better use of technical assistance to ensure that investment decisions take account of resilience features

The availability of predevelopment funding for technical assistance in the early stages of development plays a key role in ensuring that shovel-worthy projects receive investment.

Case studies #5 and #6 demonstrate the important role of multinational technical assistance in reducing predevelopment costs for national and city governments. In addition to more technical assistance, several considerations can ensure more effective uptake of resilience. For example, developing a review board, either national or international, that can certify that technical assistance does not negatively impact resilience (like an expanded green bond review). Similarly, building a coalition or conglomerate to help unify streams of technical assistance to improve their efficiency, would benefit technical assistance globally, since many of the technical assistance offerings are siloed and lack an understanding of other initiatives. Lastly, enhancing the capability of the practitioners on the ground can result in closing the capacity gap more permanently.

Recommendation #6: Develop a repository of case studies on investing in resilient infrastructure, based on a set of agreed criteria and principles

Learning from practice can illuminate existing pathways to investment in resilience or create new ones to educate and inspire others to find their own ways and act. Following the proof-of-concept presented in this paper, the development and dissemination of a repository of curated resources that can support practitioners on how to move successfully from concept to investment decision could help scale up and accelerate infrastructure resilience financing. Resources should comprise best practice case studies based on a set of criteria and principles (see Section 3), and playbooks aimed at each of the stakeholder groups involved in the development of infrastructure. In this regard, think tanks with practical expertise across a range of contexts should spearhead the development of these knowledge resources.

Recommendation #7: Ensure that the right experts are consulted at appropriate points in the project development

Technical experts such as engineers, climate scientists, urban planners, behavioral and social scientists, and ecologists play a key role across a project's lifecycle by ensuring that investment decisions adhere to the right set of priorities and are grounded in deep domain knowledge and good, evidence-based practice. Because of the nature of the complex, systemic challenges inherent in the development of resilient infrastructure, technical-expert input should be multidisciplinary and include system thinking capabilities, which can be drawn from international best practices and adapted to the local context. Methodologies, such as PCRAM,[55] rely on the right group of experts coming together to provide input for the decision-making process at appropriate stages.

ANNEXES

ANNEX 1 – CASE STUDIES

Case Study #1: District of Columbia Water and Sewer Authority (DC Water)

Learning from successful integration of green-gray infrastructure and use of adaptable financial mechanisms to meet performance standards	
Country/Geographic region[56]	United States/ North America *Local Project*
Country Income Level Classification[57]	High-income
Hazard(s) mitigated	Stormwater runoff via precipitation (climate adaptation included)
Type of financing[58]	Debt (Environmental Impact Bond)
Type of governance	Public Utility
Lever of change	Desire to integrate green infrastructure (nature-based solutions)
Main Actors	• District of Columbia Water and Sewer Authority (DC Water) • Environmental Protection Agency • Other Washington D.C. government departments • Quantified Ventures
Case study Summary	DC Water and its partners financed a nature-based solution with the first-ever Environmental Impact Bond (EIB to remediate stormwater and sewer pollution across Washington D.C.
Key Takeaways	• DC Water altered the project several times to increase resilience, based on new information and new standards, and to reduce costs • Green infrastructure served as a lever of change by presenting an economically viable alternative to grey infrastructure's high capital costs and by generating sufficient interest to finance an experimental project • The EIB was not a 'brand-new' financial product, but rather a product adapted from a different sector

Project Rationale

By the early 2000s, Washington D.C.'s joint stormwater and sewer system had begun polluting local waterways to increasing levels. This 19th-century system was not designed to manage the demands of the city's urban development and population growth. Pollution levels spiked, especially following severe rainfall and flooding events, as increased stormwater runoff overwhelmed the already strained wastewater system.[59]

In 2005, the U.S. Environmental Protection Agency (EPA) mandated that DC Water develop a plan to mitigate the likelihood and impact of major pollution events. EPA also mandated that DC Water consider green infrastructure and spend $3 million on green infrastructure pilot projects. DC Water developed a $2.6 billion initial project, which relied on the construction of three large tunnels beneath the Anacostia, Potomac, and Rock Creek watersheds.[60]

Project Development

Although DC Water implemented some changes in the first years of the project, progress on the major aspects of the retrofit remained difficult to implement for technical and financial reasons. The project's initial design faced challenges, as subsequent studies found that it did not account for increased rainfall due to climate change projections. In addition, the project's repayment structure threatened to overburden taxpayers. The repayment structure initially charged customers artificially low rates per the cost of the project, with rates increasing more than twentyfold over the next nine years.[61]

DC Water and other city departments collaborated to meet these challenges. DC Water incorporated new climate rainfall projections into its models. DC Water also aligned with other city departments to mitigate the anticipated effects from climate change. Several assessments and plans from this collaboration noted the importance of maintaining infrastructure continuity across a range of climate scenarios.[62]

DC Water's collaboration on these initiatives aided in its decision to incorporate nature-based solutions to reduce project costs. Following several years of consideration, DC Water concluded that green infrastructure solutions could replace the Rock Creek Tunnel and shorten the Potomac Tunnel. The new plan replaced these tunnel lines with rain gardens, rain barrels, permeable pavements, bio-retention planters, parks, and other nature-based solutions.[63]

Project Implementation

The new plan faced challenges with financing, however, which was due to concerns regarding how nature-based solutions would perform. Models predicted that nature-based solutions could reduce pollution by reducing runoff into the system. Nonetheless, verifying the accuracy of the modeling was more difficult given the limited number of green infrastructure solutions, especially for a project of DC Water's size and scope. A traditional municipal bond would not cover DC Water if the project did not reduce enough runoff.[64]

DC Water partnered with the advisor Quantified Ventures to develop and issue the first-ever Environmental Impact Bond (EIB) for part of the project (Rock Creek) in 2016. Modeled on a social impact bond, this bond used performance-based metrics to hedge project performance uncertainties for DC Water yet remain attractive to investors.[65] Goldman Sachs and the Calvert Foundation became investors. The $25 million EIB was structured as a tax-exempt municipal bond with a 30-year maturity. The bond functioned much like a

standard bond except for a one-time mandatory tender date at the bond's five-year mark. At this date, the EIB could pay out based on the project's performance.[66]

The EIB employed a 3-tiered payout scheme based on the project's performance at reducing runoff. In the third tier ('underperformance'), investors would make a risk transfer payment of $3.3 million to DC Water, which could be used to cover costs. If the project performed in tier 2 ('acceptable performance'), then no party would make a payment. In the case of project 'overperformance', DC Water would make a $3.3 million payment to investors. DC Water still would benefit from a tier 1 scenario since runoff reductions of that scale were expected to reduce costs by more than $3.3 million.[67]

Table 4 - EIB Performance and Payout Metrics

Tiers	Performance	Performance-Based Payment
3: 'Underperformance'	Runoff reduction <18.6%	Investors pay DC Water $3.3M
2: 'Acceptable Performance'	18.6% ≤ Runoff reduction ≤ 41.3%	No payment
1: 'Overperformance'	41.3% < Runoff reduction	DC Water pays investors $3.3M

The Rock Creek project's performance in 2019 and 2020 was evaluated against a baseline of no green infrastructure. This project was found to have reduced runoff by nearly 20%, placing it in tier 2. These results indicate that the EIB successfully enabled DC Water to implement a more experimental project.[68] In recent years, other municipalities across the United States from Georgia to California have used EIB to finance a range of projects. It is anticipated that the early successes of EIBs will increase adoption in the years ahead.[69]

Timeline

Date/Period	Description	Actors Involved
Mid-20th century – Early 2000s	DC Water's combined stormwater/sewer system no longer could handle capacity, especially during flooding events, increasing sewage levels in DC's rivers, and resulting in lawsuits. Pollution levels eventually violate the Clean Water Act (CWA).	DC Water, Environmental Protection Authority (EPA), Various class-action lawsuits
2005	In response to the CWA violation, DC Water develops $2.6B long-term Control Plan to limit pollution. The plan would involve a substantial retrofit of three river tunnel systems. As part of this suit, the U.S. EPA requires that DC Water consider Green Infrastructure and spend $3M on a pilot project.	DC Water, Greeley, Hansen LLC
2008	EPA study finds that hydrological models developed for the project may have discounted higher expected levels of rainfall due to climate change. DC Water adds additional 20% capacity margin to models as a result.	EPA, DC Water

