**“Words into Action”**

**A Guide for Multi-Hazard Early Warning Systems**

Consultative version – Draft 0

**A person holding a steering wheel

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**Chapter 1**

**Introduction**

Considering the expected increase in the frequency and intensity of extreme events due to climate change, early warning systems (EWS) are seen as a key component of disaster risk reduction (DRR) strategies as they can help to reduce loss of lives and assets.

Economic losses produced by disasters have increased over the last five decades, but at the same time, there has been a decrease in loss of life associated with hydro-meteorological hazards; this success has been attributed to effective EWS, based on advancements in monitoring and forecasting of weather-related hazards, among other factors.

As EWS for specific hazards and consequences have many common elements, the use of a common Multi-hazard EWS framework enables sharing of lessons learnt, create economies of scale, and eventually reinforce sustainability of the system. While governments and stakeholders recognize the benefits of multi-hazard EWS they do not count yet with systematic guidance on how to implement them and monitor their effectiveness.

In 2015, Member States adopted the Sendai Framework for Disaster Risk Reduction 2015-2030 to reduce the human and economic loss caused by disasters and avoid the creation of new risks. To help implement this Sendai Framework, the UN Office for Disaster Risk Reduction (UNDRR) has launched the Words into Action (WiA) Guides as a series of guidelines, based on global expertise, communities of practice, and networks of Disaster Risk Reduction (DRR) practitioners. The guidelines provide practical, specific advice on implementing a people-centered approach to DRR in line with the Sendai Framework.

Contributing to the WiA series, the UNDRR, The United Nations Platform for Space-based Information for Disaster Management and Emergency Response (UN-SPIDER) from the United Nations Office for Outer Space Affairs (UNOOSA) and the World Meteorological Organization (WMO) have led the elaboration of a new WiA guide to provide practical guidance to the implementation of the Sendai Target G with special focus on Multi-hazard Early Warning Systems (MHEWS). This WiA aims to provide advice for governments, stakeholders, and partners on how to institutionalize, operate, monitor, and strengthen people-centred inclusive approaches for multi hazard early warning systems.

Organized in 4 chapters, this Words into Action Guide focuses on offering the knowledge to enable the actionability of effective (multi-hazard) early warning systems. This introduction as Chapter 1 set the scene and present the rationality for the reinforcement of EWS. Chapter 2 presents critical content to implement and sustain effective (MH)EWS, including the description of the governance mechanisms to support their operation. Chapter 3 focuses on the Early Warning and Early Action chain, as well as the main approaches and functions that facilitate their application. Chapter 4 includes some monitoring and evaluation available mechanisms to assess the access and benefits of the implementation of Early Warnings and Early Actions.

**Setting the scene**

Earthquakes continue to destroy or damage infrastructure of many types and continue to top the list regarding the number of people killed or injured. Tsunamis in coastal areas, although less frequent, also trigger massive losses in many sectors of developing. The tsunami triggered by the Great Eastern Japan earthquake in March 2011 generated many losses in industry, agriculture, public and private infrastructure, ports, airports, and nuclear power plants. Hurricanes, typhoons, and cyclones also batter coastal areas and their compound manifestation in terms of powerful winds, storm surges, and intense precipitation trigger flash flooding, landslides, and other cascading effects. Droughts, while do not regularly cause substantive infrastructure or housing damage, result on major disruptions to agriculture sector and some industrial sectors representing a critical challenge to water and food security, disrupting livelihoods and are events that affect the largest number of people in countries and regions.

Over the past decade, an average of 206 million people were affected annually by storms, floods, droughts and wildfires[[1]](#footnote-2). Economic losses attributed to disasters have reached US$ 2.97 trillion affecting over 4 billion people worldwide in the last twenty years, in comparison with the US$ 1.63 trillion of economic losses affecting 3 billion people from 1980 -1999[[2]](#footnote-3). This increment may be attributed to climate induced events.

Due to climate change, hydro meteorological events are expected to be more frequent and intensified in the coming years[[3]](#footnote-4) affecting lives, assets, and livelihoods of at-risk populations. Climate change is increasing risks and exacerbating the vulnerability of exposed people by slowly undermining their livelihoods, for example, gradually damaging their livelihoods through incremental changes, like sea level rise and its consequent salinization of land that decrease crop yields every year affecting farmers and rural populations.

Disasters have been eroding hard-won development gains in communities worldwide, disproportionally affecting those most marginalized . Correspondingly, inefficient development processes, that leave exposed populations to hazardous events and vulnerable to their impacts, are creating risk conditions for devastating situations. Moreover, disasters affecting poorest and marginalized populations increase their risk condition, exacerbating vulnerabilities to new disasters, creating a vicious circle where disaster risk measures are critical element to implement. Taking the above into account, since the 1990s, international efforts have been reinforced to address the challenges of risks conditions through disaster risk management strategies.

Graphic: Disaster Impacts: 1980-1999 vs 2000-2019. Source: CRED/UNDRR, 2020

Chart, bubble chart

Description automatically generatedRecognizing early warning systems as an effective strategy of disaster risk management, in its article 7c, the Paris Climate Change Agreement calls for the “Strengthening scientific knowledge on climate, including research, systematic observation of the climate and early warning systems in a manner that informs climate services and supports decision making.”

The systemic impact of disasters is manifested in several interconnected affected sectors in society, as seen with the Covid-19 pandemic. While improvements have been made in terms of early warnings, disaster preparedness and response, the increasingly systemic nature of disaster risk, have continued to rise the cost of disasters requiring greater reinforcement of disaster risk governance (CRED & UNDRR, 2020) and its subsequent implementation of risk reduction policies, between them, enhancing effectiveness early warning – early action value chains and reinforcing practicalimplementation of EWS as a way to substantially reduce economic losses , minimize disruptions and diminish the number of affected populations by disasters.

**Chapter 2**

**Establishing and sustaining effective early warning systems**

The occurrence and intensity of some extreme weather events are more frequent nowadays. The most recent IPCC report notes that approximately 3.5 billion people[[4]](#footnote-5) are highly vulnerable to climate impacts of severe weather events. Intensified episodes of floods, droughts, heat waves and other climate related hazards increase the risk condition of vulnerable populations, which threatens their lives and livelihoods. Furthermore, ‘rising temperatures and rainfall are increasing the spread of diseases in people, such as dengue fever, and in crops, livestock and wildlife’[[5]](#footnote-6) thus provoking cascading hazards with the corresponding impacts affecting different sectors and the development processes.

In addition to this, geo-related hazards such as earthquakes, tsunamis, or volcanic eruptions are also threatening exposed populations. Those hazards may be less frequent than meteorological hazards but usually have devastating impact, causing enormous losses and elevated number of casualties. Just as an example, ‘in 2015, one million people had to evacuate from their homes after a powerful earthquake struck off the coast of Chile’[[6]](#footnote-7). Those hazards along with ‘underlying factors such as poverty, land degradation and conflicts aggravate exposure and vulnerability’[[7]](#footnote-8) exacerbating risk conditions of populations.

One of the fundamental mechanisms to reduce the impact of disasters is the implementation of effective Early Warning Systems embedded in governability frameworks which foster their institutionalism and generate conditions for their sustainability.

This chapter offers guidance on how to establish Early Warning Systems (EWS) or shift from EWS to MHEWS focusing on inclusion factors and offering key tools to reinforce governability and sustainability aspects.

**2.1. Establishing inclusive multi-hazard early warning systems**

Rural populations depending on climate conditions for the maintenance of their livelihoods; indigenous peoples living in marginalized conditions or in exposed areas; people with disabilities living in inequitable conditions; children or elderly people highly dependent on others; or women carrying with excessive loads of work are considered groups at-risk that will be the most impacted by disasters in the coming years. If preventive measures are not dramatically increased, those or any other exposed group will be the expected losses of future disasters.

The implementation of EWS can support strategies to reduce risks and leave no one behind as they can trigger *early actions* mitigating disaster’s impact, as the case of evacuation of livestock before flooding, vaccination programs before an envisioned epidemic or distribution of resistance seeds for drought periods. This section presents the information to allow hazard-specific warning systems to evolve towards more inclusive and coherent multi-hazard EWS along with key approaches and emerging trends that will enable countries and localities reduce impact of disasters, reduce their risks and increase their resilience.

**2.1.1. Multi-Hazard Early Warning Systems (MHEWS) definition and approaches**

**a. Definition**

**What is an Early Warning System?**

The open-ended intergovernmental expert working group on indicators and terminology relating to disaster risk reduction, which report was adopted by UN General Assembly resolution A/71/644 in December 2016has defined an EWS as an integrated system of hazard monitoring, forecasting and prediction, disaster risk assessment, communication and preparedness activities systems and processes that enables individuals, communities, governments, businesses, and others to take timely action to reduce disaster risks in advance of hazardous events (UNDRR, 2016). In other words, an EWS comprise different components working in a harmonized way to provide information and advice to respond and anticipated threats/risks.

The traditional definition of EWS considers 4 components to implement EWS[[8]](#footnote-9), however, a consensus has risen over the last few years for the addition of a fifth umbrella element: the governance and institutional arrangements that shape EWS and enable early action.

As traditionally stated, the following are the four key and interrelated components for an effective EWS:

1. Disaster risk knowledge based on the systematic collection of data and disaster risk assessments.
2. Detection, monitoring, analysis and forecasting of the hazards and possible consequences.
3. Dissemination and communication, by an official source, of authoritative, timely, accurate and actionable warnings and associated information on likelihood and impact; and
4. Preparedness at all levels to respond to the warnings received.

These four interrelated components need to be coordinated within and across sectors, actors, hazards and multiple levels for the system to work effectively The ***overarching governance component*** perform as an articulating factor to ensure institutionalization, enable coherence and reinforce integration amongthe four components for a proper operation. A key mechanism for enhanced accountability consists on ensuring needs feedback mechanism for continuous improvement. Failure in one component or a lack of coordination across them could lead to the failure of the whole system.

***Why a Multi-hazard EWS?***

A Multi-Hazard Early Warning System (MHEWS) aims to address several hazards and/or impacts of similar or different type of hazards in contexts where events may occur alone, simultaneously, cascading or cumulatively over time. These cascading impacts, which threaten communities, assets, public infrastructure and in some cases impact the whole country, may have interrelated effects which are considered under a multi-hazard approach.

A MHEWS takes the advantage of in place mechanisms, tools, and platforms (e.g., from hazard observation to alerting systems) for alerting people at risk about the occurrence of different threats, their potential impacts and the ways to prevent, avoid or minimize them. Multi-hazard early warning and early action mechanisms coordinated under a multi-hazard framework and engaging multiple disciplines, partners and stakeholders increase the efficiency, consistency, and coherence of early warnings and the early actions they enable,

. Moreover, the use of a common MHEWS approach supports the creation of economies of scale, reinforcing sustainability of the system and enabling lessons learnt sharing.

An integrated, multi-hazard comprehensive risk analysis puts an EWS on a sturdier foundation. For the implementation of a MHEWS a comprehensive risk and vulnerability analysis and impact, damage and loss data systems should be strengthened as a base for prioritizing hazards of concerns, to which a country or community is exposed, and identified the most relevant, efficient and inclusive early action that can be undertaken Most damaging hazard risks for which early warning and early action are most effective, should be prioritize. A multi-hazard governance framework should enable more effective financing mechanisms and more impactful early warning – early action value chains. Harmonized approaches for warning dissemination, risk communication and preparedness minimize inefficiencies, maintenance costs and duplication, while maximizing investments on awareness, education, and preparedness.

Moreover, a greater efficiency can be achieved with less human and financial resources, centralizing the implementation of EWS at any level minimizes system maintenance and number of required staff[[9]](#footnote-10).

**Shift from EWS’s technical aspects to the enhancement of social components of MHEWS**

Effective EWS need to be both end-to-end and people-centered, this means, they should initiate actions from the moment a hazardous event is detected, and they should focus on helping communities interpret and react to messages. The objective of people centered EWS is to empower people threatened by hazards ***to act in a timely and appropriate manner***, to reduce the risk of death, injury, damage, or loss of livelihoods.

However, early warnings by themselves will not lead to early or responsive action. For Early Warnings to result in protective or mitigating action for at risk communities, they must be timely and actionable, this means that it is necessary to have pre-identified the optimum times at which decision makers at all levels- from the government to community members- need to receive the information in order to take action. Early Warnings must also be disseminated through trusted channels and means, shared in a clearly understandable, actionable and interpretable way by non-technical people. Without these factors in the design of EWS, it is unlikely that EW will consistently result in impactful actions[[10]](#footnote-11).

Similarly, some other factors can intervene so that people can take action after a warning, such as the proper understanding of the impending hazard; the perception of their risk; the trust on the source of information; the reliability of the communication channels, and the correspondent protective actions individuals are able to take depending on capacities: lead time, awareness of the response actions recommended, means for taken action ( e.g. routes to evacuate, physical means to escape and shelter), knowledge of the measures to be taken and ability to undertake them, etc. or impediments they may have, physical disabilities, persons in charge of other persons with reduced mobility, language of the warning message or lack of information about proper measures to take.

The implementation of timely, effective and appropriate actions when a warning is issued indicates the effectiveness of the system. Technologies and methodologies in place are crucial components of an effective system but not the only ones to consider assessing their effectiveness. Social factors are enabling or not the implementation of timely and appropriate actions. Designing people centered EWS means work in an engaged manner with potentially affected communities taking the needs of the entire population into account, including the ones of the most vulnerable.

**b. People-centered effective, inclusive, and accessible MHEWS**

People-centered early warning systems are designed and implemented from the bottom up, beginning with communities at risk to ensure that such communities and individuals become an integral element of the MHEWS, and to ensure that such communities are well prepared to respond in case a warning is issued. Such systems promote the use of indigenous and local knowledge when assessing the potential occurrence of an event whenever possible. These types of early warning systems build on the notion that those communities at risk have inherent capacity, they are resilient and can protect themselves[[11]](#footnote-12).

