Sectoral Guide Consultation Version 1

Climate information & early warning systems

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Contents

Abbreviations

AE	Accredited entity
AED	Annual expected damage
AF	Adaptation Fund
CIEWS	Climate information and early warning systems
CREWS	Climate risk and early warning systems
CIS	Climate information services
CAP	Common Alerting Protocol
DRR	Disaster risk reduction
EWS	Early warning services
FbA	Forecast-based action
GBON	Global Basic Observing Network
GCF	Green Climate Fund
GEF	Global Environment Facility
GFCS	Global Framework for Climate Services
IB-MHEWS	Impact-based multi-hazard early warning systems
ICT	Information and communications technology
IoT	Internet of Things
LDC	least developed country
MSMEs	Micro, small and medium-sized enterprises
MHEWS	Multi-hazard early warning systems
NAP	National Adaptation Plan
NAPA	National Adaptation Programme of Action
NDA	National Designated Authorities
NDC	Nationally Determined Contribution to the Paris Agreement
NFCS	National Framework for Climate Services
NFW	Non-financial wealth
NMHS	National Meteorological and Hydrological Service
RCOF	Regional Climate Outlook Forum
SDGs	Sustainable Development Goals
SOFF	Systematic Observations Financing Facility
SIDS	Small island developing states
ToC	Theory of Change
UNFCCC	United Nations Framework Convention on Climate Change

Executive summary

The Green Climate Fund (GCF) is the world's largest dedicated fund helping developing countries respond to climate change. It was established by the United Nations Framework Convention on Climate Change (UNFCCC) in 2010 and has a crucial role in supporting the developing countries in achieving their commitments and ambitions toward meeting the goals of the Paris Agreement. GCF is dedicated to boosting climate finance for developing countries and has set an ambitious agenda with its Strategic Plan for 2020-2023. Despite the global pandemic, GCF is providing increased support, helping developing countries build a low emission, climate-resilient recovery. The GCF Sectoral Guide series supports the progressive work programme approved for 2020-2023, providing evidence-based information for impactful projects in priority investment areas and giving further momentum to making GCF operations more efficient and effective.

There are eight result areas that GCF has targeted because of their potential to deliver a substantial impact on mitigation and adaptation in response to climate change. Result areas provide the reference points that guide GCF and its stakeholders to ensure a strategic approach when developing programmes and projects while respecting the needs and priorities of individual countries. The Climate Information and Early Warning Services (CIEWS) result area inter-relates with climate change actions in other sectors, and these cross-sectoral issues are addressed through multiple result areas in a complementary manner, as shown by the examples in Table ES-1.

Table ES-1: Cross-references with other Sectoral Guides

Sectoral Guide	Cross-Sectoral issues addressed
Climate information and early warning systems	• Strengthening hydromet monitoring, development of climate Information services/climate advisories and impact-based multi-hazard early warning systems, and application of CIEWS for investment and financial decisions to manage climate risks.
Agriculture and food security	• Climate advisories for agricultural production and projections for longer term planning.
Cities, buildings, and urban systems	• Urban disaster risk reduction and management informed by CIEWS (integrated urban CIEWS services). • Climate information for climate-resilient infrastructure design.
Ecosystems and ecosystem services	• Use of CIEWS for forestry, land use/land cover change, fisheries, marine, and related natural systems.
Forest and land use	• CIEWS used to reduce risk of climate extremes (forest fires in dry and hot periods).
Energy access and power generation	• Use of climate advisories for multi-purpose dam, solar, and wind energy operations and climate projections for longer term planning.
Health and wellbeing	• Direct impact of climate-related disasters, avoided via preparedness and early warning systems. • Reduced adverse health impacts from malnutrition, exposure to pollutants, heatwave, lack of access to water and the environmental and public health.
Water security	• Use of CIEWS for integrated water resources management and investment planning. • Climate information for the design of water systems infrastructure.
Low emission transport	• CIEWS use for efficient transport and logistics planning. • Climate information for transport systems design.
Energy efficiency	• Use of climate advisories to optimise energy efficiency (demand and supply analysis). • Climate information systems especially coupled with IOT (Internet of Things) would provide the measurement and verification data which is the cornerstone of Energy Service Company (ESCO) contracts.

GCF Climate information and early warning systems Sectoral Guide

Between 1970 and 2019, 79% of disasters worldwide involved weather, water, and climate-related hazards. These disasters accounted for 56% of deaths and 75% of reported economic losses associated with natural hazard events. The intensity and frequency of climate-related disasters are projected to increase as climate change intensifies, thus presenting a significant risk to achieving the UNFCCC and its Paris Agreement and Sustainable Development Goals (SDGs). Transformation is driving investment in reliable climate information services (CIS) and impact-based multi-hazard early warning systems (MHEWS) to support well-informed, science-based decision-making. Paradigm shift can be achieved through adaptation and mitigation approaches that invest systematically in the value chain of CIS, MHEWS, and effective fast response capability. Without international support, it can be challenging for developing countries to establish and operate the fit-for-purpose hydrological and meteorological (hydromet) services required to achieve this.

Paradigm shifting pathways

(1) Pathway 1: Strengthening climate information services – generating relevant, science-based information to guide how governments assess policies, institutions, and investments to build resilience not only at the level of individual projects but system wide. This information will feed into integrated planning tools such as National Determined Contributions (NDCs), National Adaptation Plans (NAPs) and long-term strategies. Robust climate services can be made widely available through modernising hydromet services with a focus on technical capacity development and institutional effectiveness. This will establish the five components of the Global Framework for Climate Services (user interface platform; climate services information system; observations and monitoring; research, modelling, and prediction; and capacity development).

(2) Pathway 2: Promoting impact-based MHEWS and early action – *making robust early warning and early action services widely available*. The establishment of people-centred, end-to-end, and impact-based MHEWS can save lives, protect livelihoods and development gains, and manage climate-related risks more effectively. Support will target disaster risk knowledge; detecting, monitoring, analysing, and forecasting hazards and possible consequences; warning /advisory communication and dissemination; preparedness and response capability; and effective coordination mechanisms. It will also promote and support anticipatory action with a specific focus on building the resilience of the most vulnerable communities.

(3) Pathway 3: Improving CIEWS for investment and financial decisions – *climate information supporting systemic resilience frameworks, asset design and structuring, and innovative financial solutions.* Improving availability and access of CIEWS data to help increase resilience against climate-induced damages. The development of CIEWS analytics for climate-resilient infrastructure will support consideration of climate shocks (extremes) and stresses across different decision timelines from day-to-day operations and management through to designing and planning for long-term climate change. The development and application of CIEWS analytics for policy and decision-making in adaptation, mitigation, and disaster risk finance and investments constitute a paradigm shift for asset owners across all GCF result areas. It will support the digital economy, weather derivatives and commodities markets, and insurance companies in protecting their investments against medium- to long-term risks. The focus is on strengthening approaches for assessing, avoiding, reducing, and transferring the risks and adverse impact of climate-related disasters, and thus increasing the resilience of assets and vulnerable populations.

Barriers and enablers to achieving paradigm shift

A number of barriers hinder the provision and uptake of CIEWS, including:

(1) **Lack of enabling environment for institutional effectiveness.** Coordination, information, and data sharing are often limited among / between government and non-governmental entities, each of which plays a key role in the CIEWS value chain.

(2) **Lack of coverage and scale for effective service delivery.** The quantity and quality of hard and soft infrastructure are inadequate to ensure delivery and uptake of information.

(3) **Uncoordinated interventions.** The convergence of multiple disharmonious interventions limits the effectiveness of existing support to developing countries. The CIEWS playing field is crowded, often with numerous donor and development agencies funding similar activities in countries.

(4) **Limited governmental finances and budgets.** Constrained salaries and funding for National Meteorological and Hydrological Services limits operating and maintaining equipment.

(5) **Technical complexities of hydromet operations.** Despite the continued advances in global capability, considerable challenges remain for developing countries to build and operate national CIEWS effectively.

(6) **Market barriers to monetising value creation.** The lack of an enabling environment, appropriate policies, incentives, funding, and entrepreneurial culture discourages climate resilient practice.

(7) **Limited quality of climate data and forecasts.** Reliable timely forecasts are essential for making robust financial and investment decisions.

(8) **Achieving sustainable 'last mile' effectiveness.** Even when the CIEWS exist they do not necessarily reach the last mile communities or translate into effective early actions.

Role of GCF in financing paradigm shifting pathways

GCF offers a four-pillared approach to drive implementation of the paradigm shifting pathways at scale: (1) Transformational planning and programming; (2) Catalysing climate innovation; (3) Mobilization of finance at scale; and (4) Coalitions and knowledge to scale up success.

To date, GCF has the biggest portfolio in the modernisation of hydromet services and early warning systems globally, reflecting its mandate to promote a paradigm shift towards low emission and climate-resilient pathways in developing countries. Growth of CIEWS in developed countries is driven by a vibrant private sector (including energy, aviation, large-scale agriculture, and infrastructure resilience). By contrast, very limited growth has been observed in Africa, least developed countries (LDCs), and small island developing states (SIDS). GCF is uniquely placed to unlock the barriers to the CIEWS market in developing countries by supporting governments to de-risk the investment environment and provide the incentives to crowd in private sector investments. A significant and growing component of CIEWS is Information and Communication Technology (ICT) services. GCF will leverage the ICT revolution – increasing efficiency and decreasing cost of acquisition – to transform the CIEWS landscape in developing countries. GCF works with National Designated Authorities (NDAs), Accredited Entities (AEs), and other partners to support financing transformative projects in CIEWS project origination, development, and implementation.

By making investments through the three investment pathways, GCF can support developing countries catalyse a paradigm shift in the CIEWS result area. Table ES-2 shows potential investments in the pathways with respect to each of the four pillars.

Section 5 features case studies that demonstrate how innovative approaches can make the difference in addressing the central elements of a successful paradigm shift in climate information services, impact-based MHEWS and early action, and CIEWS for investment and financial decisions, supporting delivery of benefits through all of the GCF result areas.

GCF investment criteria

Proposals to GCF are assessed based on six GCF Board approved investment criteria:

(1) **Impact potential**: to what extent does the project or programme contribute to the achievement of GCF objectives and result areas?

(2) **Paradigm shift potential**: degree to which the proposed activity can catalyse impact beyond a one-off project or programme investment.

(3) **Sustainable development potential**: how do the actions align with national SDG priorities? What are expected environmental, social, gender, and economic co-benefits? What are the wider benefits and priorities?

(4) **Recipient needs**: vulnerability and financing needs of the beneficiary country and population.

(5) **Country ownership**: beneficiary country ownership of, and capacity to implement, a funded project or programme, policies, climate strategies, and institutions.

(6) **Efficiency and effectiveness**: economic and, if appropriate, financial soundness of the programme or project.

Section 6 provides examples of how these criteria could pertain to the CIEWS paradigm shifting pathways.

Table ES-2: Possible actions for each paradigm shifting pathway following the four pillars of the GCF Strategic Plan

		Actions across the pillars of the GCF Strategic Plan			
Climate Information and EWS		**Transformational planning and programming**	**Catalyzing climate innovation**	**Mobilization of finance at scale**	**Coalitions and knowledge to scale up success**
Paradigm-shifting pathway	**Strengthening climate information services**	• Support establishment of National Framework for Climate Services to strengthen generation and uptake of climate services. • Mainstream CIS in policies and plans across all priority sectors. • Enhance CIS for projects across the 8 result areas, NAPs, NDCs, and national development plans. • National and regional optimisation of investments in hydromet.	• Support establishment of National Framework to operationalise GFCS at scale. • Enhance hydromet service provision, optimising infrastructure through regionalisation and gap-filling. • Introduce new public-private partnership business delivery models. • Build e-infrastructure to reduce cost and enhance efficiency. • Create enabling environment for growth in hydromet services.	• Optimise GCF financial instruments to match needs of beneficiaries. • Use innovative financing solutions (including blended finance). • Enhance resource mobilisation from SOFF, GEF, and AF. • Ring-fence national climate funds and other funding sources for hydromet services. • Scale up government budgetary allocation for hydromet services.	• Establish knowledge platforms for sharing best practices in modernisation of climate services. • Use institutional collaborative platforms to enhance knowledge in CIS, digital technologies and business delivery models. • Identify best practices and lessons learned to strengthen political, policy and governance capacity in hydromet services.
	Promoting impact-based MHEWS and Early Action	• Integrate IB-MHEWS in planning, policy and decision making at all levels. • Enhance mechanisms for strengthening capacity at all stages of IB-MHEWS value chain. • Community engagement in designing and implementing forecast-based action at all levels, including indigenous knowledge. • Project pipeline development. • Develop/update of anticipatory action systems and protocols for prioritized hazards.	• Make fit-for-purpose IB-MHEWS widely available by strengthening capacity. • Enhance community-based MHEWS through capacity building of communities and institutions. • Pilot disaster communications systems using digital technology and other innovative channels. • Enhance mechanisms for delivering and scaling up FbA.	• Introduce innovative financing solutions (including blended finance). • Learn from and replicate successful financing of MHEWS. • Scale FbA through dedicated funds, insurance, market-based mechanisms, and standard resource allocation processes. • Embed FbA in financing and delivery systems at scale, working with private sector and informal non-banking institutions.	• Set up institutional collaborative platforms for climate-informed surveillance systems, assessments, and policies. • Create community knowledge platforms, including marginalised groups. • Use knowledge brokering, knowledge management, monitoring, evaluation and learning, impact evaluation and feedback in IB-MHEWS and FbA. • Identify and select evidence-base for FbA. • Systematically measure effectiveness of national MHEWS.
	Improving CIEWS for investment and financial decisions	• Develop systemic resilience framework. • Strengthen the use of digital technologies for climate investment and financial decisions. • Enhance the use of climate analytics for managing financial risks in public sector markets. • Enhance the use of climate analytics for managing risks in private sector markets. • Develop project pipeline. • Promote CIEWS in climate risk management and decision making under uncertainty for climate proofing adaptation projects, and infrastructure. • Support action to address policy and regulatory barriers to use of information (mainstream climate in design standards), including for green infrastructure.	• Use asset design and structuring. • Promote digital technologies and enabling environment for climate investment and financial decisions. • Establish marketplace for digital technology in climate finance. • Increase use of climate analytics for managing financial risks. • Promote use of CIEWS information and climate risk management and adaptation design upstream of project cycle (country, sector level). • Promote use of CIEWS information in system-based approaches for infrastructure (network resilience).	• Scale up financing of climate analytics and digital technologies. • Employ digital technology start-up funding through crowdsourcing. • Obtain climate analytics start-up funding for managing investment and financial risks in private sector through crowdsourcing • Support innovative finance mechanisms for infrastructure resilience, including blended finance, and risk financing. • Integrate climate risk management in PPPs. • Support private sector and community investment in climate-resilient infrastructure. • Extend existing financing arrangements to enable system-level and adaptation management/ pathway approaches.	• Establish knowledge platforms for sharing best practices in CIEWS for infrastructure climate risk management and adaptation and digital technologies and climate analytics for climate finance and investments. • Establish innovation hub for climate analytics. • Support community infrastructure resilience. • Support knowledge brokering, evaluation and learning for climate resilient infrastructure and digital technologies in climate finance.

