Tracking Investments in Climate Resilient Infrastructure

Building Resilience Against Floods and Droughts

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CLIMATE POLICY INITIATIVE

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ABOUT CLIMATE POLICY INITIATIVE

CPI is an analysis and advisory organization with deep expertise in finance and policy. Our mission is to help governments, businesses, and financial institutions drive economic growth while addressing climate change. CPI has six offices around the world in Brazil, India, Indonesia, the United Kingdom, and the United States.

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EXECUTIVE SUMMARY

Losses from natural catastrophes like floods and storms set a record in the first half of 2022, costing USD 75 billion, 22% above the 10-year average of the last decade (Swiss Re, 2022). 2022 saw Europe's worst drought in 500 years and one of the most devastating floods in Pakistan. These floods and droughts have resulted in deaths and the destruction of critical infrastructure providing essential services for economic and human development, especially for vulnerable populations. Currently, almost 90% of global climate finance focuses only on climate mitigation, i.e. through renewable energy generation, low carbon transport, agriculture, and water management. As the impacts of climate change accelerate, investments in climate resilient infrastructure must be equally prioritized to prevent deaths, reduce the lock-in of climate vulnerability, and avoid economic losses in the decades to come.

The proliferation of investments in climate resilient infrastructure, 'CRI' hereafter, is essential for delivering on the goals of the Paris Agreement, particularly Article 2.1b which aims to enhance adaptive capacity and strengthen climate resilience as well as Article 2.1c which states that all financial flows should be aligned with a low carbon and climate-resilient development pathway. Incremental investments in climate resilient infrastructure are no longer sufficient to meet the scale of this challenge (UNFCCC BA, 2020). The OECD estimates that USD 6.9 trillion worth of infrastructure investments would be needed annually by 2030 to meet the sustainable development goals (OECD, 2018). Innovative approaches are required to ensure that public and private investments in infrastructure are aligned with the resilience goals of the Paris Agreement (OECD, 2022).

Tracking and reporting on CRI investment is essential but challenging. Tracking CRI investments allows us to measure progress on the resilience goals of the Paris Agreement and understand investment gaps, barriers, and opportunities to further scale and channel finance into geographies and sectors that need it most. Assessing the landscape of CRI investment also helps build consensus on who can and should do what, and where and how it can be done most efficiently, thereby accelerating positive interventions in CRI.

However, there is currently no common definition of CRI investments. It is a broad concept due to the nuances involved in defining climate adaptation and resilience, as well as the spectrum of potential solutions that could be used across sectors to ensure infrastructure is made climate resilient. Particularly in the private sector, disclosure of CRI investments is limited (if not non-existent) and is difficult to compare, given inconsistent definitions and methodologies. There is no comprehensive asset-level data, as well as a lack of clear standards and benchmarks for assessing the performance of CRI over time. The challenge is compounded by different organizations using different accounting approaches for adaptation and resilient investments as either incremental, proportional, or total cost of the project (UNFCCC BA, 2020).

This study is a first-of-its-kind attempt to evaluate options for tracking CRI investments. The proposed methodology creates a more granular view of data gaps and methodological challenges in tracking CRI investments and ways to address them. We define "climate resilient infrastructure," as infrastructure projects that align with five high-level climate resilience principles based on five core features of climate resilience, summarized in Figure ES1. These resilience principles are primarily adapted from the Framing Paper on Climate-resilient Finance and Investment (OECD, 2022), MDB Framework for Climate Resilience Metrics (IDB, 2019), and Joint MDB Assessment Framework for Paris Alignment (MDB, 2021). Together, these principles constitute the most comprehensive framework to conduct an accurate tracking of CRI investments.

Figure ES1: Climate resilience principles of CRI projects based on five core features

PROCESS-BASED	CONTEXT-SPECIFIC	IMPACT-FOCUSED	SYSTEMIC	DYNAMIC
Project design is informed by physical climate risk assessments and climate scenario modeling	Project addresses, responds, or reduces climate risks by implementing the CRI activities	Project makes local community more resilient by improving results like project performance, outputs, outcomes and impacts	Project meets minimum safeguards and is aligned with national adaptation plans	Project monitors and dynamically evaluates investment decisions

Source: *Adapted from the OECD framing paper on climate-resilient finance and investment (OECD, 2022), MDB Framework for Climate Resilience Metrics (IDB, 2019), Joint MDB Assessment Framework for Paris Alignment (MDB, 2021)*

This study is the first step in operationalizing these climate resilience principles for tracking CRI investments. Considering the limited availability of data, we could only operationalize three of the five climate resilient principles using a step-by-step approach, summarized in Table ES1. Detailed information on the approach is provided in Section 3.

Table ES1: CPI's approach in identifying CRI investments

Barriers	CPI approach
Lack of standard definition	**Step 1: Proposed a set of climate resilient principles** based on five core features of climate resilience that CRI projects should meet (Figure ES1).
Broad scope	**Step 2: Narrowed the scope for this analysis**: Focused on the impacts of floods and droughts on four critical sectors: (i) water & wastewater; (ii) transport; (iii) energy; and (iv) agriculture, forestry, and other land use (AFOLU) and the cross-sectoral solutions. Included grey, green, and blue infrastructure types and both structural and non-structural solutions (more information in Section 3 and Annex 4).
Lack of source data	**Step 3: Collected asset-level data** collected from various public and private infrastructure investment databases for investments in 2019/2020.
Inadequate standards and benchmarks	**Step 4: Identified CRI projects by operationalizing three of the five resilience principles** to the extent possible given the data constraints by: • Relying on self-reported adaptation projects • Developing an operational taxonomy of CRI solutions • Applying keyword methodology to create a CRI database • Comparing per capita CRI investments to highly vulnerable countries as per ND-GAIN Vulnerability Index
Non-uniform accounting	**Step 5: Tracked investments by estimating the total cost of the CRI projects in the database** and moving beyond the conservative yardstick of counting incremental investments in adaptation.

The approach is piloted across four critical sectors: (i) water & wastewater; (ii) transport; (iii) energy; and (iv) agriculture, forestry, and other land use (AFOLU), as well as in cross-sectoral solutions. To simplify this initial effort, we focus on two water-related climate shocks—floods and droughts—but consider the potential to replicate the analysis for a variety of other shocks and stresses, such as heatwaves and sea-level rise. Future editions of this analysis can incorporate alignment with net zero transition scenarios. We assess grey, green, and blue infrastructure and both structural and non-structural CRI solutions. **This pilot led to the creation of a first-of-its-kind global database of more than 4000 CRI projects financed in 2019/20 which inform the findings of the study.**

DATA DISCLOSURE AND TRANSPARENCY ISSUES

Publicly available information on how infrastructure projects align with the climate resilience principles and how much investments went into those projects is key to the methodology outlined in this study. However, our analysis identified, as anticipated, that the level of information available and disclosed by different infrastructure databases in the public and private sector varies significantly. Therefore, significant gaps persisted, which in many ways affect the breadth and quality of our findings. This stems from underlying knowledge gaps in terms of operationalizing the resilience principles in assets and investments by public and private investors, such as:

- **Poor reporting on material physical risks:** For multilateral development banks (MDBs) and members of the International Development Finance Club (IDFC) the analysis of which physical climate risks were identified and addressed at the project-level is implicit in the process-based approach recommended by the Common Principles for Adaptation Finance Tracking. However, there is no granular reporting by public financial actors. No precise geographical location of infrastructure investments is reported in the OECD-CRS system nor in the primary surveys we conducted. The lack of reported data on geographical location hindered our capacity to link physical climate risks with investment data.
- **Lack of accessible and consistent data on project results:** Different organizations use different metrics to assess the performance of the projects they develop and invest in. Also, the project descriptions provided by public financiers in the OECD-CRS system or in CPI's primary surveys do not explicitly mention how the project results are improved to withstand the impacts of climate change. The impacts of CRI investments are also highly context specific. The limited ability to identify CRI projects extends to evaluating alignment with national technical standards and adaptation plans.
- **The wider universe of infrastructure investments is difficult to track:** Given limited data, the scope of this study was limited to measuring investments towards CRI projects reported in the most relevant, publicly available databases. However, there are various other ways in which infrastructure investments can be made climate resilient. For example, through domestic budgetary allocations on development projects, implementation of technical standards and codes, etc. The confidentiality issue, lack of standardized databases, and a lack of incentive to report hindered our access and analysis of such investments.

KEY FINDINGS

Piloting the methodology to create a first-of-its-kind global database of more than 4000 CRI projects financed in 2019/20, we find that investments in CRI are only a fraction of total investments in critical infrastructure sectors.

For every USD 1 spent on CRI, USD 87 was spent on infrastructure projects which do not integrate climate resilience principles. This suggests that investing in CRI is still in its nascent stages. As global infrastructure investment needs are counted in trillions, there is an immediate need to integrate climate resilience principles in all infrastructure investment decisions. Failure to do so will result in locking-in climate risks in long-lived infrastructure assets and making businesses and communities vulnerable to the increasing impacts of climate change. Despite the urgency, there is no common metric, incentives, nor concrete roadmaps to track progress.

In 2022, less than 30% of participating infrastructure entities in the GRESB Infrastructure Asset Assessment 2022 used physical scenarios for evaluating resilience strategies at the asset level. The majority (80%) of them are based in Europe or North Americas and fall in the energy, water, and transport sectors. Less than 60% of the reporting entities (USD 686 billion in asset value) systematically assessed material financial impacts of physical climate risks. Almost all of them (98%) flagged exposure to acute climate hazards such as floods, storm surges, and heat stress.

Climate-related disclosure standards for companies and investors are yet to integrate the double materiality aspects of physical climate risks which assess the impacts of infrastructure investments on the systemic and community resilience. TCFD recommendations have had a positive impact on the climate risks disclosure ecosystem but the metrics and targets for physical climate risks are less evolved than that of transition risks and are accompanied by little effective guidance. Further development would be required to address these aspects.

Various stakeholders across the infrastructure lifecycle must be mobilized to overcome these knowledge gaps, data barriers, and methodological challenges to improve future tracking exercises at the asset level. This study's overarching recommendations for all stakeholders are to:

1. Collectively agree upon common, comparable, and credible climate resilience principles which are applicable to both public and private infrastructure investors.
2. Enable and incentivize the alignment of investments to the agreed climate resilience principles by setting standards, metrics, targets, and encouraging transparent disclosures.
3. Make investments aligned with the agreed climate resilience principles.
4. Monitor and evaluate progress to determine what further reporting is needed to inform assessments on how much more climate finance is needed to make investments resilient.

Table ES2 highlights recommendations at the actor level, building on the overarching recommendations for stakeholders.

Table ES2: Recommendations by actor

Actor	Recommendations
Governments and regulators	• Set appropriate technical resilience standards for CRI. • Mainstream physical climate risk assessments into government processes. • Mandate disclosures for companies and investors aligned with existing frameworks and promoting double materiality.
Development financial institutions	• Agree on common definitions, principles, and metrics for climate resilience impacts and investments. • Provide transparent leadership by publicly disclosing information on decision drivers for choice of scenarios and models, trade-offs, and opportunity costs of adaptation and resilience investments. • Improve the reporting of material physical risks in their own investment portfolios.
Private financial institutions	• Integrate climate resilience principles in asset-level investments. • Focus on moving beyond resilience of governance and strategy to setting targets for investing in resilience and disclosing them. • Improve reporting of material physical risks in their own investment portfolios.
Data aggregators	• Create a taxonomy for CRI solutions at the sectoral or country level. • Move beyond conventional ESG metrics to integrate resilience metrics, targets, and indicators. • Build standardized geospatial data for assets and risks.
Industry coalitions	• Establish a common approach to CRI investments. • Facilitate multi-stakeholder collaboration.

CONTENTS

1. INTRODUCTION

Globally, we are witnessing the damage caused by climate change. In 2022 alone, European countries lost roughly EUR 9 billion due to the worst droughts in the last 500 years. The devastating 2022 floods in Pakistan have impacted more than 30 million people. These floods and droughts have resulted in deaths and destruction of critical infrastructure which provides essential services for economic and human development, especially for vulnerable populations. Current climate-related investments in infrastructure largely focus on the mitigation of climate change by reducing greenhouse gas (GHG) emissions through renewable energy generation, low carbon transport, agriculture, and water management. However, as the impacts of climate change accelerate, investments in making infrastructure climate resilient must be prioritized as well (Thacker et al., 2021).

The concept of "climate resilient infrastructure," or CRI hereafter, in literature describes infrastructure that has been designed to withstand, respond to, and recover from the impacts of climate change (OECD, 2018). Given the longevity of infrastructure assets, implementing CRI is essential to avoid locking-in vulnerability and creating stranded assets. **The proliferation of CRI investment will be critical for delivering on the Paris Agreement (Article 2.1c), which represents a commitment for all financial flows to be aligned with a climate-resilient, low carbon development pathway.** The OECD estimates that investments of USD 6.9 trillion from public and private actors are needed annually by 2030 for climate action and infrastructure development (OECD, 2022).

Tracking and reporting on CRI investment is essential but challenging. Tracking CRI investments will allow for a better understanding of investment gaps, barriers, and opportunities to further scale and channel finance into the geographies and sectors that need it most. Assessing the landscape of CRI investment will help build consensus on who can and should do what, and where and how it can be done on the most efficient basis. However, there is currently no common definition of CRI. It is a broad concept due to the nuances involved in defining climate resilience, as well as the spectrum of potential solutions that could be used across sectors to ensure infrastructure is made climate resilient. Particularly in the private sector, disclosure of CRI investments is limited (if not non-existent) and is difficult to compare, given inconsistent definitions and methodologies (LTIIA, 2022).

This study is a first-of-its-kind attempt to investigate options for tracking CRI investment. By doing so, this work responds to Article 2.1c of the Paris Agreement—as it relates to climate resilience—and the need to a) review solutions and actions to be tracked and b) understand which finance flows that go towards realizing those solutions should be tracked (UNFCCC BA, 2020). This study is intended as a working document as it aims to contribute to the ongoing discussions of how to define and track CRI investments. The goal is to identify barriers, data gaps, and methodological challenges in tracking CRI investments and suggest recommendations for stakeholders to overcome them. **To that end, the study is primarily aimed at reporting entities in the public and private sector and data and analytics organizations to work towards more data harmonization.** For governments and regulators, it outlines the enabling environment needed to track and report CRI investments. It can also inform industry associations and multi-industry coalitions about resilience principles and the metrics needed to define and operationalize CRI investments.

Distinguishing Adaptation and Resilience Finance

Tracking adaptation finance and resilient investments have many similarities in terms of process-based, context-specific approaches, but their objectives and outcomes are supposed to be different. The Joint MDB adaptation finance tracking methodology aims to determine the amount of finance dedicated to specific adaptation activities at the sub-project or project level. For example, the construction of flood dykes and barriers. This follows a principle of conservativeness to ensure that adaptation finance is not overreported.

Resilience finance tracking means determining if the entire asset and investment is addressing material physical climate risks and vulnerabilities and is aligned with a country-specific, climate-resilient development pathway. (For example, a climate resilient water infrastructure project in flood prone cities in Tamil Nadu, India).

Therefore, adaptation finance can be counted as incremental or proportional investments in adaptation activities while resilience finance can be counted as the total value of the project that is resilient to climate change (OECD, 2022).