The ‘people-centred’ elements require systematic approaches and diverse activities spanning the four elements of early warning systems, such as: identifying target population, especially the vulnerable and disadvantaged and interacting with them to determine needs and capacities; conducting community meetings and involving communities in exploring and mapping their risks and planning their responses; fostering the development by communities of monitoring and warning systems for local hazards; generating public information tailored to target groups; developing formal mechanisms for community representatives to monitor and oversee warning system design; providing training for observers, authorities and communicators who operate the warning system; and providing exercises and simulations to enable people to experience and practice warning interpretation and responses[[12]](#footnote-13).

An effective and people centered MHEWS that follow the principle of *leaving no one behind* should consider and integrate the needs of all individuals and groups of an at-risk community. The UNDRR has indicated 3 aspects to achieve the latter, they need to be *inclusive* of the need of different groups presents in the community; *accessible* and understandable to all of them; and *actionable*, enabling the implementation of early actions to reduce their disaster risk. This means that timely, accurate, reliable, and understandable information reaches everyone in the right way to enable them to act appropriately.

Box 3: 3 aspects for effective and people centred MHEWS. Source: UNDRR, 2022

**3 aspects for effective and people centered MHEWS**

Effective MHEWS requires to be i. *inclusive* of the needs, perspectives, priorities, and meaningful participation of the many different people in society, which vary according to their age, sex, disability, gender roles, sexual orientation, literacy, language, cultural practices, race, geographic location, socio-economic position, among many others; ii. *accessible* to all, ensuring that information can reach everyone who may be impacted, and in a way that can be easily understood by all, regardless of their individual circumstances including disability, literacy, and language; and iii. *actionable*, providing information that includes potential impacts and recommended action that people should take, which enables people to reduce their disaster risk, and potential damages and loss.

Designing a people-centered early warning system requires a successful blend of bottom-up and top-down approaches. It is based on strong governance; institutional and social arrangements and it demands technical resources and reliable communication mechanisms. Three pre-conditions are essential when designing the system[[13]](#footnote-14):

* A governance model which recognizes the value of conducting activities in the context of disaster risk reduction, including early warning practices, as opposed to a governance model that only recognizes the need to prepare for and respond after the event has impacted a community.
* Acceptance that the system is being designed to empower communities at risk to minimize losses through the provision of strategic information in a timely fashion. Such a conviction implies that all stakeholders, including communities at risk, share a responsibility in the design, implementation, and routine operation of the system.
* Acceptance that the system can only be operational if it involves the active participation of a variety of individuals and institutions with voice in the decisions and identified roles on the operations, from the local to the national level in many cases, and the international level in selected cases.

Marginalized people (i.e. those who are marginalized on the basis of age, sex, disability, race, ethnicity, cast, religion, migration status, socio-economic status, place of residence, and sexual orientation and gender identity) are often those most overlooked by early warning systems, and require special consideration and focused attention to ensure they are not left behind[[14]](#footnote-15).

The notion of the “last mile” in EWS became more noticeable when the Indian Ocean Tsunami Early Warning System was being designed in 2005. The approach is based on the notion that plenty efforts are put into implementing an EWS, but there is gap in conveying the information to the people who need it when they need it, to produce appropriate responses.[[15]](#footnote-16)

This “last mile” approach has its origins in the telecommunications sector to reach potential end-user who are not yet connected to the telecommunication network. The aim of last-mile efforts is to ensure that the system uses a variety of communication channels to ensure that warnings reach those who are at risk and exposed to the hazard[[16]](#footnote-17).

**Community-based EWS**

Community-Based Early Warning Systems (CBEWS) are anchored in the communities and co-managed by the communities at risk, this is to ensure optimal connections, especially in the context of larger scale threat, such as tsunami EWS. They are based on a "people-centred" approach that empowers individuals and communities threatened by hazards to act in sufficient time and in an appropriate manner in a bid to reduce the possibility of personal injury, loss of life, damage to property, environment, and loss of livelihood. CBEWS can operate for single or multiple hazards and can focus on slow onset as well as rapid onset events, providing communities, practitioners, and local organizations -involved in disaster risk management- with advance information of risks that can be readily translated into prevention, preparedness, and response actions. CBEWS ensure mechanisms for a two-way communication, reflective of and informed by local capacities and vulnerabilities in close coordination with local authorities.

CBEWS are designed with these criteria[[17]](#footnote-18):

* The instruments to monitor hazards must be simple and practical, so that all people (not only technical trained ones) can use them effectively. Such instrumentation must be easy to maintain and replaceable on a quick basis and at a reasonable cost, so than the system can work on a continuous basis. Local observations of hazards complement that information that is supplied by national observatories in charge of monitoring those hazards.
* CBEWS include local volunteers that contribute to its routine operation of the EWS.
* CBEWS are embedded in the structure of disaster management agencies, spanning from the national to the local level. The local disaster management committees are given the additional task to manage the CBEWS with the support of those at risk.
* The root of the CBEWS in the structure of disaster management committees ensures the provision of technical and institutional support by the national disaster risk management agencies to the CBEWS
* Frequent meetings with community leaders, people at risk in communities, regularly updated contingency plans and routine drills are used to empower community members to take ownership of the CBEWS.

The true essence and significance of CBEWS is community empowerment. CBEWS supports local people to be capable and empowers them to protect and prepare themselves and contribute to make them more resilient to natural hazards and prevent human disasters. Communities are in the best position to implement measures to avert, minimise and address disasters and their impacts.

The basic requirements of a CBEWS are that individuals and institutions have knowledge about what is threatening them, good understanding of potential impacts, can communicate threats as they evolve, and that they are able to respond effectively and appropriately.

The essential features of Community-Based Early Warning System are:

* Knowledge of hazards and subsequent risks at community level is critical to ensure all members of the community can constructively engage in the design of their EWS[[18]](#footnote-19).
* All community members especially the vulnerable groups should be involved at all stages and elements of the CBEWS from designing to operating the systems, receiving the warning messages, and responding to the warning.
* Measures taken should be based on the needs of everyone in the community including the most vulnerable people in the community, this will strengthen that the community members will own the process and system through a mmeaningful participation in the decision-making process of early warnings.
* Multiple linkages and feedback communication paths, particularly from potential affected population should be established.
* CBEWS measures will enhance the capacity of the community members to deal with their situation.
* Meaningful participation in the decision-making process of early warnings.

**Importance of connecting Community Based to national Early warning Systems**

**Integrated community based EWS**: The real potential of CBEWS is where they are integrated and operate seamlessly with national systems. In countries where central EWS provide monitoring, analysis and forecasting of hazards, and communications channels the CBEWS can operate complementary to this. This does not overlap, duplicate, or undermine the operations or authority of either the CBEWS does not remove the duty of care from the national system, it enhances this duty of care for the local community. National EWS relies on CBEWS for local hazard observations to complement hazard monitoring systems. CBEWS plays a critical role in informing national EWS especially in local areas where no hazard observations can be made by National EWS. Data and observations from CBEWS greatly inform National & CBEWS Standard Operations Procedures[[19]](#footnote-20).

**Isolated community based EWS**: In remote situations or in countries with limited national capacity, communities themselves can develop their own standalone EWS. In these situations, the system will be built around local capacities and respond to local priorities and needs. These systems can be simple manual observation and warning or can be more complex and use remote monitoring of such a river level gauges or rainfall gauges. The system is heavily dependent on local capacities and can benefits from lived experiences and function well where indigenous knowledge of natural hazards supports the EWS and creates demand for the EWS.

Regardless of the type and setting of the CBEWS the essence of a CBEWS is that the system is designed, operated, and maintained by the communities themselves. While establishing the system the community will explore external support from different individuals, communities, organizations, and institutions. It is essential that the community develops and maintains close coordination and links with these stakeholders. The community should lead all steps of the establishment of the early warning system. It helps to develop ownership and contributes to the sustainability of the system.

The following steps should be considered when establishing a community based early warning system:

1. **Design**: this includes activities to identify whether the establishment of an early warning system will be the right intervention to mitigate the problems that the community is facing. The basic information should be collected in consultation with key persons in the community. The following information can be collected but other information may be relevant.

* Frequency and severity of past hazards
* Vulnerable households and groups
* Exposure and Spatial distribution
* Existing social groups
* Indigenous early warning practices
* Capacity and culture of the community

The community will be the key actors and decision makers to ensure successful outcome of the mapping, analysis, and effectiveness of the CBEWS design. This participatory process assumes the people are the experts, who know the reality of their community. The community will enhance knowledge of their hazards, vulnerability, exposure, and capacities through a mapping and gap analysis process. All concerned community members, groups and organizations will be actively involved in this process.

1. **Formation of Early Warning Management Committee**. In some communities the establishment of a committee to manage the early warning system may be needed. The functions of the committee apart from managing the system, is to link with different stakeholders for technical, managerial, and financial support. The members of the management committee will be oriented about their rights, roles, responsibilities, and tasks. It is vital to ensure that all vulnerable groups are well represented in the management committee. In some cases, local disaster management committee, which is a hub of the hierarchical disaster management structure, takes over this task.
2. **Observation & Monitoring**: Based on the situation analysis an observation-and monitoring system should be developed by the community. National hydro-meteorology services may already have daily weather observation, these should be assessed to determine whether they provide the relevant information for the CBEWS. It is critical to understand the relationship between the observation stations and local communities. This should include considerations of the quantity and quality of the monitoring devices, human resources available, capacity building needs, and communication options, additional equipment, and necessary maintenance.
3. **Communication and Dissemination**: This focuses on transferring and translating of information gathered during observation and monitoring of the hazard and its translation into actionable information, to the residents of the hazard prone areas and disaster risk reduction stakeholders. A reliable and well-organized dissemination system should be in place for on time information dissemination. It is therefore essential to develop and agree on a flow of information which needs to be well understood by all stakeholders. The system should be effective and efficient to reach all end users, and ideally should have multiple channels of communication and dissemination to add redundancy in case one channel fails.
4. **Preparation for Response**: Preparation for response is the final stage in the establishment of CBEWS. This step totally relies on the previous steps and will only be effective when they are fully functional. This step will empower the community to be well prepared to anticipate and respond effectively to disasters. Hence, anticipatory action is the most crucial component of early warning system. Early warning systems will only make sense if all involved stakeholders have the relevant knowledge, capability and are ready to respond before or when the hazard occurs. The previous steps will ensure that the communities have relevant knowledge of hazards, their vulnerability, and capacities, observation, monitoring of hazards and how to communicate and disseminate warning. However, the community will still need a concrete plan to be prepared and to respond to disasters. The effectiveness of response depends on the following critical components: availability of lead time; clear understanding of the warning information and the actual risk; trust in warning information; knowledge on how to prepare and respond; experience of hazards, disasters, and warnings; well-structured contingency action plans; and trainings, awareness campaigns and simulation/drills.
5. **Follow-up, review & learning**: This final step focuses on initiatives for follow-up, learn and to build sustainability in the system. It will constitute the fine tuning of the system with real time experience and changes in the situation and environment. It may be easy to establish a CBEWS but sustaining the system will be difficult without review and learning. Sustainability is the ability to maintain the system over a long period of time. In simple words it means that the community itself will be able to continue and maintain the EWS either by their own means or have the know how to access the means from other sources. Early warning in this context will be an integral part of risk reduction built on existing structures and having access to technical support.

**Gender responsive Early Warning Systems**

Gender responsive EWS would result in outcomes that reflect an understanding of gender roles and inequalities and which through utilizing a gender analysis try to ensure equal and fair distribution of benefits, as well as equal participation. This is the most realistic and what we are working towards within UNDRR[[20]](#footnote-21).

Women frequently are one of groups most affected to disasters, not because they are fundamentally more vulnerable than men, but due to normalized gender norms, dress codes, roles, and relationships in family settings. This means that society have generated increased risk conditions for women. To be aware of this inequity can be the first step towards considering gender factors during the implementation of gender responsive EWS. To illustrate the latter some naturalized roles and norms that put women in a major vulnerable condition will be listed[[21]](#footnote-22).

* In many countries, women of different ages are directly responsible for the care of children, sick or older family members and therefore less likely to be willing to evacuate alone, or delay evacuation due to rescuing family members or valuables.
* In the 2015 earthquake in Nepal, more women and girls died because they were assigned indoor chores and, furthermore, there were fewer men present in the country at the time of the earthquake due to the higher emigration rates of men.
* In the Pacific region, many women do not have equal access to technology, communication, and services, and thus miss out on critical information. This is particularly true for women and other marginalized groups in rural or isolated areas, due to a lack of communications services or social barriers, putting them out of reach of life-saving information.
* Women can also be placed at greater risk through a lack of timely and relevant information about imminent hazards. The channels through which women and men get information from also differs. A study in Nepal determined that 71% of men received early-warning information through a formal source, such as government or INGOs, whereas 51% of women received their information through informal social sources, such as word of mouth from community or family members.
* Women trying to escape the 2004 south east tsunami of Asia died, among other reasons, because they were not able to swim as they were not train before and due to the use of heavy clothes to cover their bodies which blocked their ability to easily move.
* With higher rates of informal and care family work, the capacities for women to sustain themselves financially can also be limited, making it more difficult to recover from sudden economic setbacks. Scenarios such as these often result in women facing increased disaster risk, and ultimately experiencing the worst impacts of disasters.
* Women’s voices are often absent from key decision making about disasters, and as a result do not have their needs adequately met. In many Pacific communities, women, in particular older women, women with a disability, and groups experiencing disadvantage or marginalization, are often excluded from decision-making processes, both within their own families, as well as within wider local and national systems and governance.

When women in all their diversity are actively engaged in the development and implementation of disaster management laws, policies, and operational plans and procedures, and MHEWS identify and address the diverse needs of different groups, DRR efforts become more inclusive and accessible, and ultimately more successful.

Although not an explicit requirement of many current MHEWS guidelines and standards, the establishment of women led MHEWS have been shown to make a significant contribution to the effectiveness of national MHEWS and can play a key role in ensuring such systems are inclusive and accessible to all[[22]](#footnote-23). When women are engaged at all levels in DRR efforts, the needs, and priorities of different groups of women and the wider community are more thoroughly considered and addressed.