1 Introduction

The Green Climate Fund (GCF) is the world's largest dedicated fund helping developing countries reduce their greenhouse gas emissions and enhance their ability to respond to climate change. It was set up by the United Nations Framework Convention on Climate Change in 2010 and has a crucial role in upholding the Paris Agreement, supporting the goal of keeping the average global temperature rise well below 2°C and pursuing efforts to limit the temperature increase to 1.5 °C above pre-industrial levels. It does this by channelling climate finance to developing countries, which have joined other nations in committing to climate action. It has set an ambitious agenda with its Strategic Plan for 2020-2023 (GCF, 2021b). Despite challenges related to the global pandemic, GCF is providing increased support to developing countries, helping them to build a low emission, climate-resilient recovery.

There are eight result areas that GCF has targeted because of their potential to deliver a substantial impact on mitigation and adaptation in response to climate change. Result areas provide the reference points that guide GCF and its stakeholders to ensure a strategic approach when developing programmes and projects, while respecting the needs and priorities of individual countries. CIEWS are highly cost-effective climate change solutions that also support climate change actions in other GCF results areas. These cross-sectoral issues are addressed through multiple result areas in a complementary manner, as shown by the examples in Table 1.

Table 1: Cross-sectoral issues addressed throughout the series

Sectoral Guide	Cross-Sectoral issues addressed
Climate information and early warning systems	• Strengthening hydromet monitoring, development of climate Information services and impact-based multi-hazard early warning systems, and application of CIEWS for investment and financial decisions to manage climate risks.
Agriculture and food security	• Climate advisories for agricultural production and projections for longer term planning.
Cities, buildings, and urban systems	• Urban disaster risk management informed by CIEWS (integrated urban CIEWS services). • Climate information for climate-resilient infrastructure design.
Ecosystems and ecosystem services	• Use of CIEWS for forestry, land use/land cover change, fisheries, marine, and related natural systems.
Forest and land use	• CIEWS used to reduce risk of climate extremes (forest fires in dry and hot periods).
Energy access and power generation	• Use of climate advisories for multi-purpose dam, solar, and wind energy operations and climate projections for longer term planning.
Health and wellbeing	• Direct impact of climate-related disasters, avoided via preparedness and early warning systems. • Reduced adverse health impacts from malnutrition, exposure to pollutants, heatwave, lack of access to water and the environmental and public health.
Water security	• Use of CIEWS for integrated water resources management and investment planning. • Climate information for the design of water systems infrastructure.
Low emission transport	• CIEWS use for efficient transport and logistics planning. • Climate information for transport systems design.
Energy efficiency	• Use of warning information/climate advisories to optimise energy efficiency (demand and supply analysis). • Climate information systems especially coupled with Internet of Things (IOT) would provide the measurement and verification data which is the cornerstone of Energy Service Company (ESCO) contracts.

1.1 Climate information and early warning systems context

Between 1970 and 2019, 79% of disasters worldwide involved weather, water, and climate-related hazards. These disasters accounted for 56% of deaths and 75% of reported economic losses associated with natural hazard events. The situation is particularly acute in small island developing states (SIDS) and least developed countries (LDCs). Since 1970, economic losses due to weather, climate- and water-related hazards for SIDS are estimated at USD 153 billion. Climate-related deaths in LDCs are estimated at 1.4 million people (70% of the total deaths) (WMO, 2020). The intensity and frequency of climate-related disasters are projected to increase as climate change intensifies, thus presenting a significant risk to achieving the UNFCCC and its Paris Agreement and SDGs. Transformation is driving investment in reliable climate information services (CIS) and impact-based multi-hazard early warning systems (MHEWS) to support well-informed, science-based decision-making. Given the significant cost-benefit ratio and the potential for averting and minimising disaster risk, there is growing interest and demand for GCF to expand these services, particularly in developing countries most vulnerable to the impacts of extreme weather and climate, and to related compound events. On 23 March 2022 the United Nations Secretary-General António Guterres announced an ambitious new target to ensure every person on Earth is protected by early warning systems within five years (WMO, 2022).

Paradigm shift can be achieved through adaptation and mitigation approaches that invest systematically in the value chain of CIS, MHEWS and effective fast response capability. Importantly, this includes incentivising CIEWS for investments and financial analytics, supporting long term planning and preparedness and promoting low emission and climate-resilient development. Without international support, it can be challenging for developing countries to establish and operate the fit-for-purpose hydrological and meteorological (hydromet) services required to achieve this paradigm shift.

1.2 Organisation of the document

This Guide has seven sections. After this introduction, Section 2 provides an overview of the global adaptation and mitigation context of CIEWS; Section 3 highlights the barriers and opportunities to achieving a paradigm shift in the CIEWS sector; Section 4 provides guidance on how to scale up and catalyse public and private investment; Section 5 provides case studies that demonstrate paradigm shift potential; Section 6 provides specific guidance for the development of impactful projects and programmes based on GCF investment criteria; and Section 7 concludes the CIEWS Guide.

The GCF Programming Manual (GCF, 2020a) provides information on the GCF project cycle, along with project development tools for full-size projects.

2 Global Context

2.1 Scientific basis: why are CIEWS relevant to climate action?

CIEWS reduce climate vulnerability to weather and climate extremes.

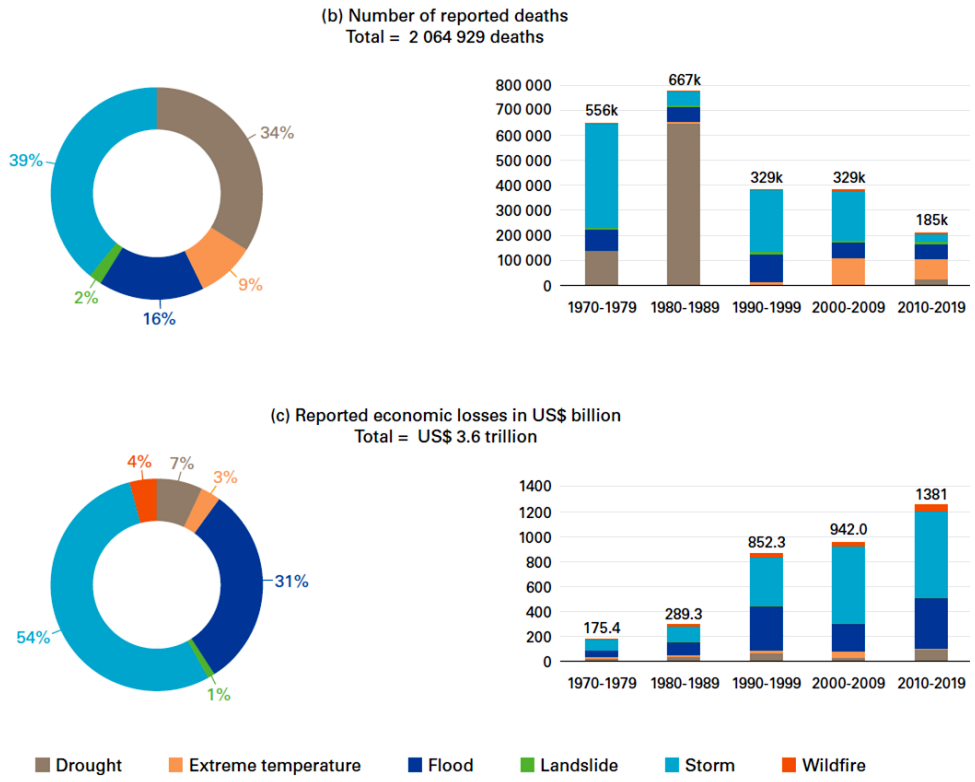
CIEWS provide strong, evidence-based information to make informed investment decisions for a low-emissions, climate-resilient global economy. They can increase the resilience of vulnerable populations and enhance the capacity of local communities to adapt to future changes in climate. With natural hazard occurring nearly five times as frequently as in the 1970s (WMO, 2015), CIEWS are more crucial than ever for reducing climate vulnerability:

- CIS equip decision makers across all eight GCF Results Area with better information to help individuals and organisations make climate-smart decisions (GFCS, 2022).
- People-centred MHEWS empower individuals and communities to act in a timely and appropriate manner to protect lives and livelihoods and so reduce the impact of weather and climate extremes (WMO, 2017).

Many estimates exist for the impact of weather-, climate and water-related disasters. The World Meteorological Organisation (WMO) has identified 11,072 such disasters worldwide since 1970, resulting in 2.06 million deaths and US$ 3.64 trillion in losses (WMO, 2021), (Figure 1). Storms, floods and droughts caused the most deaths and largest damages.

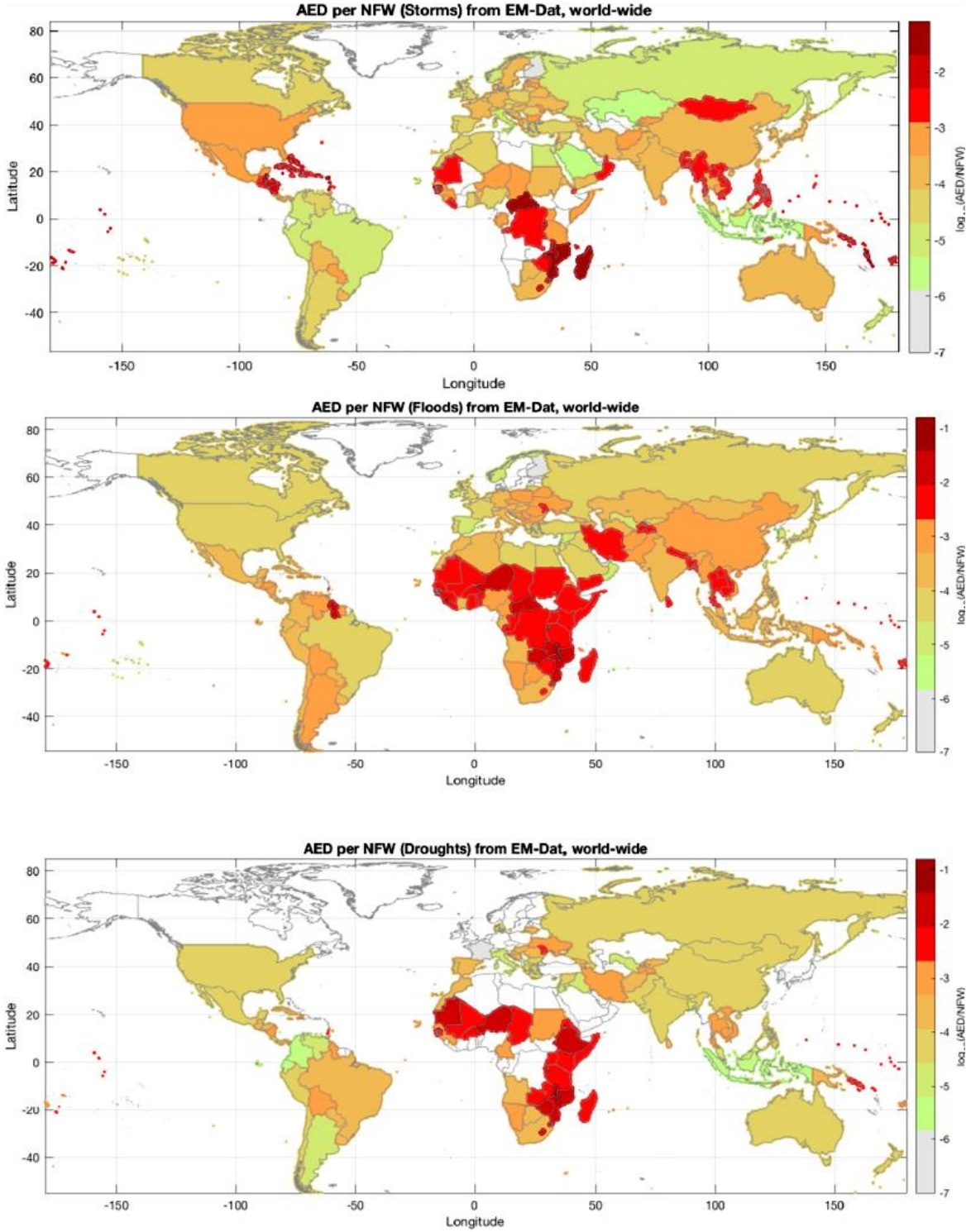
A similar analysis of disasters between 1970 and 2017 (Mühlhofer, 2019) assessed the impacts by country relative to asset values (Figure 2). In absolute terms, the greatest monetary damages are predominantly in South-East Asia, Latin America, Europe and North America. Greatest damages relative to GDP are experienced by SIDS, mainly due to storms, and African countries (mainly due to floods and droughts).

Figure 1: Global deaths and economic losses from weather, climate and water related disasters



Source: (WMO, 2021), referencing Emergency Events Database (EM-DAT), 1970–2019.

Figure 2. Worldwide annual expected damage (AED) per non-financial wealth (NFW) from storms, floods, and droughts



Shows AED relative to countries' asset values (non-financial wealth). Log-scale. Overall, relative metrics put more emphasis on small and poor countries: among the 10 countries with highest annual damages (4.5% – 30% of GDP) are Malawi, Tuvalu, Dominica, Mozambique, Guinea-Bissau, Gambia, Vanuatu, Burundi, Grenada, and Central African Republic. Absolute metrics highlight damages to large and wealthy countries: among the 10 countries with highest annual damage (USD 1.5 – 30 billion) are USA, China, Japan, India, Puerto Rico, Germany, Thailand, United Kingdom, Mexico, and Australia.

Source: (Mühlhofer, 2019).

The impacts of climate change, extreme weather events, and associated natural hazards and disasters are projected to become more frequent under increasingly adverse climatic conditions. Absolute damages, losses, fatalities, and casualties are therefore expected to increase. A continuing upward trend in both economic development and world population growth further fuels this tendency. These increasing risks threaten efforts to eradicate poverty and achieve the SDGs.

While the average number of deaths recorded for each disaster has fallen by a third since 1970, the number of recorded disasters has increased five times, and the economic losses have increased by a factor of seven. Between 2010 and 2019, the percentage of disasters associated with weather-, climate- and water-related events increased by 9% compared to the previous decade – and by almost 14% with respect to the decade from 1991 to 2000. This trend is a combination of increased exposure to hazards, an increase in population in exposed areas, changes in hazard frequency and intensity, and improved documentation of the occurrence of hazard events and associated losses (WMO, 2020).

As climate change continues to threaten lives, ecosystems, and economies, risk-based CIEWS are increasingly seen as key to building resilience and thus reducing losses and damages. The majority of Parties to the United Nations Framework Convention on Climate Change (UNFCCC) (including 88% of LDCs and SIDS) that submitted their Nationally Determined Contributions (NDCs) identified CIEWS as a top priority (WMO, 2020).

The Sendai Framework for Disaster Risk Reduction (UNDRR, 2015) specifically mentions CIEWS in one of its seven global targets:

> *Target (g): Substantially increase the availability of and access to multi-hazard early warning systems and disaster risk information and assessments to people by 2030.*[1]

The Framework urges a paradigm shift in how risk information is developed, assessed, and utilised in CIEWS, disaster risk reduction (DRR) strategies and government policies. It states

> *"In order to reduce disaster risk, there is a need to address existing challenges and prepare for future ones by focusing on monitoring, assessing and understanding disaster risk and sharing such information and on how it is created; strengthening disaster risk governance and coordination across relevant institutions and sectors and the full and meaningful participation of relevant stakeholders at appropriate levels."*

Four priorities for action encompass activities at local, national, regional, and global levels to achieve a "substantial reduction of disaster risk and losses in lives, livelihoods and health and in the economic, physical, social, cultural and environmental assets of persons, businesses, communities and countries" (Figure 3).