Remarkable efforts have already been made in tracking the 'incremental or proportional costs of adaptation,' which is a share of finance dedicated to certain adaptation activities including infrastructure adaptation. This accounting approach is followed by international public climate finance providers, which use the Common Principles of Adaptation Finance Tracking or OECD-Rio markers to report adaptation finance. But this approach is not proliferated beyond international public financiers potentially due to the high technical skills and capacity needed to undertake these methodologies. Given the prevalence of growing climate risks, it is likely that there is more investment in climate-resilient infrastructure than is tracked but practitioners have neither the incentive nor the resources to separate and report on incremental climate-resilient costs (CPI, 2020; UNFCCC BA, 2020).

To overcome these knowledge and data gaps, it is critical to go beyond tracking incremental adaptation finance to track broader finance flows, both public and private, domestic and international, that are building resilience of the entire assets and aligning investments to that goal. Further rationale for this approach is explained in Section 3.

Tracking CRI investments starts with defining it and identifying CRI projects from existing infrastructure databases. To this end we devised our approach around five climate resilience principles that all CRI projects need to meet. Together, these principles constitute the most comprehensive framework to conduct an accurate tracking of CRI investments.

Granular information on how the projects are mainstreaming different resilience principles to withstand the impacts of climate change, from the outset and over time, is key to operationalize this tracking approach, which is not always available in the public domain. In the absence of this information, we developed our own approach to identify CRI projects within the scope of this analysis and a set of assumptions based on extensive literature review. The proposed approach is piloted to estimate CRI investment in 2019 and 2020 across four sectors: (i) water & wastewater; (ii) transport; (iii) energy; and (iv) agriculture, forestry, and other land use (AFOLU) and cross-sectoral solutions. It is confined to floods and droughts, with the potential to replicate the analysis for a variety of other shocks and stresses such as heatwaves and sea-level rise.

The study is structured as follows:

- **Section 1 discusses the existing barriers** to defining and tracking CRI investment.
- **Section 2 proposes an approach** to overcome each of these barriers to track and report on CRI investment.
- **Section 3 discusses the quantitative findings** from piloting this methodology along with a case study on CRI investments in India.
- **Section 4 concludes with ongoing data gaps and tracking challenges** and summarizing lessons learned.

2. BARRIERS TO TRACKING INVESTMENTS

Identification of CRI investments in current climate finance tracking exercises is limited because of a variety of obstacles. In this section, we describe some of the main challenges of tracking CRI investments:

Lack of common definition	Broad scope and lack of source data	Inadequate standards
The precise bounds of CRI projects as compared to other infrastructure projects are blurry	Infrastructure assets are complex to aggregate	Existing technical standards are not up to the mark and used incosistenly

The precise bounds of CRI projects as compared to other infrastructure projects are blurry: In theory, CRI reflects critical infrastructure assets and services that are planned, designed, built, and operated in a way that they anticipate, prepare for, and adapt to changing climate conditions (OECD, 2018). Building infrastructure resilience is generally viewed as disruption management: to prevent, absorb, recover, and transform from disruptions caused by a hazard in a timely and efficient manner. However, in practice, it is quite challenging to operationalize this definition and identify if the infrastructure is climate resilient or not for a variety of reasons:

A. **Climate resilience is process-based and context specific** which often necessitates the use of multiple impact metrics that can evaluate the project performance, outputs, and outcomes. Climate adaptation and resilience does not have a single impact or resilience metric, equivalent to the tons of CO2e that is commonly used for mitigation. This makes specifying the resilience component rather difficult. However, there is a common understanding among engineering professionals that designing for resilient infrastructure will only reduce infrastructure disruptions. The goal of infrastructure resilience is to minimize service disruption to an 'acceptable' level of reliability to customers and the local community (UNDRR, 2020).

B. Resilience can be conceptualized as **a dynamic and iterative process** as the data and information on climate risks and adaptation solutions evolve which makes tracking CRI challenging (GIIA, 2020).[1]

Infrastructure assets are complex to aggregate. Infrastructure refers to the fundamental facilities serving a country, city, or area, including the assets, services, and systems with both structural and non-structural elements necessary for its economy to function (EU Commissions, 2017). Infrastructure is deeply intertwined with all economic and social sectors of society (Oughton et al., 2018). Infrastructure assets often have long lifespans during which they engage and interact with a complex web of services and systems, creating

1 It is difficult to define a desirable level of resilience for CRI. For example, a water treatment plant could be built informed by climate risk mapping and with an intention to withstand a 1 in 50-year flood. This could align with the CRI definition advanced in this report. However, if an even more extreme flood of 1 in 100-year return period occurred and badly damaged the plant, it would be difficult to determine whether the plant should be defined as CRI.

interdependencies. As a result, infrastructure usually does not have a universally accepted definition and most infrastructure features are hard to accurately measure and report at a granular level. Therefore, collecting infrastructure asset level data at a global scale is particularly difficult as there are limited initiatives that collect bottom-up data.[2]

Existing technical standards and rating systems are not up to the mark and used inconsistently. Well-defined technical codes and regulations are one of the simplest ways of delivering climate resilient infrastructure (Hallegate et al, 2019).[3] These existing codes and standards develop the design guidelines using the most probable scenarios and historical weather patterns. But the uncertainty of future climatic events are posing challenges to the validity of these traditional codes and standards (EBRD, 2017).

Current technical standards aiming to promote climate resilience face conflicting goals of consistency and ease of use contrasted with context-specificity and capable of managing uncertainty around climate risks. Nevertheless, progress is being made in reconciling the two goals. More than 200 codes, guidance, standards, and rating systems, both voluntary and mandatory, are available worldwide for infrastructure project developers to build and maintain CRI. These standards tend to operate in silos, without coherence or consistency, and are not the norm (GCA, 2020; ICSI, 2021). Additionally, data on the users of these standards is not publicly available either due to confidentiality issues or lack of incentive to report publicly and there is no common database to capture these climate resilient infrastructure investments.

2 Examples include GRESB, Global Water Intelligence Desalination data, IJGlobal Project Finance database, World Bank Private Partnership in Infrastructure (PPI) data.

3 Besides technical codes which are mandated by infrastructure regulators, there are standards, guidance documents, tools and rating systems voluntarily adopted by various stakeholders in the infrastructure lifecycle, such as project developers, asset owners and managers, investors etc.

3. THE APPROACH

This section describes the approach taken in this analysis to address difficulties specific to tracking CRI investments. Figure 1 shows the step-by-step approach taken in this study to reconcile existing definitions, leverage the available data, and resolve methodological constraints. Further details on the concepts and assumptions captured in this section are available in the Annex.

Figure 1: Step-by-step approach to tracking CRI investments in this study

1	2	3	4	5
Define CRI	**Set Boundaries**	**Collect asset-level infrastructure data**	**Identify CRI projects from database**	**Track investments into the CRI projects**
Outline the features and criteria for climate resilience	Limit the boundaries of the study for type of infrastructure, sectors, activities and climate risks	Collect data on infrastructure projects from public and private infrastructure databases	Operationalise the resilience principles in different databases, to the extent possible, with a set of assumptions	Estimate the total cost of the projects, wherever given or not

STEP 1: DEFINE CRI

In theory, CRI captures critical infrastructure assets and services that are planned, designed, built, and operated in a way that anticipates, prepares for, and adapts to changing climate conditions (OECD, 2018b). Applying this definition to asset-level data is challenging in practice because available data largely does not include consistent information on whether the assets and services captured would align with CRI definitions.

To operationalize the definition in practice for tracking investments, we adapted the high-level principles of climate resilient laid out in the 2022 OECD Framing Paper on climate-resilient finance and investment (OECD, 2022) and MDB framework for Climate Resilience Metrics (IDB, 2019) and Joint MDB Assessment Framework for Paris Alignment (MDB,2021) to the context of this study.[4] The five resilience principles compiled in this study align with the five main features of climate resilient investments namely:

1. **Process-based approach:** Unlike mitigation finance, adaptation and resilience finance needs to undertake a process of design and diagnostics to assess the project-specific climate risks to assets, activities, and beneficiaries at the outset based on which the commitment of financial, human, and technical resources is decided.
2. **Context-specificity:** Adaptation and resilience finance is largely context dependent. Whether an investment has adaptation and resilience outcomes depends on specific local risks and vulnerabilities and which context and location specific activities are implemented to address those risks and vulnerabilities.

4 OECD (2022) lays out the high-level principles of adaptation-aligned finance from extensive review of literature on frameworks and taxonomies such as EU Taxonomy, World Bank Resilience Rating System, Joint MDB Paris Alignment Approach, CBI Climate Resilience Principles and EBRD Paris Alignment Methodology

3. **Impact focused:** Resilience finance not only builds resilience of the assets and investments but also builds resilience through the assets of the wider community and system.
4. **Systemic resilience:** Resilient investments should not undermine the resilience of the wider community and should do no significant harm by maladaptation. It should also align with the relevant adaptation or resilience strategies at the national, regional, or local level.
5. **Dynamic in time**: Resilience is a dynamic concept and needs to be monitored over time.

We treat these features as the starting point for developing the climate resilience principles, summarized in Table 1.

Table 1: Summary of Climate Resilience Principles Used to Define CRI

No	Resilience Principles for CRI projects	What is the core focus?	Examples of resilience metrics
1	Project **design** is informed by physical climate risk	Conducting climate risks and vulnerability screening or assessment in the context of the project.	• Design based on climate risk assessment and vulnerability screening • Physical scenario modelling used to inform the design
2	Project addresses, responds, or reduces climate risks by implementing **context specific** CRI solutions	Addressing, responding or reducing the project specific climate risks and vulnerabilities identified by committing resources and integrating resilience considerations in all project stages	• Number of early warning systems set up and operated • Number of drip irrigation systems installed • Construction of water treatment plant in a drought prone area • Kms of improved drains, climate resilient roads network, increased road lifespan
3	Project makes local community more resilient by improving **results** like project performance, outputs, outcomes and impacts	Tracking the impacts of the project to ensure that it builds the resilience of local communities	• Reduction in dry or wet days by 2050 • Percentage of households with sufficient drinking water during dry days • Travelled time reduced in flood zones • Reduced number of infrastructure disruptions and time for restoration
4	Project meets **minimum** safeguards and is **aligned** with national adaptation plans	Avoiding adverse outcomes such as maladaptation and ensuring alignment with national priorities and sustainable development goals	• Compatibility with NDCs, NAPs, LTS • Compliance with local environmental laws, safeguards existing technical codes and regulations
5	Project monitors and **dynamically** evaluates strategies and plans	Implementing strategies to monitor performance of the asset over time as climate risks and vulnerabilities evolve and adapt the project accordingly	• Plans for periodic climate risks and vulnerability assessment and decisions • Use of modelling tools for assessing evolving climate risks and opportunities

Source: Adapted from (OECD, 2022), (IDB, 2019), (MDB, 2021)

STEP 2: SET BOUNDARIES

After establishing what CRI means in the context of this study, the CRI investment tracking exercise, we limited the scope or boundaries of the analysis given the data and time constraint. Figure 2 demonstrates what type of infrastructure, sectors, interventions, and climate risks fall within the scope of this work. This scope then becomes the basis for identifying CRI solutions and projects from the global infrastructure databases collated in the next steps.

Figure 2: Boundaries of CRI for this Study

Type of Infrastructure	Sectors	Type of Interventions	Type of Risks
▪ Grey ▪ Green ▪ Blue ▪ Hybrid	▪ Water and Wastewater ▪ AFOLU ▪ Transport ▪ Energy ▪ Cross-sectoral	▪ Structural/Hard ▪ Non-structural/Soft	▪ Floods ▪ Droughts

Type of Infrastructure: The boundaries of this methodology are not limited to the conventional notion of the built environment but rather include a broad array of grey, green, and blue infrastructure. Grey infrastructure captures a more capital intensive, fixed infrastructure that is designed and constructed with engineered materials, usually concrete or steel. Green and blue infrastructure describes infrastructure composed of natural elements, like vegetation, farmland, forestry and water bodies like coastal, marine ecosystems which is generally more cost-effective and allow for more ecosystem-based adaptation services. These types of infrastructure can be connected and designed to work together in hybrid and more resilient infrastructure systems (GCA, 2020).

Sectors: This study examines CRI solutions in four broad critical infrastructure sectors and cross-cutting solutions in: 1) water and wastewater, 2) agriculture, forestry, and other land use (AFOLU), 3) transportation, and 4) energy systems. This study defines critical infrastructure as infrastructure assets and services that deliver essential functions to communities and the loss or compromise of which would result in severe socio-economic consequences to society, loss of life and irreversible damage to the physical environment, including climate, hydrology, and soils (Resilience Shift, 2021). The four sectors assessed in this study are highly interconnected and any disruption in the provision of one could quickly lead to severe losses and damages in the entire network and community (C40 Cities, 2017).[5]

Type of interventions: The CRI solutions listed in this study not only contribute to hard but also softer infrastructure like technologies, tools, services, supply chains, etc., because they have a key role to play in enabling climate resilience (CBI, 2019).

Type of climate risks: This study specifically focuses on CRI solutions building resilience against two water related acute shocks, droughts and floods.

1. Acute shocks often pose severe challenges to infrastructure due to sudden disruptions to critical services and damages to assets, compared to chronic stresses which impact infrastructure more gradually.
2. Two of the acute shocks, floods and droughts, affect the greatest number of people globally among all natural disasters (EMDAT, 2022).
3. The impacts of these climate hazards on infrastructure are relatively well understood.
4. This study lacks the capacity to analyze all climate risks but holds potential for replication in future.

5 Please see Annex 1 for an overview of definitions of critical infrastructure used by different global organizations and national governments.

We acknowledge that the actual impacts of climate shocks will depend on the location, design, vulnerability, exposure, and management of the infrastructure. Table 2 gives high-level examples of some impacts for water and wastewater sectors.[6]

Table 2: Examples of the Impacts of Floods and Droughts in the Water and Wastewater Sector

Sector	Increased patterns of precipitation (floods, storms)	Decreased patterns of precipitation (droughts)
Water	• More risk of overtopping river embankments. • Asset damage or failure leading to outage or unplanned closures • Risk to health and safety of staff • Increased costs for repair and maintenance • Changes in quantity and quality of watershed runoff and in the resulting non-point source pollution loads to receiving waters	• Loss of water pressure and water supply • Poor water quality from the source that may require additional treatment to meet drinking water standards • Inability to access alternative and supplementary water sources because of high demand by and competition from other users • Increased customer demand • Increased costs and reduced revenues related to responding to drought impacts
Wastewater	• Overwhelming drainage systems • Increased probability of sewer flooding/ overflows/spills	• Decrease in effluent quality and flows can damage infrastructure and reduce the effectiveness of existing treatment processes

Source: (GCA, 2021)

STEP 3: COLLECT INFRASTRUCTURE ASSET DATA

This study is informed by the asset-level data collected from various public and private infrastructure investment databases and focuses on new, primary investments made in 2019 and 2020. The majority of asset data tracked in this study comes from databases that inform CPI's Global Landscape of Climate Finance. Two additional data sources, Desal Data by Global Water Intelligence (GWI) and World Bank Private Participation in Infrastructure (PPI) data were included in this study to fill the data gap on private investments in climate resilient infrastructure. This database was then used to identify CRI projects following the approach outlined in the next steps.

Table 3: Databases Included in this study

Databases covering public investments	Databases covering private investments
• The Organization of Economic Co-operation and Development's Development Assistance Committee (OECD-DAC), Creditor Reporting System (OECD-CRS) • Biannual surveys of development finance institutions conducted by CPI • Climate Funds Update (CFU)	• Bloomberg New Energy Finance (BNEF) • Climate Bonds Initiative (CBI) • Convergence Blended Finance • International Energy Agency (IEA) • IJ Global Project Finance • Desal Data by Global Water Intelligence (GWI) – additional data • World Bank Private Partnership in Infrastructure (PPI) – additional data

6 For an overview of the impacts of floods and droughts on all critical infrastructure sectors included in this study, see Annex 2.