Date/Period	Description	Actors Involved
2000s - Early 2010s	External groups continue to lobby DC Water to consider green investment.	National Resource Development Council (a chief proponent)
2010s – 2016	DC Water begins to consider nature-based solutions aspects of the project. City departments come together to determine ways to make Washington D.C. more sustainable, culminating in a suitability plan in 2013. The Department of Energy and Environment spearheads a plan that highlights the importance of green infrastructure to meet the project's resilience goals.	DC Water, Washington D.C. Government agencies (especially Department of Energy and Environment)
2005-2015	High capital expenditures to retrofit tunnel systems are expected to transfer large burdens on DC residents	-
2015- 2016	DC Water halts the project to incorporate green infrastructure solutions into the project. In 2016, DC Water issues a new plan that substantially incorporates nature-based solutions.	DC Water
2016	DC Water issues first-ever EIB to finance green infrastructure components for the Rock Creek project component.	DC Water, Quantified Ventures
2017 – Present	Execution of new plan.	DC Water
2021	Project performance for EIB found to be within tier 2 ('acceptable performance')	DC Water, Quantified Ventures

Lessons Learned

DC Water benefitted from a regulatory environment that encouraged or mandated that it meet certain resilience targets. EPA, non-governmental agencies, and public stakeholders highlighted the need for pollution reduction, the importance of climate modeling, and the benefit of nature-based solutions. In addition, DC Water benefitted from being a large municipal provider with national recognition and the ability to raise capital, which probably played a role in its success.

- **Green infrastructure can be a lever of change to move projects forward and encourage investment.** Green infrastructure generated significant interest from external sources and from within Washington D.C.'s city government to adapt to climate change. DC Water did not have to incorporate green infrastructure significantly into the design by mandate; however, careful consideration of green infrastructure led DC Water to conclude that it presented the most viable economic option as well. Green infrastructure also produced several co-benefits including green jobs, more than half of which DC Water pledges to be local jobs. The project's nature-based solutions also have provided co-benefits in terms of recreation and beautification for city residents.

- **Financial instruments from other sectors can be successfully adapted.** The development of the EIB to finance a green infrastructure solution shows how a project can adapt an existing financial instrument to meet the needs of a non-traditional project. Traditional financial products could not adequately incorporate project uncertainty or capture longer-term benefits of DC Water's green solution. The EIB adapted performance mechanisms from a social impact bond to better meet these needs. DC Water shows that innovative financing does not necessitate the creation of a completely new financial instrument, but rather the creative application of an existing one.

- **Collaboration and adaptability are key success factors for good governance.** The project also relied on good governance, which is best demonstrated by the project's collaboration and adaptability. DC Water collaborated with financial advisories, engineering firms, departments, other agencies, and NGOs to ensure regulatory compliance, develop new strategies or solutions, and to incorporate other citywide initiatives. This collaboration highlights the importance of using each stakeholder's strengths. For example, DC Water relied on external entities for climate change models and financial advisories to develop the EIB.

- **Iterative processes to incorporate better data need to be built in the project.** DC Water's adaptability presents a case study regarding how a municipal department can overcome limited pre-development resources, insufficient knowledge, and changing standards. DC Water developed the project out of necessity to meet EPA compliance. DC Water incorporated new information and new standards that made the project more resilient as climate rainfall models were developed. Their adaptability also enabled them to revise their approach ten years into the project, negotiate new targets with EPA (stormwater runoff), and attract investors to finance the nature-based solutions project.[70]

Case Study #2: Caribbean Catastrophe Risk Insurance Facility and Anguilla Electricity Company

Learning from the use of parametric insurance policy for hurricane events	
Country/Geographic region	Anguilla (U.K. Territory)/Caribbean *Regional Program*
Country Income Level Classification	Unrated (Territory)
Hazard(s) mitigated	Hurricanes
Type of financing	Debt (Parametric Insurance)
Type of governance	Multinational Facility and Owner/Operator Utility
Lever of change	'Build back better' (secondary effect)
Main Actors	• Caribbean Catastrophe Risk Insurance Facility (CCRIF) • Anguilla Electricity Company (ANGLEC) • Caribbean Electric Utility Services Corporation (CARILEC) • World Bank
Case study Summary	The impact of hurricanes on electrical infrastructure prompted the Caribbean Catastrophe Risk Insurance Facility (CCRIF) to develop a parametric insurance policy for electrical utilities following hurricane events. Anguilla Electricity Company (ANGLEC), which sustained significant damage during Hurricane Irma in 2017, was the first company to purchase this policy.
Key Takeaways	• CCRIF used its original parametric insurance policies as templates to innovate new solutions, like the electrical utility policy, or update legacy solutions with relative ease • Multi-national organizations like CCRIF can fill a need by developing economically viable solutions that are difficult for infrastructure owners and operators to outsource to the private market or develop in-house • Rapid liquidity can help utilities avoid transferring significant repair costs to their consumers, which is particularly important during times of recession or economic vulnerability

Project Rationale

The aftermath of severe weather events in the early 2000s prompted a need for a multi-national facility that could transfer risk and provide rapid liquidity relief to sovereign countries in the Caribbean. The Caribbean Catastrophe Risk Insurance Facility (CCRIF) was founded and capitalized in 2007 by a consortium of sovereign countries and multinational entities. To maximize the speed of payouts, CCRIF developed a parametric insurance model funded by traditional and capital markets. Unlike indemnity insurance, parametric insurance distributes funds based on pre-established triggers, which significantly reduces

the time needed to distribute relief funds (see Figure 5 and Figure 6 below for more information). CCRIF's earliest policies focused on earthquakes and tropical cyclones.[71]

Over the next decade, CCRIF provided nearly $200 million in rapid liquidity to Caribbean member states. CCRIF also adapted its parametric insurance model to develop new offerings for other types of weather events, such as excess rainfall. In 2014, CCRIF restructured by separating its policy offerings into different portfolios, which reduced risk across offerings, and began to offer products to Central American countries in 2015.[72] CCRIF's vision to offer rapid liquidity for other entities set the stage for its development of an electrical utilities policy.

In 2017, Hurricane Irma hit the British island territory of Anguilla with class 5 force, damaging public and private buildings, closing schools, and making most roads impassable. The hurricane almost completely destroyed the electrical transmission and distribution networks of the island's sole electricity provider, Anguilla Electricity Company (ANGLEC), producing cascading failures across other basic services such as the hospital and the island's vital desalination plant.[73]

With the assistance of international aid, ANGLEC was able to restore power to hospitals and a few other critical facilities on the island within a few days. Most Anguillans remained without power for weeks or months. Although the power restoration was accelerated by sound leadership and international support, ANGLEC leaders noted that the lack of rapid access to funding hindered the speed of the recovery process and strained its recovery.[74] ANGLEC quickly burned through its $5.9 million USD reserves. Total recovery costs exceeded ANGLEC's reserves by almost fourfold.[75]

ANGLEC's experience following Hurricane Irma demonstrated the need for utilities to develop a source of rapidly deployable funds to accelerate financial assistance following a major hurricane. There were no insurance options or other financial instruments to cover ANGLEC's risk at an acceptable premium, however.[76] Rapid funding also may have enabled ANGLEC to rebuild to a higher standard across its networks. Following Hurricane Irma, for instance, ANGLEC was granted a loan by the Caribbean Development Bank and a grant from the European Investment Bank to rebuild its distribution system to international standards.[77]

Project Development

Although Anguilla was not the first island to sustain significant power outages, experiences like ANGLEC's helped to prompt CCRIF and its partners to develop a risk transfer policy that utilities could not purchase on traditional insurance markets. CCRIF partnered with the Caribbean Electric Utility Services Corporation (CARILEC), a group of electrical providers and other stakeholders across the Caribbean, for technical expertise and guidance.[78] CCRIF and CARILEC had been discussing the possibility of developing a policy for electrical utilities

several years prior to Hurricane Irma. The Irish government provided more than $1 million to support the policy's development.[79]

Determining an appropriate trigger played an important role to ensure that the policy achieved a risk transfer that made good financial sense for the insurer and the purchasing utility. Given historical damages to utilities like ANGLEC, the policy focused on transmission and distribution components of the electrical network. Based on input from CCRIF, CARILEC, and other partners, the models developed for this trigger indicated a strong relationship between wind speed and damages (See Figure 5).[80]

CCRIF borrowed its most current hurricane model to determine impacts. During the early stages of development, CCRIF held several meetings with its partners, including the World Bank, to determine which electric utilities would be eligible for the policy (public, private, etc.). Following a determination that the facility would offer the policy to public and private utilities, ANGLEC quickly became a candidate for a pilot policy, as ANGLEC had expressed interest in purchasing coverage. CCRIF's model required that utilities provide data on their transmission and distribution assets to determine the utilities' exposure to the hazard, which ANGLEC provided over several months. After determining exposure, CCRIF developed exceedance probability curves to determine expected losses. From these models, CCRIF created several coverage options for ANGLEC. ANGLEC ultimately opted for higher frequency coverage that did not cover all its assets (for a lower premium), effectively using the policy as a replacement for its reserve fund.