Having women design and lead these projects broadens the perspectives and experiences that inform decisions, ensures the right messages reach the right people, and improves accountability to communities.[[23]](#footnote-24)

**2.1.2. Enable a Multi Hazard EWS Approach by integrating hazard-specific early warning systems**

A MHEWS may be built from scratch, it may be constructed by extending an existing hazard-specific warning system, or existing hazard-specific warning systems may be combined. Once created a MHEWS will likely need to be extended to additional hazards with time. Many of the steps are common among these approaches. Since most countries have an early warning system of some sort, we focus on the issues of extending and/or combining warning systems.

1. **A common framework: advantages, implications & requirements**

The essence of a MHEWS is that warnings of multiple hazards are produced and communicated in a consistent manner. There can be considerable advantages in doing so.

If aspects of the warning system, such as formatting, communication, and evaluation, can each be dealt with by a common package, preferably through digital solutions, there can be significant cost savings, as overlap and duplication can be avoided. Since warnings need to be disseminated in multiple forms and through multiple channels to reach all of those at risk, the saving from only having one package for each that covers all hazards, can be substantial.

Warning messages may be more widely received and more easily recognized and better understood if they are presented in the same format and come from the same source. Familiarity with the format and meaning will be reinforced by the greater frequency of warnings received for multiple hazards. With a common framework, it should be easier to ensure that warning messages for related hazards are consistent and complementary, avoiding possible confusion in users and enabling actions that address compounding effects and minimize cascading effects.

To achieve a common framework, the warning system will need to find a compromise among perceived needs for the different hazards, particularly where the warnings originate in different organizations, or where there are different users for the warnings. These compromises need to be worked out in partnership, with every partner taking time to understand the viewpoint of every other partner and develop mechanisms that address different needs.

A common framework serving multiple hazards will be more complex and will take longer to design. Upgrades will also be more complex, and more testing will be needed for each release to ensure that all aspects of the system are free of faults. To avoid failure, it is necessary to allow this additional time in the schedules.

A multi-hazard warning system will involve many participants, usually in multiple organizations. Prior to building the system it is important to have an enabling governance structure in place. This may involve multiple information producers, multiple information communicators, and multiple user organizations. Well-defined roles and responsibilities are essential for an effective and accountable governance of multi-hazard early warning systems.

Similarly, funding will be required, most likely from central and/or local government, and if possible, the provision of funding should be tied to the creation and maintenance of a partnership structure that can ensure the continuity of the warning service. While it is possible to define a common framework that is independently implemented in multiple locations for different hazards, it is generally found to be beneficial and to save costs if delivery mechanisms are shared. In this case, a cost sharing structure needs to be agreed to fund the cost of hosting the shared facility. A shared multi-hazard warning system has more demands placed on it and the costs of system failure are therefore greater. Where possible, shared systems should have a remote backup that can be brought into use if the primary system fails for any reason.

An EWS enables people or communities at risk to act on time to reduce damage or loss when a disaster strike. To accomplish this an EWS must have the capacity to ‘warn’ or provide timely and proper advice to implement agreed actions that protect lives and livelihoods of communities at risk.

The proper implementation of this system requires the interrelated work between key components in connection with those who need to receive the warnings. An *end-to-end* warning system integrates a complete set of components that links those who need to hear messages to act accordingly to others who compile and track the hazard information of which messages are composed’. (IFRC, 2012).

1. **Some building blocks for the implementation of a MHEWS**
2. Define the scope of the MHEWS in collaboration with potential users, partners, and funders

* Which are the hazards that present the highest risk and which of those could/should be incorporated in a MHEWS - the top two hazards, or more, or all?
* Are warnings required for a city, a province or state, or for the whole country? Many considerations are different for cities, where loss of essential services, such as power or water, may be much more significant than for rural areas. On the other hand, the direct impacts of hazards may be more dangerous in a rural environment, especially to those not familiar with the area.
* What are the lead times required – minutes, hours, days, months?

1. Define a governance structure for directing, funding, managing, producing, and using the warning system

* Which organization / organizations will manage the system and who will they report to? This is a critical decision but may be made later in the design process.
* In many cases a change to the legislative framework will be needed to establish a MHEWS. For instance, if existing legislation places responsibility for warnings of hazard x on one organization and warnings of hazard y on a different organization, new legislation may be needed to place shared responsibility for delivery of warnings of x and y, perhaps with specific responsibilities for parts of the system also defined. A legal or contractual framework will also be needed in many countries, especially if private sector partners are involved (e.g., media organizations). This is particularly the case where liability for failure may be attributable.
* Government funding may be specified in the legislation, but if not, a separate funding plan is required, not just for building the system, but for maintaining it, including regular upgrades to maintain the security and resilience of the digital systems. In the absence of government funding, development costs may be obtained from international donors or from national or international NGOs, but ongoing maintenance and development costs need to be identified from regular funds of the participating organizations.

1. Define pre-settings of the system

* Since each partner will use different technical terms and some terms will be used to mean different things by different partners, a common terminology should be documented for use in the MHEWS.
* Outputs should be co-designed iteratively with user groups ensuring that the views of the most vulnerable are heard and considered.
* Inputs and outputs at each stage of the production chain should be agreed among the partners.

1. Identify the delivery channels that will reach users

* Start with the media used by most people to access existing services. These will most likely be broadcast radio and television, but it is important to use up to date survey results to confirm this. Many younger people rely on social media for their information, but the choice of media will vary between countries and with time.
* Identify groups that particularly need to be reached. Some of these may be business sectors dealing with vulnerable groups such as schools and health facilities. Others may be the vulnerable groups themselves, e.g., migrant communities or itinerant workers. These need to approach directly to identify needs, including choice of media.
* Consistent information should be disseminated as widely as possible. This can be facilitated by using the Common Alerting Protocol.

1. Select the data sources

* Information is needed to identify the anticipated hazards, the people, property, and services that will be exposed to them, and their vulnerability. Hazard information may come from official organizations, such as a weather or volcano service, or it may come from a specialized source, such as a dam operator or power company that is looking at downstream hazards caused by the weather.
* Exposure information may come from a mapping agency: either public or private but may also be obtained by commissioning a project to extract data from satellite imagery. It must be remembered that people move, so the exposure of people will vary between day and night, weekday and weekend, winter, and summer. While it may not be possible to obtain quantitative information about these differences, they need to be part of the tool kit used in deciding where to warn and when.
* Vulnerability data is the most difficult to obtain. Generally, it can only be obtained by talking to people. For instance, the conditions under which infrastructure will fail can only be determined by expert engineering analysis. When first built this information may be part of the design, but as structures age, this becomes increasingly difficult to assess. The vulnerability of people is closely associated with poverty, but also with gender, health, employment, and access to services.
* If warnings are to be acted on, they should come from a trusted source. Trust is built from experience, so it is important that the source information should be the best available. For weather services, this means using both international and in-house sources according to their relevance and accuracy. For emergency managers, it means using official sources wherever possible, supplemented, if necessary, with other sources of proven accuracy.
* Some data will require expert interpretation, which may be obtained from the originators or from other experts, e.g., in academia. An ongoing relationship with information providers and interpreters will be helpful as requirements change and data are updated.
* An update frequency should be defined at the outset. Hazard forecasts may need to be updated every hour for intense rainfall but only every day for drought. Exposure information should be adjusted daily to take account of special events, such as outdoor rallies. Where urban development is taking place, mapping information may need to be updated several times a year, whereas rural areas may need refreshing infrequently.

1. Put an evaluation system in place

* Evaluation is an essential component of a warning system. The funder is likely to require a project evaluation to demonstrate that their money was well spent. More importantly, the operator will need evidence with which to justify continued operation and maintenance, and for future upgrades.
* Part of the evaluation system is to measure the accuracy of the warning information. For this, standard verification scores can be used.
* It is also important to know who the warning reached – e.g., the percentage of the at-risk population – and who it didn’t reach – e.g., vulnerable groups who may have been disproportionately impacted.
* Most important, however, is to measure the response. Did it result in decisions that save lives, reduced economic loss, and protected public services?
* It is also important to gather information on the cost of the response. For instance, economic losses due to evacuation, shutting down of transport services etc.
* This information should be gathered routinely, in the same way that the hazard and warning information is produced routinely. In that way, trends can be identified, weak areas can be addressed, and successes can be used to build trust.

1. Training and education

* Implementing a MHEWS probably means changing the way warnings are issued, their format, and possibly the channels that are used. Those involved in producing the warnings need to be trained, both in the technical aspects of the new processes, and in the objectives of the warning system.
* Those who will be receiving the warnings need to be educated in what to expect and in how they can use the warnings to protect themselves and their property.
* Intermediaries who communicate the warnings need to be trained in how to interpret the new formats and content for the benefit of their audiences.
* Training and education are ongoing requirements. This is particularly so for seasonal hazards, for which refresher training is needed at the start of each season. For producers, this may involve revisiting parts of a training manual. However, many centers find it helpful to have a short workshop and discussion to re-orientate people to the new challenges. For users it may take the form of a multi-media advertising campaign.

**2.1.3. Four components to look at: highlighted issues**

**How does an EWS work?**

To put in place an effective EWS, its four interrelated components, plus the governance mechanisms should be properly working together in a harmonized way.

1. Disaster risk knowledge based on the systematic collection of data and disaster risk assessments.
2. Detection, monitoring, analysis and forecasting of the hazards and possible consequences.
3. Dissemination and communication, by an official source, of authoritative, timely, accurate and actionable warnings and associated information on likelihood and impact; and
4. Preparedness at all levels to respond to the warnings received.

To achieve this, [The Checklist for MHEWS](https://library.wmo.int/index.php?lvl=notice_display&id=20228#.YoIq5C8Rp0t)[[24]](#footnote-25) developed by the International Network for MHEWS (INMHEWS) can be followed to ensure all steps are contemplated and integrated in the MHEWS. The implementation of the following 4 components, plus the overarching governance component, can ensure and integral approach for an end-to-end MHEWS.

Additionally, participation of key partners and representatives from different sectors in society will strengthen the sustainability of the EWS and ensure its pertinence, therefore it is necessary to remember the need to have women, persons with disabilities, migrants, indigenous people, and other groups with specific needs, involved in the design and operationalization of any EWS.

1. **Disaster risk knowledge**

Diagram

Description automatically generatedRisks arise from the combination of hazards, exposure of people and assets to the hazards and their vulnerabilities and coping capacities at a particular location. Sometimes development process creates risk conditions or the increasing of the vulnerability of certain groups when marginalized populations are not taken priority attention or when suitable risk assessments are not implemented before any project.

Graphic Risks factors: Practical Action, 2020

Assessments of risks require systematic collection and analysis of data and should consider the dynamics and compounding impacts of hazards coupled with vulnerabilities resulting from unplanned urbanization, changes in rural land use, environmental degradation, and climate change. The level of risk can change depending on the actual impacts and consequences of hazards, vulnerability conditions and exposure of different groups. Therefore, a comprehensive risk assessment must include a valuation of the community’s coping and adaptive capacities, including available resources, developed plans, social protection policies in place, among other capacities. It is also important to gauge the perception of the level of risk faced by those who are vulnerable, this can offer an idea of their potential reactions after issuing of an alert.

**Disaster risk knowledge**

‘Comprehensive information on all the dimensions of disaster risk, including hazards, exposure, vulnerability, and capacity, related to persons, communities, organizations and countries and their assets’.

WMO, 2019

Studies of human interaction and reactions to warnings can also provide insights to improve the performance of early warning systems. Risk assessments should be used to identify the location of vulnerable groups, critical infrastructure, and assets, to design evacuation strategies including evacuation routes and safe areas accessible for all, including people with physical or mental impediments. It will also be important to expand warning messages to include possible impacts of hazards and the potentially affected infrastructure, geographical area, or specific groups. Maps based on risk assessments help to motivate people, prioritize needs and interventions and guide preparations for disaster risk management measures, including prevention, preparedness, and response.

**The following steps will help put the above into action:**

* Incorporate multi-Hazard approach based on local / national risk assessment.
* Promote a systematic integration of risk and impacts of disasters into the warning process.
* Incorporate mechanisms for the integration of lessons learned from previous warnings. A formal feedback process ensures that the system continually evolves and improves based on previous experience.
* Ensure the compilation of information on risks and indigenous knowledge to identify risks and potential anticipatory actions.
* Identify the location and the level of vulnerability of different groups of the exposed population, assets, livelihoods, institutional services, critical infrastructure, and other elements which can be addressed with the MHEWS.
* Ensure that vulnerable groups understand how the system works, and how they should respond to warnings.

1. **Detection, monitoring, analysis and forecasting of the hazards and possible consequences**

Continuous monitoring of hazard parameters and their precursors (when available for a particular hazard) is essential to generate accurate warnings in a timely fashion that allow sufficient time for the affected community or communities to enact their disaster management plans appropriate for that hazard. The systems used for detection and monitoring, which could be automated, should allow for strict quality control of the data under international standards when these are available. There must be a sound scientific basis to the system and reliable technology for (i) monitoring and detecting hazards in real time or near real time; and (ii) providing forecasts and warnings 24 hours a day, 365 days a year. It must also be monitored and staffed by qualified people. Academic and scientific centers can play crucial roles providing qualified advice and valued data for the enhancement of EWS, however their 24/7 commitment should be guaranteed, forecast could be needed any time, any day.

Warning services should have a multi-hazard perspective (e.g. heavy rainfall may not only trigger flooding but also landslides, the warning for which may come from a separate authority) and be coordinated whenever possible to gain the benefit of shared institutional, procedural and communication networks and capacities. Data, forecasts, and warnings should be archived in a standardized way to support post-event analysis and improvements of the system over time.

**Detection, monitoring, analysis and forecasting of the hazards and possible consequences**

‘Multi-hazard monitoring and forecasting services with a sound scientific and technological basis’

WMO, 2019

**The following steps will help put the above into action:**

* Ensure the implementation of adequate systems for hazard & observation monitoring. Consider the establishment of hazard monitoring networks, and the integration of other sources of data from regional and international sources.
* Develop and implement capacity-building strategies. This will strengthen technical capabilities in the operational and technical agencies responsible for monitoring and forecasting of severe events.
* Ensure a multi-disciplinary and multi-agency coordination to improve forecasting tools.
* Reinforce mechanisms for sharing information and adopting common data standards and methodologies when different institutions implement the hazard monitoring. This will ensure access to forecast information and interpreted data from countries outside of the region in case of transboundary hazards.
* Reinforce and fill the gaps of monitoring systems for specific hazards. Partnerships with academic / scientific entities may help to strengthen capacities, making sure that they can provide continued service (24/7).