CIEWS also contribute to sustainable development. The 2030 Agenda for Sustainable Development addresses early warning and gives it an important role across the SDGs, such as in food security, healthy lives, resilient cities, environmental management, and climate change adaptation. In particular, Target 1.5 of Sustainable Development Goal 1 (UN, 2022) is:

> *"By 2030, build the resilience of the poor and those in vulnerable situations and reduce their exposure and vulnerability to climate-related extreme events and other economic, social and environmental shocks and disasters."*

[1] See (PreventionWeb, 2022) for indicators to assess progress towards this target.

Figure 3: The Sendai Framework for Disaster Risk Reduction 2015-2030:
Four priorities for action that encompass activities at local, national, regional, and global levels.

Source: (UNDRR, 2015).

The Paris Agreement stipulates early warning systems as one of the major focus areas to enhance adaptive capacity, strengthen resilience, reduce vulnerability, and minimise losses and damages associated with the adverse effects of climate change. The UNFCCC Warsaw International Mechanism for Loss and Damage highlights CIEWS as a key measure for averting losses and damages associated with adverse effects of climate change (UNFCCC, 2022).

2.2 Global baseline: where the sector is today?

Capacity to deliver and access CIEWS is highly uneven across regions and countries

Reliable CIS and impact-based MHEWS enable well-informed, science-based decision-making, leading to improved outcomes and benefits for stakeholders across multiple sectors. These services strengthen resilience and reduce losses and damages.

The development and incorporation of science-based climate information and prediction into planning, policy, and practice on the global, regional, and national scale underpin better adaptation to changing climate and better management of the associated risks. According to WMO, by 2019 (WMO, 2019):

- 137 countries reported providing CIS to the agriculture and food security sector, especially in Africa and Europe.
- 19 Regional Climate Outlook Forums (RCOFs) and two inter-region climate outlook forums were operational as one of the most widely used mechanisms for developing and communicating user-driven products and services.
- 46 countries had established or were in the process of establishing National Frameworks for Climate Services (NFCS).

However, the capacity to deliver and access CIEWS is highly uneven across regions and countries. One of the key challenges is strengthening the global-regional-national hydromet system needed to operationalise and deliver these services at a country level, particularly in developing countries, so that everybody benefits.

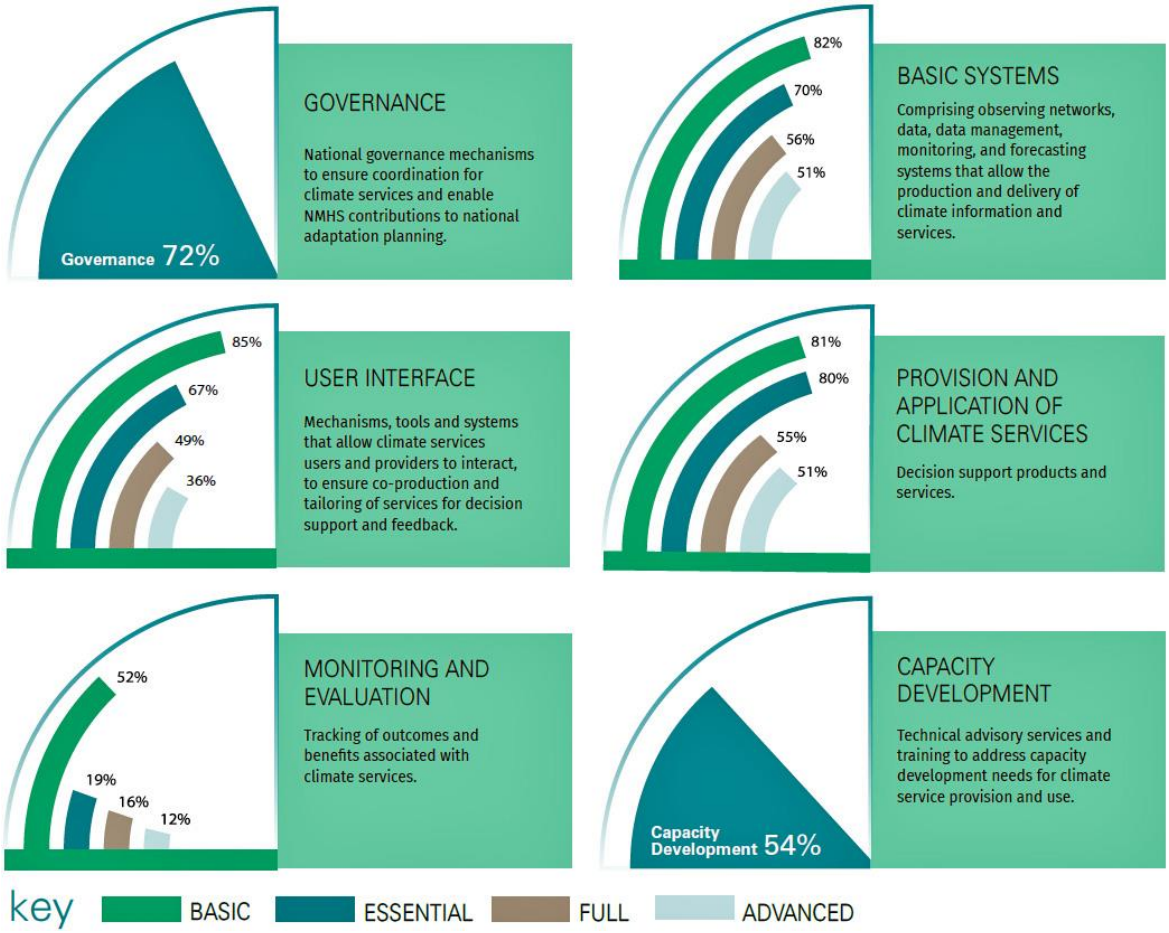
All National Adaptation Plans (NAPs) prepared to date mention early warning systems to support them in their adaptation efforts in the agriculture and food security (46%), health (30%), and water management (24%) sectors. However, plans to implement CIEWS NDCs, National Adaptation Programmes of Action (NAPAs), and NAPs are not consistent with evidence on the ground. A review of the 174 submitted NDCs, 51

NAPAs, and 11 NAPs revealed major gaps in risk acknowledgement and adaptation efforts. Countries have alarmingly low awareness of their need to advance adaptation efforts in the face of increasing climate risks. Out of 194 storm-affected countries, 53 mention being at risk from storms in those documents, and only 41 plan concrete action; similarly, 100 out of 190 flood-affected and 92 out of 143 drought-affected countries acknowledge the respective risks. Even fewer countries envision specific measures to adapt to storms, floods, and droughts: countries with adaptation plans incur only 2.8%, 17.3% and 8.1% of the respective global annual damages (Mühlhofer, 2019).

There are key gaps in global CIS provision

In 2019, the WMO *State of Climate Services* report analysed NDCs and NAPs to identify needs for CIS to support adaptation, particularly in the agriculture and food security sector (WMO, 2019). Functional capacities were assessed[2] in six groups: governance, basic systems, the user interface, capacity development, provision and application of CIS, and monitoring and evaluation of socio-economic benefits. A global aggregate of the findings is shown in Figure 4.

Figure 4: Functional capacities for the provision of CIS in 95 countries that provided data to WMO.



The percentages of "yes" answers to checklist questions addressing each of the above areas is shown in the graphs, based on data from 95 countries who provided data to WMO. Many of the functional capacities assessed by the checklist constitute "basic", "essential", "full" or "advanced" functionalities. The graphs show the percentages of "yes" and "no" responses to the questions in each of the above areas, for each functional capacity level, from the data provided.
Source: (WMO, 2019).

[2] It should be noted when interpreting the results of this report that data were only available for 95 out of 193 WMO Member States and territories.

The report identified six key gaps in global CIS provision. While the report primarily addresses the agriculture sector, the findings are applicable across the wider scope of CIS provision:

(1) Need for capacity strengthening in key regions. Institutional capacities need to be strengthened in many countries to complete the CIS value chain for adaptation planning and decision making. Capacity gaps in Africa and SIDS are the most urgent.

(2) Weak monitoring and evaluation of socio-economic outcomes and benefits of CIS. Systematic documentation of adaptation outcomes and return on investment are essential for financial sustainability. While there has been progress on governance, monitoring and evaluation remain weak.

(3) Systematic observation gaps. Today important observational data from many developing countries are either missing or insufficient for the weather prediction systems that underpin CIS, and this gap is getting worse at an alarming rate. Lack of integrated networks, the fundamental mismatch between today's developing country financing of observations, the value these observations create for the global public good, and a lack of sustained and predictable finance for capacity development continue to be the primary obstacles, aggravated by limited awareness among senior decision-makers of the use and benefits of these unique observations.

(4) Lack of coordination and data sharing. Service delivery depends on the operational exchange of data and products within the global-regional-national system, and a lack of data sharing results in sub-optimal availability and use of CIS. Co-production of CIS between National Meteorological and Hydrological Services (NMHSs) and other institutions remains limited due to the lack of agreements and resources.

(5) Last mile barrier. Even when relevant information is produced at the national level, the information may not reach the intended end-user(s). Information produced by NMHSs should be co-created with, and tailored to, the needs of users. Employing new technologies is needed to improve information access and use.

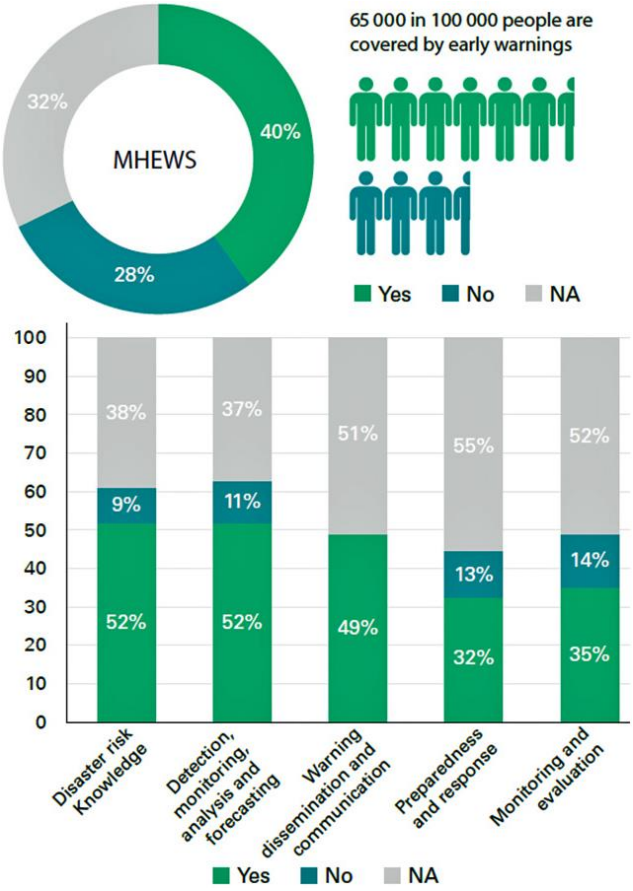
(6) Need to prioritise research modelling and prediction. Considerable work is needed to downscale global climate model outputs[3] for country-level decision-making. Some of the major operational and research organisations are assisting countries with downscaling. Regional climate change projections organised by the Coordinated Regional Climate Downscaling Experiment are also being used to inform impact assessments and adaptation plans. Transitioning research results into operations will entail interactions between the research and operational communities to address the needs of users, stakeholders, and decision-makers. Furthermore, for some hazards, e.g. flood depth and severe storms, downscaling alone is insufficient to support key decisions and other approaches are often needed.

MHEWS are a top adaptation priority, but substantial capacity gaps remain

Early warning systems are a top adaptation priority in 88% of the NDCs submitted by LDCs and SIDS. However, it is of great concern that over half of countries still do not prioritise or mention them. Of those who do, over half do not yet have MHEWS established, while the remainder has existing systems that need to be upgraded. A recent WMO *State of Climate Services* report (WMO, 2020) assessed countries' progress in implementing MHEWS, as summarised in Figures 5 and 6. Figure 5 shows the percentage of countries with MHEWS, coverage per region, and coverage for LDCs and SIDS. Frequently, systems are directed at multiple (undefined) types of "climate-related hazards"; less than half mention a specific hazard or types of hazards that they intend to warn, and the majority do not specify the system's purpose any further.

[3] The Coupled Model Intercomparison Project involves more than 40 climate modelling centres from some 20 countries to deliver updated decadal climate predictions and climate projections around future scenarios to inform UNFCCC processes and Intergovernmental Panel on Climate Change assessments. These global datasets provide an important foundation but need to be downscaled to provide the level of local detail required for local impact assessments and adaptation plans.

Figure 5: Countries that reported having a MHEWS and capacity by value chain component



Source: (WMO, 2020).

Figure 6: Countries with MHEWS and coverage (by 100.000 people) per region and for LDCs and SIDS

Source: (WMO, 2020).

Globally, only 40% of countries report having MHEWS in place. In the countries providing data, just 6.5 out of 10 people on average are covered by early warnings. While there are many successful cases of MHEWS, shortcomings persist, with low capacity for effective communication, preparedness and response, and monitoring and evaluation.

The following statistics illustrate various components of the MHEWS value chain:

(1) 113 NMHSs (of the 193 Member States and Territories) participate in WMO World Weather Information Service, a platform for sharing authoritative forecasts.

(2) 72 NMHSs participate in regional warning platforms in Asia and Europe.

(3) Only 61 NMHSs implement quality management systems for hydromet services, mainly in Europe.

(4) 84% of NMHSs provide forecasting and warning services for floods and drought.

(5) 64 countries are covered by the WMO Flash Flood Guidance System, benefiting about 3 billion people worldwide by providing real-time informational guidance on the threat of small-scale flash flooding.

(6) Only 49% of NMHSs provide products and services (through TV, SMS, web app and similar), and of these, only 24% use the Common Alerting Protocol (CAP) for disseminating warnings.

(7) Only 26% of LDCs and 38% of SIDS use web applications and/or social media.

(8) 67% of countries have an established DRR governance mechanism, but just 32% of local governments have a plan to act on early warnings.

(9) Only 12 NMHSs have conducted socio-economic benefit studies in the past ten years.

It is becoming urgent for more countries to transition from hazard-based forecasting to identifying the potential impacts as part of a forecast – from communicating "what the weather will be" to "what the weather will do" to more effectively trigger early action based on the warnings. However, only 39% of NMHSs indicated that they currently provide impact-based services.

Africa and South America have the weakest MHEWS capacity (Figure 6). In Africa, six out of ten people are not covered by early warnings. Africa also lags behind other regions in CAP and monitoring and evaluation of MHEWS-related outcomes and benefits. Meanwhile, capacity in the Southwest Pacific, which includes many SIDS, is higher than the global average in all MHEWS component areas in countries where data are available. LDC SIDS are significantly underreported, however. Further work is needed to improve country reporting on climate information and MHEWS capacity, especially from SIDS, to obtain a complete picture.

The WMO *State of Climate Services* report (WMO, 2020) identified the following gaps relating to the successful implementation of MHEWS in developing countries:

(1) **Overall, too few countries have MHEWS in place.** Just 40% of countries report having MHEWS. Increased and more comprehensive reporting would provide a complete picture of global needs (Figure 5).

(2) **One-third of the population is not covered by early warnings.** Warning dissemination and communication are consistently weak in many developing countries – and improved, more readily available communication technologies (such as CAP) are not being fully exploited.

(3) **Capacity worldwide to translate early warning into early action is insufficient – especially in LDCs.** LDCs in SIDS and Africa face numerous capacity gaps, especially with full value-chain MHEWS. Translating early warnings to early action requires national and local plans, including knowing how to act once the warning has been released.