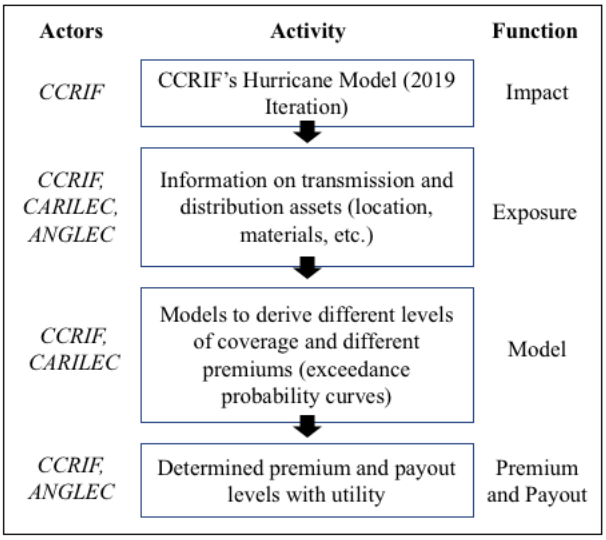

Figure 5 - Development of Utilities Policy

Following several years of development, ANGLEC purchased the first electrical utilities policy in 2020, marking the first purchase of a CCRIF policy by a private entity.[81] The utility policy was based on CCRIF'S standard parametric insurance policies. The triggers, premiums, and payouts were adapted to meet the needs of an electrical utility company

(see Figure 6). CCRIF asserted that the facility could payout $5.46 million in the facility's standard time of two weeks or less.[82]

Following a successful year of insurance coverage, ANGLEC increased its utility policy in 2021. ANGLEC did not receive a payout since Anguilla did not experience significantly bad weather during the policy period.[83] As of this writing, no other electrical utility has purchased CCRIF's utility policy. CCRIF and other key stakeholders expect that several utilities will follow ANGLEC's lead in the near future, particularly given the policy's promotions by CARILEC and other major entities.[84]

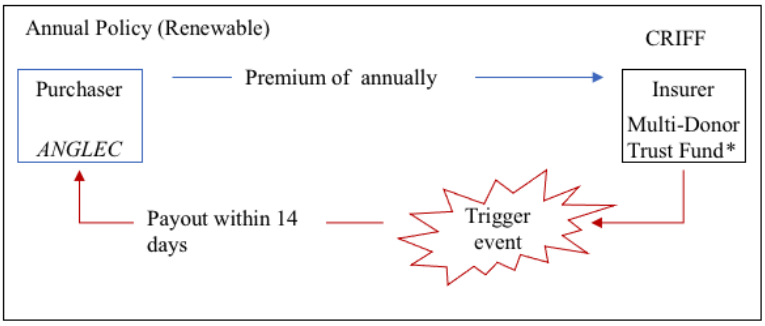

Figure 6 - Utilities Policy Trigger Mechanism

Timeline

Date/Period	Description	Actors Involved
2004-2007	A consortium of countries and organizations establish the Caribbean Catastrophe Risk Facility (CCRIF) to develop a risk transfer mechanism with the ability to payout quickly. The earliest policies covered tropical cyclones and earthquakes for sovereign states in the Caribbean.	World Bank, Caribbean Development Bank, several country governments, original member countries[85]
2007-2013	CCRIF has success with early payouts and receives international recognition for risk transfer activities. The facility expands its offerings to include other types of weather events, such as excess rainfall.	CCRIF and partners[86]
2014	CCRIF restructures to become CCRIF SPC to segregate its different policy portfolios to avoid risk from spreading from one portfolio to the others.	CCRIF, World Bank, Caribbean Development Bank
2015	CCRIF begins to offer policies to Central American countries.	CCRIF, World Bank, and the Council of Ministers of Finance of Central America, Panama and the Dominican Republic (COSEFIN), Governments of Nicaragua, Panama, and Guatemala
2015-2018	Impacts like Hurricane Irma on Anguilla's electrical infrastructure play a role in prompting CCRIF to develop a policy for electrical utilities.	CCRIF

2018-2020	With funding from the Irish government CCRIF designs a policy based on the relationship between windspeeds and direct damages to electrical transmission and distribution components.	CCRIF, Caribbean Electric Utility Services Corporation (CARILEC), Government of Ireland
2020	CCRIF conducts an overhaul of triggers and models used in its legacy policies and introduces two new policies: a fishery policy and an electrical utility policy. Anguilla Electricity Company (ANGLEC) serves as the pilot project and purchases the first utility policy.	CCRIF, partners, (especially CARILEC), ANGLEC[87]
2021	Following the success of the policy during its first year, ANGLEC increases the premium and payout of the policy.	ANGLEC,CCRIF

Lessons Learned

This case also demonstrates the importance of assistance from multi-national entities to enhance infrastructure resilience. CCRIF met ANGLEC's needs by developing a competitive insurance option that ANGLEC could not outsource to the private market or develop in-house. Key lessons learned include:

- **Parametric insurance is a relatively simple, adaptable, and flexible solution**. CCRIF's history of iterating parametric insurance policies enabled the facility to adapt its parametric models into its electric utility policy. In the future, CCRIF or another insurer could offer parametric insurance to cover a range of hazard scenarios for electric utilities, such as earthquakes, or other utilities, such as water/wastewater or transportation. In addition, speed of funding may enable owners to rebuild to higher standards due to the immediate availability of funding.

- **Collaboration and partnerships played a key role in developing a robust electrical utility policy**. CCRIF outsourced some of the technical knowledge of electrical utilities to CARILEC and relied on the utilities, ANGLEC in this case, to provide data on their assets to determine exposure. CCRIF collaborated with ANGLEC to determine which coverage option would best meet ANGLEC's needs, which required direct collaboration between CCRIF and its utility clients.[88] The collaboration enabled CCRIF to adapt the policy more effectively to the client's exposure and needs.
- **Insurance policies necessitate the continual improvement of risk analysis and design standards**. Engineers like CARILEC and climate scientists play a critical role in continuing to update models and designs. This work benefits investors and utilities by enhancing understandings of risk (or at least risk priorities) and by developing ways to reduce it. Standardizing designs and assessments on an international level also could encourage investment.[89] CCRIF demonstrates a way for investors to incorporate new knowledge by actively including these stakeholders in policy design and by building in periods for revision and review (annual policies).

- **The speed of insurance payouts could aid in 'build back better' efforts**. Following Hurricane Irma, ANGLEC expressed a desire to rebuild its transmission and distribution assets to higher international standards. The utility noted that lack of immediate funding hindered this effort, as some of the interventions required to build back better were more costly than the baseline solution to return power to the electric grid. Although CCRIF did not develop the policy with a requirement to build back better, rapid liquidity could allow utilities like CARILEC to do so.

- **Stakeholders need to be educated on the benefits and pitfalls of insurance products.** Despite a multitude of benefits, it may be best for utilities to incorporate CCRIF products with other financial risk mechanisms, if possible, since CCRIF policies cover a specific range of scenarios and often do not cover total damages. Consortiums, such as the Insurance Development Forum, are exploring ways to expand coverage and increase inclusion, which will help entities like ANGLEC increase risk coverage in the future.[90] Increasing education on the function and limits of parametric insurance could also help purchasers better understand their coverage.