STEP 4: IDENTIFY CRI PROJECTS

After collating asset-level data for infrastructure projects, we identify which projects are climate resilient using the definition, resilience principles, and scope set in Steps 1 and 2.

Ideally, integrating all five resilience principles (captured in Step 1) would be the standard for tracking infrastructure investments as resilient to climate change and aligned with the Paris Agreement. However, it is quite challenging in practice, based on publicly available information, to analyze if projects fulfill these criteria. Infrastructure databases have different capacities to report on the information needed to analyze these criteria.

Infrastructure databases analyzed in this study provide little to no spatial data required for Resilience Principles 1: improving the quality of the project design as it is more implicit in the methodology of implementing adaptation projects. Collecting data on sub-national or regional assessments of climate risks and geotagging projects at the same level of granularity would be an ideal way to draw connections between projects location and relevant climate risks and vulnerabilities. However, in practice, the databases included in this analysis do not disclose spatial data on precise location of the projects tracked nor if the projects conducted climate risk assessments. This information is implicit in the methodology of reporting adaptation finance from international public financiers. The MDBs and members of the International Development Finance Club (IDFC) follow the Common Principles of Tracking Adaptation Finance[7] and the reporting entities of the OECD-CRS systems follow the OECD-Rio markers which require them to set the climate risks context and intentionally address them in the reported adaptation projects.[8]

The infrastructure databases analyzed in this study include some information to fulfill Resilience Principle 2: implementing context specific CRI solutions. This information includes project descriptions, project objectives, and solutions. The sectors and sub-sectors also provide a hint of targeted solutions but not all financiers provide this information and not at the required granularity.

None of the databases provide granular information on resilience criteria 3, 4, 5 at the asset level. Table 4 summarizes the strengths and weaknesses of different databases to provide granular information on the resilience criteria.

7 https://www.eib.org/attachments/documents/mdb_idfc_adaptation_common_principles_en.pdf

8 https://www.oecd.org/dac/environment-development/Revised%20climate%20marker%20handbook_FINAL.pdf

Table 4: Overview of data coverage across public and private funding sources

Funding source	Data source	Does the database have information on the resilience principles				
		1. Process-based	2. Context-specificity	3. Impact-focused	4. Systemic resilience	5. Monitoring & Evaluation
Public	OECD-DAC	1	2	0	0	0
	DFI Surveys	1	1	0	0	0
	IDFC	1	1	0	0	0
Private	IJ Global	0	1	0	0	0
	BNEF	0	1	0	0	0
	IEA	0	1	0	0	0
	World Bank PPI	0	2	0	0	0
	GWI – Desal Data	0	1	0	0	0
	GRESB/TCFD	1	0	0	0	0

0 – No information, 1 – Partial information, 2 – Full information

In the absence of granular reported information on the fulfillment of each criterion in detail, we relied on a set of proxies and assumptions and could only operationalize three out of the five principles. More details are outlined in Table 5.

Table 5: Approach for Operationalizing the Resilience Principles to Identifying CRI Projects and Create a CRI Database

No	Resilience principles for CRI projects	CPI approach to identify CRI projects from databases
1	Project **design** is informed by physical climate risk	• For international public financiers: Rely on the self-reported adaptation projects • For private financiers: Apply the criteria to the extent possible. For example, in the case of desalination plants, we assumed that they address the drought risks at the project locations
2	Project addresses, responds, or reduces climate risks by implementing **context specific** CRI solutions	• Develop our own list/taxonomy of CRI solutions falling within the scope of the study. • Apply keyword methods to identify CRI projects from the databases
3	Project makes local community more resilient by improving **results** like project performance, outputs, outcomes and impacts	In the absence of information on how project outputs/outcome metrics and on alignment of with country-specific adaptation plans and climate resilient development pathways, we used a proxy analysis of comparing the per capita CRI investments to the ND-GAIN vulnerability score of the country.
4	Project meets **minimum** standards and is **aligned** with national adaptation plans	This criterion is not considered to identify CRI projects in this analysis due to lack of information.
5	Project monitors and **dynamically** evaluates strategies and plans	This criterion is not considered to identify CRI projects in this analysis due to lack of information.

For the first principle, we relied on self-reported information on adaptation projects, which CPI collects through primary surveys, especially for international public financiers. For the private sector, we apply the requirement of conducting climate risk assessment only to the extent possible and when not possible, we resort to a simpler method of relying on analyzing the second principle alone.

To analyze the second principle, we collated a list of possible CRI solutions (referred to as Taxonomy) in four critical sectors that potentially build resilience against floods and droughts. Projects that undertake these solutions were identified from the infrastructure databases using keywords created for each activity. After the initial keyword search using advanced data science techniques, manual screening of the shortlisted projects was done to inspect the accuracy of the results. Table 6 gives a high-level overview of the possible CRI solutions in the water and wastewater sector. See Annex 4 for more information on the taxonomy for all four sectors.

Table 6: Overview of Possible CRI Solutions in the Water and Wastewater Sector

Sub-sector	Category of CRI solutions	CRI Solutions	Primary climate hazard	Type of Infrastructure	Type of Intervention
Water	Water treatment and supply	• Construction of water treatment plant • Construction of water distribution networks	Drought	Grey	Hard
	Desalination and other drought solutions	• Desalination plant construction • Water reuse • Boreholes and tube wells • Construction and expansion of reservoirs	Drought	Grey	Hard
	Increased efficiency of water supply and use	• Repair/Maintenance /Upgrade of water treatment plants and distribution systems • Leakage management, detection, and repair of pipes • Increased use of water efficient fixtures and appliances • Renewable energy solutions for water treatment	Drought	Grey	Hard
	Planning and strategic solutions	• Water Safety and Continuity Plans • Climate and Natural Hazard Risk Assessments • Flood monitoring and alerting systems	Drought, Flood	Grey	Soft
	Water collection and storage	• Rainwater harvesting • Water storage • Reinforcement of river basins	Drought	Grey	Hard
	Floodproofing	• Dykes and berms	Flood	Grey	Hard
Wastewater	Wastewater collection and treatment	• Wastewater plant construction • Wastewater collection infrastructure	Drought	Grey	Hard
	Sustainable drainage systems	• Sewer repair and maintenance • Stormwater retention systems • Permeable pavements • Stormwater runoff management through solutions like bioswale and soak ways	Flood	Grey	Hard

STEP 5: TRACKING INVESTMENTS

Once the CRI projects are identified and a database is created, the final step taken in this analysis is to quantify the CRI investments into those projects.

To estimate investment in CRI projects at the asset level, CPI uses the investment metric 'total cost of the project' which is slightly more accessible than incremental adaptation costs. **Nevertheless, the application of the 'total cost of project' investment metric also comes with significant challenges** as different databases have different capacities to provide information on the total cost of the project depending on the funding source. The data on the 'total cost of the project' is slightly more accessible than incremental investments, especially for private investments. The intention of this approach is not to erode the tracking methodology set out by the Common Principles of Adaptation Finance Tracking which recommend the incremental investment accounting approach for adaptation finance, but rather to take a step towards filling the data and knowledge gaps between the public and private sector on adaptation and resilience investments and provide supplementing data tools for decision makers. The methodologies are explicitly different, therefore, the finance flows that use these two methods are not directly comparable.

The private databases for infrastructure projects only report the total cost of the projects and not incremental cost.

We estimated the full CRI investment amounts from the reported adaptation finance for the MDB funded CRI projects. Among the international public financiers, CPI collects investment data from MDBs and IDFC through its primary surveys and compliments it with disclosures made by these actors in the OECD-CRS system.[9] Even though the MDB and IDFC recommend the use of incremental cost of adaptation to report adaptation finance, in practice, only the MDBs are following the incremental approach while other DFIs, climate funds, and governments providing bilateral climate finance still report the total cost of the projects (UNFCCC BA, 2020).[10]

For estimating the CRI investments by MDBs, we devised a metric called the resilience coefficient where:

Resilience coefficient = Incremental adaptation finance/Total cost of the project

The resilience coefficient is publicly disclosed by MDBs in the OECD- CRS database on climate finance as the 'share of climate finance in underlying commitments' but not for all projects. Therefore, we derived the total cost of these adaptation projects using a step-by-step approach.

- First, we shortlisted all the adaptation projects funded by the MDBs as reported in the OECD-CRS database for 2019 and 2020.
- Then, we calculated the average resilience coefficient for these projects at the sectoral level (Table 7).
- Third, we applied this coefficient to the reported adaptation financing values of CRI projects in our database that are funded by MDBs.

9 The OECD Development Assistance Committee (DAC) Creditor Reporting System (CRS) includes the most comprehensive, publicly available, activity-level data on climate-related development finance, concessional and non-concessional.

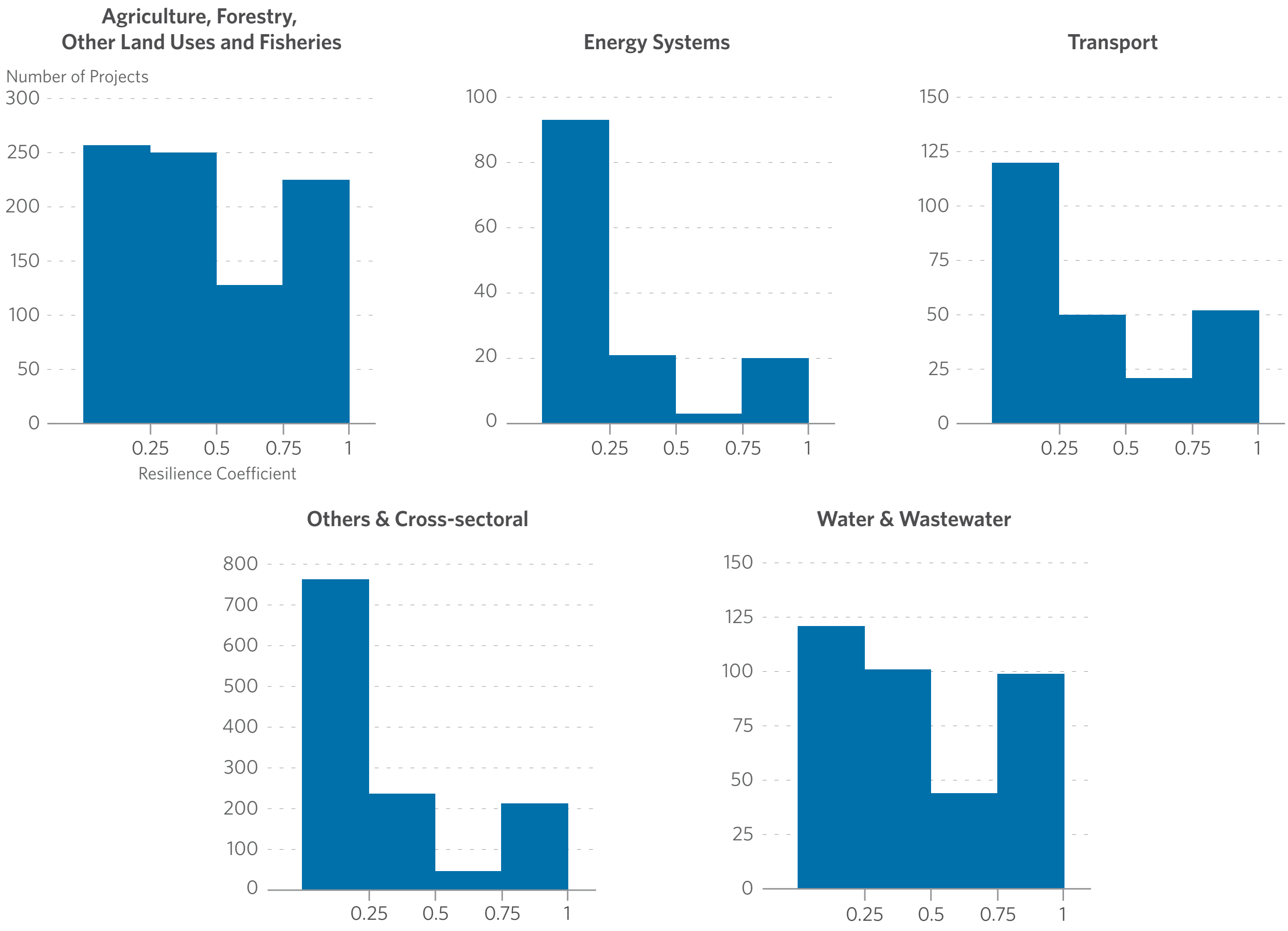
10 Please see Annex 4 for a summary of approaches for reporting adaptation finance by MDBs, IDFC and bilateral governments providing climate finance in theory and in practice.

Table 7: The estimated values for the resilience coefficient at the sectoral level

Sector	Average Resilience Coefficient
Agriculture, Forestry, Other land uses and Fisheries	0.49
Water & Wastewater	0.47
Transport	0.40
Others & Cross-sectoral	0.31
Energy Systems	0.25

As shown in Figure 3, the resilience coefficient is less than 0.25 for the majority of the adaptation projects funded by MDBs in all sectors. This means that the MDBs are reporting less than 25% of the total cost of the project as incremental adaptation finance. The variability across sectors is dependent on several factors such as the type of projects, type of adaptation solutions, baseline exposure and vulnerability, type of climate risks, etc. But the low share of adaptation also suggests that it is cost-effective to undertake adaptation solutions across sectors. Having said that, it is important to keep in mind that total project cost cannot be accounted as a CRI investment unless it is looked at from a holistic perspective of how the project integrates all the climate resilience principles together.

Figure 3: Number of projects by sector vs resilience coefficient



In summary, this section demonstrated how this study proposed a methodological approach of defining CRI investments using the climate resilience principles and operationalize it given the data constraints to track and report on CRI investment in a holistic way.

4. FINDINGS

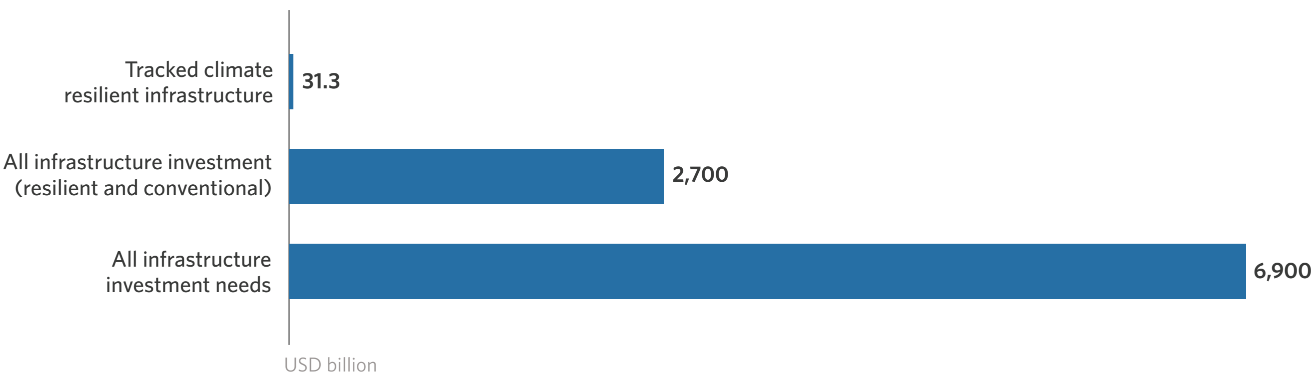
4.1 ANALYSIS OF GLOBAL CRI INVESTMENTS

Based on available data and the approach stated in the prior section, we find that investments in climate resilient infrastructure are only a fraction of total investments in infrastructure sectors.