1. **Warning dissemination and communication**

Warnings must reach those at risk. Clear messages containing simple, useful, and usable information are critical to enable Early Actions and response by organizations and communities that will help safeguard lives and livelihoods.

The fundamental objective of early warning is that people in harm's way get timely messages prompting them to take the necessary actions to save lives and livelihoods. Strong growth in information and communication technology networks and services and a growing information society are increasing the number of communication platforms and channels and delivering new opportunities to reach communities at risk.

Trust is a big part of effective risk communication. If the information source cannot be trusted, those at risk may not respond proactively to the warnings – and it takes long time to establish trust. Early involvement of civil society representatives could enhance the confident of those at risk and enable them *act* when needed.

Regional, national, and local communication systems must be pre-identified and appropriate authoritative voices established. The use of multiple communication channels is necessary to ensure as many people as possible are warned, to avoid failure of any channel, and to reinforce the warning message. Drills and simulations can be an excellent way to practice and recognize set warning & communication channels.

**Warning dissemination and communication**

‘Communication and dissemination systems (including the development of last-mile connectivity) ensuring people and communities receive warnings in advance of impending hazard events, and facilitating national and regional coordination and information exchange’

WMO, 2019

There are numerous standards and protocols used by alerting authorities to transmit warnings. The Common Alerting Protocol (CAP) is an international standard format for emergency alerting and public warning, developed by the International Telecommunication Union and promoted by several agencies. It is designed for “all-hazards”, that is, hazards related to weather events, earthquakes, tsunamis, volcanoes, public health, power outages, and many other emergencies.

As the number of information and communication technology networks, services, and users are growing, they are offering more opportunities to deliver alerting messages to those at risk. People may be reached through landline phones, via TV and radio, mobile networks and the internet, including social media and mobile apps, but also through the more traditional use of sirens. Sending the same alerting message over multiple platforms increases coverage and impact, as well as trust in the alert. Confusion is also avoided when a standardized alerting format, such as the Common Alerting Protocol (CAP), which is a simple but general format for exchanging all-hazard emergency alerts and public warnings over all kinds of Information and Communication Technologies – ICT networks, is used.

Incorporation of multiple forms of ICT is also key to ensure warning messages are received by all people, without discrimination of age, gender, ability, or location. Vulnerable groups, including persons with disabilities, older adults, people in marginal or remote areas without access or connectivity, women and girls, individuals with low literacy levels, indigenous peoples, migrants, are often in a higher risk during the disaster, thus their needs should be taken into careful consideration when disseminating the alerts through mixed channels.

To understand the opportunities that an increasingly digital society has it is important to understand the reach of communication channels. In terms of **mobile networks**, ITU estimates that by the end of 2021, 95 per cent of the world’s population had access to a mobile broadband network. Active mobile broadband subscription worldwide has reached more than 6 billion in 2021 and mobile services have become an essential part of most people’s lives. As they have profoundly shaped the way people acquire information, they play a key role in emergency early warning systems.

A growing number of countries are taking advantage of mobile networks and technologies to send alerting messages, including location-based technologies, such as location-based SMS or Cell Broadcast (CB). CB can send text messages to large number of subscribers and roamers located in a specific area, without needing to know the number of the mobile devices. Messages will be sent out in the users’ desired language in seconds regardless of whether the network is congested or not. The message, which is instantly recognizable as an alert with a special standardised ringtone and vibration, will be displayed automatically on the screen of the end user’ mobile devices, if the devices are configured to support and receive alerts. Text-to-speech is possible for people with visual disabilities1.

Similarly, and driven also by growing mobile networks, Internet uptake has increased significantly, including during the Covid-19 pandemic, when many people relied on online services. Today, more than 60 per cent (or 4.9 billion people) of the population are using the Internet2. This has given rise to many new emergencies alerting services, including mobile apps, or app-based alerting systems. These are alerting solutions based on public warning mobile applications that allow app providers to send location-based alert messages through the internet without the cooperation of mobile network operators. People at risk can receive the alert messages in their mobile phones, tablets, or laptops. The main challenge of this channel is to encourage large numbers of the population to install the app, which may involve marketing costs for awareness campaigns. For foreign visitors, they might not be aware of the apps when traveling to a new country, or able to use them. It’s also important to ensure the apps should provide the warning information in accessible formats and in different languages, with captioning, sign language interpretation, and audio files. Similarly, contents published on the websites should be in accessible formats.

**The case of the European Electronic Communications Code (EECC)**

Several countries have also passed specific regulations, including to ensure that communities at risk benefit from the growing number of digital platforms and communication channels. For example, in the EU, the European Electronic Communications Code (EECC) Article 110(1) stipulates that “By 21 June 2022, Member States shall ensure that, when public warning systems regarding imminent or developing major emergencies and disasters are in place, public warnings are transmitted by providers of mobile number-based interpersonal communications services to the end-users concerned.” Article 110 states that the public warning system must be able to send geo-targeted emergency alerts, that the public alerting system must be able to operate without an opt-in requirement and be accurate enough to reach a very high percentage of people quickly, including visitors in their native languages. Other countries, including Peru and India have put in place similar systems.

Many of those online use social media, which has become a critical component in all four phases of disaster management. Public safety organizations can plan response strategies and provide updated and accurate information to the public. Examples include social media platforms such as Facebook, Instagram or Twitter through which alerts can be disseminated quickly, and widely to help broadcast important safety information, build situational awareness, and allow the public to share live information, including through photos, graphics, audio, and video. It also allows people to subscribe to notification systems that send messages relevant to emergency situations. Since it is not possible to control messages on social media, and misinformation can be a major challenge, it is important for users to verify the information, and rely on official data and notifications. Many governments have developed their own applications and information channels to inform their citizens. Despite some challenges, increasingly, the value of social media is recognized and considered an important channel by emergency services to reach specific groups.

Other communication channels that remain of critical importance to reach a maximum number of people include sirens, including electronic sirens able to make spoken announcement and transmit voice alerting messages through long distances landlines, and TV and radio. In the case of emergencies, TV and radio broadcasting can play a fundamental role in informing the public about an imminent danger, including breaking news alerts that can interrupt the usual programming. Radio and television broadcasting services are particularly useful when physical access to an area is difficult and/or mobile networks are unavailable. To ensure accessibility, alerts should be also disseminated in audio and visual formats through sirens and electronic displays in public spaces such as railway platforms, consumer markets, parks, so that people without access to personal ICT devices can be reached. When possible, graphics and images should be displayed in addition to text.

**The following steps will help put the above into action:**

* Use concise and clear standards for the warning, to prevent interpretation problems. Implement standardized nomenclature, protocols and/or national and international codes. The international Common Alerting Protocol (CAP) can be used to standardize the warning message content and to develop unified standards (ITU, 2007).
* Strengthen telecommunication systems and technology. This will prevent shortcomings related to equipment updating / upgrading and linkages with Regional Telecommunication Hubs.
* Strive to include public's interests and relevant concerns on the warning alert. the development of "impact-based warnings", that provide additional information on the potential impacts of the forecasted hazard, can offer information which motivates action and response.
* Identify potential warning levels depending on the feasibility of the implementation of various levels or warnings.
* Promote partnerships between all players to ensure that consistent and complementary warning messages are issued from a single recognized, official, and “accredited” source.
* Promote media and private sector involvement. Technical agencies involved in the development of hazard warnings and their stakeholders (e.g., disaster risk managers, media, and public sector) need to be trained to ensure that warnings are understood and that effective actions can be conducted.
* Warning and communication strategies should ensure that the right warning messages are conveyed to the right people, at the right time, with the right information.

1. **Preparedness and response capabilities**

It is essential that people understand their risks, know, and recognized the national warning service, and comprehend how to react to the warning messages. Education and preparedness programmes play a key role. Informative campaigns in local radio stations, tv programs and door to door outreach activities can support the dissemination of early actions after warnings are issued. The distribution of posters and flyers that can be stuck in churches, bus stations, markets and shopping centers or posted in social media channels can help to remind key messages regarding different phases of EWS or early actions to take after warnings.

It is also essential that disaster management plans include evacuation strategies that are well practiced and tested involving the participation of those at-risk and considering their situation. Most vulnerable groups often have specific needs of language, physical impediments, or extra loads of work to carry with them, such as women taking care of children, sick or elders.

**Preparedness and response capabilities**

‘Institutions and people enabled to act early and respond to a warning through enhanced risk education’

WMO, 2019

People should be well informed on options for safe behavior to reduce risks and protect their health and their livelihoods, know available evacuation routes and safe areas, implement drills to assess their preparedness capacities, understand the protocols to follow, and know how best to avoid damage and loss of property.

**The following steps will help put the above into action: ( TO BE REVISED)**

* Make sure that Early Actions and Response plans are publicly disseminated. Local institutions can support dissemination process (e.g., schools, universities, medical centers, farmer markets, etc.).
* Implement frequent and assessed simulation exercises and evacuation drills with the participation of communities and groups at risk.
* Evaluate and strengthen local capacity to develop and implement response and early actions, taking into consideration the needs of specific groups. (e.g., disabled, and ill people, indigenous people, women with persons in charge, the elderly, young children, etc.).
* Use participatory approaches and include traditional knowledge to make the warning content more accessible (i.e., for the warning wording).
* Ensure MHEWS considers interoperable mechanisms. Close interaction among EWS operators will enhance synergies that will result in an increased EWS effectiveness.
* The demarcation of evacuation routes, safe areas and evacuation strategies should include vertical evacuation, which will be very useful in case of tsunamis and flooding in general.

## **2.1.4. The basics for an effective operationalization**

* 1. **Common principles**

In 2015, the World Meteorological Organization with other partners developed a global evaluation about the state of Early Warning System[[25]](#footnote-26). This coincided with the end of the implementation of the Hyogo Framework of Action for Disaster Risk of Action (2005-2015), an international agreement to reduce loss of assets and life after disasters. After a deep analysis and the study of relevant national

and local cases they concluded that the following 10 principles associated with the implementation of EWS are leading important reduction of losses. ‘Despite the individualized approaches to the operation of their MHEWS, the countries/territories have incorporated 10 common characteristics that have led to reductions in losses of life and property from hydrometeorological hazards within their respective jurisdictions’.

Box xx: Ten common principles for effective EWS. WMO, Geneva, 2015

**Ten common principles for effective EWS**

1. There is a strong political recognition of the benefits of EWS reflected in harmonized national to local disaster risk management policies, planning, legislation, and budgeting.
2. Effective EWS are built upon four components: (i) hazard detection, monitoring, and forecasting; (ii) analyzing risks and incorporation of risk information in emergency planning and warnings, (iii) disseminating timely and “authoritative” warnings; and (iv) community planning and preparedness.
3. EWS stakeholders are identified, and their roles and responsibilities and coordination mechanisms clearly defined and documented within national to local plans, legislation, directives, Memorandum of Understanding, etc.
4. EWS are supported by adequate resources (e.g., human, financial, equipment) across national to local levels and the system is designed and for long-term sustainability.
5. Hazard, exposure, and vulnerability information are used to carryout risk assessments at different levels as critical input into emergency planning and development of warning messages.
6. Warning messages are (i) clear, consistent and include risk information; (ii) designed with consideration for linking threat levels to emergency preparedness and response actions (e.g., using colors or flags) and understood by authorities and the population; and (iii) issued from a single (or unified), recognized and “authoritative” source.
7. Warning dissemination mechanisms can reach the authorities, other EWS stakeholders and the population at risk in a timely and reliable fashion.
8. Emergency response plans are developed considering hazard/risk levels and the characteristics of the exposed communities.
9. Training on hazard and risk awareness as well as emergency preparedness integrated in various formal and informal educational programmes with regular drills to ensure operational readiness.
10. Effective feedback and improvement mechanisms are in place at all levels of EWS to provide systematic evaluation and ensure system improvement over time.
    1. **The need for consistent warning messages**

The public awareness and understanding of early warning alert messages are often compromised by the high variety of schemes, color codes and pictograms within countries and even more when comparing practices in different countries**[[26]](#footnote-27)**. The growing importance of international business and trade, tourism as well as increased labour and refugee migration call not only for national, but also internationally harmonized warning schemes. The international community has recognized this shortcoming and in global frameworks it states: “Develop early warning systems that are people centered, in particular systems whose warnings are timely and understandable to those at risk, which take into account the demographic, gender, cultural and livelihood characteristics of the target audiences, including guidance on how to act upon warnings, and that support effective operations by disaster managers and other decision makers.” The World Meteorological Organization (WMO) stresses that in most countries, the public is very diverse, with different backgrounds, experiences, perceptions, circumstances, and priorities. Any attempts to communicate with the public must reflect this diversity. The UN system came up with some universal values in support of the Sustainable Development Goals (SDG). The second principle is to “leave no one behind”. This principle is normally meant to include members of society, discriminated against because of gender as well as ethnicity, age, class, disability, sexual orientation, religion, nationality, indigenous, migratory status. Leaving visitors behind in the face of an emerging threat of a natural disaster is not in harmony with the SDG values.

In some countries progress has been made to harmonize different warning schemes. For example, the USA has standardized its Volcano Alert System (VALS), replacing all locally developed systems with a common standard. However, such efforts are few and quite limited in scope leaving a lot of room for improvements, especially on international level.

Therefore, it is deemed necessary that warning messages follow consistent approaches including color codes (e.g. green, yellow, orange, red, for increasing dangers, probably followed by blue for an “all clear” status) and pictograms. Alert levels in a standardized system will be quickly recognized by the public such as the traffic lights scheme has demonstrated in many countries worldwide. Confusion would be further reduced if multi-hazard early warning systems follow the same numbers of alert levels for different hazards. The alert levels may have different threshold in the respective countries, but the messages and their appearance should be easily understood by everyone.