Case Study #3: Philippines Energy Development Corporation

Learning about the importance of partnerships and innovative financing in developing an environment of increased organizational and physical resilience	
Country/Geographic region	Philippines/East Asia & Pacific *Provincial Projects*
Country Income Level Classification	Lower-Middle Income
Hazard(s) mitigated	Earthquake, Hurricane, Landslide (climate adaptation included)
Type of financing	Debt (Green Bond)
Type of governance	Private Utility
Lever of change	EDC's renewable energy policy unlocked green financing
Main Actors	• Philippines Energy Development Corporation (EDC) • The International Finance Corporation (IFC) • Macquarie Infrastructure and Real Assets (MIRA)
Case study Summary	Following a series of severe weather events in 2017, the renewable energy company Philippines EDC and its partners developed an approach to prioritize the implementation of risk reduction measures to protect key assets. The IFC funded the implementation of this strategy at the Malitbog plant. EDC Philippines benefitted from a regulatory environment that was amenable to green finance and resilient projects.[91] Pre-established governance structures related to risk and capacity in disaster risk reduction allowed EDC to engage with different departments and incorporate new assessment tools, which enabled it to understand and reduce risk and to develop mitigation measures focused on resilience.
Key Takeaways	• A robust governance structure incorporated risk reduction during non-disaster periods and a partnership mindset with local stakeholders exceeded the service provider mindset • Using an innovative financing mechanism can encourage the development of a new local market, as in the case of the IFC's peso-backed green bond

Project Rationale

The Philippines is consistently evaluated as one of the most at-risk countries to natural hazards, notably flooding, tropical cyclones, earthquakes, landslides, and volcanic eruptions. The Asian Development Bank estimates that disaster events have impacted the entire population more than once over, have caused approximately 23,000 deaths, and have resulted in $20 billion in damages between 2000 and 2016. Many of these hazard risks are expected to increase due to climate change.[92]

In 2017, a series of hazard events impacted the country and crippled some of its electricity generation, including the private company Philippine Energy Development Corporation (EDC). EDC was the largest producer of 100% renewable energy in the Philippines (and remains the largest producer as of this writing), with a generation portfolio of geothermal, hydroelectric, wind, and solar generation. EDC's geothermal production was the largest piece of this portfolio, generating more than 60% of the Philippines' geothermal energy and making it one of the largest geothermal producers in the world.[93] In July, a 6.5 magnitude earthquake and subsequent landslides damaged some of EDC's geothermal plants in Leyte Province. Malitbog Geothermal Power Station, EDC's largest generating station, suffered damage.[94] Several months later, winds and severe rainfall from Tropical Storm Urduja further damaged plants including Malitbog, reducing Malitbog's generation capacity by 50%.[95]

Project Development

To develop a strategy, EDC used its well-established risk governance structure, which was upheld by its risk management policy. EDC's risk management policy fostered a culture of risk management, established a framework to mitigate risk, and allowed EDC to update the risk management program in alignment with international standards and practices. Risk management practices were incorporated in the execution of the company's strategy and integrated vertically across all levels of the company into planning, budgeting, organizational structure, and project design. At the senior level, the Risk Management Committee of the Board assisted EDC's Board of Directors by evaluating and providing recommendations on risk measures on a consistent basis, collaborating with other committees and departments, and crafting new guidance as needed.[96]

EDC built on its previous understanding of these risks by incorporating better modeling of potential slope failure and landslides into VAR.[97] EDC also collaborated with local communities and local stakeholders to better understand risks. From this assessment, EDC identified 31 small mitigation projects across its generation and distribution network. These projects were expected to cost approximately $6.3 million in aggregate but would reduce risk to nearly $90 million in assets.[98] Many of these projects focused on developing early geohazard warning systems at plants and enhancing weather forecasts. Several areas were also retrofitted by reconfiguring and strengthening pipelines and cooling towers to protect against earthquakes, landslides, and typhoons.[99]

In addition to these smaller projects, damages sustained at the Malitbog plant presented a larger opportunity to build back better. Previous EDC assessments found that Malitbog was experiencing more outages than it should for the age of the plant.[100] EDC also assessed Malitbog in its VAR approach and found that increasing the plant's resilience and adding capacity presented the most economically sound decision in the long run, particularly considering EDC's growth in customer base. EDC Philippines also contracted Jacobs Engineering Group to assist with damages and to develop a project to improve the plant's

resilience. This project would include retrofitting some of the plant's geothermal wells and distribution systems.[101]

EDC Philippines and its investors could fund the $6.3 million in smaller project costs but wanted financing to cover the approximately $90 million needed to restore and strengthen the Malitbog plant. The IFC had an interest in expanding its bond offerings to the Philippines, which they hoped would lead to the development of a local market for green bonds. This sentiment seemed to be shared by several institutions.[102]

IFC began offering green bonds in 2010 as part of its climate-related loan portfolio and, by 2018, had issued several billion dollars in green bonds. Green Bonds are fixed-income instruments that target 'green' projects, such as renewable energy, energy efficiency, and sustainable forestry. In addition to attracting investors based on their environmental impact and compliance with environmental, social, and governance (ESG) standards, green bonds can offer tax or similar incentives. IFC instituted clearly defined project selection criteria to identify and fund climate projects, or climate-related aspects of projects, which could be funded with green bonds. Like World Bank green bonds, IFC used Norway's Center for International Climate Research (CICERO) to provide a second opinion regarding whether a candidate project met green bond principles for climate projects. IFC refined its selection criteria with the help of external reviewers, including CICERO.[103]

Project Implementation

In June 2018, IFC issued the first AAA peso-denominated green bond for approximately $90 million with a fifteen-year maturity. The bond was intended to support EDC with restoration and resilience efforts at the Malitbog plant. The bond quickly attracted investment from several major players within the Philippines, including Sun Life Financial (Philippines Branch) and Insular life.[104]

These efforts seem to have reduced risk to EDC Philippines' assets, allowing EDC to expand its generation capacity and its offerings to other clients. EDC began some of these projects in late 2017 and commenced the Malitbog project after receiving funds. In 2019, the year following the bond's issuance, EDC increased the number of customer facilities it supplied by 28%. In addition to increasing resilience to physical assets, IFC's green bond also paved the way for EDC Philippines to issue its own green bonds. EDC established a similar procedural model for green bond issuance as the IFC, with clearly defined guidelines for projects and a second reviewer. EDC issued its first bonds in 2021 for several small projects across its portfolio.[105]

Lessons Learned

In addition to noting the importance of the enabling regulatory environment that Philippines EDC benefitted from, key lessons learned include:

- **The role of established governance structures and existing capacity.** EDC did not have to develop new inter-departmental collaborations around risk or emphasize the

value of risk to secure internal buy-in. EDC Philippines also had a solid understanding of its risks, which it expanded following hazard events in 2017 and new modeling. These factors helped EDC to design, prioritize, fund, and begin to execute resilience projects and other 'build back better' initiatives quickly and effectively in the months following the hazard impacts. In this light, EDC highlights the importance of developing governance structures committed to risk and resilience during periods of no disasters. Although the development of these structures can be accelerated through leadership, buy-in, and mandate, EDC's experience with risk governance highlights the case of governance structures that adapted incrementally over 20 years to address new risks and serve communities.

- **A holistic vision can be enacted by leveraging green infrastructure finance approaches**. IFC's peso-backed green bond was innovative not necessarily due to the financial mechanism used, but for a vision of what it could bring for local investment. IFC and other investors anticipated that the first green bond issued for the Philippines could create a market for local green bond investments in the country. Although some sectors in the Philippines, particularly the government, have issued green bonds backed by foreign currency, energy companies like ACEN have issued peso-backed bonds worth tens of millions in USD.[106]

  EDC also looks to benefit from local, peso-backed investment in green bonds for its projects. EDC's commitment to renewable energy was a lever that allowed it to unlock green bond financing for restoration and resilience projects following these hazard events. For instance, EDC was not the Philippines' only electricity provider to be severely impacted by tropical storm Urudja. The corporation's commitment to green energy and its project scope, however, seem to have made it an attractive candidate for the first peso-backed green bond.