For every USD 1 spent on CRI, USD 87 was spent on infrastructure projects which do not integrate climate resilience principles. This suggests that investing in CRI is still in its nascent stages. As global infrastructure investment needs are counted in the trillions, there is an immediate need to integrate climate resilience principles in all infrastructure investment decisions. Failure to do so will result in locking-in climate risks in long-lived infrastructure assets and making businesses and communities vulnerable to increasing impacts of climate change.

We find that up to USD 31.3 billion was invested annually in CRI projects in 2019/20.[11] This represents just about 1.1% of the average annual infrastructure investment in that period. The OECD estimates indicate that around USD 6.3 trillion of infrastructure investment is needed each year to 2030 globally to meet development goals, increasing to USD 6.9 trillion a year to make this investment compatible with the goals of the Paris Agreement (OECD, 2018). Globally, an annual average of USD 2.7 trillion was invested in infrastructure sectors like energy, transport, and water in 2019/20 (GIH, 2022).[12] To realize Paris Agreement goals, all this new and existing infrastructure investments from public and private sector need to be made climate resilient (Figure 4). Despite the urgency, there is no common standard and metric nor other concerted efforts, incentives, or concrete roadmaps to track progress.

Figure 4: CRI Investments in 2019/20 Compared to Needs, USD bn



11 CPI reports two-year averages (2019 and 2020) to smooth out annual fluctuations in data

12 The numbers for investments in AFOLU sector are not included in this analysis. If those numbers are added, the share of climate resilient infrastructure investments in the total infrastructure investments globally would be even lower.

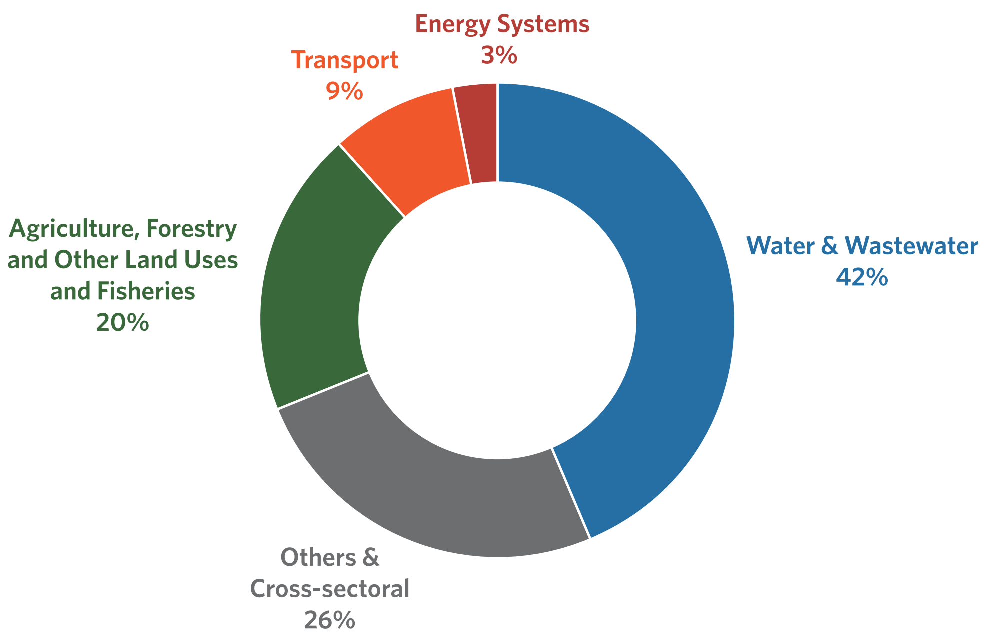
We find that there were close to 4,000 new primary investments in 2019/20 across different databases that can be classified as climate resilient infrastructure projects given the information available and methodology developed for the purpose of this study. Out of the total tracked, USD 7.6 billion in investments from CRI projects were reported in private databases like the GWI- Desal Data, World Bank PPI, IJGlobal, IEA, and CBI.

Lack of publicly available, granular information on how infrastructure projects align with resilience principles 3,4, and 5 has affected the quality of the findings of this study. However, even with these limitations factored in, our work still provides key insights on the state of CRI investments.

FINDINGS BY SECTOR

The water and wastewater sector received the highest share of the tracked CRI investments in 2019/20 (42%, USD 13.1 billion) among all the assessed sectors (Figure 5). This is followed by other and cross-sectoral flows (25%, USD 8 billion), AFOLU (20%, USD 6.8 billion), transportation (9%, USD 2.8 billion), and energy systems (3%, USD 867 million). Figure 5 gives the breakdown of climate resilient infrastructure investments by sector in 2019/20. The high share of water and wastewater is partly due to the capital-intensive nature of large water and wastewater treatment and desalination plants, but it also underscores the high relevance of water and wastewater infrastructure to build climate resilience against floods and droughts.

Figure 5: Climate Resilient Infrastructure Investment by Sector, in 2019/20



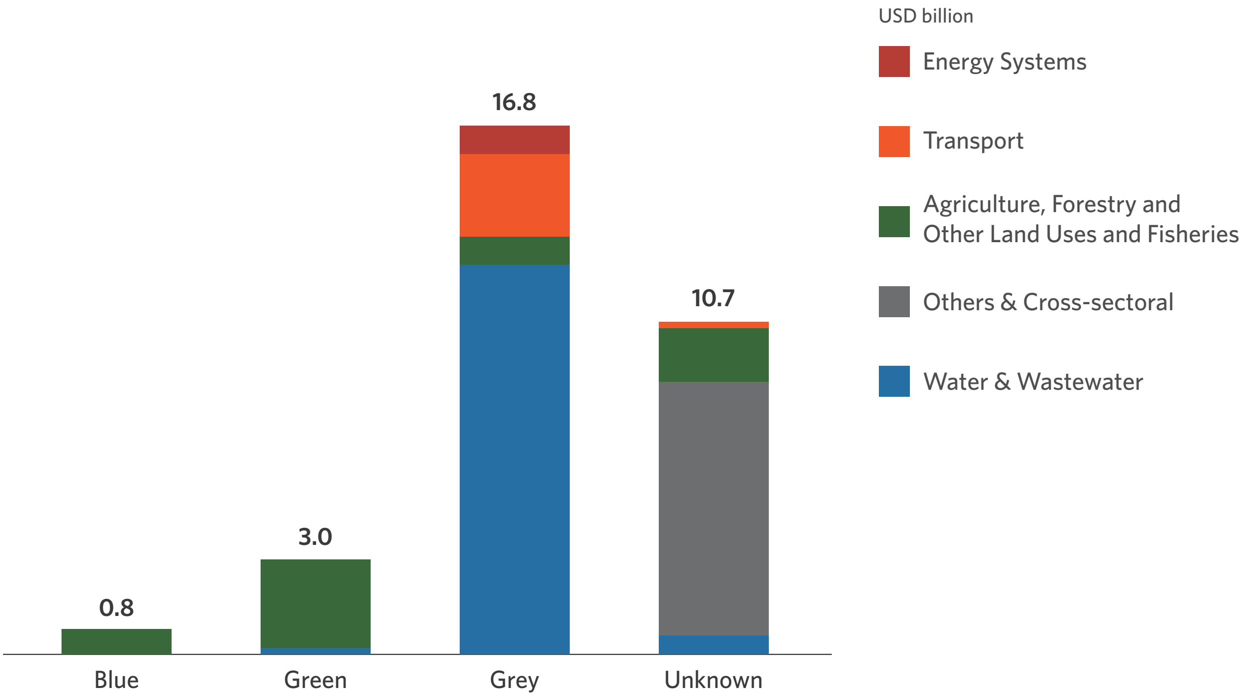
TYPE OF INFRASTRUCTURE

Of the tracked investments, more than half (53%) of the CRI investments target grey infrastructure in the water and wastewater sector (40%), transport (8%), energy (3%) and AFOLU (2%). This is partly due to the capital-intensive nature of large water and wastewater treatment and desalination plants (Figure 6). All CRI projects tracked from the World Bank PPI,[13] IJ Global, and GWI- Desal Data[14] that integrated the climate resilience principle 2 as per the taxonomy of CRI solutions are grey infrastructure solutions in the water and wastewater sector.

Green infrastructure received less than 10% of the tracked CRI investments. More than 92% of the green infrastructure was concentrated in the AFOLU sector, roughly 30% of which went towards nature-based solutions, ecosystem-based adaptation, urban green spaces, and coastal management practices solutions such as mangrove plantation, coral/oyster reef restoration, wetlands, and urban green farming. About 10% went towards projects with components of crop diversification, soil health and land management, and nutrient and pest control practices.

The precise type of infrastructure for the remaining 37% of tracked CRI investments was unknown. Tagging the infrastructure projects for the type of infrastructure being built was not possible due to the cross-sectoral nature of the projects and lack of granular information. Solutions such as policy building, training and capacity support, disaster risk management, and early warning systems majorly fall under this category.

Figure 6: CRI Investments by Sector and Type in 2019/20, USD bn



13 We could tag 92 projects in the database that have integrated the adaptation activities as per our Taxonomy. We came across 32 other projects in the World Bank PPI data from the energy and transport sector which had keywords for flood management solutions as per our Taxonomy. However, upon manual inspection of project documents, they are not included in the analysis because it was unclear how the resilience options are integrated in practice.

14 According to the GWI-Desal Data, the market size of desalination was estimated to be roughly around 16 billion in 2019/20 (CAPEX and OPEX). However, only projects worth USD 1.4 billion had good coverage of data for actual capital expenditure for desalination plants which were then included in this analysis as potential climate resilient infrastructure investments.

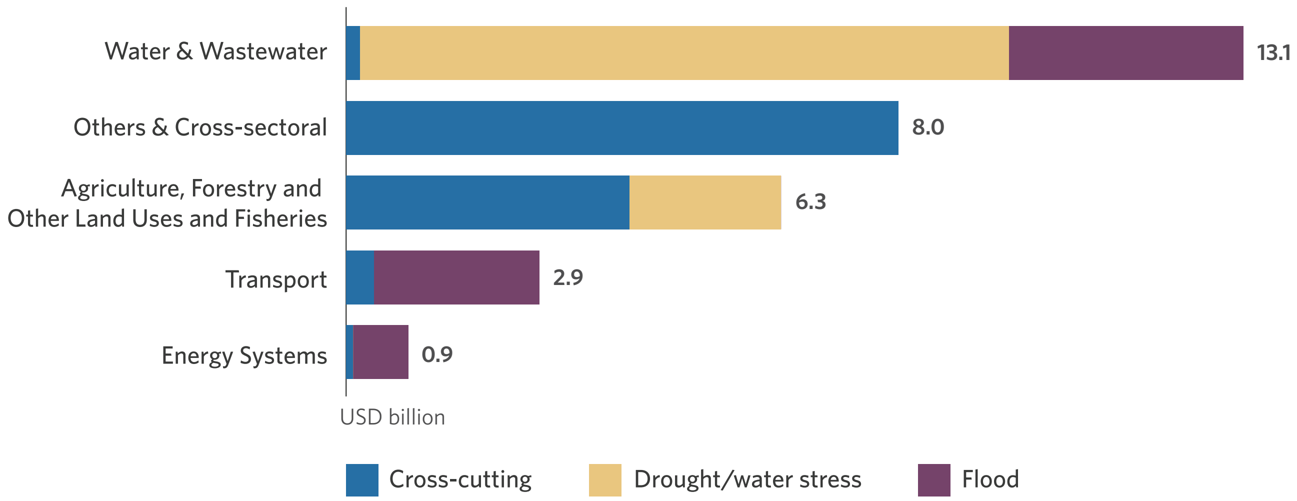
TYPE OF CLIMATE RISKS

Within the tracked CRI Investments, potential drought resilience building projects received 40% investments, followed by those building floods resilience (20%). About 40% of the tracked CRI investments have cross-cutting benefits.

Most CRI investments that provided resilience against droughts went to the water and wastewater sector (80%). Almost half of the investments that targeted flooding also went towards the water and wastewater sector, followed by the transport (32%) and energy (18%) sectors through CRI solutions such as repairs, maintenance, and upgrades of roads, highways, and electricity grids. The high share of CRI investments in the water and wastewater sector reflects the sectors' high climate vulnerability and potential for building resilience to both droughts and floods.

Roughly 40% of all tracked investments went towards projects with cross-cutting benefits. These investments were mainly split between other and cross-sectoral projects (60%), AFOLU projects (35%), and transport (5%). For these cross-sectoral projects, it is difficult to identify the primary climate risk the projects are targeting either due to their multiple objectives or due to the lack of granular data.

Figure 7: CRI Investments Building Resilience against Flood and Droughts, 2019/20, USD bn



SOURCES AND INSTRUMENTS

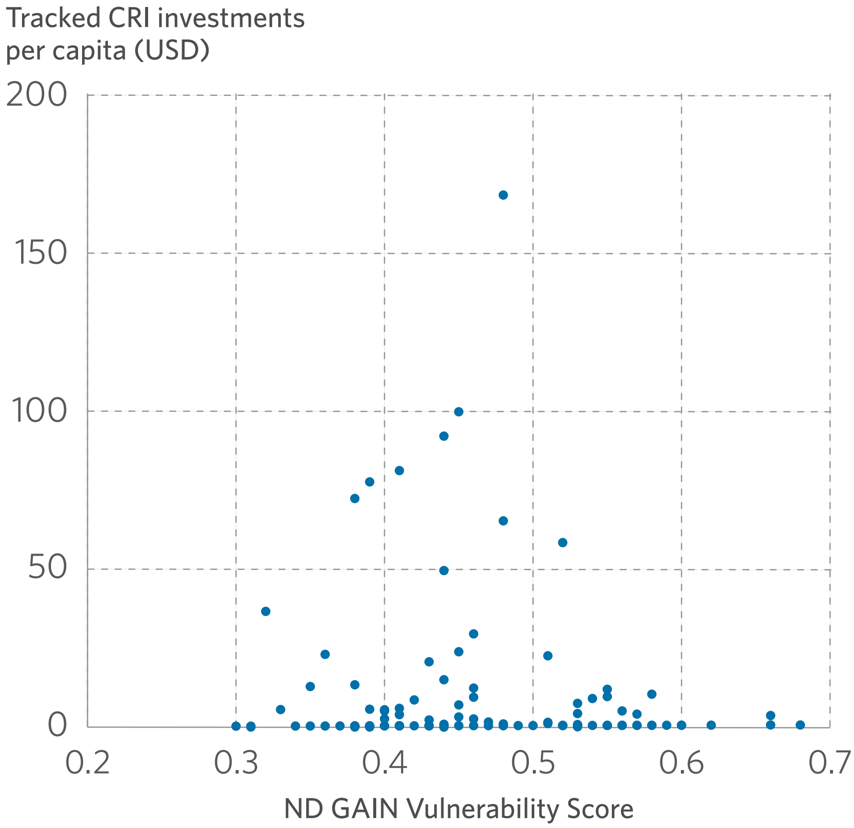
Most CRI projects were financed by public financial institutions in 2019/20 (83.5%, USD 26 billion) while private finance lags. Multilateral DFIs were the largest source of funding for climate resilient infrastructure projects (45%, USD 14.2 billion) in 2019/20, followed by bilateral climate finance by governments (15.5%, USD 4.8 billion), and DFIs (11%, USD 3.5 billion).