(4) **Sustainable observations are key but inadequate.** Observations are inadequate in Africa, the Southwest Pacific, South America, and Antarctica. The number of fully reporting African upper-air

stations decreased from 57% in 2011 to just 22% in 2019, while just 26% of surface network stations reported according to requirements.

(5) **There is a need to improve tracking hydromet finance flows for MHEWS and associated services and benefits.** Although annual tracked climate finance crossed the half-trillion-dollar mark for the first time in 2018, tracking hydromet finance flows to support MHEWS is insufficiently detailed to assess the degree to which it is effectively targeted. Harmonisation of reporting would permit better analysis of where investment is needed and of returns on these investments.

(6) **Tracking socio-economic benefits is inconsistent.** Overall, tracking and reporting socio-economic outcomes and benefits from MHEWS is inconsistent and non-standard. As investment increases, there is a need to significantly strengthen benefit assessment and reporting.

(7) **More data is needed specifically on SIDS.** Only 24 SIDS provided data, which severely constrains what can be said about the current state of MHEWS in the remaining SIDS.

2.3 Global adaptation and mitigation potential: where does the sector need to be?

Effective CIEWS require holistic investment focused on end-user needs

The social and economic impacts of climate change and the consequent adaptation needs are becoming increasingly significant as climate change gathers pace. As weather-, climate- and water-related hazards become more extreme, the current piecemeal approach to delivering CIEWS is inadequate to address the scale and urgency of challenges and demands.

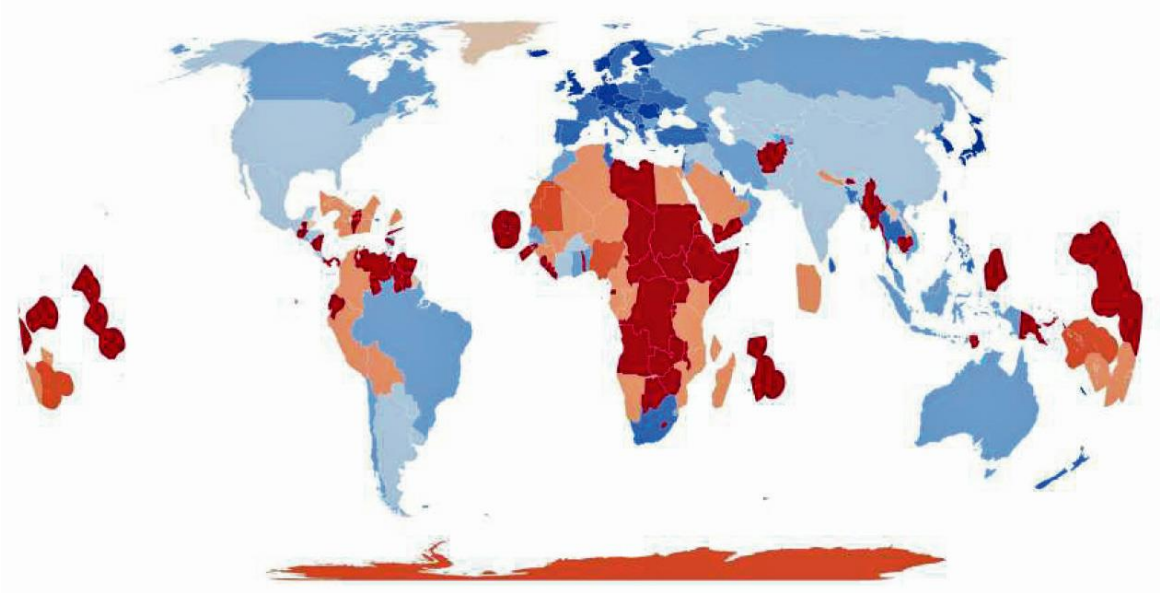
Evidence suggests that the benefits of investing in the global-regional-national hydromet system outweigh the costs by about 80 to one (Kull, 2016). While investments have increased substantially over the past decade, more and better investments are needed to ensure the provision of high-quality CIEWS through an end-to-end people-centred, multi-hazard, impact-based approach that builds resilience, minimises risks, saves lives, secures livelihoods, and helps communities build back better after disasters.

Investments are needed in a more holistic, less piecemeal manner – in both the national-regional-global integrated hydromet system on which CIEWS in all countries depend and in overcoming the “last mile” barriers impeding the full use and benefit of CIEWS. Services must be shaped through full participation with local communities as actors, rather than passive recipients, such that information provided is tailored according to the user needs at the local level and presented in a way and in a language that is comprehensible for decision-making.

To strengthen sustainable networks, careful planning and resource allocation covering maintenance and consumables; staff development, training and retention; planning for equipment replacement; data archiving; and data dissemination emerge as top needs (WMO, 2019).

Weather and climate-related disasters are not gender-neutral. Women are often placed at greater risk through a lack of timely and relevant information about imminent hazards and a lack of equal access to technology. Moreover, women’s voices are often absent from the design and decision-making around CIEWS, and as a result, do not have their needs adequately met. Well-designed initiatives that provide for the full and effective participation of women can advance substantive gender equality and the empowerment of women, while ensuring that sustainable development, disaster risk reduction and climate change objectives are achieved (WMO, 2022a).

Figure 7: The horizontal resolution of surface observations, actively reporting and sharing data internationally during January 2020



Legend: Blue shades: meet GBON requirements; red and tan shades do not

Source: (Alliance for Hydromet Development, 2020).

Filling the gaps in the global observing system – the importance of GBON and SOFF

Systematic observations are the foundation for effective climate action and sustainable development. However, important observational data are missing in several parts of the world, particularly in Africa and SIDS. Africa has the highest percentage of non-reporting stations for supplying timely data to global modelling centres, with large gaps even for basic hydromet data such as temperature, pressure, and precipitation.

In 2019, recognising the foundational importance of observations to providing all hydromet services, the World Meteorological Congress agreed to establish the Global Basic Observing Network (GBON) (WMO, 2019a), setting out a clear obligation for all nations to acquire and exchange essential observational data. However, most developing countries currently fall well short of the required standard (see Figure 7).

Achieving sustained global GBON compliance will require substantial investment, strengthened capacity, and long-term resources for operation and maintenance. WMO has estimated that observations in LDCs and SIDS will need to be increased 28 times over their current levels for surface stations and 12 times for upper air stations (Alliance for Hydromet Development, 2020), which is highly unlikely to be achieved without concerted international support. An innovative financing approach is required that values the global public good that these observations provide, ensures coherence of development activities, provides long-term resources beyond time-bound projects, incentivises country performance, and ensures investment sustainability – beyond business as usual.

GCF is now working with other international development, humanitarian and financial institutions, and WMO on the Systematic Observations Financing Facility (SOFF) (Alliance for Hydromet Development, 2021) which will provide long-term finance and technical assistance to establish and maintain GBON compliance. The SOFF became operational as of 30 June 2022 with WMO, UNDP, and UNEP as the co-founders.

SOFF will address shortfalls of current models of financial and technical assistance for basic observations by:

(1) Applying an optimal and internationally agreed global design and metric to guide investments – the GBON requirements.

(2) Focusing on data sharing as a measure of success.

(3) Providing long term support, using results-based finance to substantially contribute to operations and maintenance costs, recognising the global public good created by these observations.

Any GCF project proposals that include installing meteorological observation equipment should ensure full compliance with the GBON standard and SOFF operating regime, and full integration and complementarity with NMHS and other relevant hydromet networks.

Building human capacity

Arguably some of the greatest challenges to the sustainable development of CIEWS relate to building human capacity. While most externally financed modernisation projects include training, these projects are finite and do not provide for the long-term investment in staff development. Poor educational provision, uncompetitive public sector salaries, and poor career prospects affect NMHS recruitment and retention. There is strong competition for qualified scientific, technical, and managerial staff, with private sector employment often more financially attractive.

The Climate Risk and Early Warning Systems (CREWS) initiative hosted by WMO provides technical assistance to LDCs and SIDS in support of CIEWS, including twinning between NMHSs and other capacity-building initiatives. So far, this has mainly focused on technical aspects, with relatively little engagement with sector users.

Investing in institutional transformation is a crucial element of the GCF vision to support country-driven transformation through catalytic investment. Alongside sustained technical assistance funding, a key priority is to deliver lasting investment in the institutional and human capacity needed for developing countries to fully integrate climate information and risk into planning, policy frameworks, project design, and delivery (GCF, 2019). NHMSs will also need to have sufficient, sustained internal (government) funding, based on government policies which support their expanded role.

2.4 Barriers to application of CIEWS for adaptation and mitigation

Barriers or constraints that make it difficult for governments, individuals, and businesses to plan and implement adaptation actions (Klein, 2014) impede decisions or action. These include physical and ecological, technological, financial, information and cognitive barriers; social and cultural barriers (Adger, 2009); or market and policy failures.

While these apply to all areas, specific challenges for the development and application of CIEWS include:

- Lack of enabling environment for institutional effectiveness. Coordination, information, and data sharing are often limited within government and different government agencies or ministries, which do not systematically work together or share information appropriately, as well as within government and different government agencies or ministries, which do not systematically work together or share information appropriately, as well as between government and non-governmental entities, each of which plays a key role in the CIEWS value chain. Policies to remove barriers to uptake and investments in CIEWS are not in place within national and local governments.
- Uncoordinated interventions limit the effectiveness of existing support to developing countries. The CIEWS playing field is crowded, with various donor and development agencies funding similar activities. This often leads to duplication of effort while lacking inter-operative connections between CIEWS networks, straining the limited capacity of national systems to provide coordination.
- Limited governmental finances allocated to NMHSs, disaster management, and related agencies. This constrains salaries, as well as operating and maintaining equipment, forecasting systems, early warning, and the broader anticipatory action activities. Freezes on recruitment lead to inadequate resources for early warning and early action and thus limit the ability of the relevant institutions to expand or develop new products or services (Lennard, 2018).

- Market barriers to creating enabling conditions. In efforts to transfer technology, policy analysts and decision-makers must adapt policies to local circumstances such as the climate, demography, structure of economic activities, and level of decentralisation of a country, as well as a country's energy and fiscal context, and the degree of market development for low carbon products and services (UNDP, 2011).

In terms of the specific pathways identified in this guide, climate-informed advisory and risk management services have limitations in respect to the timeliness, quality, and completeness of data, and they are often not adapted to local needs in terms of accessibility, affordability, use of technology, and applicability to user decision making.

There are also barriers to mitigation, which apply to all sectors, and are documented in the energy efficiency Sectoral Guide.

2.5 Financing adaptation and mitigation: how much will it cost to meet these targets?

The GCF Strategic Programming document (GCF, 2019) notes that for a 1.5 °C pathway, more than USD 2.38 trillion would need to be invested annually in mitigation through the energy system. Adaptation investment needs are more difficult to quantify because of the relationship to mitigation pathways and the greater difficulty of identifying resilience investments as a component of underinvested infrastructure, but estimates have been steadily rising. Annual climate adaptation costs in developing countries could reach USD 300 billion in 2030 and, if mitigation targets are breached, as much as USD 500 billion by 2050. Inaction risks costing more (UNCTAD, 2021). Recent studies estimate that strong action to combat the climate challenge would deliver a net global economic benefit of USD 26 trillion by 2030 (GCEC, 2018).

In this context the cost of implementing CIEWS is small. In response to the United Nations Secretary General's new target to ensure every person on Earth is protected by early warning systems, the WMO has called for an investment of USD 1.5 billion by 2027 to improve the quality of CIEWS and related infrastructures, especially in LDCs and SIDS (WMO, 2022).

3 Paradigm shifting pathways

3.1 Drivers of change across paradigm shifting pathways

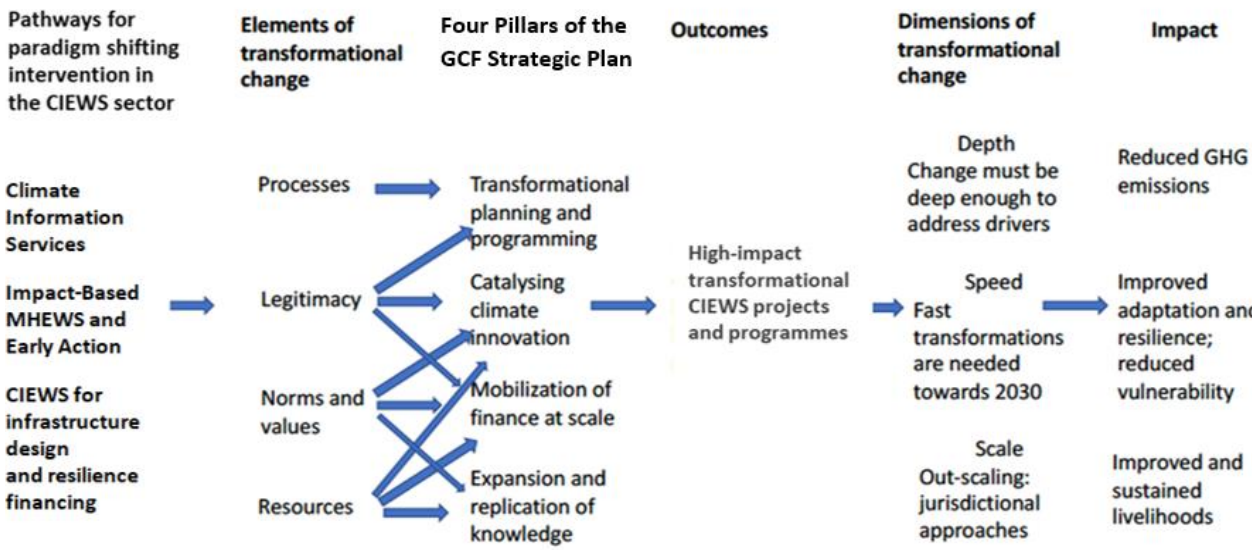
Low- and middle-income countries must commit to long-term processes to achieve a paradigm shift in CIEWS to increase resilience to effectively manage the risks of a changing climate. The term "paradigm shift" refers to the degree to which a proposed investment can catalyse impact into medium or long-term sectoral change beyond a one-off project investment (GCF, 2020; GCF, 2020a)Through the 2020-2023 Strategic Plan, GCF seeks to help countries and implementing partners support paradigm shifts by significantly improving the design and quality of projects to achieve sustainable results.

Projects/programmes are expected to assess their contributions to paradigm shift twice during their lifespan by applying the three assessment dimensions: scale, replicability, and sustainability (GCF, 2021). Scale is the degree to which there has been a significant increase in quantifiable results within and beyond the scope of the intervention. Replicability is the degree to which the GCF investments exported key structural elements of the proposed programme or project elsewhere within the same sector as well as to other sectors, regions or countries. Sustainability is the degree to which the outcomes and results of GCF investments are sustained beyond completion through the creation of a structural and financial base as well as climate resilient practices. Typically, these dimensions may be assessed beyond the lifetime of a project/programme and cannot be easily attributed to the GCF investments alone. The urgency of the climate crisis emphasises early outcomes achievable in five to ten years (the 2030 goal) over those achievable in 30 years (the 2050 goal) because each "missed year" increases the size and complexity of the tasks ahead.

To maximise impact and paradigm shift, GCF adopted a Strategic Plan based on transformational planning, catalysing innovation, mobilising finance at scale, and knowledge replication. Four elements identified as important for transformational change are processes, norms and values, resources, and legitimacy. Mapping these onto the four pillars of the GCF Strategic Plan (Figure 8) facilitates action towards a paradigm shift across different stakeholders, rights holders, institutions, geographies, and processes as follows:

(1) **Transformational planning and programming:** climate compatible processes for planning and policy frameworks, ensuing transparency, access to information, participation, equity, and sustainability, to guide and bring legitimacy to the process.