- **Including customers and local communities is a key success factor.** EDC's business model aims to serve as a partner to customers and local communities, which has produced co-benefits and has increased resilience to the entire network. Following disaster events, EDC collaborated with local stakeholders to understand the impacts of outage events. EDC also enhanced capacity through these collaborations. For instance, EDC's response units shared knowledge with local stakeholders through emergency response trainings. Several of EDC's resilience projects also rehabilitated and reinforced some roads around its areas of operations, which have produced co-benefits for locals.[107]

Case Study #4: Climate Investor Two

The importance of grants or public funds to 'prime the pump' for private investment in infrastructure resilience	
Country/Geographic region	Kenya/Sub-Saharan Africa Thailand/East Asia & Pacific *Global Program*
Country Income Level Classification	Lower-Middle Income Country Upper-Middle Income Country
Hazard(s) mitigated	Water salinization due to sea level rise (climate adaptation included) Water contamination from pollutants (climate adaptation included)
Type of financing	Debt/Grant (Blended Finance)
Type of governance	Public Utility
Lever of change	Decarbonization (for both projects)
Main Actors	• Climate Fund Managers (CFM) • Finance Development Company (FMO) • SNV Netherlands Development Organization • World-Wide Fund for Nature • Solar Water Solutions • Azur
Case study Summary	Climate Investor Two (CI2) is an infrastructure fund using a blended finance approach that invests in private equity water, water-based energy, and ocean infrastructure projects in emerging markets.
Key Takeaways	• CI2 closed its first round at $675 million in November 2021 with an innovative financing structure composed of three stages: a development fund, a construction equity fund, and a climate credit fund. • Blended finance was an enabler to accelerate the development of, and subsequent investment in, resilience solutions like solar-powered desalination units in Kenya and two waste-to-energy facilities in Thailand. • The fund's management and advisory boards guide the investment strategy providing independent governance, which optimizes the capital allocation framework.

Program Rationale

Climate Fund Managers (CFM) is an investment manager that offers green assets to institutional investors at market rate returns in both private debt and private equity. It uses blended finance to attract public and private capital to projects mitigating climate change and building resilience in emerging economies to the consequences of climate change. It was established in 2015 as a joint venture between the Finance Development Company (FMO), the Dutch development bank, and Sanlam Infraworks, an infrastructure specialist. Its goal is to respond to three market barriers for sustainable development (1) protracted project construction timelines due to a lack of appropriate financing, (2) high cost of capital

because of perceived market risk, and (3) green investment opportunities for private investors.

CFM's first fund is Climate Investor One (CI1) – a $930 million infrastructure fund investing in private equity in renewable energy assets, focused on developing renewable energy infrastructure projects across Africa, Asia, Latin America, and the Caribbean. Climate Investor 2 (CI2) was established in 2019 as a follow-on project between FMO and Dutch non-profits SNV Netherlands Development Organization and the World-Wide Fund for Nature of the Netherlands.

Like CI1, CI2 has a blended fund structure but shifts the investment focus from only mitigation to adaptation and mitigation. CI2 focuses on three thematic areas: water, water-based energy, and oceans, including: municipal and industrial water and wastewater supply, desalination, bulk water supply, waste and wastewater to energy, and riverine and coastal ecosystem management and protection. CI2's investments aim to build community resilience through increased adaptive capacity to climate stresses and by addressing climate risks and vulnerabilities identified during project development.

Program Development

The investment criteria and capital allocation framework are governed by CFM and its founding shareholders. CI2's governance approach was built from CI1's model. The fund is comprised of two separate legal entities - the Stichting Development Fund and Coöperatief Construction Equity Fund U.A., both of which have delegated day-to-day management authority on decision-making to CFM. Governance structures include a Funds Advisory Board, which has extensive representation of both the donor and commercial investors, and two independent investment committees which approve final investment decisions taken by the Development Fund and Construction Equity Fund. Together, these legal entities, the Fund's investment committees, and the advisory board guide the investment strategy.

Program Implementation

CI2 is structured to finance projects across three stages: 1) a development fund (DF), 2) a construction equity fund (CEF), and 3) a climate credit fund. The DF is a wholly concessional capital pool funded by donor contributions that aims for capital preservation and mobilizes private capital into the CEF (see Figure 7). The DF offers up to 50% of the planning and development costs of the projects along with technical assistance. CI2 extended development funding into a number of projects, all of which have a climate mitigation benefit, climate adaptation benefit, or both. CI2 uses a preferred investment criteria to select cases.[108]

Equity financing of up to 75% of construction costs is available under the CEF. The CEF is tranched into three tiers with unique risk-return profiles, thereby creating a revenue distribution waterfall where senior investors receive returns first before remaining gains flow

down to more junior investors. The most senior tier (USD 400 million) of the CEF earns a AAA-rated fixed return and targets institutional investors seeking large ticket sizes. In November 2021, CI2 reached first close at $675 million. The second tier of commercial investors and first-year concessional capital have final targets of $400 million and $200 million each. CI2's credit fund (USD 1 billion), yet to be launched, can cover up to 50% of post-construction debt in the operational phase.

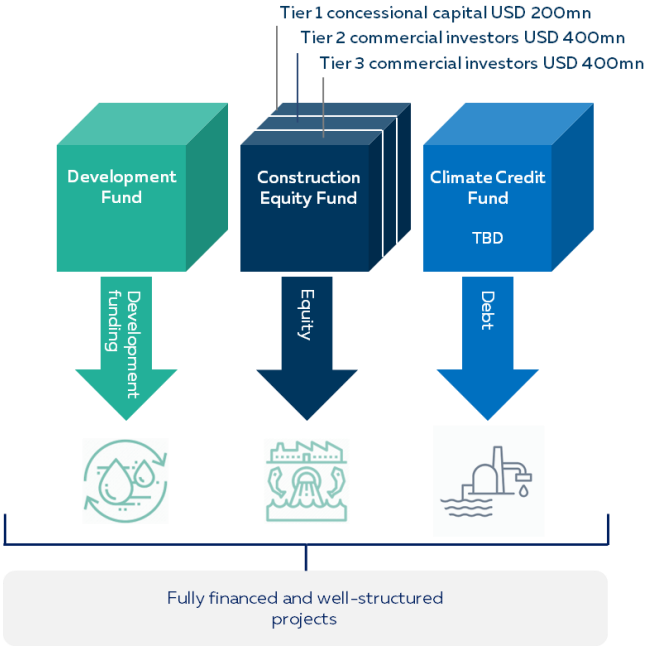

Figure 7 – CI2's Finance Structure

Two notable projects implementing climate resilience infrastructure from CI2 are Solar Water Solutions (SWS) in Kenya and Azur in Thailand. CI2 is working with SWS to provide development and construction equity capital for stand-alone solar-powered desalination units in Kitui County, Kenya. CI2 has invested nearly $2 million in the project, which is expected to treat 1,667 m^3 of water per day, bringing improved drinking water to 22,500 people. This project provides a climate adaptation solution by providing access to clean water, building resilience against physical climate risks from freshwater sources in Kenya becoming salinized due to sea level rise.

In northern Thailand, CI2 is working with Azur Pacific Capital Management to develop two waste-to-energy facilities that will incinerate an estimated 570 tons per day of municipal solid waste each, generating a combined 20 MW of power. CI2 has invested up to $5 million to help ramp up the project past its early-stage development into conducting more in-depth feasibility studies and gain approval from Thailand's Ministry of Interior to secure the solid waste. The project is explicitly funded to support climate mitigation and sanitation and proper management of waste, which is critical to mitigating toxic contamination of ground and surface water that could occur from flooding as Thailand is one of the ten most flood-affected countries in the world.

Timeline

Date/Period	Description	Actors Involved
2014-2015	Climate Investor One (CI1) is endorsed by the Global Innovation Lab for Climate Finance (the Lab)	Finance Development Company (FMO), Sanlam Infraworks, Climate Policy Initiative

2015	Climate Fund Managers (CFM) was established to manage CI1	FMO and Sanlam Infraworks
2016	Government of the Netherlands provides CFM bridge-capital to focus on staffing and pipeline generation and CI1 signs its first term sheet for a 15MW solar PV facility	Government of the Netherlands and Climate Fund Managers (CFM)
2017	CI1 announces its first close at $412 million and approves its first development fund for the Tra Vinh Wind Project in Vietnam	CFM
2018	Green Climate Fund approves $100 million investment into CI1 finishing its third close at $535 million. The first CI1 Construction Equity Fund (CEF) deal is also approved for a commercial and industrial solar PV platform in conjunction with Cleantech Solar	Green Climate Fund, CFM
2019	CI1 reaches its final close at $850 million and CFM's second, adaptation-focused fund, CI2 is launched	FMO, SNV Netherlands Development Organization, and the World Wide Fund for Nature
2020	CI2 project in Kenya, Solar Water Solutions, begins development	CFM, Solar Water Solutions
2021	CI1 completes 9 project assets under development with 6 equity transactions successfully closed. CI2 announces first close at $675 million.	CFM

Lessons Learned

CFM's CI1 and CI2 funds provide a replicable model to increase capital flows towards the renewable energy and adaptation sectors. Their experience demonstrates three insights related to innovative finance regarding how to facilitate sustainable growth in developing economies.