GEOGRAPHY

The most vulnerable countries are not the highest recipients of the tracked CRI investments in 2019/20. Of the tracked investment, more than a quarter of the CRI went to East Asia and Pacific, followed by Sub-Saharan Africa (17%), South Asia (15%), and Latin America & Caribbean (15%). About half of the tracked CRI investments were concentrated in the top 15 countries.[15]

Limited to no correlation exists between CRI investments and climate risks and vulnerabilities faced at the country level (Figure 8). ND-GAIN Vulnerability Index scores a country's exposure, sensitivity, and ability to adapt to the negative impact of climate change. Our analysis suggests that there is no correlation between the per capita CRI investments made towards CRI projects in a country and the country's vulnerability to climate change as assessed by the ND-GAIN Vulnerability Index. However, it is imperative to note that this analysis is constrained by the sparse information available on spatial characteristics of the CRI investments such as precise location, material climate risks at the sub-national or local project level, etc.

Figure 8: CRI Investments per Capita in 2019/20 vs ND-GAIN Vulnerability Index

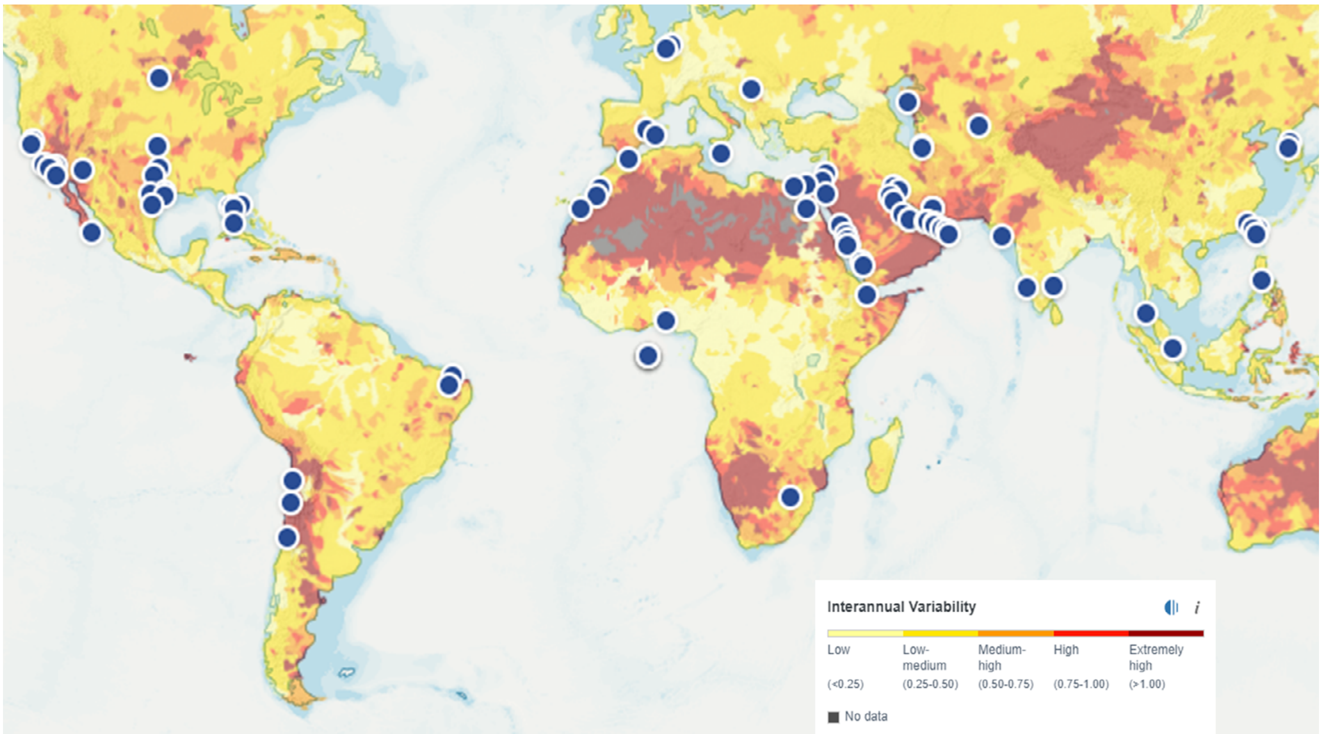


15 This finding reveals the extent of data gaps in tracking CRI investments. We lack standardized and comparable data on infrastructure investments from US, Canada, Western Europe and Central Asia especially on how the investments mainstream resilience principles.

Positive correlation exists between water stress and desalination plant investment[16] at the project level. Among all the databases analyzed, only Desal Data by GWI provides information on the precise geographical coordinates of the desalination plants. This information is crucial to demonstrate the tremendous potential disclosure of spatial data and material physical risks hold in directing investments where they are needed the most. For example, we mapped the location for geo-tagged desalination plants[17] on to the water stressed areas with high interannual variability[18] as predicted by WRI Aqueduct Water Risk Atlas.[19]

Figure 9 shows that a positive correlation exists between water stress and desalination investments. Such spatial financial analysis will allow investors to better measure and manage climate-related risks and harness opportunities (CGFI, 2021). Reporting the geospatial information of infrastructure investments will enhance the ability to identify CRI projects with more confidence, especially in the absence of reported data on resilience principles 3, 4, 5 by infrastructure developers and investors.

Figure 9: Mapping of desalination plants (2015-2022) to water stressed areas globally



Source: *Desal Data by GWI, WRI Aqueduct Water Risk Atlas*

16 Since desalination plants are one of several methods to provide larger and more secure water supplies we cannot make conclusions about the investments in resilient water supplies as a whole. We should also note that though we have classified desalination plants as a type of climate resilient infrastructure investment, desalination plants do have risks that can limit resilience, such as vulnerability to intermittent energy supplies and increased GHG emissions from fossil fuel use.

17 Awarded between 2015-2022

18 Interannual variability measures the average between year variability of available water supply, including both renewable surface and groundwater supplies. Higher values indicate wider variations in available supply from year to year. WRI Aqueduct 2019

19 Aqueduct Water Risk Atlas, which maps and analyzes current and future water risks across locations. More information is here https://www.wri.org/aqueduct

4.2 CASE STUDY – THEORY AND PRACTICE OF CLIMATE RESILIENT INFRASTRUCTURE IN INDIA

BACKGROUND

The state of Tamil Nadu in India is one of the most vulnerable states exposed to flooding and droughts. In 2016, drought was declared in 31 out of the 32 districts. More than 500 people lost lives in the devastating floods of 2015 which caused over USD 3 billion in infrastructure damages (WRI, 2022).

In 2016, Asian Development Banks supported the Government of Tamil Nadu for Capacity Development and Technical Assistance (CDTA) project for strengthening the water related infrastructure and building climate resilience in the vulnerable coastal cities in Tamil Nadu. ADB undertook detailed climate risk and vulnerability assessments for Cuddalore, Thoothukudi and Chennai and made several strategic and actionable recommendations (ADB, 2019).

This case study assesses how do the recommendations of the CDTA project for the city of Cuddalore align with the climate resilience principles outlined in the study and how we can estimate the adaptation and resilience investments in this context. Table CS1 provides a snapshot city profile with key context for the analysis that follows.

Table CS1: City Profile

Issue	Description
Population, Area	173,636, 27.79 km²
Water and wastewater resource issues	• Unorganized expansion is leading to urban planning issues • Existing water storage, supply and stormwater drainage network is insufficient, old, dilapidated, not planned for climate change • Cuddalore lies in a low-lying coastal zone and 20% of the town is prone to floods • Severe droughts in dry season and over-exploitation of ground water • 33% of irrigation water is lost from evaporation, transpiration and seepage in canals which increases the water demand • Only 10-12% households are connected to the sewerage network. • Solid waste collection system does not fully cover slums, fishermen colonies and semi urban areas; No waste segregation at source exacerbating flooding

Project Analysis: The project is fully aligned with four out of five climate resilience principles and partially aligned with the requirements of monitoring and evaluation over time. As a first of its kind CRI project in India, there are several aspects of CDTA project which carefully enhance the climate resilience of assets, services and communities they serve, summarized below in Table CS2.

Table CS2: Summary of alignment of the CDTA project with resilience principles

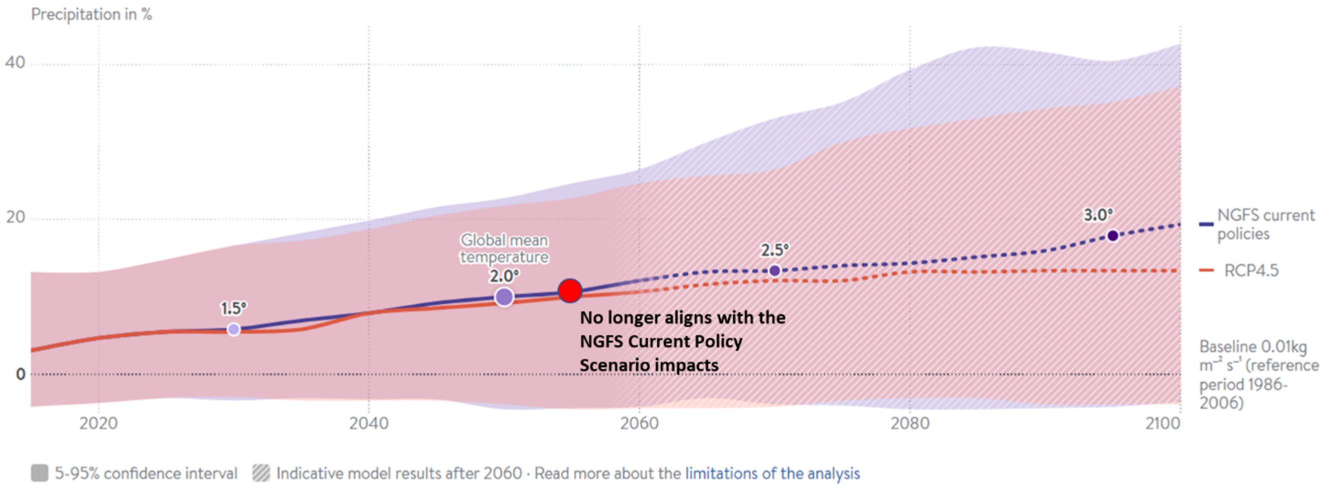
Resilience Principles	Process-based	Context-specificity	Impact-based	Systemic	Dynamic
Level of Alignment	Fully Aligned	Fully Aligned	Fully Aligned	Fully Aligned	Partially Aligned
Best Practices	Advanced basin-wide study of existing water and wastewater related issues and a **holistic water balance model.** Variations in precipitation and sea level rise are simulated using **10 downscaled regional climate models (RCP 4.5)** to give water levels with different return periods by 2100.	Detailed **list of activities** recommended with both grey and green infrastructure and hard and soft measures for reducing flood and drought risks. **Grey Structural measures:** Construction of hydro structures, extending drainage capacity. Construction of embankments, sandbar dredging. **Green measures:** Nature based solutions, agronomic changes.	Demonstration of **clear improvements in quantitative and qualitative outputs** and outcomes due to implementation of recommended activities such as: Outputs • Increased water supply by 459 MCM • Reduction in water deficits by 20% by 2020, 24% in 2025 and 37% inn 2050 Outcomes • 20%-50% reduction in flood depth • 100% households connected to sewage network	**Poor and vulnerable groups** benefiting from all recommended actions. The project **goes beyond what's mandated** by national technical standards and codes as there are no laws at national and state level to regulate flood management.	**Institutionalize optimized planning and decision making** processes by setting up operational centers for integrated water resource management (IWRM) and early warning systems (EWS). **No process to integrate dynamic decision making based on evolved climate resilient development pathways.**

The project does not optimally integrate systems to make dynamic decisions based on the uncertainties involved in climate change scenario modelling. Probabilistic climate scenarios provide an essential foundation for analyzing the impacts of climate change on infrastructure and identification of appropriate CRI solutions. They are, however, subject to uncertainties in the underlying carbon emissions, natural variability and implementation of climate policies (Mehta et al.,2019). More efforts are needed to align the project design, implementation and results with evolving emissions and net zero scenarios. The alignment would imply that the project can withstand the impacts of climate change over time, ideally throughout the project lifespan (CPI, 2020).

Figure CS1 gives an example of the alignment of this project designed using the IPCC RCP 4.5 scenario to the NGFS Current Policy Scenario[20]. NGFS CPS assumes that only current climate policies are implemented which can lead to high physical climate risks in the future. The red line shows relative percentage change in precipitation over time in the province Tamil Nadu of India based on the IPCC RCP 4.5 scenario. The blue line shows the same in the NGFS Current policy scenarios.

20 Some organizations like NGFS (Network for Greening the Financial Systems) have been developing climate change scenarios based on the current and future implementation of climate change policies and plans. They also provide information on country and region-specific climate change impacts under these scenarios.

Figure CS1: Case Study – IPCC RCP 4.5 scenario vs NGFS Current Policy scenario – Precipitation (%) from 2010-2100 in Tamil Nadu, India



Source: *NGFS Climate Impact Explorer*

Figure CS1 demonstrates that around 2050, the design of this water and wastewater infrastructure project which is based on percentage variation in precipitation as predicted under the IPCC RCP 4.5 climate scenario modelling will be outperformed by the same predicted under the NGFS current policy scenario. In that sense, the infrastructure will not be able to withstand the impacts of climate change by 2050 if no ambitious climate action beyond current policies is implemented. **The timing of upgrade to the infrastructure needs to be chosen carefully to make sure that it responds to such uncertainties attached to the probabilistic climate scenario modelling as the complexities of climate risks, policies and impacts evolve over time.** It also shows a need for strategic communication between physical climate scenario developers (scientists, statisticians, policy analysts) and infrastructure developers and investors to correctly interpret the climate scenario models.

ESTIMATION FOR ADAPTATION AND RESILIENCE FINANCE

This case study attempts to estimate the share of adaptation finance and total resilience based on the publicly available information. Our analysis suggests that all activities except the construction of large, capital-intensive hydro structures and wastewater treatment plants can be counted as adaptation solutions (Table CS3). We estimate the adaptation cost of the project to be USD 36.7 million (24% of the total cost) while the total cost of the project, USD 174 million, can be counted as CRI investments.[21]

21 This represents the team's best effort at estimation based on the available public information and the methodology suggested in this study

Table CS3: Breakdown of CDTA Project Activities and Estimated Costs

Project Activities	Primary Climate Risk	Type of Infrastructure	Type of Intervention	Estimated cost (USD mn)
Construction of 103 hydro structures like ponds, check dams, terracing, recharge pits and wells	Floods, Droughts	Grey	Hard	123.7
Construction of sewerage treatment plant (STP)	Drought	Grey	Hard	4.5
Effluent treatment plants in industrial clusters	Drought	Grey	Hard	4.9
***Design, modelling, training and capacity building for the construction of hydro structure**	Droughts	Grey	Soft	4.3
***Agronomic changes Sprinkler, surge, and drip irrigation, canal lining, crop diversification, training**	Droughts	Green	Soft	0.8
***Groundwater management to prevent salinity**	Droughts	Grey	Soft	1.0
***Operational center for IWRM**	Drought	Grey	Soft	3.0
***Flood mitigation – Dredging of the sand bar**	Flood	Grey	Hard	3.8
***Flood mitigation – Construction of embankments**	Flood	Grey	Hard	2.4
***Flood mitigation – Regulation of storm water**	Flood	Grey	Hard	18.6
***Operational center for FF&EWS**	Floods, Droughts	Hybrid	Soft	2.6
***Asset management plan(s)**	Drought, Flood	Hybrid	Soft	0.6
***Reduction of non-revenue water**	Drought	Hybrid	Soft	0.4
***Household sewerage interconnection to main grid and awareness program**	Floods, Droughts	Grey	Hard	0.1
***Nature-based solutions**	Floods, Droughts	Green	Soft	0.1
***Solid waste management**	Floods	Grey	Soft	0.2
***O&M costs/year**	Floods, Droughts	Hybrid	Hard	3.1
Total Cost (counted as CRI investments)				174.4
Adaptation Cost (counted as adaptation finance)				41.6
Resilience Coefficient				0.24

* potential adaptation-related activities

4.3 PHYSICAL CLIMATE RISK DISCLOSURES BY FINANCIAL SECTOR

The recommendations of the Task Force for Climate Related Financial Disclosures (TCFD) was a transformational moment for standard, credible and decision-useful voluntary disclosures on climate risks at portfolio level. It has 11 recommendations around four key thematic areas of investments governance, strategy, risk management, and metrics and targets. In 2021, more than 1500 financial institutions, responsible for assets worth USD 217 trillion, have supported the TCFD recommendations. Recent TCFD guidance from UN Principles of Responsible Investment (PRI) for real assets investors suggested that growing materiality of climate risks besides regulatory and public pressures are key drivers for infrastructure investors to systematically address climate risks and disclose them effectively (UN PRI, 2021).