Graphical user interface, website

Description automatically generated

Graphic: Diversity of flood early warning levels, colors, and symbols. Developed by Olaf Neussner, 2022

* 1. **Interoperable EWS**

Exchangeable data among EWS operators has increasingly been explored not only in cross bordering countries, where transboundary hazards impact without bordering considerations, but within national early warning systems when cascading impacts of one hazard can trigger new hazards.

A key issue regarding interoperability is the need to ensure that all parameters are measured and reported in the same units to facilitate their combination. In a similar fashion, interoperability of data streamed over the internet will be essential to enhance its use in MHEWS around the world[[27]](#footnote-28).

For example, if an earthquake occurs in the southern coast of Peru in South America, and if conditions are ideal, a tsunami may follow some minutes after. Timely sharing/exchange of earthquake parameters, and sea level conditions and information/alert bulletins between EWS operators in Peru and Chile will be crucial for the evacuation of potential affected coastal populations in the south of Peru and in the North of Chile.

Interoperable data can play a fundamental role for the improvement of the effectiveness of such EWS and lastly impact in the reduction of losses of assets and lives after a disaster. The interoperability of an EWS can be understood as ‘the faculty of the EWS components and products to exchange and make use of and disseminate authorized information between local, national & regional networks in real time when needed’.[[28]](#footnote-29) Among the benefits of an interoperable EWS are:

* The improvement of risk assessments and hazard impact modelling and their forecasting as they integrate qualified data from different sources.
* Enhancement of the content of different data bases.
* Foster cooperation between institutions in charge of the monitoring and analysis of hazards with disaster risk management organizations and economic / production sectors.
* A close interaction among EWS operators will enhance synergies that will result in a increased EWS effectiveness.

The following table provides an example highlighting the significance of an interoperable EWS.

**The importance of the interoperability in regional tsunami early warning systems**

The establishment and development of regional tsunami early warning systems (see section 2.2.5) provided opportunities for several countries in different regions to establish national centres for tsunami early warning systems. This has promoted the establishment of several national centers known as Tsunami Service Providers (TSPs) offering a service to those countries wishing to receive it in each region. Tsunami Service Providers operate with slightly different procedures based on their best-practices and network configurations, covering different geographical areas, including partial overlap. This can result in different solutions of both earthquake parameters and threat/alert levels, for example as observed in recent events such as the Kos-Bodrum tsunami in 2017 and the event south of Crete on May 2020. An increased interoperability is therefore desired, to improve efficiency and handle the intrinsic uncertainty deriving from independent and simultaneous real-time analysis performed by each TSP.

Box xx: The importance of the interoperability in regional tsunami early warning systems.

Based on inputs from Denis Chang Seng, UNESCO/IOC, 2022

## **Capacity building strategies**

Capacity building can be seen as either central pillar and or cross cutting supportive framework for EWS. It spans across all the EWS elements from risk knowledge to response. Capacity building strategies, competence-development frameworks, best practices, tools and methods and approaches vary in scope, scale and forms depending on hazard and risk to be governed. National, regional, and international organizations and agencies often conduct training seminars, webinars, and other outreach programs to build capacities of EWS actors, decision-makers, as well as the public, on various aspects of MHEWS. Regular drills and exercises are practical capacity building tools to create a culture of preparedness from national authorities down to the people at risk, and this is showcased for example, by the regular regional Tsunami WAVE exercises where people is regularly trained on evacuation strategies after a warning is issued. The content and modalities of capacity building activities should reflect the need of the training audience, which can be very diverse due to the different institutions managing and operating an EWS.

## **2.2. Enhancing / establishing governance mechanisms for EWS**

**2.2.1 Set the stage and connect the dots**

MHEWS need to be developed and operated within a governance architecture that integrates several elements including institutional frameworks and norms, arrangements among institutions and other actors which ensures the timely allocation of resources for its routine operation. An effective governance fosters the active participation of institutions and other stakeholders, facilitates mediation, negotiation, deliberation, cooperation, and partnership among stakeholders. Good governance will allow the MHEWS to operate in a transparent and accountable fashion, and with equity and legitimacy[[29]](#footnote-30).

1. **Know your key partners and platforms**

The design, implementation and operation of any people-centered early warning system requires the contributions and co-ordination of a wide range of individuals and institutions, especially the people being affected[[30]](#footnote-31). For a (multi-hazard) early warning system to operate effectively, national, regional, and local governments in coordination with at-risk groups should define together a comprehensive framework identifying roles, responsibilities, and relationships of all stakeholders within the system. Therefore, the first step is to identify all stakeholders which need to be involved**.**

The principal stakeholders may include representatives from:

* Community-based organizations representing / including the voices of groups which may have special needs: indigenous peoples, elderly, women led organizations, people with disabilities or illness, migrants, among other groups.
* Local & national governments as well as regional and international organizations.
* The disaster risk management authorities at the national, regional, and local levels.
* Scientific and technical agencies responsible for monitoring issuing hazard warnings or advisories (e.g. National Meteorological and Hydrological Services, health authorities, geological services, ocean observing organizations, universities, etc.).
* Humanitarian and relief organizations and NGO working in the zone (e.g. National Red Cross and Red Crescent Societies, UN agencies, religious institutions, among others.
* Public and private communication entities.
* Private sector, small local businesses, tourism operators and restaurants.
* Representatives of different sectors, such as transportation, agriculture and food security, energy supply and demand, health and epidemics, water resource management, telecommunications and education (e.g. schools, institutes and informal education).

1. **Local actors**

Communities, particularly those most vulnerable, are fundamental to people-centered multi-hazard early warning systems. They should be protagonist in the development and operation of early warning systems, recognizing the hazards and potential impacts to which they are exposed and be supported to take actions to minimize the threat of loss or damage. Participation of at-risk communities and local actors is essential to ensure that local risk perceptions are understood and considered to support a more risk-informed preparedness; and warning delivery channels and messages are tailored to reach all type of users, match their information needs and enable them to take protective action.

Local governments are also at the center of effective early warning systems. They should be empowered by national governments, have considerable knowledge of the hazards to which their communities are exposed and be actively involved in the design and maintenance of early warning systems. They must be aware of standard advisory / warning information that will be shared through the EWS and be able to advise, instruct and engage the local population in local disasters reduction plans which increases public safety and reduce the possible loss of community ‘s livelihoods.

1. **National actors**

National governments are responsible for high-level policies and frameworks that facilitate early warning and for the technical systems that predict and issue national hazard warnings. Similarly, they should provide support to local communities and different sectors to develop operational capacities to sustain and improve EWS.

Moreover, national governments should interact with regional and international institutions and agencies to strengthen early warning capacities and ensure that warnings and related responses are directed towards the most at-risk populations, following international and standard procedures.

1. **International actors**

International bodies, such as United Nations agencies, the IFRC, intergovernmental or multilateral organizations can provide international coordination, standardization and support for national early warning activities and foster the exchange of data and knowledge between individual countries and regions. Support may include providing advisory information, technical assistance, and policy and organizational assistance necessary to aid the development and operational capabilities of national authorities or agencies. The following table presents an overview of institutions working at global or regional level monitoring different kind of hazards.

|  |  |
| --- | --- |
| **Hazard** | **Global organizations working on EWS monitoring** |
| **Severe weather / storms** | • **Severe Weather – WMO**  https://severeweather.wmo.int/v2/ • **Central Pacific Hurricane Center** https://www.nhc.noaa.gov/?cpac • **Seasonal Climate Forecast** https://iri.columbia.edu/our-expertise/climate/forecasts/seasonal-climate-forecasts/ • **Rainfall Forecast in Context - IFRC / International Research Institute for Climate and Society**  <http://iridl.ldeo.columbia.edu/maproom/IFRC/index.html>   * **Global Data-Processing and Forecasting System**   <https://wmo.maps.arcgis.com/apps/dashboards/7c3d45e5003a417988bad63e91ad8748>  Numerical Weather Prediction products and services in all time-scales for weather, climate, water and environment |
| **Flooding and Landslides** | • **International Flood Network** http://www.internationalfloodnetwork.org  • **International Consortium of Landslides** <https://icl.iplhq.org>   * **Flood and Drought Monitors - UNESCO Intergovernmental Hydrological Programme (IHP) and Princeton Climate Institute (PCI)**   <http://hydrology.soton.ac.uk/apps/> |
| **Drought** | • **Humanitarian Early Warning Service**  www.hewsweb.org/drought/ • **Global Information and Early Warning System** www.fao.org/giews/english/index.htm • **Famine Early Warning System**  www.fews.net/ |
| **Wildland Fire** | • **Global Fire Monitoring Center** www.fire.uni-freiburg.de |
| **Earthquakes, volcanoes, tsunamis** | • **Global Tsunami Early Warning and Mitigation Programme** <https://ioc.unesco.org/our-work/global-tsunami-early-warning-and-mitigation-programme>  • **International Tsunami Information Center - ITIC** http://itic.ioc-unesco.org/index.php • **US Tsunami Warning Center – Pacific Tsunami Warning Center (PTWC)** http://www.tsunami.gov • **UNESCO/IOC Sea Level Station Monitoring Facility** http://www.ioc-sealevelmonitoring.org/map.php  • **US Geological Survey and Global Volcanism Program** https://volcano.si.edu/reports\_weekly.cfm • **Geofon - German Research Center for Geosciences** https://geofon.gfz-potsdam.de |
| **Health emergencies** | * **World Health Organization - Health Emergency Dashboard** https://extranet.who.int/publicemergency |

Table 3: Global organizations working on EWS monitoring. Adapted from IFRC, Geneva, 2012

1. **Know your regulatory frameworks and institutional arrangements**

Vertical and horizontal communication and coordination between early warning stakeholders can support the effective governance of EWS, this includes considering actors at local, national, and regional level from different sectors in society (agriculture, health, infrastructure, education, etc.).

‘Well-developed governance through robust frameworks and supported by a long-term commitment to early warning systems is necessary to support development and sustainability of sound EWS’[[31]](#footnote-32). Once key partners and stakeholders are identified and their roles have been established, the local and/or national EWS plans should be shared with the ones that haven’t participated in their development. The identification of regulatory frameworks, relevant institutions mandate and set up protocols for EWS enable to acknowledge and recognize stated responsibilities of key partners working around the EWS.

**b.1. Advocacy mechanisms**

Even a small group of interested partners can initiate discussions around the importance to implement and sustain EWS. Considering that it is a national government’s responsibility to create, maintain and update EWS at all appropriate levels and for all groups at risk, the implementation of institutional arrangements can support the community involvement in the developing and implementation of EWS. Their active participation supports their sustainability in time, since all groups at risk are involved in the EWS, including the most vulnerable ones and their special needs, if required.

Furthermore, disaster risk governance in all its aspects of policies, strategies, legal and regulatory mechanism, all-of-society accessible and inclusive approaches is considered the enabler for effective and sustained early warning systems and should be an integral part of any climate and disaster risk management system. *Investment and financing* in technologies, forecast-based financing and shock responsive social protection, and capacities for managing risks at all sectors and levels are required to ensure implementation of any MHEWS that enables action to reduce exposure and risks to hazards, minimize impact of disaster events. Advocacy mechanisms can support the elaboration of funding strategies involving interested stakeholders and potential partners.

It is important to know that the establishment of Early Warning Systems is a global political and legal obligation. Governments have the responsibility to protect people through EWS as stated in the 1992 Rio Declaration and reinforced in the Sendai Framework for Disaster Risk Reduction, the Paris Agreement, and the Sustainable Development Goals, international frameworks adopted for most of the countries affected by different kind of hazards. Moreover, it is also implicit in the human rights obligations of most countries under international and national laws, including the rights to life, equality, health, among others’ rights[[32]](#footnote-33).

|  |  |  |
| --- | --- | --- |
| **Name** | **Year** | **Description** |
| **The Rio Declaration** | **1992** | The original Rio Declaration Principles 18 and 19 refer to states’ “duty to inform” including: the immediate notification of any “disasters or other emergencies that are likely to produce sudden harmful effects on the environment” and “prior and timely notification and relevant information to potentially affected states on activities that may have a significant adverse transboundary environ- mental effect.”  Principle 10 demands that individuals gain “appropriate access to information concerning the environment that is held by public authorities.” |
| **The Sendai Framework** | **2015-2030** | The Sendai Framework for Disaster Risk Reduction 2015-2030 recognizes that early warning systems (EWS) play an important role in reducing the risk of death, injury, disease, loss of livelihood and damage to property from disasters. It urges a paradigm shift towards an impact-based, multi-hazard risk-informed integrated approach for multi-hazard early warning system (MHEWS, Target G), |
| **The Sustainable Development Goals (SDG)** | **2015-2030** | An effective EWS saves lives, assets, protect livelihoods, land and infrastructures and supports long-term sustainability. The SDGs address early warning, particularly those related to food security (SDG 2), healthy lives (SDG 3), resilient cities (SDG 11) and climate change adaptation (SDG 13).  Specifically, Goal 3. Target 3.d, refers: ‘Strengthen the capacity of all countries, in particular developing countries, for early warning, risk reduction and management of national and global health risks’[[33]](#footnote-34). |
| **The Paris Agreement** | **2016** | Early Warning Systems are crucial components of climate change adaptation strategies and disaster risk management actions. They support process to avoid or reduce the damages caused from different kind of hazards, exacerbated by climate change.  The Article 8 of the Paris Agreement indicates that ‘Parties recognize the importance of averting, minimizing and addressing loss and damage associated with the adverse effects of climate change, including extreme weather events and slow onset events, and the role of sustainable development in reducing the risk of loss and damage’[[34]](#footnote-35). Accordingly, areas of cooperation and facilitation to enhance understanding, action and support may include, in the first-place early warning systems. |

Once international frameworks are known, national and local regulations in place should be recognized and analyzed as well to understand set up roles and mandates of local authorities to implement the 4 interrelated components of an EWS:

If local resources and capacities are not enough, public – private partnerships are good options to explore to ensure the financial sustainability of the process. See section 2.3 to continue reading about partnerships.