- **Aligning investment instruments to focus on distinct risk periods in the project lifecycle lowers the cost of capital and accelerates timelines**. This is known as fit-for-purpose financing, and it remains rare among blended finance instruments in the market. This set-up replaces the need for project developers to arrange a mix of assistance packages from donors in the preparation phase and avoids the prohibitive costs and strict terms of debt financing for construction.

- **A governance structure that can aggregate many projects is critical to attract institutional investors at scale and deliver projects locally.** CFM's fund structure aggregates the development of individual projects to meet the investment return expectations of large investors and can deliver large ticket sizes – a central challenge in attracting private investors to developing countries. This structure also allowed CFM to

access large-scale institutional investors by encompassing different technology types, geographies, and stages of the project finance cycle.

To do so, CFM's multi-governance structure is flexible and modular. Each component of the structure is focused on a specific aspect of project delivery, which allows the fund to aggregate projects for investors yet assist in the delivery of local projects. Leadership (CFM and Funds Advisory Board) oversees the collation of projects that are high-impact and will attract investment. Following successful rounds of investing, these projects are transferred to international partners, who assist in the development and execution of the project.

- **Flexibility and adaptability in transaction design can prove critical to successful fundraising.** This includes structuring different fund terms for concessional and commercial investors to reconcile the differing mandates of impact vs. return-oriented investors. Examples include the integration of a first-loss mechanism into the repayment waterfall and establishing a wholly concessional development fund to expedite a project's progress into the construction phase, thereby mitigating the high-perceived risks of the project pre-construction phase.

Case Study #5: The City Climate Finance Gap Fund

Learning how to overcome limited resources in project development and preparation	
Country/Geographic region	Kosovo/Europe & Central Asia *Global Program*
Country Income Level Classification	Lower-Middle Income
Hazard(s) mitigated	Flooding and Carbon Reduction (climate adaptation included)
Type of financing	Grant (Technical Assistance)
Type of governance	City Government
Lever of change	A core focus of the fund is urban decarbonization efforts
Main Actors	• World Bank • European Investment Bank (EIB) • German Government • Global Covenant of Mayors for Climate and Energy (GCoM) • Other City Networks (C40, ICLEI, and CCFLA) • City of Pristina Government
Case study Summary	The City Climate Finance Gap Fund (Gap Fund) is a multi-donor initiative launched in September 2020.[109] It aims to help cities in developing and emerging countries realize their climate ambitions by turning low-carbon, climate-resilient ideas into strategies and finance-ready projects.
Key Takeaways	• Gap Fund is a unique collaboration between implementing agencies (the World Bank and the European Investment Bank), donors, and city networks (GCoM, C40, ICLEI, and CCFLA)[110] • Since its inception, the Gap Fund has supported 80+ cities worldwide by mobilizing more than 7M euros in early-stage project preparation

Program Rationale

The global urban population will grow by 2.5 billion between 2018 and 2050. Nearly 90% of this growth is concentrated in Asia and Africa, increasing the share of the world's population living in urban areas to 75%.[111] However, poorly managed and sustained rapid urbanization, along with the growth of cities in LMICs, results in an increasingly high proportion of the world's population being vulnerable to extreme weather events.

A high proportion of the world's population most affected by extreme weather events is concentrated in urban areas.[112] The increased frequency and intensity of weather events is expected to constrain cities' ability to provide basic services, maintain infrastructure, provide adequate housing, and ensure resident's livelihoods and health. These impacts are expected to be exacerbated in the following decades, given that urban land expansion is

likely to occur in geographical regions of increasing vulnerability to extreme climate events. [113]

Pristina, Kosovo's capital city, has grown from approximately 204,725 people in 2015 to approximately 218,700. Despite this growth, two-thirds of the city's people do not live near shops, health clinics, markets, nurseries, sports facilities, or public spaces, and only 6% are connected to the heating network. Air pollution, partly due to two coal-fired power plants, individual coal heating systems, an increase in automotive use rather than public transport, and congestion and flooding, presents problems.

Efforts to successfully limit global warming hinge on cities like Pristina, and their capacity to innovate and take the lead on local actions, especially creating more efficient systems to reduce emissions. Cities account for more than 70% of global energy-related GHG emissions, with transport, waste, and buildings being the most significant contributors. Scaling up investment in sustainable urban infrastructure will be essential to limit global temperatures and to strengthen climate change adaptation and resilience. This is particularly the case due to a general lack of pre-development funding for these projects, which can impede their execution.

Program Development

To fight against the effects of climate change, the Gap Fund was established in 2020 to help cities in LMICs, like Pristina, transition toward low-carbon and climate-resilient pathways to limit the temperature increase to 1.5 degrees Celsius. The Gap Fund provides a range of technical assistance and capacity building to support climate-smart planning and investment in cities in developing and emerging countries. Gap Fund offerings include:

- providing city planners with upstream technical assistance and tailor-made tools to enhance cities' low-carbon planning and resilience efforts to address urban sprawling growth;
- helping city leaders build a pipeline of high-quality, climate-smart urban investments, with a focus on early and often underfunded stages of project preparation;
- facilitating the connection between cities and prospective financing partners, such as World Bank or EIB lending, or third-party financiers; and
- leveraging international collaboration and partnerships with the Global Covenant of Mayors and city networks to learn from each other and standardize approaches.

The Gap Fund supports cities through two implementing agencies: the World Bank and European Investment Bank (EIB), in partnership with GIZ. The World Bank and EIB bring a unique mix of long-standing expertise in sustainable development, climate finance projects, and urban renewal. Each implementing agency administers a multi-donor trust fund with strong coordination between the separate World Bank and EIB Secretariats under the 'One Gap Fund.' This unique collaboration is the backbone of the Gap Fund's success in supporting cities, assuring the cities are getting the most effective and efficient

support in their journey to realize their climate ambitions. Early donors were government entities in Germany and Luxembourg.

The Gap Fund developed clear governance and operations procedures, especially as they relate to project selection. Donor committees provide informal guidance for the fund throughout the year and hold a formal meeting annually. The fund also coordinates with network partners using working groups and partnership forums. Standardized coordination and established governance principles allow the fund to streamline the project selection process, which occurs on a rolling basis.

A project is eligible if it is presented from a developing and emerging country, has climate action potential, is a clear ownership from the local government, is situated in an urban area and is in the early stages of development (strategic planning or pre-feasibility studies).[114] The fund first evaluates a project on a set of criteria. If successful, the project is assigned to either the World Bank or EIB secretariats. The secretariats meet with their regional teams to collect additional data to prioritize the remaining projects. The regional team engages with selected projects following this prioritization. The fund monitors and publishes selection criteria and selection results to enhance transparency and inform potential applicants of some potential pitfalls.

Program Implementation

By the end of 2021, the first batch of the Gap Fund approved technical assistance activities to support 44 cities in 26 countries. Among these activities was a project in Pristina supported by the World Bank. The approved activities supported cities in identifying sources of urban GHGs, designing scenarios to notice how urban growth and form will affect future GHG emissions, and prioritizing critical policies and infrastructure investments. The grants also facilitated coordination between local and national climate change action planning to help build low carbon, resilient, and livable cities.

Pristina was the first city to conclude grant activities as of June 2022. The grant enabled the city to plan strategically for and invest in low-carbon and climate-resilient urban development. It focused on providing analytical advice and sharing knowledge to enable a low-carbon and climate-resilient urban development trajectory and technical assistance for early-stage preparation of low-carbon and climate-resilient investments and financing mechanisms. Before the city partnered with the Gap Fund, urban planning policies were falling behind in acknowledging the impacts of the climate and the benefits of planning for long-term sustainable development. Planning and investments in transport and energy needed to be updated to be climate smart.

The 18-month Gap Fund initiative helped city officials in Pristina's urban planning, energy, and transport to work together to better plan, design, and invest in the city's green development and achieve its climate goals. Experts from the Gap Fund trained city officials to review the urban planning, transport and energy investment, and the policy decisions

outlined in Pristina's draft Municipal Development Plan (MDP). This revision allowed the city to gauge whether it was climate-smart, driving sustainable urban development, and supporting the well-being of its people.