But TCFD metrics for physical climate risks are less evolved than transition risk metrics with little guidance. TCFD published a special guidance in June 2021 on climate-related metrics and targets but with limited information on physical risks (TCFD, 2021). Metrics in the physical risk category included percentage of assets or activities vulnerable to physical risks. Metrics in the capital deployment category included investment in climate adaptation measures like soil health, irrigation, technology. These metrics roughly align with the Resilience Principles 1 and 2 in this study on assessing physical climate risks and investing in improving the project implementation. In addition, there is no detailed guidance on how to improve disclosures on the recommended metrics unlike the detailed guidance for metrics and targets on climate mitigation and transition risks such calculation of Scope 1, 2, 3 emissions or net-zero targets.

Unsurprisingly, less than 20% asset managers supporting TCFD conducted any physical scenario modelling to assess climate risks in 2021. As per TCFD 2022 status report, physical climate risks are either perceived to be less eminent or there are significant data gaps in assessments which require detailed information on the location of company assets, their nature (type, vulnerability, adaptations), the use of localized or regional climate models, and challenges with acute event attribution to climate change which are not provided by investee companies (TCFD, 2022).

Nevertheless, TCFD has had a positive impact on the physical climate risks disclosure ecosystem. Many ESG frameworks such as CDP, GRESB, UNPRI, which traditionally relied on their own set of metrics and models for benchmarking the ESG performance of individual assets, are aligning with the TCFD requirements and are including physical climate risk-related indicators.[22]

GRESB Infrastructure Asset Assessment is one such ESG benchmarking platform which started a separate resilience module in 2017. In 2020, GRESB incorporated the resilience-related indicators into the risk management aspect of its Assessments (Box 1).[23] GRESB assesses whether the reporting entity has successfully reported against each of the 11 recommended disclosures by TCFD. Currently, unlike that of transition risks, the data reported at asset-level on metrics and targets for monitoring and tracking of physical climate risks is very limited. Only the resilience strategy and risk management related indicators are

22 CDP Technical Note on TCDF Reporting, GRESB Assessments

23 Most of these indicators are not weighted ESG scoring methodology yet so only a few asset owners are prioritizing on disclosing this information.

being reported at asset-level.[24] High-level analysis of these disclosures in the 2021 GRESB's Infrastructure Asset Assessment are summarized below.[25]

Box 1: Risk Management Indicators in GRESB Assessment of Infrastructure Assets

Climate-related risk assessment using:

- Resilience of strategy to climate-related risks: If scenario analysis is used, select from a list.
- Physical risk identification: If material physical risks are identified, select from a list.
- Physical risk impact assessment: If material financial impacts of physical risks are identified, select from a list.

Source: *Adapted from "2022 GRESB Infrastructure Reference Guide" and aggregated data from GRESB collected by CPI*

In 2022, less than 30% of participating infrastructure entities in GRESB used physical scenarios for evaluating resilience strategies at asset-level. About 60% of the participants, with more than USD 700 billion in asset value, report that they have a strategy to understand and manage climate risks, both transition risks and physical risks. Less than half (40%) of them reported that their processes consider future physical climate scenarios. The majority (80%) of them are based in Europe or the Americas and more than 75% fall in either energy, water, or transport sectors.

Less than 60% of the reporting entities (USD 686 billion in asset value) systematically assessed material financial impacts of physical climate risks. Almost all of them (98%) flagged exposure to acute climate hazards such as floods, storm surges, and heat stress.[26] Transport assets and network utilities are reported to be most vulnerable to these hazards with more than USD 390 billion in asset exposure (Figure 10).[27]

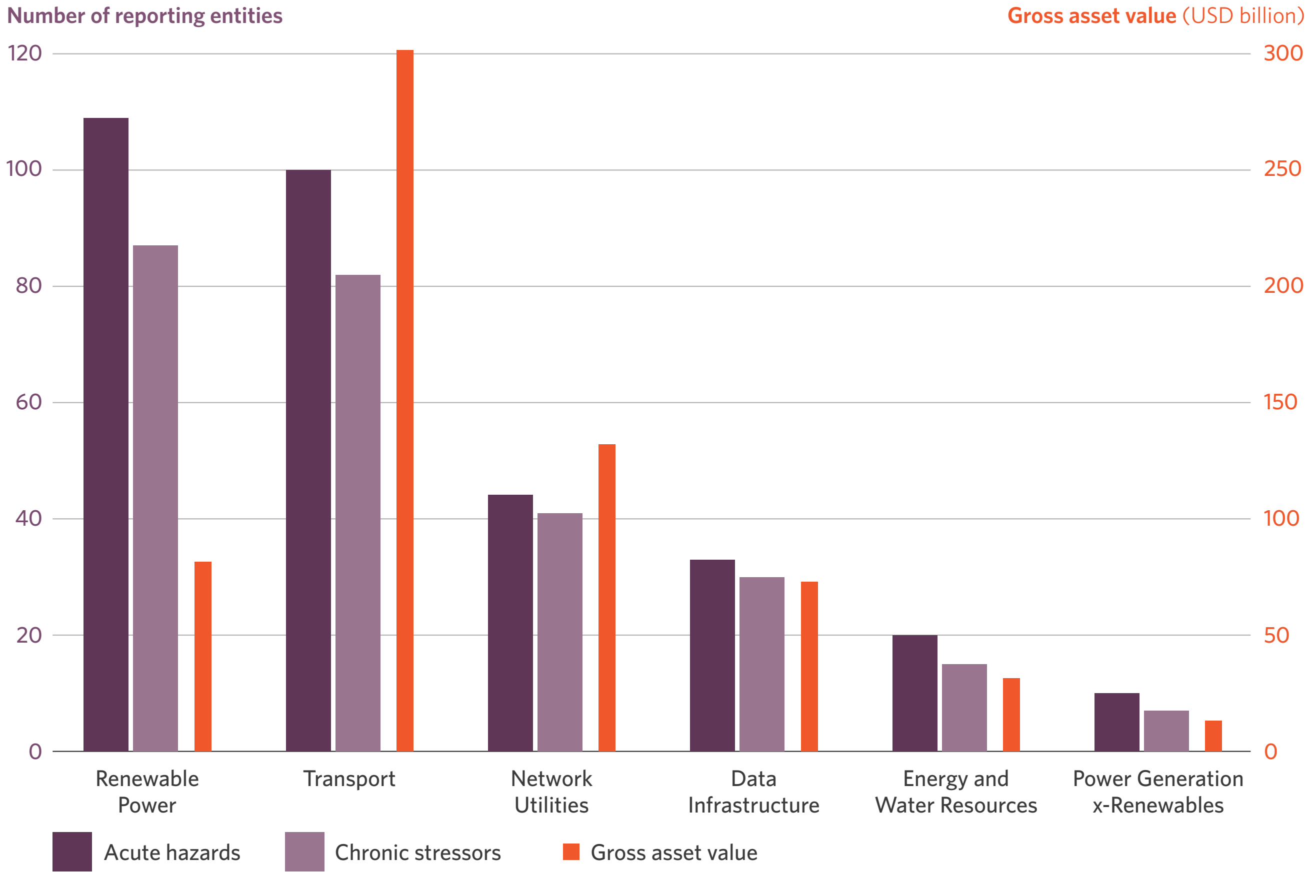
24 Sample TCFD Alignment Report at Asset level 2021

25 We could not access asset-level data for this assessment as per GRESB confidentiality rules.

26 Other acute and chronic stresses infrastructure assets are reported to be exposed to are: Storm surge, Heat stress, Rising mean temperatures, Precipitation stress, Drought stress, Fire, weather stress, Extratropical storm, Rising sea levels, Hail, Tropical cyclone

27 GRESB uses the Infrastructure Company Classification Standard (TICCS for sectoral classification

Figure 10: Infrastructure entities reporting across sectors with material financial impact of physical climate risks (GRESB, 2022)



Overall, the guidance on physical risk assessments is fast increasing in the financial sector. In 2021, TCFD, UNEP FI, and GCA issued a joint statement encouraging financial institutions to adopt physical climate scenario analysis-based climate risk assessment. Publishing such disclosures will enhance climate resilience through the financial sector and into the wider economy (UNEP FI, 2021) UNEP FI prepared a comprehensive overview of climate risk assessment methodologies in 2021. EBRD and GCA also prepared a guidance on physical climate risks and opportunities aligned with TCFD disclosures (EBRD & GCA, 2021).

Climate-related disclosure standards are yet to integrate the double materiality aspects of physical climate risks which assess the projects' impacts on systemic and societal resilience.

There are three new proposals which are shaping the narrative of climate-related disclosure standards for private entities in 2022 namely The U.S. Securities and Exchange Commission's (SEC) proposed rule for "The Enhancement and Standardization of Climate-Related Disclosures for Investors", ISSB's Exposure Draft IFRS S2 Climate-related Disclosures and the Corporate Sustainability Reporting Directive (CSRD) adopted by the EU parliament in November 2022.

All three disclosure standards have significant commonalities in that they build upon the four key thematic areas of the TCFD recommendation reducing the burden on reporting entities. The standards have great benefits of enhanced understanding of companies and investors to collect and manage physical climate risks related data using climate scenario models. More efforts are needed to improve disclosures through granular metrics on physical climate risks for different hazard types, locations, and investment metrics for financial impacts on enterprise value (IIGCC, 2022).

However, one of the biggest divergence is in the approaches for physical risk management, specifically impact or double materiality aspect, which promotes that climate risks and opportunities for companies and financial institutions can be material from both financial and non-financial or impact perspective.[28] Currently only the EU CSRD directive incorporates the double materiality of climate risks into the disclosure framework as obligation for organizations to report their climate impacts on the society and environment in addition to their exposure to climate risks.

This comparative analysis suggests that even though these new disclosure standards will reduce information asymmetry on resilience principles 1 and 2 in this study on how the entities identify and manage physical climate risks, some information needs will remain unaddressed especially on resilience principles 3, 4, and 5 on improvements on project impacts, capacity to build systemic climate resilience and monitoring impacts over time. The future iterations of the climate-related disclosure frameworks need to integrate the double materiality aspects which can lead to more consistent and compatible understanding of impacts of physical climate risks among the public and private infrastructure investors and entities.

28 Double materiality concept acknowledges the fact that risks and opportunities for companies and financial institutions can be material from both a financial and non-financial or impact perspective. Double materiality recognizes that companies and financial institutions must manage the impacts of climate change on their own operations but and take responsibility for the adverse impacts of their investment's decisions on people, society and the environment. (Deloitte, 2022)

5. DATA DISCLOSURE AND TRANSPARENCY ISSUES

Publicly available information on how infrastructure projects align with the resilience principles and how much investments went into those projects is key to the methodology outlined in this study. Some of this data CPI was able to collect or estimate. However, data coverage varies significantly across different public and private infrastructure databases due to the lack of consistent and transparent data disclosures. Therefore, significant gaps persisted, which hinder the breadth and quality of the findings of this study. They are outlined below.

Poor reporting on material physical risks: Identifying and addressing material physical risks is fundamental to building CRI projects. In the public sector, for MDBs and members of IDFC, this is implicit in the process-based approach recommended by the Common principles for Adaptation Finance Tracking which suggests that all adaptation projects should clearly set out the climate risks and vulnerabilities specific to the projects. However, there is no reporting of which physical climate risks were identified and addressed at project-level by these public financial actors. No precise geographical location of infrastructure investments is reported in the OECD-CRS system or in CPI's primary surveys to enable CPI to conduct this analysis. In contrast, in the private sector, infrastructure investors are starting to report on how they are integrating physical climate modelling for building resilience strategies and which physical risks have material financial impacts (see section 4.3), albeit to a limited degree. Moreover, many infrastructure developers and investors don't have a common understanding of specific material climate risks relevant to each sector.

Lack of common taxonomy of CRI solutions: Lack of guidance on standard list of CRI solutions at sectoral or country level makes it challenging for this study to assess if the projects are climate resilient. In the absence of such guidance, this study required creating its own list of CRI solutions. In the private sector, actors often do not tag solutions as adaptation or resilience even when the projects are incorporating these considerations, in the absence of common definitions and methodologies. This underscores the need for standardization.

Lack of data on project results: Different organizations use different output and/or outcome metrics to assess the performance of the projects they develop and invest in. The project descriptions provided by public financiers in the OECD-CRS system or in CPI's primary surveys do not explicitly mention how the projects results are improved to withstand the impacts of climate change. Lack of access to both ex-ante and ex-post measurement of project performance at asset-level prevents a thorough assessment. In the private sector, some of the databases like Desal Data by GWI reported on some impact metrics like population served. A closer examination of the GRESB ESG performance indicators suggests that they are focused on some output-related indicators such as use and efficiency of energy, water, and waste, in addition to GHG emissions and certifications at the asset level, but no results-based resilience-related indicators are currently being assessed (Box 2). Therefore, the alignment of infrastructure projects with resilience principle 3 could not be assessed at this stage.

Box 2: ESG Performance Indicators in GRESB Assessment of Infrastructure Assets

- Implementation of environmental actions
- Energy use over time
- Greenhouse gas emissions over time
- Water use over time
- Biodiversity & habitat
- Health & Safety
- Infrastructure certifications and awards

Source: *Adapted from "2022 GRESB Infrastructure Reference Guide"*

The wider universe of infrastructure investments is difficult to track: Given data availability, the scope of this study was limited to measuring financial flows towards CRI projects reported in the most relevant databases that are publicly available. However, there are various other ways in which infrastructure investments are made resilient. For example, through domestic budgetary allocations on development projects, implementation of technical standards and codes, expenditure on research and development, public and private partnerships etc. Few countries have common or harmonized public accounting standards, and the relevant infrastructure expenditure items are often mixed in with other types of expenditures. Confidentiality issues and lack of incentive to reporting hinder access to information on private investments in infrastructure at the asset level.

6. CONCLUSION AND RECOMMENDATIONS

Mainstreaming climate resilience into existing and new infrastructure will be critical to our wellbeing and economic development as extreme climate events increase in frequency and intensity. While incremental investments in specific adaptation solutions remains important, only by mainstreaming climate resilience in all critical infrastructure now can we prevent the socio-economic losses that will otherwise be realized in coming years.

Through our analysis we conclude that climate resilient investing is still in its nascent stages and only a fraction of new infrastructure is actively integrating the climate resilience principles. This is problematic as global infrastructure investment needs are counted in the trillions and there is an immediate need to build resilience into all infrastructure investment decisions. However, today, there is no common standard and limited data reporting, thus, no concerted effort nor concrete roadmap to track progress.