Figure 8: Elements of transformational change linked to the four pillars of GCF Strategic Plan



(2) Catalysing climate innovation: enabling policy, institutional and technological innovations for policies, laws, business models, projects, land-use practices, and forest management to harness multiple benefits.

(3) Mobilization of finance at scale: using a range of financial instruments to reduce risks and barriers to investment in CIEWS; countries can unlock local capital (resources) and improve access to commercial or other markets.

(4) Coalitions and knowledge to scale up success: resources needed to shift finance flows include strengthened capacity of institutions and people, and available and accessible information (data, maps, and best practices). Sharing lessons learned, methods (traditional and scientific), and standards, projects and programmes can contribute to global financial flows for transformational pathways toward low-emission and climate-resilient development.

3.2 Three paradigm shifting pathways for CIEWS

Robust evidence from research such as the Intergovernmental Panel on Climate Change, the broader CIEWS community of practice, and the GCF portfolio show that transformational benefits can be realised across all GCF result areas by ramping up investments in three, interlinked CIEWS pathways. The following sub-sections articulate the vision, barriers, and possible actions for achieving paradigm shifts in each pathway. Projects may target one or a combination of the pathways, and do not need to target all three.

3.2.1 Pathway 1: Strengthening climate information services

Vision: *reliable climate information to strengthen resilience through timely and effective decision-making.*

This pathway enables the creation of relevant, science-based information for MHEWS (Pathway 2) and investment and financial decision making (Pathway 3) through modernising hydromet services, with a focus on technical capacity development and institutional effectiveness. It has two sub-components: modernisation of hydromet services and regional hydromet programmes. These are pre-requisites for strengthening weather and climate information to enable CIEWS to become an integral component of development planning.

Modernisation of hydromet services aims to establish the five components of the Global Framework for Climate Services (GFCS): user interface platform; climate services information system; observations and monitoring; research, modelling, and prediction; and capacity development.

GCF investments focus on:

- Optimising CIS through regional and national approaches.
- Upgrading operational infrastructure and gap filling.
- Improving provision from basic services to essential and then full services.

In addition, investment supports business delivery models that integrate quality management, sustainability, and upscaling investments. It adopts digital technologies to significantly transform the generation, management, and delivery of climate services. E-infrastructure is central and consists of digital technologies (software and hardware), resources (data and information services, digital libraries, historical data digitisation), people, and the network of institutions responsible for e-infrastructure usage and management.

GCF leads investments in the “Internet of Things” (IoT); big data analytics and artificial intelligence; satellite technologies and decision sciences; along with broader global e-infrastructure development. Cloud technologies enable economies of scale in providing common but differentiated weather- and climate-on-

demand services (such as software-as-a-service, platform-as-a-service, hardware-as-a-service, and infrastructure-as-a-service) for countries or for regions with countries that have common climatic characteristics.

Regional Hydromet Programmes: GCF invests in regional programmes with centralised infrastructure, such as regional cloud-based forecasting systems and observational networks, as a more efficient and effective approach, compared to uncoordinated national projects. Systems will be integrated into existing WMO Regional Climate Centre models that service regional economic communities. Investments will also support regional political and policy approaches based on the Regional Economic Commissions and WMO Regional Associations to strengthen the mainstreaming of climate services into regional integration and trade by leveraging on the successes of the RCOFs in climate-resilient development planning. Observations data policy should conform with the WMO Unified Data Policy for free and unrestricted data exchange (WMO, 2021b).

Wherever appropriate, investments will complement the work of national hydromet agencies and WMO by drawing on, and aligning with, existing institutions, frameworks and mechanisms such as disaster management agencies, other ministries, universities and research institutions international organisations, NGOs and citizen scientists.

To engage the private sector in both of the above sub-components, fully private and public-private partnership arrangements are adopted based on GCF and WMO policy recommendations on private sector engagement. Financing approaches focus on deploying an appropriate range of GCF financial instruments based on the needs of beneficiaries (grants for public goods only). Innovative financing architecture includes blended finance and leverages funds from, for example, the SOFF, Global Environmental Facility, Adaptation Fund, National Climate Funds and private sector funding sources. Furthermore, the readiness, NAP, and country programming support are used to support the establishment of regional and national frameworks for climate services, legislation, policy, and governance frameworks to drive investment and uptake of climate services in the private and public sectors. Investments enable the establishment of climate services innovation hubs, bringing together vibrant ICT start-ups, climate scientists, socio-economists, and business sector specialists to create the next generation of the climate services industry in developing countries.

3.2.2 Pathway 2: Promoting impact-based MHEWS and early action

Vision: *Timely and effective anticipatory action that protects lives, livelihoods and development gains.*

This pathway focuses on making people-centred, end-to-end, and impact-based early warning and action services widely available. It comprises two sub-components: impact-based MHEWS and forecast-based action.

Impact-Based Multi-Hazard Early Warning Systems (IB-MHEWS): This sub-component targets the modernisation of core disaster alert and coordination mechanisms and the broader early warning systems components:

- Disaster risk knowledge.
- Detection, monitoring, analysis and forecasting of hazards and possible consequences.
- Warning/advisory dissemination and communication.
- Preparedness and response capabilities.
- Effective coordination mechanisms (actors and actions).

It focuses on short- to medium-term risks (including slow-onset weather-related disasters) by optimising, establishing, and scaling up mechanisms for delivering IB-MHEWS, in accordance with UNDRR and WMO standards, with links to community development programmes, government contingency plans and shock-responsive social protection mechanisms, international preparedness and response, and private sector business continuity programmes.

The development of a *Multi-Hazard* Early Warning System to respond to systemic risk requires engagement beyond NMHSs, to build a national coalition of data and service providers from multiple government agencies (including national disaster management agencies, energy, highways, agriculture, environment, for example), together with academia, NGOs and the private sector, working in close partnership with end user communities as actors, rather than passive recipients, to develop effective 'last mile' response. Equity will be an important consideration to ensure inclusive, anti-discriminatory delivery and uptake, with a particular focus on those currently broadly excluded from benefitting from such information and related services. Inclusivity should include considerations of language, literacy levels, and other aspects of access.

Note that whilst MHEWS are generally based on short- to medium-range forecasts, longer-range hazard risk projections can identify priority areas for the development of more tailored early warning systems. For example, predicting whether an area is expected to experience a higher frequency of floods compared to drought can help in specifying the type of early warning system required.

Forecast-based Action (FbA): This sub-component draws on IB-MHEWS to target three broad areas:

- Before a hazard occurs. Forecasts of climate hazards linked to in-depth analysis of the impacts to directly trigger anticipatory action (which may include anticipatory finance), i.e. before and during the onset of climate/weather hazards.
- During and immediately following a climate hazard. Analysis is linked to a forecast of likely impacts and used to create a trigger to release finance for early action and early response as shocks emerge, but before they have unfolded into fully-fledged disasters.
- Across multiple time scales. Multiple sources of impact-based multi-hazard early warning information, such as climate, market, and conflict-related information, are used to forecast the impact of a shock or series of shocks before impacts emerge or become acute.

Investment in FbA includes forecasting and decision-making mechanisms, timing and planning early action, and financing early action, including sequencing forecast-based financing with traditional insurance to maximise impact and reduce insurance payouts and premiums. The mechanisms for delivering FbA could include linking to community development programmes, government social protection and safety nets, and international humanitarian response.

For private sector engagement, the pathway offers fully private sector solutions as well as public-private partnerships that target the broader risk management landscape, including business continuity and creating new markets through providing services to the government and the broader private sector. Financing will cover the full range of GCF financing instruments (including result-based payments). GCF investments include grants for public goods and services targeting the most vulnerable population, communities, and their assets. FbA investments are achieved through blending GCF financial instruments with dedicated FbA funds and funding windows, insurance and contingent finance, market-based mechanisms, such as disaster insurance schemes and risk capacity, and standard resource allocation processes. In addition, FbA could be scaled up by embedding financing and delivery systems linked to community development programmes, governments and social protection and safety nets, and international humanitarian response funding.

For both sub-components, readiness investments will support knowledge brokering, including monitoring, evaluation and learning, impact evaluation and feedback in forecast-based action. The evidence base for FbA will focus on earlier response and reduced response time so that support gets to people faster, averting

suffering and helping to prevent more severe impacts; decreasing the cost of response through greater prepositioning and early procurement; and better-quality programme design through pre-planning with more preventive measures and potential cost-benefits in non-crisis periods.

Selected barriers and possible actions to paradigm shift in strengthening CIS and promoting IB-MHEWS are shown in Table 2.

Table 2: Selected barriers to paradigm shift through Pathways 1 and 2

Barrier	Description
Lack of enabling environment for institutional effectiveness.	Coordination, information, and data sharing are often limited between government and non-governmental entities, each of which plays a key role in the CIEWS value chain. Policies to remove barriers to uptake and investments in CIEWS are not in place within national and local governments.
Lack of coverage and scale for effective service delivery.	The quantity and quality of hard and soft infrastructure may be inadequate for ensuring delivery and uptake of information.
Uncoordinated interventions limit the effectiveness of existing support to developing countries.	The CIEWS playing field is crowded, with various donor and development agencies funding similar activities in countries. This often leads to duplication of efforts while lacking inter-operative connections between CIEWS networks, straining the limited capacity of national systems to provide coordination.
Limited governmental finances allocated to NMHSs.	Financial constraints on salaries, and on the operation and maintenance of equipment and forecasting systems, often lead to freezes on recruitment and limit NMHSs' ability to expand or develop new products or services.
Technical complexities of hydromet operations.	Despite the continued advances in forecasting capability from global modelling centres and the increasing availability of forecast data to all users, considerable challenges remain for LDCs in building the capacity to operate national CIEWS effectively.
Market barriers to creating enabling conditions.	There is rarely one market barrier preventing the adoption of new technologies. In efforts to transfer technology, policy analysts and decision-makers must adapt policies to local circumstances, such as the climate, demography, structure of economic activities, and level of decentralisation of a country, as well as a country's energy and fiscal context, and the degree of market development for low carbon products and services.
Achieving sustainable 'last mile' effectiveness	Even when the CIEWS exist they do not necessarily reach the last mile communities or translate into effective early actions, due to insufficient or ineffective community engagement. Some sectors are historically more primed to leverage FbA (e.g, agriculture) and others less so (e.g., health). For the latter, careful work needs to be done on end-user engagement, trust-building, and awareness raising.

3.2.3 Pathway 3: Improving CIEWS for investment and financial decisions

Vision: *strengthening climate information for assessing, avoiding, reducing, and transferring the risks and adverse impacts of climate-related disaster to increase the financial resilience of vulnerable populations and infrastructure and other assets.*

This pathway aligns with Sendai Framework Priority 3, *Investing in disaster risk reduction for resilience* (UNDRR, 2015). It focuses on CIEWS analytics (decision science and technologies) for infrastructure design and operation, policy and decision-making in climate risk finance and investments to reduce long-term disaster risk. It supports consideration of infrastructure shocks (extremes) and stresses across different decision timelines from day-to-day operations and management to designing and planning for long-term

climate change. The application of CIEWS data to climate risk finance and investments constitutes a paradigm shift for asset owners (public and private) across all GCF result areas, the digital economy, weather derivatives and commodities markets, and insurance companies that seek to protect their investments against medium- to long-term risks. Specific GCF investments would include prevention and mitigation, preparedness, response (excluding humanitarian assistance), recovery, and reconstruction to build back better.

This pathway comprises two sub-components: CIEWS data for infrastructure design; and CIEWS data for resilience financing.

CIEWS investments for climate-resilient infrastructure design

The first sub-component aims to improve the availability of information for building climate resilience into infrastructure project lifecycles and for upstream planning and system-level analysis, leading to more resilient infrastructure design, for example, in new road or energy projects (adaptation in projects, sometimes also called climate proofing). There are also opportunities to increase the uptake of IB-MHEWS for infrastructure (see Pathway 2).

Investments in infrastructure and its associated services and users (including businesses, governments, and people) have traditionally been designed to be resilient to extreme climate events, using information on historical risks. However, infrastructure has a long lifetime, and infrastructure built over the next decade will operate under very different climate conditions compared to today. Climate change may affect operating costs or revenues, while the increasing frequency and severity of extreme weather could cause asset damage or failure. In turn, this can affect the function or services provided by infrastructure assets. Infrastructure decisions can also have wider implications, as they lock in development patterns for decades.

At the same time, there will be an increase in infrastructure investments (including 'green' infrastructure) that target climate change risk mitigation as the primary objective (adaptation projects) to protect people, investments, and economic activity, for example, new coastal defence infrastructure to reduce the effects of sea-level rise. There will be an increased demand for CIEWS information to help design these new investments.

Several studies have demonstrated the economic benefits of investing in resilient infrastructure in low-and middle-income countries, particularly the avoided cost of infrastructure damage and disruptions. One such study (Hallegatte, 2019), examining the critical infrastructure systems of power, water and sanitation, transport and telecommunications, concluded that the additional cost of making these assets climate-resilient amounts to just 3% of overall investment and provides positive economic returns with a net lifetime benefit of USD 4 for each dollar invested in making the infrastructure climate-resilient.

However, providing and using CIEWS for these investment decisions is challenging, not least due to future uncertainty (both in terms of future scenarios and climate model outputs). In response, a suite of Decision Making Under Uncertainty (DMUU) approaches are being proposed, using principles such as robustness, diversity, flexibility, and learning, to build climate resilience into infrastructure (Asian Development Bank, 2020). These include using tools such as robust decision making, adaptive management, adaptation pathways, and real options analysis. Such approaches require different types of information or data, which calls for the development of specific CIEWS. Complementing this is a growing recognition of the need to think about a more system-wide and strategic approach to making infrastructure systems resilient (Asian Development Bank, 2021). The Financial Stability Board Task Force on Climate-related Financial Disclosure framework provides guidance on methodologies and tools for considering current and future climate risks (FSB-TCFD, 2022).

This pathway strengthens information for decision-making across multi-sectoral infrastructure investments and systems. Complementing Pathway 2, these investments strengthen the use of CIEWS for assessing, avoiding, reducing, and transferring the risks and adverse impacts of climate extremes, climate variability,

and climate change, to increase resilience. This includes information for the design of climate-resilient infrastructure (climate proofing) and new adaptation infrastructure projects, information for the operation of this infrastructure and the services it provides, and information for infrastructure users. The provision of this information links to the increase in resilience in the other Sectoral Guides, i.e. for cities, buildings, energy infrastructure, transport, and includes ecosystem-based approaches as well as traditional engineered infrastructure.

GCF supports governments, the private sector, and communities in developing and using CIEWS for investment decisions for making infrastructure, associated services, and users climate-resilient. It invests in information and supports the uptake of its use (policy, regulatory, planning, and decision-making processes) in the project cycle for infrastructure and also in upstream and system-wide infrastructure planning. This includes readiness, country programming, NAP and NDC support, and project design and appraisal. GCF supports CIEWS for climate proofing planned infrastructure projects and new adaptation projects, including information and support for ecosystem-based approaches and green infrastructure, as well as conventional infrastructure.

This approach scales up information for risks over a range of decision timelines, from short-term to sub-seasonal to seasonal timescales and climate information for climate-smart infrastructure design. It includes information at the level of individual infrastructure projects (including services) but also for infrastructure systems.