Local leaders also gained skills to place alternatives to urban planning, policies for energy and transport, and investments to help Pristina transition to a low-carbon, climate-resilient city by 2040. The initiative helped to refine a series of interlinked recommendations for local leaders, including:

- Urban growth: Promoting a denser city will curb Pristina's environmental impact and protect the city's investments in transport and energy while managing urban sprawl. Implementing the Local Green Building code to ensure building regulations promote sustainable urban growth.
- Transport: Robust and increased coordination during the planning and provision of different public transport services can translate into expanded walkways and cycle lanes, providing alternatives to using individual vehicles. Developing low-carbon public transport corridors and investing in bus/train/tram services linking the city with other urban areas encouraging the use of public transport.
- Land Use and Urban integration: Increased multi-purpose land use and structures to ease access to social infrastructure, planning new educational and health facilities, and facilitating access to existing ones linking to transport planning.
- Infrastructure: Expanding the district heating network and supporting a transition to clean, domestic energy while upgrading the city's stormwater and sewage control to limit flood risk.

Lessons Learned

The shared vision between the Gap Fund team and the city of Pristina helped to harness the potential of integrated, climate-smart city planning to achieve climate and environmental goals. The recommendations will nurture human well-being and lay the foundation for Pristina's cross-sectoral approach to urban development.

- **Investing in planning is key to resilient infrastructure development.** Planning and policymaking inform how projects are prioritized and which costs and benefits are included**.** Nonetheless, planning and policy development are often overlooked and underfunded. The Gap Fund's work in Pristina enabled the city to develop policies that would encourage resilient infrastructure, which will have an impact on all projects in the future.

- **Technical assistance is key to accelerate transition toward resilient urban infrastructure.** Attention and funding for pre-development activities, along with policies and regulations, are not receiving sufficient attention from cities due to limited resources, or from investors, due to lack of returns or difficulty capturing benefits. Technical assistance can meet this gap, which will produce ripple effects down the project development chain.

Case Study #6: Ghana Roadmap for Resilient Infrastructure in a Changing Climate

Co-developing a roadmap of prioritized climate adaptation investment options	
Country/Geographic region	Ghana/Sub-Saharan Africa *Global Program*
Country Income Level Classification	Lower-Middle Income
Hazard(s) mitigated	Climate-related hazards
Type of financing	Grant (Technical Assistance)
Type of governance	National Government
Lever of change	Meeting SDG Targets and Related Frameworks
Main Actors	• Ghanian Government • Global Center on Adaptation (GCA) • UNOPS • UNEP • Oxford University
Case study Summary	*Ghana: Roadmap for Resilient Infrastructure in a Changing Climate* (the Roadmap) identifies the country's climate adaptation needs across the energy, water, and transport sectors. A prioritized roadmap of investments and policies accompanied by relevant financing options was co-developed with government stakeholders.
Key Takeaways	• Decision-makers need better tools and data to provide actionable information on how to identify adaptation needs in the country and to prioritize infrastructure investments that will address the existing and future risks of climate impacts, needs and gaps through informed investments that are more cost-effective in the long term, including nature-based solutions • Adaptation investment options need to be based on the country's needs and backed by robust research and analysis to provide evidence-based, impactful adaptation projects and enabling environment interventions for funders and financiers to invest • Ghana is committed to implementing the Roadmap of 35 adaptation investment options and to building a more sustainable, resilient, inclusive, and prosperous society. However, the government cannot do this alone and requires additional financial resources from development partners and private sector

Program Rationale

Climate change impacts are expected to increase Ghana's exposure to hazards such as flooding and frequent and intense droughts, threatening its socio-economic growth, development, and lifeline infrastructure. Future energy availability for about a quarter of a million people in rural parts of Ghana is threatened by drought, given their reliance on wood fuel for household energy generation. Climate risks also threaten major components of the country's electricity generation and transmission due to exposure to drought and flooding. An infrastructure assessment reveals that 54% of dams assessed are exposed to floods and 23% to droughts under high hazard by 2050. Furthermore, 13-14 million people risk losing access to healthcare due to disruptions in the transport sector in the Eastern, Central and Western regions. Expected damage loss across the country under a high-flood scenario in 2050 could reach US $3.9 billion in damages to roads and highways, which is triple the estimated $1.3 billion invested in transport infrastructure in Ghana in 2019.[115]

Infrastructure resilience is central to achieving Ghana's sustainable development by safeguarding the economy and society. Infrastructure also plays a role in 92% of Ghana's SDGs.[116] Despite their importance to the country's development, these infrastructure systems are not designed to cope with the impacts of climate change. Repeated cycles of acute and chronic climate change could halt economic growth, strain public finances, and threaten to disrupt or even reverse progress towards achieving the SDGs. Exposure of these infrastructure systems prompted a need to prioritize investments in areas with the greatest adaptation needs and focus on improving the resilience of women and other vulnerable groups who are disproportionately impacted by climate events and have limited resources to recover from the damages.

Ghana: Roadmap for Resilient Infrastructure in a Changing Climate (the Roadmap) was developed under the leadership of Ghana's Ministry of Environment, Science, Technology and Innovation (MESTI) and by the Global Center on Adaptation (GCA), in collaboration with the United Nations Office for Project Services (UNOPS), the University of Oxford, and the United Nations Environment Program (UNEP). As a new type of study for the country, the Roadmap quantifies Ghana's climate adaptation needs across the energy, water, and transport sectors and provides a prioritized roadmap of investments and policies accompanied by some relevant financing options.

Program Development

The Roadmap was developed in partnership with government stakeholders engaging 119 individuals across more than 20 government ministries and organizations to align and inform Ghana's national strategic plans and priority areas for investment in infrastructure. The whole-of-government participatory engagement process aimed to instill ownership of climate adaptation solutions across the relevant government entities responsible for infrastructure development and operation. This effort required strong endorsement from the government and coordination across agencies in different sectors and data sharing to ensure the availability of up-to-date and high-resolution information on climate hazards

and infrastructure assets, and to prioritize adaptation options based on the existing priorities of each sector.

The Roadmap utilized nearly 100 data sources, including geospatial datasets and policy documents. The participatory nature of the stakeholder engagement process used the best available data and expert knowledge from partners and stakeholders across the country, including national and local government ministries and agencies, utilities, and the academic community. Personnel from these entities formed the project's Technical Working Group (TWG). Over the course of 18 months, the TWG provided inputs for the analysis and coordinated the prioritization of national adaptation needs, along with the final selection of adaptation options for the roadmap to ensure that those options were grounded in evidence and aligned with government objectives and capacity.

The Roadmap employed a new methodology and used tools from partners to develop a novel geospatial assessment of 156 nationally significant built and natural infrastructure assets across 4 different hazard types and 11 areas of the enabling environment for the entire infrastructure lifecycle. The study methodology comprised a four-tier approach of: (i) quantifying infrastructure adaptation needs geospatially and at the asset scale; (ii) evaluating adaptation investment and policy options exhaustively within the built, natural and enabling environments; (iii) developing a roadmap of prioritized adaptation investment and policy options for meeting the quantified needs and contributing to national development priorities (the SDGs, NDCs and Gender impacts); and (iv) identifying potential sources of financing for the adaptation options identified.

This systemic approach to detailed infrastructure planning is built on the previous work undertaken by the government and partners. The Government of Ghana demonstrated its commitment to enhancing resilience of its society through development of the study by collecting expertise across the government. The government also used the results of this study to inform strategically relevant plans and policies such as the National Adaptation Plan (NAP) and the revised Nationally Determined Contributions (NDCs).

Program Implementation

The key findings from *Ghana: Roadmap for Resilient Infrastructure in a Changing Climate* found significant risks from flooding, drought, and other climate-driven hazards across the energy, water and transport sectors. Based on the climate risks identified, the study proposed 35 adaptation options, which were prioritized on their suitability for addressing identified risks, government needs, and co-benefits to broader sustainable development objectives by the proposed options. These 35 adaptation options were identified through desk-based research and participatory stakeholder workshops, which included representation from across the Government of Ghana and its ministries, agencies, utilities, and other organizations. Project concept notes were developed for these shortlisted options that include: 16 options involving investment in the natural environment, 15 involving built infrastructure, and 13 involving enabling environment components as well

as nine solutions transcending these areas. Of these solutions, 11 are cross-sectoral or have application to more than one sector.