**b.2. Assess the Institutional Capacity**

MHEWS must be operated within the framework of disaster risk reduction. This call to incorporate early warning in disaster risk reduction strategies was already noted in the Conference Statement stemming from the 2nd International Early Warning Conference held in Bonn, Germany, in October 2003. To strengthen this notion, the Hyogo Framework for Action, and the Sendai Framework for DRR include early warning as key priorities for action.

The governance framework should address and encourage the assessment of risks based on scientific, local, and indigenous knowledge; the dialogue among specialists or experts, government agents, community leaders, those at risk, and other stakeholders to design, operate and improve the system; and Standard Operating Procedures (SOPs) that include top-to-bottom and bottom-to-top actions[[35]](#footnote-36) carried out as part of its routine operation.

At the national level, MHEWS should also be incorporated in norms and legislation related to DRR. In some countries this may require a review and amendment of existing legislation of technical institutions such as meteorological offices or volcanic observatories, as such existing legislation may grant such technical institutions the mandate to operate monitoring networks, carry our forecasts and issue warnings as necessary.

In a similar fashion, national disaster management agencies should also incorporate and operationalize their segment of early warning systems as these institutions as some of those that have to response to warnings initially.

The following factors were found at the base of solid and sustainable experiences rolling out EWS[[36]](#footnote-37).

* Strong political commitment, solid institutions with developed capacities.
* Durable institutions and their capacities.
* Involvement and coordination of a broad range of actors (individuals and institutions) with responsibility and accountability for their functions.
* Strong inter-linkages between different EWS elements and stakeholders – communities, local and national governments, regional and international organisations and institutions, nongovernmental organisations (NGOs) and the private sector – and between general disaster risk reduction agendas.
* Good communications.
* High levels of public awareness and appreciation of the benefits of EWS.

When dealing with the establishment and maintaining of an early warning system, it is necessary to know and review legislation and institutional arrangements in place on this matter. The established mechanisms of coordination between key stakeholders, plans of action as well and resources allocated can offer an overview of the situation with regards governability associated to EWS.

Where interagency cooperation is strengthened, and roles, responsibilities, and institutional arrangements for early warning communication are disseminated, mandates and communication lines between different agencies are clearer. Standard Operating Protocols and Common Alerting Protocols reinforce the interaction of the 4 components of the EWS[[37]](#footnote-38) and between key stakeholders involved in its implementation.

## **2.2.2. Legal, policy and regulatory frameworks for Multi Hazard Early Warning Systems**

The implementation of early warning systems (EWS) will be framed within governance mechanisms. Legal, policy and regulatory frameworks set rules, roles, and responsibilities that affect each EWS key component, such as (i) the development of disaster risk knowledge through comprehensive hazard mapping and vulnerability assessments; (ii) the monitoring and forecast of hazards by means of high-quality equipment, scientific methodologies and available local knowledge; (iii) the communication and dissemination of accredited, timely, accurate, clear, and feasible warnings; and (iv) the preparedness at all levels to respond to received warnings.[[38]](#footnote-39)

Legal, policy and regulatory frameworks are essential instruments of institutional arrangements and governance since they affect management/governance strategies. By indicating how to address and solve issues, they shape the response of actors and local community members[[39]](#footnote-40). These frameworks help to clearly understand the government’s role about the implementation of EWS, define the responsibilities of different actors/sectors, facilitate planning and monitoring strategies, promote the understanding between actors, and enable the conditions for a successful implementation of EW-EA chain.

The Early Warning – Early Action chain ‘refers to acting prior to a hazard materializing based on warnings, rather than responding only once the hazard materializes’. For a successful implementation of early actions, a Forecast Based Action (FbA) mechanism should be previously enabled. This mechanism initiates *early actions* when a forecasted event surpasses or exceeds a previously defined threshold[[40]](#footnote-41) (e.g., a 75% probability of a category 3 typhoon). The implementation of actions that focus on preventive measures has proved to be more effective at reducing risk and losses.

Decision-makers must develop policies and regulations that properly ensure ‘early warning, early action’. For that purpose, they can pre-identify FbA mechanisms as a key element for the implementation of *Early Actions*. Authorities should also order relevant government actors to develop FbA mechanisms, and integrate them into existing planning processes, rather than creating parallel ones. This will ensure a comprehensive perspective, necessary to avoid duplication of effort and/or gaps that could lead to contradictory information and to imprecise operational protocols[[41]](#footnote-42).

Additionally, it should be noted that the development and implementation of rules and protocols would vary for rapid onset hazards (i.e., a tsunami) and for slow onset hazards, (i.e., cyclones, drought, etc.). Implementation times can play a critical role and the setting up of proper laws, policies, and protocols pose specific challenges. Likewise, transboundary hazards will need institutional arrangements and special coordination mechanisms between EWS in bordering countries. This coordination will lead to a clear warning communication and dissemination strategy at all levels and to an enhancement of data sharing related to risk knowledge and hazard detection.

1. **Communication and coordination lines**

Since risk and hazard information comes from different national agencies, there will be cases where decision-makers may not have a comprehensive set of data available. This situation could lead to under-informed decisions.

A particular effort is necessary to improve communication lines between different agencies. For this purpose, each agency responsible for the different elements of the Early Warning and Early Action chain should implement Standard Operating Protocols (SOP), Communication Protocols, or Codes of Conduct. This definition of protocols will strengthen institutional capacity, thus enhancing co-ordination and co-operation among government entities and non-state stakeholders. The success of the warning communication and dissemination[[42]](#footnote-43) component (as well as the whole EWS) relies on defining ‘*Who does what’* in the EW - EA chain.

The benefits of developing and implementing protocols[[43]](#footnote-44) are:

1. Harmonization of decisions on issuing warnings and the corresponding warning levels. This usually takes place at institutions responsible for hazard monitoring and for warning dissemination (‘provider organizations’).
2. Agreement to a decision on whether to officially call for an evacuation.
3. Translation of the warning message into guidance for the community at risk. In most countries, disaster management organizations are involved in the dissemination of warnings to the population and in decision-making on whether to call for evacuations.

The coordination between EWS actors at all levels can also be established through legal frameworks. Laws and decrees establish mandates, roles, and responsibilities in different EWS areas. By defining responsible actors’ actions, they allow for strengthened accountability. Besides, they enable and promote stakeholders’ engagement in decision-making. Standards, incentives, and penalties promote investments and order budget allocations, as well as policies, practices, and processes dictated by law assign responsibilities to institutions or individuals. Therefore, to prevent weak institu­tional structure and performance, which can often lead to unclear roles, ineffective actions, and limited impact of risk-reduction measures[[44]](#footnote-45), the creation of institutional mechanisms, such as coordination bodies, is necessary.

Similarly, communication and warning dissemination protocols should reach the whole population at risk, paying special attention to disabled people, young children, indigenous peoples, or remote communities hard to reach.

Clear and effective regulatory frameworks allow specific measures that ensure timely and appropriate actions against disaster risks. The following section lists suggested measures to reinforce the actionability of EWS since the governance lens and institutional arrangements.

1. **Suggested measures to implement**

Regarding Risk Knowledge

* Establish clear standards for the systematic collection, sharing and assessment of risk information and data related to hazards, exposure, vulnerabilities, and capacities.
* Ensure the definition of roles, responsibilities, and institutional arrangements for EWS at all levels. Put a particular emphasis on developing mandates and methodologies for multi-hazard risk assessments and warning dissemination.
* Implement standardized and institutionalized hazard, risk, and vulnerability assessment methods for the country, and a nationwide risk zoning policy based on risk maps. For this purpose, use relevant national regulations and guidance documents, and make them accessible to all people at risk.
* Acknowledging the importance of risk perception, local knowledge, and trust for effective reaction.
* Integrate early warning issues into national or local plans instead of developing parallel planning documents, ensuring that national / local contingency plans are UpToDate.

Regarding hazard detection

* Ensure the arrangements for data sharing in case of transboundary hazards (i.e., plagues, tsunamis, droughts, etc.)
* Ensure laws and regulations that promote the provision of funds and resources to acquire and maintain hazard-monitoring equipment.

Regarding Warning dissemination

* Promote the implementation of technical regulations that will clarify warning details, including the definition of levels and thresholds between major and minor hazards, this will allow the implementation of pre-defined Early Actions
* Establish standard processes for generating and issuing warnings that are accessible to the whole population, especially the most vulnerable. These processes should be featured in data collection and included in EWS planning and design, to ensure that no one is left behind.

Regarding preparedness and response

* Ensure that local contingency plans prioritize assistance to everyone, especially to specific groups with difficulties to evacuate by themselves: disabled and ill people, young children, pregnant women, and the elderly.
* Ensure by law an appropriate funding for EW and EA, including funding for risk assessments, monitoring, forecasting (e.g., equipment, facilities, and personnel), and the implementation of anticipatory or early actions (implementation of livestock shelters, resources for cash transfers, development of bank of seeds, etc.).
* Implement feedback mechanisms to confirm receipt and design plans to reach the most at-risk and remote populations.
* In case of disaster-displaced population, ensure that the law protects them in case of gender violence or sexual harassment in shelters; likewise, safeguard children’s right to education and protection.

Legal, policy and regulatory frameworks represent critical cross-cutting elements for EWS and disaster risk management strategies. They can lead to effective EWS and contribute to community resilience and to efforts for a sustainable development.

**2.2.3. Accountability frameworks**

Accountability is commonly defined as the responsibility for the decisions and/or actions and the expectation to provide an explanation for them when inquired. As it is one of the guiding principles of MHEWS Policy[[45]](#footnote-46) where the levels of responsibilities can vary depending on the governance framework the MHEWS falls in, accountability could be defined as the obligation to sustain the capability of replying and responding to any queries related to the service being provided and therefore could provide an indirect measure of the vulnerability and fragility of the system itself. In that regard, perhaps the most important element of the accountability framework is having a transparent performance monitoring system based on international norms, standards and agreements being respected without compromise.

The overall efficiency of the MHEWS and its policy support is directly linked to its monitoring, evaluation and reporting processes, standards of performance for systems and structures of the MHEWS, and clear identification and agreement of roles and responsibilities to ensure efficient use of the MHEWS[[46]](#footnote-47) [[47]](#footnote-48). The accountability framework associated with these requirements can be addressed in three levels, namely at the institutional, governmental and intergovernmental level.

Institutional accountability framework is the cornerstone of the overall accountability framework pyramid and requires definition of standard operation procedures based on sound science supported with state-of-art technology. The credibility of the scientific methods utilized by the MHEWS is closely associated with the transparency of data and methods, where the latter should be continuously subject to benchmarking and independent peer-review through adopting open data and open method policies which would allow that the system outputs are reproducible[[48]](#footnote-49). The MHEWS should adopt Key Performance Indicators (KPIs) proposed globally and in the absence of such KPI’s, in close connection with the relevant scientific communities, it should develop such KPIs and use them in monitoring, evaluating and reporting on the efficiency of the system.

Governmental accountability framework is linked to the responsibilities related to provision of appropriate legislative framework, considering the need to establish required administrative frameworks ensuring effective collaboration between all stakeholders through providing clear definition of roles and responsibilities, mechanisms of multi-level arrangements, ensuring adequate financing and thus laying out the basis for effective synergies at the national, regional and global levels. The functions of the MHEWS should be clearly aligned with the strategic framework of disaster risk reduction policy.

Intergovernmental accountability framework should provide a governance and capacity building mechanism to support and synchronize the development of institutional and governmental accountability frameworks and implementation of MHEWS’ by creating synergies among practitioners and policy makers within an overall science and disaster diplomacy point of view, also ensuring that non-humanitarian elements, such as disagreements on national boundaries and acclaimed ownerships of areas of responsibilities of MHEWS would not become an obstacle specifically in the case of transboundary events. To support this approach, this framework should also promote sustainable accreditation mechanisms through independent bodies and further promote interoperability concepts through collaboration and partnerships among various stakeholders.

Transparency is the key factor of accountability, as it applies to all its components ranging from definition and agreement on clear roles to monitoring and evaluating the performance of the MHEWS. Without transparency, the basis of an accountability framework cannot be established as the stakeholders would not have the means to verify and validate the operational capabilities and effectiveness of the MHEWS. Last but not least, accountability frameworks at all levels are clear declarations on commitments of the MHEWS' and therefore key towards establishing trust and confidence among its users.

**2.2.4 International and regional cooperation for support & guidance**

International and regional cooperation underpins the development, coordination, support, guidance, and sustainability of effective Early Warning Systems. The effectiveness of an institutionalized Early Warning System can only be achieved by strong cooperation between agencies running the system and the vulnerable people. The level and scale of international and regional cooperation are related to the complexity of risk to be governed.  The International Risk Governance Council[[49]](#footnote-50) has recommended that stakeholder involvement is a function dominant characteristic of a risk. For instance, highly *complex (climate change), uncertain, and rare* hazards and *transboundary* risks (tsunami) may benefit from wider dialogue and therefore cooperation amongst, respectively, a broader base of people with expert knowledge, or all directly affected stakeholders. The involvement and cooperation of stakeholders and partners are both to ensure that the risk handling process is inclusive and responsive to those affected by it and to maximize the effectiveness and acceptability of the decisions that are made (IRGC 2005). To reach the last mile, an integrated approach built on multi-level cooperation to early warning must be based and include the needs, priorities, capacities, and cultures of those people at risk.  In the following sections, best practices and experiences in multi-level cooperation are provided in the context of hazard and risk assessments, information, and communication, monitoring and warning, and preparedness and response capacity. Cooperation opportunities are highlighted, especially concerning the UNESCO /IOC Tsunami Ready which has now established itself as a globally popular and recognized tsunami preparedness tool (UNESCO/IOC 2022) and …. It represents notable examples and guidance of a distributed early warning and mitigation solution requiring high-level negotiations, cooperation, and substantial funding for a complex, transboundary, sudden and high impact hazard.

**Tsunami Early Warning and Mitigation Systems**

In December 2004, 227,8991 people lost their lives and around US$10 billion were estimated as overall economic losses in the 14 countries affected by the 9.1-magnitude Indian Ocean earthquake and tsunami. In response, the Intergovernmental Oceanographic Commission of UNESCO (UNESCO/IOC) along with dozens of partners strengthened its support and catalyzed international cooperation to enable all countries to assess their tsunami risk, implement Tsunami Early Warning Systems (EWS) and educate communities at risk about preparedness measures. The development and coordination of the regional tsunami early warning and mitigation system in all ocean basins following the 2004 Tsunami stands out as one of the greatest multi-level cooperation efforts for support and guidance of transboundary tsunami risk and disasters.