CIEWS fostering resilience financing

The second sub-component constitutes a paradigm shift for asset owners across all GCF result areas. It supports the digital economy, weather derivatives and commodities markets, and insurance companies in protecting their investments against medium- to long-term risks. The focus is on strengthening approaches for assessing, avoiding, reducing, and transferring the risks and adverse impact of climate-related disasters, thus increasing the resilience of assets and vulnerable populations.

Digital financial technologies (Fintech) for investment and financial decisions include big data analytics and artificial intelligence-based decision support tools, internet connectivity, blockchain, IoT, as well as facilities and resources needed for effective collaboration and delivery of climate finance and investments.

Applying climate analytics for managing private sector investment and financial risks focuses on five areas to drive uptake, maximise mobilisation and impact:

- Climate funds (such as equity investment).
- Financial institutions (including green lending and risk-sharing).
- Project finance (with lifecycle financing for high impact projects).
- Climate markets (such as capital and carbon markets, structured financing solutions, and institutional investment for new markets).
- Innovation in climate and digital technology (including local innovation and market accelerators).

Applying climate analytics for managing investment and financial risks in public sector markets supports governments and all publicly owned or publicly funded agencies, enterprises, local governments, and community-based entities to integrate CIEWS-based analytics for investment and financial policy decision-making in delivering public programmes, goods, and services. Governments thus become consumers of CIEWS analytics, investment and financial products and services, and also sellers to businesses and other consumers.

Both sub-components of Pathway 3 adopt innovative financing approaches that include the deployment of the full range of GCF financial instruments based on the needs of beneficiaries (grants for public goods only) within the context of blended finance, leveraging other funding sources and instruments to protect against hazards of different frequency and severity. This includes market-based instruments, contingent financing,

and budgetary allocations. Selected barriers and possible actions to paradigm shift in improving CIEWS for investment and financial decisions are shown in Table 3.

Table 3: Selected barriers to paradigm shift through Pathway 3

Barrier	Description
Lack of historical hydromet data and future changes over lifetime	Lack of historical datasets may limit the application of CIEWS to infrastructure design, and to the assessment of how patterns of extremes and variability will shift over infrastructure lifetime. To assess market potential and changes in market demand, and to price risk and evaluate claims; the insurance and reinsurance companies need access to robust, comprehensive, reliable data with historical and spatial coverage. However, many developing countries lack readily accessible, digitised historical hydromet datasets.
Limited quality of short-term, seasonal and interannual forecasts	Reliable forecasts of consistent quality are essential for decisions based on simulated events, and to support Forecast Based Action. Forecast quality is impacted by lack of observations, science limitations, access to computing power, and data packaging (which has to be aligned with user needs).
Uncertainty with climate change projections	Future climate projections are uncertain, with wide ranges of results by scenario (e.g. warming level) and large differences between models. This uncertainty acts as a barrier to use. This can be addressed with a greater focus on decision making under uncertainty, but this requires time, resources and expertise.
Policy and regulation	There are often existing policies or regulation in place that act to prevent the use of information. For example, current design standards may make it difficult to increase infrastructure to take account of climate change.
Financing	While making climate resilient infrastructure has large benefits, it also has a cost. There is a need to consider the economic benefits of making infrastructure resilient, and which options are appropriate (considering uncertainty, considering alternatives of action versus insurance), and there are barriers to the additional finance required.
Availability of a strong CIEWS infrastructure	CIEWS are not always available at scale but are required for the effective implementation of parametric insurance products and forecast-based products. With the implementation of cloud-based and user driven CIEWS, forecast-based financing can be used.

3.3 Role of GCF in financing paradigm shifting pathways

GCF offers a four-pronged approach to drive the implementation of paradigm shifting pathways at scale. While business models, project development systems, financing structures, and the ability to attract Private Institutional and Commercial finance differ significantly across countries and regions, these approaches can support developing countries' efforts in the CIEWS result area.

To date, GCF has the biggest portfolio in modernising hydromet services and early warning systems globally, reflecting its mandate to promote a paradigm shift towards low-emission and climate-resilient pathways in developing countries. Growth of CIEWS in developed countries is driven by a vibrant private sector (including energy, aviation, large-scale agriculture, and infrastructure resilience). By contrast, very limited growth has been observed in Africa, LDCs, and SIDS. GCF is uniquely placed to unlock the barriers to the CIEWS market in developing countries by supporting governments to de-risk the environment and provide the incentives to crowd in private sector investments. A significant and growing component of CIEWS is ICT services. GCF leverages the ICT revolution – increasing efficiency and decreasing acquisition cost – to transform the CIEWS landscape in developing countries. GCF works with NDAs, AEs, and other partners to support financing transformative projects in CIEWS project origination, development, and implementation.

Key actions for each of the paradigm shifting pathways across the following four pillars of the GCF Strategic Plan are outlined in Table 4.

Table 4: Possible actions for each paradigm shifting pathway following the four pillars of the GCF Strategic Plan

		Actions across the pillars of the GCF Strategic Plan			
Climate Information and EWS		**Transformational planning and programming**	**Catalyzing climate innovation**	**Mobilization of finance at scale**	**Coalitions and knowledge to scale up success**
Paradigm-shifting pathway	**Strengthening climate information services**	• Support establishment of National Framework for Climate Services to strengthen generation and uptake of climate services. • Mainstream CIS in policies and plans across all priority sectors. • Enhance CIS for projects across the 8 result areas, NAPs, NDCs, and national development plans. • National and regional optimisation of investments in hydromet.	• Support establishment of National Framework to operationalise GFCS at scale. • Enhance hydromet service provision, optimising infrastructure through regionalisation and gap-filling. • Introduce new public-private partnership business delivery models. • Build e-infrastructure to reduce cost and enhance efficiency. • Create enabling environment for growth in hydromet services.	• Optimise GCF financial instruments to match needs of beneficiaries. • Use innovative financing solutions (including blended finance). • Enhance resource mobilisation from SOFF, GEF, and AF. • Ring-fence national climate funds and other funding sources for hydromet services. • Scale up government budgetary allocation for hydromet services.	• Establish knowledge platforms for sharing best practices in modernisation of climate services. • Use institutional collaborative platforms to enhance knowledge in CIS, digital technologies and business delivery models. • Identify best practices and lessons learned to strengthen political, policy and governance capacity in hydromet services.
	Promoting impact-based MHEWS and Early Action	• Integrate IB-MHEWS in planning, policy and decision making at all levels. • Enhance mechanisms for strengthening capacity at all stages of IB-MHEWS value chain. • Community engagement in designing and implementing forecast-based action at all levels, including indigenous knowledge. • Project pipeline development. • Develop/update of anticipatory action systems and protocols for prioritized hazards.	• Make fit-for-purpose IB-MHEWS widely available by strengthening capacity. • Enhance community-based MHEWS through capacity building of communities and institutions. • Pilot disaster communications systems using digital technology and other innovative channels. • Enhance mechanisms for delivering and scaling up FbA.	• Introduce innovative financing solutions (including blended finance). • Learn from and replicate successful financing of MHEWS. • Scale FbA through dedicated funds, insurance, market-based mechanisms, and standard resource allocation processes. • Embed FbA in financing and delivery systems at scale, working with private sector and informal non-banking institutions.	• Set up institutional collaborative platforms for climate-informed surveillance systems, assessments, and policies. • Create community knowledge platforms, including marginalised groups. • Use knowledge brokering, knowledge management, monitoring, evaluation and learning, impact evaluation and feedback in IB-MHEWS and FbA. • Identify and select evidence-base for FbA. • Systematically measure effectiveness of national MHEWS.
	Improving CIEWS for investment and financial decisions	• Develop systemic resilience framework. • Strengthen the use of digital technologies for climate investment and financial decisions. • Enhance the use of climate analytics for managing financial risks in public sector markets. • Enhance the use of climate analytics for managing risks in private sector markets. • Develop project pipeline. • Promote CIEWS in climate risk management and decision making under uncertainty for climate proofing adaptation projects, and infrastructure. • Support action to address policy and regulatory barriers to use of information (mainstream climate in design standards), including for green infrastructure.	• Use asset design and structuring. • Promote digital technologies and enabling environment for climate investment and financial decisions. • Establish marketplace for digital technology in climate finance. • Increase use of climate analytics for managing financial risks. • Promote use of CIEWS information and climate risk management and adaptation design upstream of project cycle (country, sector level). • Promote use of CIEWS information in system-based approaches for infrastructure (network resilience).	• Scale up financing of climate analytics and digital technologies. • Employ digital technology start-up funding through crowdsourcing. • Obtain climate analytics start-up funding for managing investment and financial risks in private sector through crowdsourcing • Support innovative finance mechanisms for infrastructure resilience, including blended finance, and risk financing. • Integrate climate risk management in PPPs. • Support private sector and community investment in climate-resilient infrastructure. • Extend existing financing arrangements to enable system-level and adaptation management/ pathway approaches.	• Establish knowledge platforms for sharing best practices in CIEWS for infrastructure climate risk management and adaptation and digital technologies and climate analytics for climate finance and investments. • Establish innovation hub for climate analytics. • Support community infrastructure resilience. • Support knowledge brokering, evaluation and learning for climate resilient infrastructure and digital technologies in climate finance.

- Transformational planning and programming: GCF supports developing countries in creating integrated climate and sustainable development strategies and policies. This fosters an environment conducive to green, resilient investment, including climate compatible processes for planning and policy frameworks, ensuring transparency, access to information, participation, equity, and sustainability, which guides and brings legitimacy to processes.
- Catalysing climate innovation: GCF encourages innovation in policy, institutions, business, technology, and finance by supporting enabling environments that harness multiple benefits. Enabling environments rely on norms and values, for example, shared concerns, economic and political interests, narratives, vision, and cultural acceptance.
- Mobilization of finance at scale: key to the GCF role in scaling up finance is addressing information and other market failures, supporting the enabling environment and helping mobilise international and domestic private and public funding to increase financial flows and reduce investment risks. This can include long-term and concessionary public finance, leveraging domestic funding sources, de-risking private finance (using blended finance, for example), encouraging public-private partnership (PPP) initiatives, and increasing non-market and market-based finance.
- Coalitions and knowledge to scale up success: GCF creates and shares knowledge to harmonise valuation methods and incorporate climate risks into financial decisions to align finance with sustainable development. Resources needed to shift financial flows include strengthened institutional and individual capacity, and available and accessible information (data and best practices). By sharing lessons, methods (traditional and scientific), and standards, global finance flows can contribute to projects and programmes that follow transformational pathways towards low emissions and climate-resilient development.

Many opportunities for investments in CIEWS that can further support paradigm shift are emerging due to growing private sector interest. Specific opportunities – and GCF support to capitalise on these opportunities – are as follows:

- Growing demand far exceeds supply. GCF can help close this capacity gap by scaling up effective collaboration, shifting focus from a capital-based infrastructure to a service-based approach, working with stakeholder groups, and leveraging partnerships, including those with the private sector. GCF can also support countries in developing detailed and evidence-based adaptation strategies.
- Market potential for unlocking private sector investments and participation. CIEWS generate a variety of outcomes, ranging from creating new business opportunities to reducing costs for existing businesses. GCF can support the uptake of CIEWS and investments through strengthening policy and setting up business delivery and quality management systems and processes.
- Growing commitment across global, continental, and national scales. The Paris Agreement is an enabler for investment and sets the stage for increased ambition, raising awareness of the utility of CIEWS; the SDGs highlight how development is interconnected with the causes and effects of climate change; the Sendai Framework for DRR provides concrete actions to protect development gains from the risk of disaster; and the Africa Union Agenda 2063 is the strategic framework to deliver inclusive and sustainable development for the Africa continent. CIEWS are central to implementing all these strategies simultaneously.
- Unique opportunity to enhance coherence and complementarity of investments. The climate finance investment landscape is crowded with climate and development finance institutions looking for opportunities to align their efforts to maximise impacts. The unique GCF role provides the financial glue that binds the Alliance for Hydromet Development and sets the standard for mobilising further finance at scale, allowing project proponents to access innovative and blended financial instruments.
- Leveraging private sector finance, public budgets, and public-private partnerships. Investment in CIEWS has traditionally come from the public sector and donor finance with a limited private sector

niche, including for sectors such as aviation. A vibrant private sector is now emerging as governments establish enabling environments through better policy incentives that can unblock barriers to private sector investments in CIEWS. New blended financing tools are also becoming available, with the goal of de-risking investments in climate adaptation for the private sector, and new technologies such as blockchain and machine learning are enabling new commercial opportunities from earth data.

A further opportunity for transformation in the CIEWS sector – one that has proven effective – introduces a central role for government, not as a consumer, but as a seller of services, to businesses and other consumers. Governments taking on this role can provide dual synergies through climate investments: government provides important services to society to improve the cost-effectiveness of relief expenditure and disaster management while maximising the performance of critical infrastructure. GCF can provide CIEWS for several countries, supporting a strong regional climate mitigation and adaptation project pipeline.

The GCF Programming Manual (GCF, 2020a) provides detailed guidance on how paradigm shifting pathways should be presented within the context of the funding proposal's ToC.

4 Financing paradigm shifting pathways

GCF has a role in delivering transformative changes, strategically leveraging its competitive advantage (country-driven approach, open collaboration, flexibility of financing instruments), and is designed to take more risks than other public and private investors, i.e. to accept some failures, to test and demonstrate innovative solutions, and so unlock projects that would not otherwise be possible.

GCF has a broad mandate to support the CIEWS Sector through a mix of approaches and instruments. This section provides an overview of these and sets out how to catalyse and scale up public and private investment to support the paradigm shifting pathways identified in Section 3.

Given the nature of the sector, the main focus is on the area of adaptation and integrated action rather than on mitigation. In general, it is more challenging to attract finance and investment for adaptation (UNEP, 2020) as the CIEWS sector has public goods characteristics and often delivers high societal benefits (economic return) compared to a private rate of return.

GCF grants and readiness support, therefore, remain critical for this result area, including institutional capacity building and technical assistance. Grant funds can provide support in pipeline development, project identification, and project preparation. A further core value for GCF is to promote awareness of Climate information and early warning systems outside of the sector and support integrated transformative planning, such as in climate-resilient investment in mitigation infrastructure and, more generally, in national strategies such as NDCs.

There is potential for concessionary loans to leverage public sources and opportunities to encourage or co-finance with impact investors, including philanthropic funding. Complementing this, there can be an opportunity to attract private investment with blended finance to help bridge the viability gap and improve the bankability of projects via de-risking strategies or subsidies, which is a key role for GCF. These offer potential new business lines for GCF and could help address desired outcomes with innovation.

The GCF Programming Manual (GCF, 2020a) provides further details on financial instruments and co-financing arrangements.

4.1 Financial barriers

Section 2 discussed the key barriers to adaptation at scale, including private sector investment. These include barriers around information (incomplete or asymmetric information), underdeveloped or non-existent markets, imperfect capital markets (which are unable to efficiently allocate capital or transfer risk for longer-term impacts) and positive externalities (benefits to society that do not generate additional cash flows and thus a financial return) (UNEP, 2016; GCF, 2018). This has meant that there are few investment-ready (bankable) private sector adaptation projects (Mortimer, 2021), an issue replicated in the GCF portfolio (Stoll, 2021).

While the cost of most hydromet investments is small compared to the overall adaptation investment needs, these same issues apply. Further, some issues are exacerbated in the CIEWS sector due to the dominance of existing public funding, the domestic budget gaps in national services, and the involvement of multiple donor and development agencies. In the least developed countries, it remains challenging to develop private investment in weather and climate services, given the challenges in developing viable revenue streams.