We found that the information regarding climate resilient investments available to, and disclosed by, different infrastructure databases in the public and private sector varies significantly. This stems from the underlying knowledge gaps and competing priorities in terms of operationalizing the climate resilience principles in infrastructure assets and investments. Public and private actors use diverse set of principles, standards and metrics in assessing resilience of infrastructure. These approaches need to be actively harmonized and complementarity needs to be improved for better uptake and scaling up of CRI investments.

The Paris Agreement requires that all financial flows be made consistent with a climate resilience development pathway. This means all new infrastructure investment decisions must account for resilient development pathways. Various stakeholders across the infrastructure lifecycle must be mobilized to overcome these knowledge gaps, data barriers, and methodological challenges to improve future tracking exercise. Our overarching recommendations for all stakeholders are:

1. Collectively agree upon common, comparable, and credible climate resilience principles which are applicable to both public and private infrastructure investors.
2. Enable and incentivize alignment of investments to the agreed climate resilience principles by setting standards, metrics, targets and encouraging transparent disclosures.
3. Make investments aligned with the agreed climate resilience principles.
4. Monitor and evaluate progress to determine further what reporting is needed to inform better needs assessments for how much more finance is needed to make investments climate resilient.

RECOMMENDATIONS FOR GOVERNMENTS AND REGULATORS

1. **Set appropriate levels of technical standards for CRI and align them with national adaptation plans.** Governments need to set out clear standards for climate resilience of critical infrastructure sectors for infrastructure developers to implement. These standards should also be purposefully designed to cover a variety of climate risks and scenarios; be easy to implement, updated regularly and aligned with national, long-term adaptation and resilience strategies.

   In 2020, the UK's National Infrastructure Commission demonstrated how there are significant gaps in current technical standards for infrastructure resilience across energy, water, transport and communications sectors in the UK. A key recommendation to the UK government was to publish a full set of resilience standards every five years alongside an assessment of where changes are needed to existing structures, regulatory powers and incentives to support the delivery of these standards.

   In March 2022, Government of Ghana, with support from Global Center on Adaptation (GCA) and other partner organizations, created Ghana's resilient infrastructure roadmap by conducting a climate risks assessment of energy, water and transport infrastructure systems and developing targeted adaptation options in the built, natural and enabling environments, including nature-based solutions. More governments with sufficient technical and financial capability can conduct such resilient infrastructure assessments in line with enhanced national adaptation plans. Governments with limited capacity could tailor the analysis to priority climate risks and sectors and operationalize the climate resilience principles accordingly.

   In November 2022, at COP27, the Sharm-El-Sheikh Adaptation Agenda provided a list of 30 aspirational, global adaptation outcomes by 2030. This was aimed to inform adaptation plans and strategies by defining simple, specific, measurable impact indicators which can be delivered by implementing specific high-impact adaptation solutions. Governments can further regionalize, localize and refine these adaptation outcomes and integrate them in national level technical standards for CRI.

2. **Mainstream physical climate risks assessments into government procurement, processes; bidding, operations and forward budgeting and expenditure exercises by 2025:** Once the technical standards for CRI are set and aligned with national adaptation plans, climate resilience should become a primary factor in the prioritization and selection of publicly financed infrastructure projects. Ministries of finance can take a lead in starting the consultations and necessary legislations in this regard by 2023 if and incorporating climate resilience factors into procurement documents when infrastructure projects are tendered for example in projects developed and financed through Public-Private Partnerships (PPP) models.

   The G20 Taskforce on Inclusive, Resilient, and Greener Infrastructure Investment and Financing recently called for G20 governments to establish interoperable sustainability norms for infrastructure planning, investment and maintenance especially in the face of physical climate risks. It recommended that public and private infrastructure investors should not only meet stringent ESG considerations in infrastructure development but move beyond to integrate the emerging paradigm of nature-positive investments as part of larger resilience strategies (G20, 2022). We would underline the crucial role of the G20 given their vast infrastructure spending and their influence and signaling power across many other countries.

3. **Mandate reporting disclosures for companies and investors aligned with existing frameworks and promoting double materiality:** Infrastructure and financial regulators should initiate consistent and harmonized disclosure requirements for critical infrastructure companies and investors, to enable transparency on current and future plans for physical climate risks assessment, aligning with the resilience standards and strategies, and integrating double materiality aspects of physical climate risks.

   Lessons can be learned from the Adaptation Reporting Power (ARP) that was established under the Climate Change Act in the UK to help understand climate risks posed to infrastructure providers. More than 90 organizations from all key infrastructure sectors in the UK reported into the third round of ARP in 2021 on their material physical climate risks using the latest UK climate projects scenarios UKCP18 and a range of adaptation options they are undertaking to address these risks. A number of aspects of the ARP overlap with TCFD yet despite such efforts, there remains limited information on resilient investments within the UK (UK CCC, 2021) and we would recommend making further progress on ensuring physical risk is adequately captured.

   Some efforts are underway to mandate non-financial disclosures. In November 2022, the EU parliament formally adopted the Corporate Sustainability Reporting Directive (CSRD) promoting the principle of double materiality perspective. In April 2022, the UK government mandated certain publicly quoted companies, large private companies and Limited Liability Partnerships (LLPs) to incorporate TCFD aligned climate disclosures into their annual reports. In November 2022, US White House Council on Environmental Quality, under the Federal Supplier Climate Risks and Resilience Rule, also mandated major federal contractors to publicly disclose climate-related financial risks using CDP's disclosure system, a global non-profit that works towards environmental disclosures by private and public actors.

   However, as stated in section 4.3, more disclosure standards need to embrace the double materiality perspective, especially disclosing explicitly how infrastructure investments have an impact on systemic and societal resilience holistically.

RECOMMENDATIONS FOR DEVELOPMENT FINANCIAL INSTITUTIONS (DFIS) TO IMPROVE DISCLOSURES AND EXPAND TECHNICAL ASSISTANCE

1. Work with peers, private sector, standard setters, and regulators to **agree on common language, definition, principles and metrics for climate resilience impacts and investments** for mainstreaming climate resilience in investment decision making. Enable, and demand through reporting and proactive engagement, that intermediaries, clients and suppliers demonstrate tangible progress in mainstreaming climate resilience.

2. **Play the role of a demonstrator** by providing transparent leadership on publicly disclosing information on decision drivers for choice of scenarios and models, trade-offs and opportunity costs of adaptation and resilience investments. The MDBs can share existing knowledge and best practices in mainstreaming climate resilience principles in direct and indirect operations. The DFIs have a unique role to play because of their existing networks

with wider public development bank community, governments and private infrastructure investors that they can draw upon. They can provide technical guidance, enhance disclosures and disseminate information on decision making tools. Demonstration of appropriate pricing of physical climate risks can improve market confidence and steer private investments into adaptation and resilient investments.

3. **Improve reporting of material physical risks within existing portfolios by 2023.** Currently, information on how the MDBs and the IDFC set the physical climate risks in the context of projects and address them is implicit in the methodologies used for investing in adaptation projects such as use of Joint MDB methodology for Adaptation Finance Tracking or OECD Rio Markers for adaptation finance. However, more detailed, granular and transparent disclosure is needed on physical climate risks assessments, in the context of adaptation and general development projects with more sharing of decision-making data tools and guidance. Such climate action is critical for assessing the state of adaptation action and fed into the technical dialogues for the global stock take of the Paris Agreement (GST) due in 2023.

RECOMMENDATIONS FOR PRIVATE FINANCIAL INSTITUTIONS

1. **Integrate climate resilience principles in asset-level investments.** The integration of climate resilience principle in infrastructure assets can have a variety of potential financial benefits such as increased value of assets, reduced lifecycle cost of the assets and improved revenue (GCA, 2021) Additionally, proactive management of physical climate risks will reduce the losses incurred by insurers, the public sector, and communities as a whole. However, this would require going beyond single materiality and integrating the double materiality aspects of assessing how the infrastructure investments have an impact on the systemic and societal resilience holistically.

2. **Move beyond building resilience of governance and strategy at entity level to setting targets for investing in resilience at asset level and disclosing them.** This is applicable especially for investors that already disclosing information as per the TCFD recommendations on material physical climate risks and using physical scenario modelling for building the resilience of entities' strategies and governance structures.

RECOMMENDATIONS FOR DATA AGGREGATORS FOR COLLECTING CONSISTENT, FORWARD LOOKING, DECISION-USEFUL DATA

1. **Create a taxonomy for CRI solutions at the sectoral or country level,** going beyond the process-based, conservative approach for adaptation and resilience investments that private financial institutions can adopt for their analysis of alignment with a clear set of resilience standards, metrics and technical criteria.

   The World Bank Resilience Rating System is one such rating system that provides guidance on developing climate-resilient projects and a way to assess what projects are doing to increase climate resilience. Its adoption is currently in nascent stages, but it is a positive step towards developing a common, easy to use rating system that project developers and investors from both public and private sector can adopt to select the best resilience practices. However, moving beyond a rating system to create a taxonomy of CRI solutions based on scientific and dynamic principles would be beneficial to scale up private investments.

2. **Move beyond conventional ESG metrics:** Today's mainstream ESG and market research data practices are confined by publicly available or self-disclosed data from infrastructure providers which leads to significant data gaps. The 2022 survey by The Global Adaptation & Resilience Investment Working Group suggested that only 13% of investor prioritize ESG metrics alone while 57% consider ESG metrics and climate risk metrics both equally important. ESG data aggregators should build foundations for such multi-layered data collection.

3. **Focus on standardized geospatial data for assets and climate risks:** One of the key challenges for investing in adaptation and resilience is that the physical climate risks are context and location specific which need granular geospatial data on assets and climate risks. The UK Centre for Greening Finance and Investment (CGFI) is pioneering the use of climate data and analytics for mainstreaming adaptation in green investments. Global Resilience Index Initiative (GRII) is a first attempt towards an open, globally consistent physical climate-risk and resilience data and information architecture at the asset and sub-national level. It aims to integrate resilience metrics for infrastructure investments following the work of the Oxford Program for Sustainable Infrastructure Systems. The Spatial Finance Initiative is also bringing together multidisciplinary research capabilities for creating open asset-level datasets which can be used for financial institutions to manage climate risks and analysis.

RECOMMENDATIONS FOR MULTI-INDUSTRY COALITIONS FOR COORDINATED, TRANSFORMATIVE ACTION

1. **Establish a common approach to CRI investments:** More than 200 codes, guidance, standards, rating systems, both voluntary and mandatory, are available worldwide for infrastructure project developers to build and maintain. Developing a common approach is essential for informed decision making and driving investments in CRI investments. The common approach needs to work at the intersection of net zero, just, low carbon transition and climate resilient development.

   Some initiatives are already taking shape in this direction. The Sustainable Infrastructure Label from the FAST-Infra Group (Finance to Accelerate the Sustainable Transition-Infrastructure) is an effort to create standardized, transparent disclosure and reporting systems for sustainable infrastructure while building upon already existing standards and guidelines in the market. The adaptation and resilience dimensions evaluate risks and assesses the ability of the projects for building resilience and adaptive capacity at the project and system level.

   The Institutional Investors Group on Climate Change represents one of the largest investor communities, with more than 350 asset owners and managers as members and more than USD 60 trillion assets under management. In September 2022, IIGCC published the first discussion paper on Climate Resilience Investment Framework with a range of key drivers and indicators which can support investors in managing the physical climate risks in their portfolios. The IIGCC collaborated with various industry stakeholders to make sure that a variety of perspectives are incorporated and tested before the release of the framework.

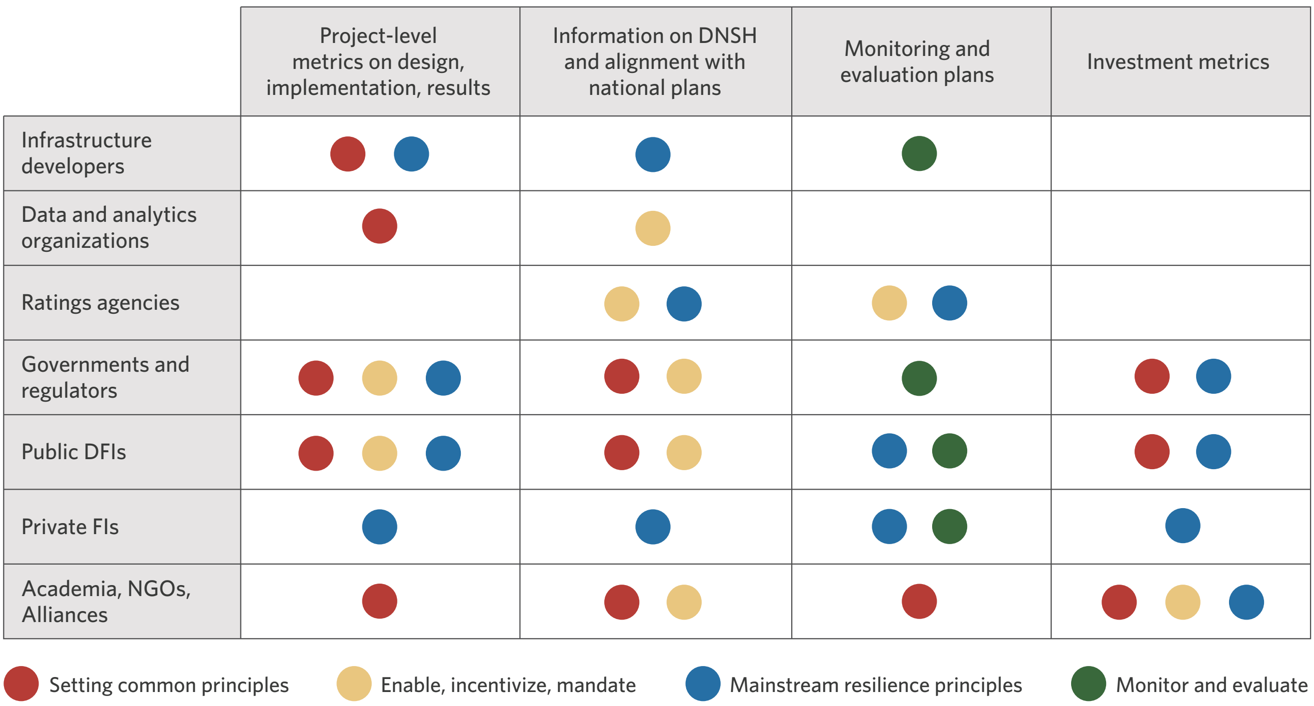
2. **Facilitate multi-stakeholder collaboration** to overcome the barrier of uncoordinated and fragmented efforts from various actors in the infrastructure investments industry and making the data available and accessible for everyone. Setting up new governance processes are often expensive and time consuming. Therefore, the umbrella of existing coalitions can be leveraged to facilitate the data collection and aggregation process on key resilience and investment metrics.

   The Coalition for Disaster Resilient Infrastructure (CDRI) is a partnership of national governments, UN agencies and programs, multilateral development banks and financing mechanisms, the private sector, and knowledge institutions. It has recently commissioned several projects that aim to promote climate and disaster risk assessment and resilience building of new and existing infrastructure systems in its member countries and in energy, transport and telecommunications sectors.

   Coalition for Climate Resilient Investment (CCRI) is also spearheading this effort in the private sector. It recently launched a tool, Physical Climate Risk Assessment Methodology (PCRAM), a global practitioner's guide that supplies the practical tools to identify and assess the resilience of infrastructure assets, portfolios and communities from the onset and throughout the project lifecycle (CCRI, 2022).