Firstly, it is to be noted that during the special sessions of the World Conference on Disaster Reduction. 18-22 January 2005, Kobe, Hyogo, Japan, the Indian Ocean countries agreed, based on national and regional cooperation, to design and establish what is known today as the Indian Ocean Tsunami Warning and Mitigation System (IOTWMS). Germany, the United States Agency for International Development (USAID), Japan, China, France and many other countries and agencies have worked through strategic collaboration and partnership within the international community, host country governments and private sector and NGO partners and at the community levels to deliver operational 24/7 tsunami early warning systems to ensure a safe ocean and coast. The InaTWMS alone cost approximately USD 450 million to establish and every year it requires between USD 50-100 million for operation and maintenance (UNESCO 2017)

Similar investments, efforts and achievements founded on international, regional, and national cooperation have been realized in the Caribbean and Adjacent Regions (CARIBE EWS), the Tsunami Early Warning and Mitigation System in the North-eastern Atlantic, the Mediterranean and connected seas (NEAMTWS) and the Pacific Tsunami Warning and Mitigation System (PTWS).

**Hazard and Risk Assessments, Information and Communication**

Over the past two decades, important tools ranging from tsunami databases, tsunami hazard assessments and modelling have been developed.  In 2005 in response to the recommendation of the IOTWMS the NOAA Center for Tsunami Research (NCTR) developed ComMIT, an internet-enabled interface for tsunami modeling which has been used around the world to generate tsunami inundation maps.  Through a collaborative effort led by International Tsunami Information Center (ITIC), the USA (NOAA, USAID/OFDA), IOC, and New Zealand developed a standardized process, training course and Manual and Guide focusing on Tsunami Evacuation Maps, Plans, and Procedures (TEMPP).  Another notable achievement demonstrating cooperation between partners, project countries and scientific organizations is the development of a first homogeneous long-term Probabilistic Tsunami Hazard Assessment (PTHA) for earthquake-induced tsunamis for the entire coastlines of the NEAM region which works in tandem with operational TEWS (TSUMAP-NEAM Project).  For the dissemination of sea level data and tsunami messages the WMO Global Telecommunications System (GTS), the US GOES, EMWIN and GEONETCAST systems have played a key role for reliable and redundant communications.

**Monitoring and Tsunami Early Warning Services**

Through cooperation arrangements facilitated by the UNESCO/IOC-led Intergovernmental Coordination Group mechanisms, there are now in total 11 Tsunami Service Provides (TSPs) established. This includes the US (Pacific Tsunami Warning Center based in Hawaii), Australia (Geoscience Australia (GA) and the Bureau of Meteorology), Indonesia ( Agency for Meteorology Climatology and Geophysics (BMKG)), India (India Tsunami Early Warning Centre), which is operated by the Indian National Centre for Ocean Information Services (INCOIS), France (CENALT), Greece (NOA), Italy (INGV), Portugal (IPMA), and Turkey (KOERI) providing 24/7 tsunami warning services for all participating Member States.

The UNESCO IOC Sea Level Station Monitoring Facility (SLSMF) currently provides real time access to a network of 933 sea-level stations globally.  This is crucial for the provision of early warning of rapid onset sea-level hazards.  JRC contributed to the IOC SLSMF through its network of over 30 "Inexpensive Devices for Sea Level Measurements" (IDSL) stations in the NEAM region.  The Joint Research Center (JRC) of the European Commission is an effective and long-standing partner cooperating with IOC and Member States contributing to the development of NEAMTWS.

The CARIBE EWS was formalized in 2005 and is the only regional tsunami early warning system which encompasses other coastal hazards.  International Cooperation has been fundamental for advancing the system. With funding from Monaco, Saint Vincent and the Grenadines, Brazil, United Kingdom and the United States for new equipment and capacity development, the sensing network grew from a dozen seismic stations and a handful of sea level stations to an integrated network of over 100 seismic stations and 80 sea level stations at its peak.  Data portals like IRIS (supported by the US National Science Foundation, NSF)) and the SLSMF) are key for the access to these data.  More recently, the US National Science Foundation has supported the integration of the Global Navigation Satellite Systems (GNSS) with 85 stations across the Caribbean through COCONET and 40 stations as part of TLALOCNet, in Mexico; now integrated into the Network of the Americas (NOTA).

**Preparedness and Response Capacity**

Tsunami warning systems must also go hand in hand with awareness and preparedness of the public. Tsunami Information Centers (TICS) in each ocean basin were established to provide information on warning systems, risks, and good practices in respect of tsunamis and other sea-level related hazards for civil protection agencies, disaster management organizations, decision makers, schools, industries in the coastal zone and the general public.

Governments, for example Italy and the Kingdom of the Netherlands have exercised high level of cooperation and provided crucial seed funding to support the formal establishment and running of the Caribbean Tsunami Information Centre (CTIC) which is hosted by the Government of Barbados while project-based funding from the United States Agency for International Development (USAID), the European Commission Humanitarian Aid Department’s Disaster Preparedness Programme (DIPECHO), the Norwegian Agency for Development Cooperation (NORAD), and the Australian Government in particular together with pilot state contributions have significantly advanced the work of the CTIC focused on the recognition of national and local communities under the Tsunami Ready Programme. Similar supports were provided towards the development of NEAMTIC.  The IOTIC also operates as a partnership between Indonesia and UNESCO/IOC, while ITIC is hosted by the USA in partnership with UNESCO/IOC.

Regional tsunami exercises are regularly conducted in each region [7 Pacific, 10 Caribbean (Chacon et al, 2021), 6 Indian Ocean since 2009, 4 NEAM region) to test the readiness of early warning systems and prepare coastal communities to tsunami risks underlines the level and scale of cooperation, coordination and efforts exercised among Member States and relevant partners. Due to relatively rare tsunami events (but high coastal exposure and risk) in NEAM region there is a need to further strengthen cooperation and networks with the Civil Protection Agencies/Organizations through the European Response and Coordination Centre (ERCC).

The UNESCO/IOC Tsunami Ready Recognition Pilot Programme is an international performance-based community recognition pilot.  The initiative is modeled after the US NOAA National Weather Service’s TsunamiReady® Program.  Implementation began in the Caribbean in 2011 and has since then extended into the Pacific, Indian Ocean and Northeast Atlantic and Mediterranean. In June 2021, the Thirty-first Session of the Intergovernmental Oceanographic Commission (of UNESCO) Assembly, approved the establishment of the Ocean Decade Tsunami Programme.  To date, nearly 30 communities in the Pacific, the Caribbean and the Indian Ocean have received Tsunami Ready recognition (tsunamiready.org).

The best practice which originated from one single country - in this case, the USA - translated through test and piloting into an internationally accepted standard for community preparedness with a high (positive) impact on community resilience. Multiple sources of funding and technical and scientific support were needed over several years to keep the momentum and complete the process, and a rigorous intergovernmental vetting mechanism was key to gain acceptability and make possible a consensual adoption of this standard. These initiatives have benefited from strong collaboration on implementation initiatives with several partners including the Caribbean Disaster Emergency Management Agency (CDEMA), the Coordination Center for the Prevention of Disasters in Central America and the Dominican Republic (CEPREDENAC), NOAA International Tsunami Information Center-Caribbean Office (ITIC-CAR) [formerly Caribbean Tsunami Warning Program], the University of the West Indies Seismic Research Centre (SRC), USAID Bureau as well as EU DG ECHO.

The JRC has also recently implemented “Tsunami Last Mile” TLM systems in Greece Turkey, and Malta. The TLM project objectives were to install technological tools to provide early warning to the populations in pilot cities; to build links between the relevant stakeholders that are involved in the tsunami warning system at regional, national and local levels; to build capacity in local communities and raise their awareness to tsunamis, and to conduct exercises that integrated the technological tools, involved the main stakeholders including the local population and demonstrated the benefit of awareness-raising. In the Caribbean, efforts towards the formal integration of other coastal hazards within the regional early warning system as well as the comprehensive integration of typical and atypical tsunami sources have been supported by USAID (2008-2010) and DIPECHO (2018 - 2020).

**New Cooperation Opportunities**

Recently, through ongoing and renewed cooperation between IOC UNESCO and partners including EU ECHO, UNESCAP etc.) new regional projects (e.g., CoastWAVE) are underway to build coastal resilience to tsunami and other sea level related hazards through science and regional cooperation.

The UN Ocean Science Decade for Sustainable Development IOC Tsunami Programme aims to further develop TEWS through technological and scientific advancements and make 100% of communities at risk of tsunami prepared and resilient to tsunamis by 2030 contributing to the societal outcome of a Safe Ocean through the implementation of the UNESCO/IOC Decade Tsunami Ready Programme and other initiatives. To deliver such an ambitious goal, the Tsunami Programme is laying out the building blocks, through an international Science Committee and International Tsunami ReadyCoalition consisting of broader stakeholders to drive and enhance international, regional to local cooperation mechanisms for support and guidance to dealing with such complex (e, g triggering sources from volcanic eruptions, underwater landslides, meteo etc.), transboundary, sudden, and high impact hazards.

**2.2.5. Emerging Technological and Information mechanisms to enhance (MH) EWS**

1. **Digital and communication technologies**

MHEWS are not only about technologies, but technological advancement and innovation have created new opportunities for enhancing disaster risk reduction and management and in all four area of multi-hazards early warning systems. Developments in disruptive technologies – such as artificial intelligence (AI), the Internet of Things (IoT), and Big Data – and innovations in such areas as robotics and drone technology are transforming many fields, including disaster preparedness, resiliency and risk reduction. The rapid spread of supporting digital infrastructure and devices – such as wireless broadband networks, smartphones and cloud computing – has created the foundation for the application of disruptive technologies for disaster management[[50]](#footnote-51).

ITU estimates that by the end of 2021, about 63 per cent of the world’s population is using the Internet and 95 per cent are living within range of a mobile broadband network, offering new opportunities for digital platforms and reaching communities at risk[[51]](#footnote-52). The fifth-generation technology standard for broadband cellular networks (5G), which outperforms the previous generations of cellular mobile technology in terms of spectral efficiency, capacity, speed, and security, promises advancements also in early warning systems. 5G communication networks, and advanced data visualization technologies, for example, are the basis for new monitoring and alerting systems, and novel applications (highlight example).

An avalanche of data is being generated by sensors, closed-circuit television, smartphones, financial transactions and Internet activities, to name just a few. While many of these data are being mined by businesses for commercial purposes, big data analytics holds enormous potential for crisis management and multi-hazard early warning systems. Examples include the analysis *of social media* communications during a disaster to understand the types of data and creators, in order to have more impact and reduce false information. Social media are playing a greater role prior and during disasters, including for MHEWS. They help inform the public on how to be prepared if a disaster occurs, where to look for information or ask for help and keeps the public informed, for example, on the location and movement of storms or other potential hazards.

Another example is the use of sensors for monitoring conditions that could trigger disasters. Improvements in cloud computing, broadband wireless networks, the sensors themselves and data analysis have led to the emergence of powerful, integrated and real-time systems referred to as the Internet of Things (IoT). Disaster management is an ideal use case for IoT applications, since sensors can send alerts about a number of potentially dangerous situations. For example, tree sensors can detect if a fire has broken out by testing temperature, moisture and carbon dioxide levels. Ground sensors can detect earth movements, which might signal earthquakes. River levels can be monitored by sensors for possible flooding.

Artificial intelligence (AI) can enhance the understanding of natural hazards and support disaster early warning AI. Considerable research is currently being devoted to the use of AI for detecting and possibly one day predicting earthquakes and for other warning systems.

One challenge during a rapidly evolving disaster is coordinating and verifying information among different stakeholders. The Blockchain distributed ledger system and chain of verified records could play a significant role in improving information control. Blockchain for more rapid and reliable collection of data during a crisis is being tested in order to reduce the spread of disease. This has relevance for disaster management since, similar to public health, agencies offering relief need to share trusted data quickly to collaborate effectively.

Finally digital platforms and services have enabled many new innovations that helped mitigate the health, social and economic costs of the Covid-19 pandemic and build resilience against future crises.

These examples illustrate how disruptive technologies and advances in information and communication technologies and digital tools today are refining processes by spreading critical information more quickly, improving understanding of the causes of disasters, enhancing early warning systems, assessing damage quickly and adding to the knowledge base of the social behaviours and economic impacts when a crisis strikes. To maximize their benefits and take advantage of rapidly changing technologies, some key **recommendations** include:

* Successful initiatives on the use of new technologies for MHEWS can only be accomplished with close cooperation and support from national, regional, and local governments. Collaboration must be built in from the beginning to ensure solutions adequately address local needs.
* Access to data is vital, and more progress must be made with private sector partners to provide data necessary to develop the best possible early warning systems.

Developing a global repository featuring information on how digital technologies are being applied for EWS would raise awareness and understanding. Many applications of disruptive technology are underway, but experiences are often not widely available or shared. An information base would be useful for identifying digital interventions that have worked, who the implementers were and other material, in order to increase understanding about which technologies are relevant for different country circumstances and types of disasters.

1. **Geo and Space based information**

Geospatial and space-based data and information are contributing more and more to the design and routine operation of MHEWS, and to their improvements as new sources of geospatial and space-based data become available for use.

In the case of space-based data and information, the space community has continually launched constellations of satellites that are contributing to improved hazard monitoring and to more precise and up-to-date assessments of elements which are exposed to hazards. Thanks to its open-data policy, the Copernicus programme facilitates access to moderate-resolution optical imagery with a pixel size of 12 meters free of charge[[52]](#footnote-53). The United States Geological Survey also allows open and free access to moderate resolution satellite imagery from the Landsat constellation[[53]](#footnote-54). Many countries, including developing countries, have now launched Earth observation satellites for their own use in disaster management applications. In addition, the space and the geospatial communities have implemented more automated processes of satellite imagery taking advance of cloud-based computing, machine learning and artificial intelligence to put in place services that offer access to geospatial information for early warning purposes in the case of several hazards[[54]](#footnote-55). In addition, several space agencies have processed vast amounts of satellite imagery to develop products such as digital elevation models (DEM)[[55]](#footnote-56) and land-use/land-cover classifications[[56]](#footnote-57).