To date, major investments in CIEWS have had a strong bias towards observational infrastructure, without sufficient attention to its sustainability or an equal focus on downstream steps in the value chain that ensure higher levels of economic benefits from enhanced reach, better user uptake, and decision effectiveness.

Therefore, to deliver a paradigm shift, GCF needs to employ its financial resources not just as a source of grant funding but also to address financial and other barriers in a systemic way. This can include considering

innovative approaches and instruments to de-risk, blend, leverage, and scale-up private sector finance, and take advantage of opportunities (Stoll, 2021) to identify market forces that innovate, engage, and direct investments towards adaptation. At the same time, GCF support to the private sector needs to align with core principles in this area (GCF, 2018) to demonstrate a climate rationale and additionality, not to investment – that could otherwise be financed by the market at commercial terms – to minimise concessionary elements and to ensure (commercial) sustainability.

4.2 Financing including Co-financing

GCF has a wide range of instruments to help deliver the three paradigm shifting pathways discussed in Section 3. Historically, grant finance has been important in the CIEWS sector, recognising the public good characteristics of foundational activities and information, and the positive societal benefits of such investment. While there are strong arguments for using grant finance, GCF projects seek to incorporate co-financing where possible to maximise the impact of GCF funds, although there is no minimum amount of co-financing required. There are opportunities to use GCF finance for technical assistance grants, as well for concessional lending.

4.2.1 Public Domestic Finance

NMHSs and other organisations involved in observation and weather/climate data collection are traditionally funded by public sector investments (domestic, bi-lateral, and multi-lateral).

National government public budgets provide predictable funding for public authorities and public research institutions active in the CIEWS sector and cover operational expenditures such as salaries, administrative expenses and equipment running costs. Without a government commitment to fund core NMHS functions, there is little chance of achieving a sustainable national hydromet capability.

However, these institutions are often under-resourced, which can mean it is difficult to expand services to provide additional services that support or deliver adaptation. In such cases, there can be a role for GCF to provide grants or concessionary lending for additional investments. Public domestic budgets and development assistance are important sources of co-financing in such cases. Investing in CIEWS has spill over benefits for other sectors, bringing wider benefit opportunities from integrated and cross-sectoral climate mainstreaming in medium-term development plans and budgeting across government. Given the large national economic benefits that NMHSs provide (WMO, 2015), further work to incentivise governments to increase the national budgets for core hydromet services is highlighted.

There will be relevant public financing elements for supporting Pathway 1 – Strengthening climate information services, especially developing CIS through modernising hydromet services for equipment, technical capacity development, and institutional effectiveness. This is relevant to both sub-components: modernisation of hydromet services and regional hydromet programmes, and there is considerable potential for private sector investment in subsequent value added (see Section 4.2.2).

Similarly, there is likely to be an important public finance component to establishing Pathway 2 – Promoting impact-based MHEWS and Early Action, especially as this is often delivered by the public sector and targets the most vulnerable. This reflects potential investment in community development programmes, governments and shock-responsive social protection mechanisms, and international preparedness, anticipatory action, and response. Readiness investments would support knowledge brokering, including monitoring, evaluation, learning, impact assessment, and feedback in forecast-based action. Forecast-based finance is emerging as a new approach to ensure prompt disbursement of funding, using climate forecasts to trigger pre-defined community-level actions to reduce the risks and impact of disasters. The approach allows for prompt intervention and investment in support of climate adaptation. Funding opportunities for

forecast-based early actions can be part of broader funds or independent initiatives. However, there are also opportunities for the private sector in business continuity programmes (see Section 4.2.2).

For Pathway 3 – Improving CIEWS for investment and financial decisions – there is a much greater potential for innovative solutions and more potential for private sector investment. This applies to all three sub-components: (1) digital financial technologies, (2) climate analytics for managing investment and financial risks in private sector markets, and (3) climate analytics for managing investment and financial risks in public sector markets.

In addition to specific budget allocations provided by government is installing a cost recovery mechanism. Such a mechanism could allow CIEWS organisations to supplement public funding with additional revenues, for example, from the aviation sector. WMO supports countries in establishing mechanisms that enable NMHSs to recover costs and make additional revenues. However, despite efforts in some countries to subsidise core public services through commercial services, this has rarely proven to be a viable option – particularly in LDCs and SIDS.

4.2.2 Private and Blended Finance Opportunities

Public funds can offer concessional lending to advance pilot projects, cover first losses, or provide guarantees or equity. These de-risking approaches could potentially allow GCF to harness significant transformative potential at these stages of financing, which tend to occur before scaling up, which would attract institutional investors and other sources of market-rate capital.

Private sector players in the CIEWS landscape are beginning to emerge in developing countries for certain services, such as aviation and agriculture, where there are viable models for revenue generation. Well-established public-private-partnership models already exist in developed countries, setting best practices for developing countries to emulate. Therefore, GCF sees private sector participation as an important element of ensuring efficiency and effectiveness as well as sustainability and scaling up of investments.

GCF can help develop ideas or attract private investment at early stages (with research and development, challenge funds, or seed funding) for large companies as well as micro, small, and medium-sized enterprises (MSMEs). GCF also funds technical assistance facilities that can help strengthen offerings and business models, and there are already examples of GCF providing support equity to investment funds for adaptation.

GCF also has a role in enabling organisations with different objectives to invest alongside each other while achieving their own objectives (financial return, social, economic, and environmental impacts, or a blend of both). This facilitation can help address risk perceptions, crowd-in finance, and address the returns that different investors may require, i.e. concessional rates for development funding with market rates for private capital. To engage the private sector in Pathway 1, there are opportunities for private and public-private partnership arrangements in line with WMO policy recommendations on private sector engagement. Financing approaches can focus on deploying an appropriate range of GCF financial instruments. For Pathway 2, innovative financing approaches (e.g. forecast-based financing) have already been tested at scale. There are opportunities to target the broader risk management landscape, including business continuity and creation of new markets through providing services to government and the broader private sector. For Pathway 3, the full range of GCF instruments can be applied to support existing and new markets and services in the digital economy with loans, equity, and guarantees. For example, GCF is already providing equity to private investment funds for adaptation to support innovative digital and agri-business markets.

As climate finance risks increase, GCF has a major role in a wider set of new financial resilience investments, which often use weather and climate information or early warning. These include catastrophe and resilience bonds (debt instruments) and de-risking instruments, such as sovereign risk pooling insurance and contingency financing – including disaster contingent financing. GCF has a potential role in market

development in these areas, including financing technical assistance and providing support to strengthen offerings and business models.

GCF support to the private sector needs to align with core principles (GCF, 2018) to demonstrate a climate rationale and additionality, not to finance investment – that could otherwise be financed by the market at commercial terms – to minimise concessionary elements and ensure (commercial) sustainability.

4.3 Complementarity and coherence

Improving complementarity and coherence in implementation requires NDAs, AEs, National Disaster Management Authorities and others to identify barriers, norms and processes for design and implementation, resources to invest in, and legitimacy. NDAs and AEs can work with GCF to align objectives with other international climate finance to support countries in identifying existing domestic financial mechanisms that can be leveraged for climate and aligned to climate change goals. GCF, NDAs, and AEs can contribute by strengthening local development institutions, establishing standards and systems, and developing guidance. Finally, while there is undoubtedly a need to leverage public domestic flows and private finance, there are broader political issues around the international commitments for adaptation finance and the potential disconnect between the "adaptation finance criteria" and the private sector reality. Thus, some care is needed in developing these pathways to ensure activities align with the UNFCCC goals and that finance flows to the poorest and most vulnerable.

4.4 GCF portfolio and financing structures

Current GCF financial instruments consist of grants, loans, equity, and guarantees. The public goods nature of CIEWS products and services has resulted in CIEWS investment dominated by grant financing. However, there is an increasing interest in creating new markets to enable the private sector to support the transition to low-emission, climate-resilient development. GCF has additional financial instruments that have transferability to this sector, including loans, equity, guarantees, as well as results-based payments. This wider variety of financial instruments and the more creative use of existing instruments can help catalyse scaled-up public and private financing. Table 5 shows how financial instruments may be characterised.

Table 5: Taxonomy of financial instruments in CIEWS

Goal of structure	Instrument	Transformational Potential	Examples
Increase likelihood of social impacts	Grants	• Some core barriers to a paradigm shift in Climate information and early warning systems are best addressed via grant finance, including readiness support, grants, revolving grants, and results-based grants, to support planning and pipeline development, institutional capacity building, technical assistance, monitoring and surveillance, and knowledge sharing. This includes foundational investments in CIEWS. • Difficulty for GCF reaching community organisations, MSMEs and "bottom of the pyramid" organisations (GCF B.23/12/Add.01) can be addressed through dedicated facilities for small grants such as its Enhanced Direct Access Facility or EDA, plus grant (alongside equity) support for business incubation facilities. • Micro to large scale.[4]	• GCF readiness grants. • GCF grants, such as GCF project Multi-Hazard Impact-Based Forecasting and Early Warning System for the Philippines, and GCF project Scaling-up Multi-Hazard Early Warning System and the Use of Climate Information in Georgia.
Improve the risk/reward profile	Loans	• The long tenures available with GCF lending may match the long-term nature of CIEWS investments. • GCF also has the flexibility to offer significant concessionality on private sector loans. At smaller and micro scale, loans providing working capital to MSMEs. As part of enhanced direct access, revolving loan funds can achieve financial inclusion of community enterprises. • GCF could further emphasise loan facilities over project-based lending. It can also take on subordinated (junior) debt (i.e. the riskiest loan tranches), to catalyse private investors by reducing their risk exposure. • Micro to large scale.	• Co-financing with MDCs, for example the GCF project for Programme for integrated development and adaptation to climate change in the Niger Basin (PIDACC/NB) provides a GCF grant which is co-financed in part by a loan (from a MDB). • Forecast-based financing – with shock response contingency funds and cash transfers, as part of social protection programmes.
	Guarantees	• GCF can issue partial (first loss) risk guarantees backing loans and bond issuance including debt-for-climate swaps. Small to large scale[5]. Guarantees catalyse finance by reducing the level of risk taken on by public or private investors.	

[4] The scale of supported projects uses GCF project size categories: Micro: <USD 10m; Small: USD 10-50m; Medium: USD 50-250m; Large: >USD 250m. See Annex I to decision B.08/02.
[5] Guarantees are unlikely to be large-scale but are often used in conjunction with debt financing (loans or bonds) for large-scale projects and programmes.

Goal of structure	Instrument	Transformational Potential	Examples
	Equity	• Anchor investor in equity funds, often in combination with other instruments Equity funds can catalyse impact investment to stimulate investing in support for social entrepreneurs and incubating early-stage businesses. GCF might also develop mezzanine financing, which is a hybrid of debt and equity that gives lenders the right to convert to an equity interest in case of default. • Micro to large scale.	• GCF project Acumen Resilient Agriculture Fund (ARAF), providing a GCF equity broadly matching co-financing equity.
	Bonds	• Provide partial credit guarantees to de-risk bond issuance, or support capacity building for the creation of green bond facilities. Targeted bonds can help overcome financing barriers to both public and private investment. Accredited multilateral development banks are well placed to issue green bonds at scale, with the added value of GCF support likely focused on partial credit guarantees to de-risk issuance in new markets and sectors. Small to large scale.	• There are a range of new bond instruments that have relevance to CIEWS, including catastrophe bonds (disaster bonds), as well as resilience bonds.
	Insurance and climate risk finance	• Insurance products can play a supplementary role, de- risking private investment as well as protecting livelihoods in the face of climate-related disasters. GCF could also play a role in market development, including financing technical assistance for new insurance services or other emerging financial instruments in this area. Examples include sovereign disaster risk insurance, agricultural insurance, and homeowner's flood risk insurance.	• Index based insurance (for example the GCF project Africa Integrated Climate Risk Management Programme is addressing insurance barriers and strengthening climate weather information services, for smallholder farmers in 7 Sahelian Countries. Nature based insurance models such as the Quintana Roo, Mexico coral reef parametric insurance policy. • Disaster contingent financing (to allow liquidity following a disaster), and risk transfer mechanisms such as sovereign risk pools.
	Public-private partnerships	• PPPs are used to leverage private investment for the provision of public goods. Public-private collaboration as part of multistakeholder dialogue is an important component in planning for transformational impacts. • PPPs are often used to address budget constraints but this can involve fiscal risks, and they can be expensive. Climate change also poses some threats to PPP models, as there may be difficulties in allocating climate risks, with implications for financing models. • GCF could play a role in technical assistance and institutional strengthening for climate-targeted or climate proofing PPP infrastructure.	• Allocating climate risks in PPPs, with tools to increase government capacity to manage.

5 Case studies

This section provides examples (from GCF and others) that span across pathways and drivers. The case studies demonstrate how public sector financing can support climate-based solutions in CIEWS.

5.1 Georgia: Scaling-up Multi-Hazard Early Warning System and the use of climate information

Pathway 1: Strengthening climate information services, transformational planning and programming

Theme	Reducing climate risk to communities by supporting infrastructure and livelihoods.		
Country	Georgia	**Project size**	USD 70.3 m (medium)
Adaptation	3.7 million beneficiaries	**GCF financing**	Grants: USD 27.1 m
EES category	Category B	**Co-financing**	Grants: USD 42.6 m In-kind: USD 0.6 m
Accredited entity	UNDP	**Co-finance ratio**	61.5%
Approval	2018	**Completion**	2025
Information	https://www.greenclimate.fund/project/fp068		

Impact potential

Georgia faces climate change-related risks, including landslides, mudflows, erosion, avalanches, floods, drought, and strong winds. These are increasing in frequency, intensity, and geographical spread due to climate change. Hence, the need for robust climate information and early warning has become a priority in managing risk to Georgia's sustainable development.

Expanding a hydro-meteorological observation network and modelling capacities will provide reliable information on climate-induced hazards, vulnerability, and risks. Specifically, scaling up Georgia's MHEWS will improve community resilience. Robust climate information has been shown to considerably reduce costs.

Approach to paradigm shift

The project has high paradigm-shifting potential through establishing robust impact-based MHEWS to secure lives, livelihoods, and assets. Innovative approaches to the generation and use of CIS have the potential to drive uptake and investments in CIEWS.

The project:

- Addresses the urgent need to modernise the hydromet agency to deliver robust CIEWS for development.
- Adopts significant co-financing innovations to drive down costs.
- Integrates hydromet infrastructure operations and maintenance costs into the annual government budget to ensure sustainability of investments.
- Focuses results on the most vulnerable people and communities, and infrastructure and the built environment.

5.2 Philippines: Multi-Hazard Impact-Based Forecasting and Early Warning System

Pathway 2: Impact-based MHEWS and early action, catalysing climate innovation

Theme	Scaling up current initiatives on disaster risk reduction and climate change adaptation.		
Country	Philippines	**Project size**	USD 20.2 m (small)
Adaptation	8.5 million beneficiaries	**GCF financing**	Grants: USD 10 m
EES category	Category C	**Co-financing**	In-kind: USD 10.2 m
Accredited entity	Landbank of the Philippines	**Co-finance ratio**	50.5%
Approval	2019	**Completion**	2027
Information	https://www.greenclimate.fund/project/sap010		

Impact potential

The Philippines is one of the most vulnerable countries to climate hazards, experiencing an average of 19 tropical cyclones annually. In 2013, Typhoon Haiyan caused infrastructure and agriculture damages of USD 760 million, claimed 6,293 lives, injured 28,689 individuals, and left 1,061 individuals unaccounted for. Studies project an increase in the intensity of tropical cyclones. Without efficient and effective interventions, the increasing vulnerability of physical and social infrastructure means that disasters are anticipated to be devastating. Studies project an increase in the intensity of cyclones, along with an increase in the vulnerability of physical and social infrastructure.