   More of these collaborations are crucial to overcome the data challenges of tracking CRI investments and measuring progress towards the resilience goals of the Paris Agreement. Figure 11 captures a panoptic view of multistakeholder engagement in addressing the data challenges identified in this study and making progress on the recommendations in a holistic way.

Figure 11: Multi-stakeholder Engagement for Addressing Key Data Gaps



7. ANNEX

ANNEX 1: DEFINITIONS OF CRITICAL INFRASTRUCTURE

There is no universally accepted definition for what constitutes or is included in 'critical infrastructure'. Sendai Framework for Disaster Risk Reduction is a leading framework which has a focus on 'critical infrastructure' and has presented a list of sectors as critical infrastructure including water, transportation and telecommunications infrastructure, educational facilities, hospitals and other health facilities. However, it doesn't prescribe common definition and recommends national governments to decide what is more appropriate in the national contexts (UNDRR, 2020).

Recently countries like the US and Romania added 'food and agriculture' sector in the list of Critical National Infrastructure sectors because of its interdependency on other sectors and high vulnerability to natural hazards.[29,30] Mainstreaming climate resilience into the agriculture infrastructure that is critical to agriculture production and processing such as soil, land, crops besides farm buildings, processing and storage units, markets etc. is critical to maintaining system-wide food security in the face of intensified climate risks like droughts and floods.[31] As the scope of critical infrastructure expands, it includes green and blue infrastructure under the umbrella of nature-based solutions (NBS) or natural infrastructure. It also being recognized that non-structural measures such as for example, policies, strategies, plans and governance to enhance the enabling environment are key to ensuring the development of resilient infrastructure.

29 https://www.fda.gov/food/food-defense-initiatives/food-and-agriculture-sector-and-other-related-activities#:~:text=The%20Food%20and%20Agriculture%20(FA,security%2C%20national%20economic%20security%2C%20national

30 https://www.fao.org/faolex/results/details/en/c/LEX-FAOC197075/

31 https://www.mdpi.com/journal/infrastructures/special_issues/agri_infra

Table A1 gives an overview of the definitions used by different global organizations and some national governments for critical infrastructure.

Table A1: Summary of Definitions of Critical Infrastructure

Source	Definition
Resilience Shift (2021) Governance of Infrastructure Resilience	The systems, facilities and assets that deliver essential functions and services (i.e., provide, protect or connect) to our society and communities, the loss or compromise of which would result in major detrimental impact on the availability, delivery or integrity of essential services, leading to severe economic or social consequences, loss of life or an irreversible change in the nature of the physical environment, including climate, hydrology, and soils.
Terminology on Disaster Risk Reduction by UNDRR, 2009	The primary physical structures, technical facilities and systems which are socially, economically or operationally essential to the functioning of a society or community, both in routine circumstances and in the extreme circumstances of an emergency.
Making Critical Infrastructure Resilient: Ensuring Continuity of Service - Policy and Regulations in Europe and Central Asia by UNDRR, 2020	Even though definitions might vary, there is a prevailing understanding among nations and organizations that critical infrastructure constitutes both physical elements (facilities, equipment, networks) and vital services (health care, safety, etc.), and that the disruption of these elements and services would pose a serious risk to the normal functioning of society and the State.
Climate-Resilient Infrastructure Officer Handbook," Global Center on Adaptation, Rotterdam, 2021	Infrastructure directly provides essential services, such as water and energy, to individuals and businesses. It also connects us to key services, such as healthcare and education, and enables us to participate in social and economic activity, by facilitating travel to work or cultural spaces. Infrastructure also protects people from climate-related hazards and helps them respond more effectively during and after crises.

ANNEX 2: CLIMATE IMPACTS ON INFRASTRUCTURE

Table A2: Overview of Impacts of Floods and Droughts on Infrastructure

Sector	Increased patterns of precipitation (floods, storms)	Decreased patterns of precipitation (droughts)
Water	• More risk of overtopping river embankments • Asset damage or failure leading to outage or unplanned closures • Risks to health and safety of staff • Increased costs for repair and maintenance • Changes in quantity and quality of watershed runoff	• Loss of water pressure and water supply • Poor water quality from the source that may require additional treatment to meet drinking water standards • Inability to access alternative and supplementary water sources because of high demand by and competition from other users • Increased customer demand • Increased costs and reduced revenues related to responding to drought impacts.
Wastewater	• Overwhelming drainage systems • Increased probability of sewer flooding/overflows/ spills	• Decrease in effluent quality and flows can damage infrastructure and reduce the effectiveness of existing treatment processes
Roads	• Damage to roadbeds for unpaved roads • Increased likelihood of road accidents • Scour damage to bridges and elevated highways • Increased costs of repair • Loss of connectivity	• Increased dustiness/sandiness of roads leading to reduced friction and visibility • Softening of bitumen roads and buckling
Railways	• Structural damage to railway track, stations and substations • Equipment damage in substations or of emergency generators, expanded train tracks and buckling	
Waterways	• Damage to port's breakwater due to overtopping • Damage to interior areas of port and equipment	• Low water levels in on-land waterways (e.g. canals)
Electricity generation	• Structural damage to hydropower and nuclear plants • Damage to electrical components and equipment, such as power or cooling • Disruption due to power outages	• Lack of water can cause services disruptions for hydropower plants, coal power plans and nuclear plants, as water is needed for cooling
Transmission and distribution	• Substations are their equipment are prone to flood damage • Diesel generators prone to flood damage • Weak distribution structures, such as wooden posts, can be undermined by scour damage or damaged in flash floods	

Source: *(GCA, 2021)*

ANNEX 3: SUMMARY OF ADAPTATION FINANCE REPORTING APPROACHES BY PUBLIC SECTOR

MDBs: When CPI collects data through its primary surveys, the MDBs report on their adaptation projects using the 'incremental cost of adaptation' approach as recommended in the conservative approach of Common Principles of Adaptation Finance Tracking. The MDBs only report on the share of the total cost of the project that is dedicated to adaptation solutions which makes sense to avoid any overreporting of adaptation finance. This can be corroborated by the MDBs disclosure of their climate-related development finance through the OECD -CRS database where they share only the climate components of the total cost of the project as climate finance. The database also reports on the share of adaptation finance as a percentage of the total underlying commitment of the project. We refer to this share as a resilience coefficient.

IDFC: In principle, the IDFC group of DFIs also follow the conservative approach of Common Principles of Adaptation Finance Tracking. However, many IDFC members report only aggregate data on climate finance at the regional or sectoral level. In the absence of project-level data and ways to corroborate their reporting through the OECD-CRS system, we assume that the IDFC group of DFIs report the total cost of the project as adaptation finance. We fully acknowledge the shortcomings of this assumption as the capacity of the IDFC members to report the incremental cost of adaptation varies and some members are more advanced in their reporting than others. However, CPI prefers to take a conservative approach in this matter, given the data limitations.

National governments: National government (29 DAC members, 3 non-DAC members) report their climate -related development finance through the OECD -CRS system. The system's reporting approach for adaptation finance is based on using the objective or purpose of the activity and drawing on Rio markers definitions and eligibility criteria. However, for 2019/20, several of these institutions also reported the total cost of the project as their adaptation finance, as reported by the OECD-CRS system.

ANNEX 4: TAXONOMY OF CRI SOLUTIONS AND TRACKED INVESTMENTS

The taxonomy presented below indicates the categories, sectors, sub-sectors, categories and solutions into which adaptation projects fit. This taxonomy builds upon the Global Landscape of Climate Finance sectoral tracking system and other relevant literature. This list of solutions and their tagging to the typology of climate risks, infrastructure and interventions is not based on scientific or technical criteria and does not aim to be comprehensive. In the absence of a universal taxonomy, it represents the team's best effort to list and tag CRI projects given the data and information challenges.

Table A4: Taxonomy of CRI solutions and tracked investments in 2019/20

Sector	Sub-sector	CRI solutions category	CRI Solutions	CRI Investments USD mn	Primary climate hazard	Type of Infrastructure	Type of Intervention	Examples of keywords
Water and Wastewater	Water	Water treatment and supply	• Construction of water treatment plant • Construction of water distribution networks	7,163.5	Drought	Grey	Hard	Clean potable drinking, piped
		Desalination and other drought activities	• Desalination plant construction • Water reuse • Boreholes and tube wells • Construction and expansion of reservoirs	2,001	Drought	Grey	Hard	Borehole, tube well, reservoir, dam, desalination, reuse
		Increased efficiency of water supply and use	• Repair/Maintenance /Upgrade of water treatment plants and distribution systems • Leakage management, detection, and repair of pipes • Increased use of water efficient fixtures and appliances • Renewable energy activities for water treatment	178.5	Drought	Grey	Hard	Modernization, rehabilitation, reconstruction, efficiency, leakage, metering
		Planning and strategic solution	• Water Safety and Continuity Plans • Climate and Natural Hazard Risk Assessments	897	Drought, Flood	Grey	Soft	Continuity, safety, risk, plan
		Water collection and storage	• Rainwater harvesting • Water storage • Reinforcement of river basins	763	Drought	Grey	Hard	Rainwater, supply,
		Floodproofing	• Dykes and berms • Flood monitoring and alerting systems	16.2	Flood	Grey	Hard	Prevention, preparedness
		Integrated watershed management	• Water retention and groundwater management • Upland conservation • Swamp access works	224	Drought, Flood	Green	Hard	Groundwater management

Sector	Sub-sector	CRI solutions category	CRI Solutions	CRI Investments USD mn	Primary climate hazard	Type of Infrastructure	Type of Intervention	Examples of keywords
Water and Wastewater	Wastewater	Wastewater collection and treatment	• Wastewater plant construction • Wastewater collection infrastructure • Reuse of sludge and anaerobic digestion of biowaste	1,860	Drought	Grey	Hard	Wastewater treatment, collection, sludge
		Sustainable drainage systems	• Sewer repair and maintenance • Rainwater harvesting from roofs and green roofs • Stormwater retention and detention systems • Permeable pavements • Stormwater runoff management through activities such as bioswale and soak ways	41	Flood	Grey	Hard	Sewer, drain, repair, maintenance, retention, permeable pavement
Transport	Highway and Roadway	Flood proofing	• Better drainage systems for highways and roads • Elevation of low-lying roads • Reinforcement of columns of bridges and elevated highways to prevent scour • Enhanced foundations and paving rural roads with gravel to prevent washing away	993	Flood	Grey	Hard	Flood barrier ; culverts, elevation
		Repair, maintenance and upgrade	• Regular/planned maintenance of road surfaces	627	Flood	Grey	Hard	Repair, maintenance
	Rail and Public Transport	Flood management activities	• Flood walls and barriers • Waterproofing and elevation of equipment in substations • Reinforcement of slopes and embankments around railways • Upgrading of drainage around the track	726	Flood	Grey	Hard	Flood walls, dykes, waterproofing
		Repair, maintenance and upgrade	• Regular/planned maintenance of track, ballast and rolling stock	96	Flood	Grey	Hard	Repair, maintenance

Sector	Sub-sector	CRI solutions category	CRI Solutions	CRI Investments USD mn	Primary climate hazard	Type of Infrastructure	Type of Intervention	Examples of keywords
Transport	Waterways	Port and waterway flood management activities	• Construction/enlargement of breakwater • Reinforcement to canal liners, floodgates and freeboard	102	Flood	Grey	Hard	Repair, maintenance
	Cross-cutting	Policy support and capacity building	• Technical assistance, climate risk assessments and monitoring	285	Flood	Unknown		Research; development
Energy Systems	Energy Generation	Climate resilience of new renewable electricity generation	• Construction of flood barriers/walls and dikes • Increased dam capacity and better spillway design for hydropower plants • Climate Risk Assessments • Policy/Regulatory support for mainstreaming climate resilience is energy planning	504	Flood	Grey	Hard	Energy, electricity disaster, flood
	Transmission and Distribution	Operation of transmission and distribution systems	• Flood barriers for substations • Elevation and waterproofing equipment in substations • Reinforcement of distribution poles	422	Flood	Grey	Hard	Resilience distribution; transmission
Agriculture, Forestry and Other Land Use	Agriculture	Agriculture infrastructure	• Food processing and storage facilities • Agricultural roads and transport • Access to markets • Supply chain management (commercialization, primary processing & storage)	1,755	Flood, Drought	Green	Hard	Roads, markets, fam facilities, supply chain, processing, storage
		Water management	• Increased water availability and efficient use through water harvesting and irrigation technologies	688	Drought	Green	Hard	Irrigation
		Policy and Capacity building	• Technical assistance • Farmer training	382	Flood, Drought	Green	Soft	Capacity, training, skills, logistics, preparation

Sector	Sub-sector	CRI solutions category	CRI Solutions	CRI Investments USD mn	Primary climate hazard	Type of Infrastructure	Type of Intervention	Examples of keywords
Agriculture, Forestry and Other Land Use	Agriculture	Risk management services	• Agriculture climate data, information and knowledge exchange • Agriculture risk forecast and monitoring services	148	Flood, Drought	Green	Soft	Risk, knowledge services
		Crop diversification	• Diversification of species and ecotypes • Use of species less susceptible to drought and floods	137	Flood, Drought	Green	Hard	Diversification; species
		Soil health and land management	• Water and drainage basins • Enhancement of soil retention through use of manure and organic fertilizer, tillage • Slow forming terraces and agroforestry	106	Drought	Green	Hard	Vertical farming; controlled agriculture
		Pest control	• Use of integrated pest control and nutrient management	10	Flood, Drought	Green	Hard	Pests, nutrient
	Livestock Adaptation		• Diversification of livestock • Modification of diets, changing feeding times and frequency • Improved vaccines and nutrition for disease tolerance	784	Drought	Green	Hard	Fodder crops, rangeland management
	Fisheries	Sustainable fish production	• Supply chain management (commercialization, primary processing & storage)	261	Drought	Blue	Hard	Aquaculture
	Forestry	Afforestation, reforestation, forest conservation	• Sustainable management of existing forest, including extraction of non-timber products • Supply chain management (commercialization, primary processing & storage)	546	Drought	Green	Hard	Wildfire control, regeneration, firewood, pulpwood

Sector	Sub-sector	CRI solutions category	CRI Solutions	CRI Investments USD mn	Primary climate hazard	Type of Infrastructure	Type of Intervention	Examples of keywords
Agriculture, Forestry and Other Land Use	Other Land Use	Nature based activities	• Coastal Zone Management- Additional or improvements in coastal and riverine infrastructures (including built flood protection infrastructure) in response to increased flood risks • Provision of sand dams • Mangrove planting to build natural barriers to adapt to increased coastal erosion and to limit saltwater intrusion into soils caused by sea level rise • Rehabilitating coral reefs, seagrass areas, wetlands • Other ecosystem-based activities	1,121	Flood, Drought	Green	Hard	Coastal flooding; sea level, mangrove; natural barrier; coastal erosion; saltwater intrusion, coral reef; seagrass
		Urban farming and green space	• Urban green spaces, farms, corridors and gardens	2.5	Drought	Green	Hard	Green farms, roofs corridors
Other and Cross-sectoral	Cross Cutting		• Financial Services (insurance)	353	Flood, Drought	Unknown	Soft	Infrastructure insurance
		Disaster Risk Management	• Emergency Response • Social Security and other financial services • Early Warning Systems • Cross-sectoral Policy and Capacity Support • Cross-sectoral Climate Resilient Infrastructure	8,026	Flood, Drought	Unknown	Unknown	Risk, knowledge services, solutions, forecast, radar

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