The project concepts provide broad geographical representation across Ghana and aim to capture its natural resource potential and harness nature-based solutions , when appropriate, to provide wider adaptation benefits. These project concept notes provide essential information for engaging potential finance sources and offer a roadmap of financing options on how public and private sector resources could be mobilized, along with financing options from more traditional sources. The study formed part of the Government of Ghana's integrated approach to building systemic climate resilience and supported the mobilization of finance for climate resilience in Ghana. The study laid the groundwork for project partners to continue to collaborate and identify implementation options for the project concepts outlined in the roadmap. GCA is building on the learning of this national program to implement a similar approach in Bangladesh and in other African countries, such as Kenya and Senegal, through local institutions.

The insights from the project also have helped to broker solutions for downstream investments. At the time of writing, GCA, in partnership with the African Development Bank (AfDB), is working to implement a Scaling Renewable Energy Mini-grid and Net Metering Program that seeks to support Ghana in the electrification of island communities and move closer to Ghana's identified development objectives, such as Sustainable Energy for All by 2030. GCA is conducting climate risk assessments on potential climate hazards in the districts that will benefit from the electrification program.

Through its Technical Assistance Program, GCA is also providing technical support to the Ghana Infrastructure Investment Fund (GIIF) as part of its application to become a Direct Access Entity to the Green Climate Fund (GCF), which will enable Ghana to be able to take greater ownership of the implementation of climate finance. Furthermore, GCA is using a data-driven approach to identify and prioritize nature-based solutions by analyzing how they can deliver value for money and protect lifeline services, not only infrastructure assets.

Lessons Learned

- **Strategically planning the financing for projects within a roadmap can help accelerate action toward a more climate-resilient future.** The national infrastructure risk and resilience program builds on state-of-the-art analytics to model the systemic risk of climate change on infrastructure assets and services. This analysis quantifies adaptation needs and helps to prioritize a pipeline of adaptation investment options. In Ghana, the national assessment is already influencing investments on the ground. Finally, the data and recommendations are currently also being integrated into the Ghana National Adaptation Plan (NAP).

- **Identifying innovative financing mechanisms incentivizes private sector engagement and financing from non-traditional sources.** The study used the Sustainable Infrastructure Financing Tool (SIFT) developed by UNOPS in collaboration with the University of Oxford to explore the range of financing options for resilient infrastructure. An assessment of Ghana's financing landscape reveals that the Government of Ghana has access to 82 infrastructure-related funds, of which it has had existing relationships with 36 (44%) within the past 10 years. In total, 78 funds (95%) provide funding for projects in the built and natural environments, whereas 58 (71%) provide funding for enabling environment activities.

  Of these funds, 51 (62%) were identified as being able to provide project preparation financing – an important area to develop full bankable project proposals – necessary to engage private sector finance in climate adaptation in the country. Securing finance for the Roadmap to address critical infrastructure adaptation needs requires robustly justified project concepts and fully prepared projects that are suitable for financing.

- **Effective capacity building requires a concerted effort and a clear plan to transfer knowledge to sectors and ministries that will implement guidance.** Implementation of the Roadmap was accompanied by a plan and concerted effort to transfer knowledge to those who would implement it. For example, the Roadmap allowed infrastructure analysts in the Government of Ghana to conduct further assessment of the country's infrastructure resilience in the future, integrating new and updated data as it becomes available. Periodic reviews and updates of the resilient infrastructure roadmap will ensure its continued relevance to Ghana's adaptation needs and emerging global priorities. Knowledge management is critical to ensure the continued use of evidence-based methods and tools across the government. Transfer of knowledge to interested stakeholders in-country through a handover of datasets and training in open-source tools used to conduct the resilience analysis will be completed.

ANNEX 2 – SCALABLE ACTIONS

Lessons learnt from case studies presented in Annex 1 were analyzed and commonalities and initial actions were identified. Table 5 and Table 6 focus on innovative finance approaches and good governance respectively, present the actions alongside the stakeholder groups who need to take the lead or support, the enablers that will facilitate their implementation, and general considerations on how to improve their scalability and transferability. Stakeholder groups comprise governments, infrastructure owner-operators, project developers/investors & financial partners, technical experts (engineers, planners, ecologists, climate scientists, etc.), and users/communities.

Table 5 - Comprehensive List of Actions Related to Innovative Financial Approaches

Action	Actors	Enablers	Scalability and transferability considerations	Case study
Make use of levers of change to increase access to financing and create wider system change.	Government Infrastructure owners-operators Supported by: Project developers/investors & financial partners Technical experts	Policy and regulation Multi-level governance	Would benefit from having a partner or regulator assist with the incorporation. Scoping to understand market trends is a key step before the implementation of financial products to develop new markets.	CS #1 CS #3
Adapt financial approaches created for other levers and/or used by other sectors.	Government Infrastructure owners-operators Project developers/investors & financial partners	Multi-level governance Public-Private sector collaboration	Ensure that the general principles of the mechanism can be applied to the context.	CS #1 CS #3
Use a 'simple' financial solution as a baseline to meet a range of more complex scenarios.	Government Infrastructure owners-operators Project developers/investors & financial partners Supported by: Technical experts	Multi-level governance Data, information, and technology	Sellers and purchasers should collaborate with a multidisciplinary team of experts. More education is needed on the merits and limitations of these products.	CS #2

Action	Actors	Enablers	Scalability and transferability considerations	Case study
Develop a rapid payout mechanism to support 'build back better' efforts	Government Infrastructure owners-operators Project developers/ investors & financial partners Supported by: Technical experts	Multi-level governance Data, information, and technology	This is also contingent on other activities, such as prioritizing recovery and rehabilitation of assets and sufficient allocation of funds during payout.	CS #2
Leverage innovative financing to develop new financial markets/additional investment for resilient infrastructure.	Government Project developers/ investors & financial partners	Policy and Regulation Multi-level governance Standards and Regulations Public-private sector collaboration	Scoping to understand market trends is a key step before the implementation of financial products to develop new markets.	CS #3 CS #4
Focus investment on distinct risk periods in a project's lifecycle to spread the cost of capital and accelerate a project's execution.	Infrastructure owners-operators Project developers/ investors & financial partners Supported by: Technical experts	Public-private sector collaboration Capacity and resourcing	Developing tailored financial strategies will benefit from the assistance of financial experts.	CS #5

Table 6 - Comprehensive List of Actions Related to Good Governance Practices

Action	Key actors	Enablers	Scalability and transferability considerations	Case study
Invest in planning and other strategic pre-development activities.	Lead actors: Government Project developers/	Policy and regulation Data, information, and	Consider regulatory or political barriers to pre-development or planning activities.	CS #1 CS #5 CS #6

Action	Key actors	Enablers	Scalability and transferability considerations	Case study
	investors & financial partners Supported by: Technical experts	technology Capacity and resourcing		
Develop review mechanisms to incorporate new data/new transaction approaches to secure regulatory approval and attract investor interest.	Government Infrastructure owner-operators Project developers/ investors & financial partners Supported by: Technical experts	Policy and regulation Public-Private sector collaboration Data, information, and technology Capacity and resourcing	Maintain vigilance that this process does not hinder execution and/or make sure that incorporation of new information or approaches occurs in practice.	CS #1 CS #2 CS #4
Leverage access to technical assistance by using a lever of change.	Government Infrastructure owner-operator Project developers/ investors & financial partners Supported by: Technical experts	Policy and regulation Data, information, and technology Capacity and resourcing	Understand the available technical assistance programs and how to leverage a project to meet their selection criteria.	CS #4 CS #5
Collaborate with expert entities to reduce the burden on modeling or project execution.	Lead actors: Government Infrastructure owners Project developers/ investors & financial partners Supported by: Technical experts	Data, information, and technology Capacity and resourcing	The expert entities would benefit from having a basis in the practical implementation of the product for the project's specific context.	All CS
Include local communities and other local stakeholders.	Government Infrastructure owner-operators	Data, information, and technology Capacity and resourcing	Bringing the 'best' mix of local stakeholders will differ across contexts.	CS #3 CS# 6

Action	Key actors	Enablers	Scalability and transferability considerations	Case study
	Supported by: users/ communities			
Include training and implementation sessions with key personnel to increase the likelihood of project implementation.	Technical experts	Capacity and resourcing	Engaging with these stakeholders during the development of these tools can increase buy-in prior to training sessions.	CS# 6

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