Lessons from Haiyan indicate that although forecasts and warnings may be accurate, the lack of understanding of risk information and its potential impact remains a challenge. Actionable risk information, warnings, and response actions are key to the effectiveness and efficiency of early warning systems (EWS). The funding proposal seeks to establish an innovative solution by building on lessons learned, best practices, and state-of-the-art multi-hazard, impact-based forecasting early warning services that will be linked with forecast-based actions to maximise impact on the ground.

The proposal is well-aligned with NDC and NAP national development plans as well as SDGs and the Sendai Framework. The best available knowledge for DRR is being applied at scale for the first time in the country. The potential for transformational impact is significant.

Approach to paradigm shift

The project:

- Strengthens the Philippines' ability to adjust to climate impact and implement long-term climate risk reduction and adaptation measures.
- Builds on best practice in MHEWS, climate-resilient development planning and investment, and forecast-based financing to reduce disaster risk.
- Leverages high-level political buy-in to demonstrate the value of GCF in climate action.
- Saves lives, livelihoods, and assets across multiple result areas, including Livelihoods of people and communities; Health and wellbeing; Health, food, and water security; Infrastructure and built environment; and Ecosystems and ecosystem services.

5.3 Monrovia Metropolitan Climate Resilience Project

Pathway 3: Improving CIEWS for investment and financial decisions

Theme	Enhancing the resiliency of vulnerable coastal communities to climate-induced sea-level rise by constructing coastal defence structures, developing a coastal zone management plan, and supporting livelihood diversification.		
Country	Liberia	**Project size**	USD 25.6 m (small)
Adaptation	1.3 million beneficiaries	**GCF financing**	Grants: USD 17.3 m
EES category	Category B	**Co-financing**	Grants: USD 4.1 m In-kind: USD 4.3 m
Accredited entity	United Nations Development Programme	**Co-finance ratio**	33%
Approval	2021	**Completion**	2027
Information	https://www.greenclimate.fund/project/fp160		

Impact potential

Liberia's capital city, Monrovia, is extremely vulnerable to climate change impacts of sea-level rise and the increasing frequency of high-intensity storms, both of which contribute to coastal erosion and shoreline retreat. Additionally, sea-level rise is threatening the sustainability of ecosystem services provided by mangroves, which is further exacerbated by urban encroachment. These changes will have a considerable impact on the fishery-based livelihoods of approximately 55,000 Monrovians, 46% of whom are women.

The project builds long-term climate resilience of coastal communities by addressing immediate adaptation priorities and creating an enabling environment for upscaling coastal adaptation initiatives. Lateral spread to other parts of Monrovia and Liberia is supported by investing in coastal protection, coastal management, and diversified climate-resilient livelihoods.

Approach to paradigm shift

These investments by the GCF and the government of Liberia will catalyse a paradigm shift in the management of Monrovia's coastal zone towards an integrated, transformative, and proactive approach. Actions address current and anticipated climate change risks and mix infrastructure and coastal ecosystems in adaptation efforts.

The paradigm shift is facilitated through initiatives to strengthen technical and institutional capacity of the government and communities in consultation with relevant stakeholders, including the private sector. By fostering partnerships, the project improves coordination on coastal management and creates an enabling environment for ongoing coastal adaptation beyond the project area and after the project implementation period.

Adaptative capacity in Monrovia is increased by:

- Safeguarding ecosystem services provided by mangroves and increasing the resilience of these ecosystems to climate change through community co-management agreements between government and communities.
- Improving community knowledge on climate change impact and adaptation practices.
- Strengthening climate-sensitive livelihoods and supporting the uptake of climate-resilient livelihoods.

5.4 Niger Basin: Programme for integrated development and adaptation to climate change

Pathway 3: Improving CIEWS for investment and financial decisions

Theme	Improving the resilience of populations and ecosystems in the Niger Basin by managing natural resources sustainably.		
Country	Benin, Burkina Faso, Côte d'Ivoire, Guinea, Mali, Niger, Nigeria, Cameroon, Chad	**Project size**	USD 209.9 m (medium)
Adaptation	14 million beneficiaries	**GCF financing**	Loans: USD 10 m Grants: USD 57.8 m
EES category	Category A	**Co-financing**	Loans: USD 35.9 m Grants: USD 82.2 m In-kind: USD 23.9 m
Accredited entity	African Development Bank	**Co-finance ratio**	67.7%
Approval	2018	**Completion**	2025
Information	https://www.greenclimate.fund/project/fp092		

Impact potential

The Niger Basin of the Sahel is one of Africa's regions most vulnerable to climate change. Over the past six decades, the total annual rainfall has reduced by 20-40%. Recurrent droughts have resulted in the increasing fragility of ecosystems and reduced social resilience that disproportionately affects women, children, and disabled people in the basin. A unique feature of this region is the presence of climate-induced conflicts between transhumance activities and local farming communities over shrinking water resources and fertile lands. This programme addresses these drivers by implementing a series of integrated and comprehensive actions that reduce the silting of the Niger River, improve natural resources management, and enhance the population's ability to adapt to climate change. It also includes some mitigation activities, for example, through forest and land use.

The programme builds on the Niger Basin Climate Resilience Investment Plan, which aims to enhance climate resilience of Member States through innovative financing of the regional and national water resource investments in robust CIEWS, institutional effectiveness through the development of core capacities of relevant institutions, as well as sustainable infrastructure for integrated water resources management. It targets fragile community livelihoods for inclusive growth and builds on the successful implementation of the Multinational Silt Control of the Niger River Basin.

Approach to paradigm shift

The project:

- Uses robust climate information to secure lives, livelihoods, and assets.
- Avoids significantly high costs and delivers social, economic, and environmental co-benefits.
- Leverages well-established high-level political buy-in to demonstrate the value of GCF in climate action.
- Includes some mitigation activities, for example, through forest and land use.

The best available knowledge for DRR is being applied at scale for the first time in the region. The potential for transformational impact is significant.

6 Investment criteria

Proposals to GCF need to align with GCF result areas and are assessed based on six GCF investment criteria[6], summarised here along with examples of how these criteria could pertain to the CIEWS paradigm shifting pathways. GCF supported actions can refer to individual projects at a site or to broader programmatic responses. See the GCF Programming Manual (GCF, 2020a) for further details.

Table 6: Investment criteria examples (not inclusive) for the three CIEWS paradigm shifting pathways

	CIEWS paradigm shifting pathways		
	Climate information services	Promoting impact-based MHEWS and early action	Improving CIEWS for investment and financial decisions
Investment criteria examples			
Impact	• Number of beneficiaries with enhanced access to weather and climate services. • Value of avoided losses or enhanced gains.	• Number of beneficiaries with enhanced access to MHEWS. • Value of avoided losses. • Number of beneficiaries (and livelihoods) of most vulnerable people and communities with enhanced climate resilience Number of new EWS and FBF instruments.	• Number of beneficiaries reached. • Number of new business models or services. • Volume of finance mobilised. • Assets made climate resilient.
Paradigm shift	• Invests across the CIEWS value chain to enhance benefits. • Identifies barriers and solutions to these, and delivers national sustainability and co-financing. • Helps mainstream CIEWS across sectors, leading to cross-sectoral and economy wide benefits.	• Invests across the CIEWS value chain to enhance benefits. • Identifies barriers to co-financing and delivers national and development partner co-finance.	• Investment across the CIEWS value chain to deliver value and scale-up. • Identifies barriers to private investment and overcomes these. • Builds private sector finance (blending co-finance) and new financial instruments. • Delivers climate-resilient investments.
Sustainable development	• Helps achieve or contribute to relevant SDGs. • Delivers environmental, social, and economic benefits.	• Helps achieve or contribute to relevant SDGs. • Reduces environmental, social, and economic impacts, including on the most vulnerable.	• Helps achieve or contribute to relevant SDGs. • Delivers economic value and wider macro-economic benefits. • Delivers environmental and social benefits.
Recipient needs	• Aligns to national priorities. • Takes account of capacity and needs of NMHS.	• Aligns to national priorities. • Takes account of capacity and needs of NMHS.	• Aligns to national priorities. • Follows WMO policy recommendations on private sector engagement.
Country ownership	• Builds on other national projects and actions. • Maintains consistency with national climate strategy or plan, including priorities identified in NDCs or NAPs.		

[6] https://www.greenclimate.fund/projects/criteria

	CIEWS paradigm shifting pathways		
	Climate information services	Promoting impact-based MHEWS and early action	Improving CIEWS for investment and financial decisions
Investment criteria examples			
Efficiency & effectiveness	• Quantifies societal benefits (full economic benefits of CIEWS – environment, social, and economic). • Quantifies economy, efficiency, and effectiveness of options.	• Quantifies societal benefits (full economic benefits of CIEWS – environment, social, and economic). • Quantifies economy, efficiency, and effectiveness of options.	• Quantifies societal benefits (full economic benefits of CIEWS – environment, social, and economic). • Quantifies economy, efficiency, and effectiveness of options.

The following linkages with GCF investment criteria need to be aligned with the recently adopted GCF Integrated Results Management Framework.

6.1 Impact potential

The potential impact can be captured as the number of beneficiaries for adaptation projects. This can include the number of people receiving CIEWS and the numbers made more climate-resilient, including the most vulnerable (of particular relevance to EWS and forecast-based financing). However, the impact potential should go beyond this. CIEWS projects lead to improved information. In turn, this information provides economic benefits to users, as it leads to positive outcomes from the actions and decisions that users subsequently take. The impact potential should therefore capture the economic benefits that CIEWS provide. These include private or market benefits, such as yield and income improvements for farmers or avoided losses from EWS, but also the societal or public benefits, with non-market benefits such as reduced health risks or environmental benefits. Projects can report on and monitor these benefits, thus considering the overall economic benefits, and be included in logical frameworks. Other metrics of impact potential, especially when moving to private sector financing of CIEWS, especially for pathway 3, could include the number (market size) of new business models or services, the volume of private sector finance mobilised, or assets under management or investments made climate-resilient.

6.2 Paradigm shift potential

The benefits of CIEWS are only generated if users make better decisions as a result of the information they receive. This means that projects should invest across CIEWS value chains. This starts with foundational activities that underpin the service, including meteorological infrastructure and observations. It then includes generating information, such as forecasts or early warnings, and communicating this information to end-users to increase the number of users reached. Finally, it includes the uptake, understanding, and effective use of the information by end-users in decisions. Projects that look at all steps – through to last-mile delivery – will achieve a higher impact.

For Pathway 1, paradigm shift can be achieved by supporting the development of sustainable national meteorological services, including through national and other co-finance, and providing the necessary conditions to allow the private sector to add value, including with new services. There is also potential to mainstream CIEWS across different sectors (or to ensure investments in one sector cascade to others) as this will generate spill-over and wider economic benefits. For Pathway 2, similar issues apply, but paradigm shift can be delivered through enhanced sharing and collaborating with partners for vulnerable communities and shifting to forecast-based finance to minimise the need for humanitarian response. This also includes co-

financing at scale. For MHEWS, there is a range of value-added opportunities that can include targeted or tailored information, including for the private sector.

For Paradigm 3, paradigm shift is delivered by overcoming barriers to private investment and supporting the development of new services and markets through blended finance options while respecting WMO policy recommendations on private sector engagement.

6.3 Sustainable development potential

CIEWS projects deliver many dimensions of development and numerous SDGs. They also deliver on multiple aspects of environmental and social benefits, not just economic (market) benefits. Projects should capture and ideally quantify the full set of these benefits.

6.4 Needs of the recipient

CIEWS projects developed bottom-up can directly address the needs of the recipient through outcomes and investments. Using a multistakeholder approach creates capacity and supports the improvement of institutions to work across sectors and thematic areas.

6.5 Country ownership

CIEWS should demonstrate consistency with national climate strategies or plans, including priorities identified in NDCs or NAPs. There is also an opportunity to mainstream CIEWS across multiple sectors – including in various sector NAPs.

6.6 Efficiency and effectiveness

For adaptation projects, the cost per beneficiary should be estimated and accompanied by indicators and estimates of the benefits the project could realise. For mitigation projects (less relevant for CIEWS), the expected tons of carbon dioxide equivalent (tCO2eq) to be reduced or avoided for every USD of GCF contribution can be calculated. The analysis can be extended to indirect and induced emission reduction.

However, projects should go beyond basic indicators to quantify the economic (societal) benefits of CIEWS, capturing non-market benefits (social and environmental benefits) as well as private (market) benefits (WMO, 2015). Proposals should also demonstrate value for money, as captured through minimising costs (control of input costs), efficiency, as captured by the economic benefit to cost ratio or net present value (ensuring inputs are translated efficiently to outputs), and effectiveness, as highlighted by the value of investing in CIEWS compared to alternatives (ensuring projects deliver maximum outcomes for the area compared to alternatives) (WISER, 2017).

6.7 Coalitions and networks to multiply GCF CIEWS portfolio impact

Challenging the status quo to achieve change can be approached by forming “change coalitions”, although the effectiveness of such coalitions depends on pre-existing conditions and how the platforms are implemented (Brockhaus, 2017). Multistakeholder processes are part of a wider interest in participatory spaces, also known as multistakeholder initiatives, forums, coalitions, networks, and platforms – bringing all stakeholders together for joint problem-solving. Coalitions are purposely organised networks of stakeholders interacting in dialogue and coordination, knowledge sharing, and implementation. Such processes can expand and replicate knowledge, disseminate good practices and methods, and support systemic change.

These collaborative spaces are becoming widespread and include such initiatives as the Local Communities and Indigenous Peoples Platform of the UNFCCC and the Dedicated Grants Mechanism. Such platforms can

involve community-level associations, knowledge hubs, and co-management bodies and support local organisations to build legitimacy and share lessons (traditional and scientific) to contribute to understanding applicable methods and standards. Successful multistakeholder processes have deeply engaged participants that have the time and resources to accompany or govern change (Sarmiento Barletti, 2020).

When enhancing complementarity and coherence, it remains important to avoid top-heavy coalitions that may not represent Indigenous peoples and women nor reflect their experiences, knowledge, and priorities. Knowledge sharing is key and usually done through central meetings or online resources. Creating alliances and synergies among participants, for example, through working groups and with other already existing platforms, is an effective way to strengthen coalitions. Under-represented groups should be more than mere "observers" and participate in management and decision making.

7 Conclusion

Reliable, timely and effective CIEWS are a key enabler for meeting the Paris Agreement and the 2030 SDGs. The CIEWS Sectoral Guide presents these critical objectives as three paradigm shifting investment pathways. For paradigm shifts to be achieved, barriers need to be removed relating to knowledge and capacities, risks, and financing. Transformative pathways require climate compatible policy frameworks and strengthening of institutional capacity across local, sub-national, and national levels, and among actors, including different sectoral ministries, such as transport, agriculture and water, the private sector, and civil society.

This Guide supports stakeholders in developing robust funding proposals based on the three strategic investment pathways in connection to the four key drivers of transformational change. The case studies highlight approaches that build effective and sustainable CIEWS and that encourage anticipatory action at individual, community, national, and regional levels, while providing robust, evidence-based information to make informed investment decisions for a low-emission, climate-resilient global economy. These cases can increase the resilience of vulnerable populations and enhance the capacity of local communities to adapt to future changes in climate. They demonstrate how innovative approaches and broad participation in decision-making processes can promote a successful paradigm shift.

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