The incorporation of higher resolution satellite imagery allows operators of MHEWS to compile the most up-to-date inventory of infrastructure and specific types of assets that is exposed to hazards. This compilation of exposed elements allows experts to improve the routine operation of these systems.  One example is the use of such information to identify evacuation strategies, including who to warn as quickly as possible (highly vulnerable groups such as children in schools, elderly in retirement homes, people in places such as commercial streets, public markets; train and main bus stations, etc.), and to outline evacuation routes for vehicles and other assets which could be mobilized to safe areas.

Space-based data and products such as DEMs, and information on land-use/land-cover are combined with in-situ data to elaborate hazard maps related to floods, landslides, tsunamis, storm surges, and other hazards.  Such analysis is often carried out using Geographic Information Systems (GIS). For example, in the case of landslides, hazard maps are elaborated using data on slope and aspect which are derived from DEMs and land-cover data derived from optical satellite imagery.  In-situ data in these cases includes geological and lithological data.

Space-based data are also contributing to monitor hazards permanently, and to track the spatial extent and path of potential events such as hurricanes, typhoons, and cyclones, as well as other types of severe weather hazards[[57]](#footnote-58).  Services implemented by the space community such as the Global Flood Awareness System (GLOFAS, [3]) are contributing to serve as potential sources of information on potential floods in the days preceding such floods.

In the case of floods, tsunamis, and storm surges, the combined use of the most up-to-date geospatial information on building infrastructure and DEMs allows experts to model how these hazards will propagate inland.  This information is useful to determine evacuation routes and safe areas, including temporary shelters.  In the specific case of tsunamis, such information is essential to determine whether vertical evacuations to high rise buildings is the only logical choice when evacuation inland is not an option[[58]](#footnote-59). An example of the use of satellite technologies in tsunami early warning is presented in Appendix B.

In a complementary fashion and using Global Navigation Satellite Systems (GNSS) such as the Global Positioning System (GPS) of the United States, voluntary technical communities are elaborating maps that can be used by operators of early warning systems.  These include voluntary efforts such as those by Open Street Maps[[59]](#footnote-60). Such maps take advantage of the capacity of smart mobile telephones or tablets to access GPS services in any place in the world.

Soon, the routine uses of cloud processing services such as Google Earth Engine[[60]](#footnote-61) and similar online, cloud-based computing platforms will allow operators of MHEWS to benefit from extremely fast computing power to process large amounts of satellite imagery to generate and access relevant information with a small amount of internet bandwidth in many regions of the world. In addition, the use of multi-temporal radar interferometry of radar satellite imagery will allow operators of early warning systems to monitor slow-moving landslides and potential deformations of volcanic domes before volcanic eruptions[[61]](#footnote-62).

**2.3. Financing MHEWS**

* 1. **Financing trends and prospects**

Multi-hazard early warnings are perceived as a public goods, the related costs are, in most cases, covered by national and local public service institutions. Early warning systems contribute directly to the protection of lives and property and provide socio-economic benefits in many sectors. Responsibilities for establishing, operating and financing early warning systems, for most hazards rests with national and local authorities.

A certain number of early warning systems, or elements of an early warning system, are regional and even in some cases global in scope and the costs, in these cases, are usually shared between countries. Certain global systems, for monitoring and/or the provision of services, managed by international organizations, obligate their members to fund and produce certain data and information, such as weather and climate observation data. This data then contributes to the production of global and regional predictions and warnings as global public goods.

An early warning, per se, has limited value, commercial or other, until its implications are understood and acted upon in the context of a group of people or institutions. Managing observation and monitoring networks for different hazards and producing prediction and warnings is a costly service while most revenues are created at the other end of the value chain. For many hazards, such as hydrometeorological extreme events, the relatively lower cost at the user end of the value chain is only possible if global data sets and the results of global forecasting centers are available (World Bank, 2020).

It is well established that official warnings can induce a high socio-economic benefit (e.g. by reducing the morbidity or reducing healthcare and safety costs). Such cost-return information is particularly relevant when prioritizing funding in a national context, when compared with other investment benefit-to-cost ratios, such as various adaptation investments in Africa (GCA, 2022).

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On the one-hand, technology innovations are reducing the costs of early warning systems. Common alerting protocols, allowing warnings to be widely disseminated through existing communication channels, have reduce the costs of the communications of warnings up to 20 times (NOAA, 2017).

Artificial intelligence and machine learning allow for considerable cost saving by substituting the collection of data and enhancing warning communications for impact-based forecasts. With today’s ready availability of automatic weather stations, the costs of operating an observation network are lower than 50 years ago (World Bank, 2020).

On the other hand, growing populations in areas exposed to hazards, such as coastal zones and higher exposure of infrastructure to disasters has resulted in a demand for more advanced prediction and warning services and increasingly sophisticated communications capacities for warnings. This, in turn, results in serious challenges for public institutions responsible for early warning systems – especially in low- and middle-income countries, to sustainably ensure the financing of their national system.

The financing of early warning system, continue, however, to be mostly covered by public funds. Civil protection and national disaster management organizations are recognized as part of national security policies and therefore mostly financed directly by State institutions. The observing, monitoring, prediction and warning for different hazards are also mostly public funded, although, different models are adopted by different countries.

Public services can be provided by a range of entities. In some cases, academic institutions and research centers will play a role for certain hazards. In some countries, national meteorological and hydrological services are required to operate on a commercial basis and to meet financial targets increasingly relying on the private sector to maximize the benefits and competition that the private sector can bring. As a result, certain observation data, prediction and forecasts data and products are commercially available, some for a fee meant to cover the cost of providing the data, others at market prices (WMO, 2019).

As for many services with public goods functions, such as water supply, railroads and education, financing of early warning systems requires a robust regulatory framework by public entities to ensure the availability and quality of such services. Effective financing of early warning systems relies on a dynamic and well structure engagement of public, private, and academic sectors drawing on their respective strengths and responsibilities.

* 1. **Innovative financing mechanisms**

Many countries are struggling to keep up with the ever-increasing demand for more sophisticated services to protect lives and assets as well as to support economies

Official development aid has provided financing for establishing and strengthening national early warning systems for many years. Mostly though bilateral cooperation and through development partners such as Regional Development Banks, the World Bank and UNDP. Financing for early warning systems was mostly tagged as science and technology, disaster risk reduction, preparedness, or humanitarian funding.

In 2005, following the Indian Ocean tsunami, a first pooled fund on the topic was established under the aegis of the Intergovernmental Oceanographic Commission of UNESCO and UNISDR (now UNDRR) to scaled up tsunami early warning systems globally. A specific early warning multi-donor trust fund for Asian countries was also established by UN ESCAP, which still operates today.

The recognition that early warning systems constitute an effective adapting tool to the impacts of climate change and the increasing intensity and frequency of related extreme events provided a step-change in financing of early warning systems. Specifically, for countries on the front-line of climate change impacts such as Least Developed Countries and Small Island Developing States.

Early warning systems, climate and weather services and observation networks became eligible for funding by financing mechanisms set-up in the context of the UNFCCC framework. Funds such as the Adaptation Fund (AF), the Global Environment Fund (GEF) saw an increase in the demand for financing of early warning systems. The Green Climate Fund (GCF) the largest of the climate finance mechanism set-up through the UNFCCC, now has a portfolio of….

In 2015, a financing mechanism, solely focused on early warning systems, was announced by France at the World Conference on Disaster Risk Reduction, in Sendai, Japan and launched later that year by five countries (joined by four more countries and the European Commission) at the UNFCCC COP21 in Paris, France. The Climate Risk and Early Warning is Systems (CREWS) initiative, is a Financial Intermediary Fund, managed by the World Bank, that finances early warning systems in LDCs and SIDS, through three partners, UNDRR, WMO and the World Bank.

In 2020, WMO initiated consultation for a similar multi-donor trust fund to finance basic surface-based observing networks in LDCs and SIDS. It is expected to contribute to the international exchange of observational data, which underpin all weather, climate and water services and products, including early warning systems. The Systematic Observation Financing Facility (SOFF) will be operational in the latter part of 2022.

The table xx below provides a non-exhaustive list of innovative financing mechanisms that are available to countries to support the financing of their early warning systems. OECD provides a more [comprehensive inventory of climate funds](https://www.oecd.org/env/cc/database-climate-fund-inventory.htm)

For low and middle-income countries, being able to access climate funds for early warning systems, often referred to in this context to climate and weather services, is an opportunity. It also represents a challenge for financing of early warning systems for hazards that are not directly link to the impacts of climate change. Mechanisms such as CREWS have adopted a full-value chain, multi-hazard approach to its operations, meaning countries can finance early warning systems for all hazard types. This is not the case, however, for other climate funds.

Accepted principles to drive effective and innovative financing of early warning systems include: improving the whole value chain in an inclusive manner; financing early action through people-centered, risk-informed approaches; adopting multi-hazard programmes; incentivizing private-sector actors to play a role, along with the academic community.

|  |  |  |
| --- | --- | --- |
| **Table…. Examples of innovative financing mechanisms for early warning** | | |
| **Name** (alphabetical) | **Scope** | **Innovative aspects** |
| Adaptation Fund (AF)  https://www.adaptation-fund.org/ | Its purpose aligned with the Paris Agreement’s stated goal of “enhancing adaptive capacity, strengthening resilience, and reducing vulnerability to climate change” Serves as a financing instrument of the UNFCCC. | - Three financing widows are available to countries that enhances direct access.  - [The Innovation Facility is offering vulnerable countries new tools and grants to foster, scale up and accelerate innovative adaptation practices and technologies. Learn more.](https://www.adaptation-fund.org/apply-funding/innovation-grants/)  - [Individuals or organizations may donate directly to the Adaptation Fund.](https://act.unfoundation.org/onlineactions/ql-Plvl-8UyPnR2kZ52-XQ2) |
| Climate for Development in Africa (ClimDev-Africa)  https://www.climdev-africa.org/ | ClimDev aims at closing climate information gaps to inform adequate policies and decision-making. The ClimDev Special Fund (CDSF) is a demand-led Fund that pools resources to finance investments in Africa for the generation and use of climate information for climate-resilient development. | - Strong leadership and ownership by African institutions.  - Established by the African Development Bank in 2009 as the investment arm of the [Climate for Development in Africa Program](http://www.climdev-africa.org/)  - Supports regional climate centers (RCCs) across Africa. |
| Climate Investment Funds (CIF)  https:// www.climateinvestmentfunds.org/ | Accelerates climate action by empowering transformations in clean technology, energy access, climate resilience, and sustainable forests in developing and middle-income countries. The CIF’s large-scale, low-cost, long-term financing lowers the risk and cost of climate financing | - Works in partnership with governments, the private sector, civil society, local communities, and six major multilateral development banks (MDBs)  - Extensive experience of weather, water and climate services through the Pilot Program for Climate Resilience (PPCR).  - All programs and operations are bound by a commitment to gender equality |
| Climate Resilience and Early Warning Systems Initiative (CREWS)  https://www.crews-initiative.org/en | Aims to increase the availability of, and access to, early warning systems, therefore reducing countries’ vulnerability, strengthening resilience and adaptive capacity in LDCs and SIDS | - Two financing windows for customized, country-led, early warning solutions.  - Draws on best available expertise aligned with approved standards and norms.  - Builds resilience of women and men with gender responsive projects |
| Global Environment Facility (GEF)  https://www.thegef.org/ | Provides funding to assist developing countries in meeting the objectives of international environmental conventions. It serves as an Operating Entity of the three Rio Conventions: biodiversity; climate change; and land degradation. Includes the Special Climate Change Fund (SCCF) and the LDC Fund | - GEF agencies have extensive experience in supporting technological, institutional, and business innovation  - Has experience in financing early warning systems and climate information programmes.  - Has a Challenge Program for Adaptation Innovation |
| Green Climate Fund (GCF)  https://www.greenclimate.fund/ | The GCF is the world’s largest dedicated fund helping developing countries to reduce their greenhouse gas emissions and enhance their ability to respond to climate change. Serves as an Operating Entity of the Financial Mechanism of the UNFCCC | - Transformational planning and programming underpinned by climate science  - Committed to climate information and early warning with USD 1.8 billion.  - Focus on modernization of hydromet services and sector applications. |
| Systematic Observation Financing Facility (SOFF)  <https://alliancehydromet.org/> systematic-observations-financing-facility/ | Seeks to support countries to generate and exchange basic surface-based observational data critical for improved weather forecasts and climate services. SOFF contributes to strengthening resilient development and climate adaptation. | - Support to sustain compliance with GBON.  - Will provide results-based finance for GBON-compliant countries to contribute to cover operational and maintenance costs and ensure continuous data sharing.  - Established as a 10-year programme with a modular implementation approach, and an initial focus on fundraising. |

**Chapter 3**

**Early Warning – Early Action within climate and disaster risk management systems**

Early warning systems – EWS are recognized tools to reduce the impact of disasters, protecting people, their properties, and livelihoods considering the valuable early and protective actions they can trigger. In order for Early Warnings to result in protective or mitigating action for communities at-risk, warnings must be timely and actionable, having pre-identified anticipatory and response actions to take as well as the optimum times at which decision makers at all levels need to receive the warning for the purpose of make informed decisions and take action. Early Warnings must also be disseminated in a clearly, understandable and interpretable way by non-technical people.

The Early Warning – Early Action chain can lead to critical benefits for the whole process of disaster risk management systems, helping to reduce economic losses and lower the number of affected populations by disasters. To strengthen their impact and sustainability, it is recommended to embed them into local or national disaster risk management systems.

This chapter presents main aspects to consider an effective implementation of an EW-EA chain. Main functions, approaches and concepts associated with EW-EA will be briefly described including some elements to consider their application into the disaster risk management framework.

* 1. **Managing risks through social protection systems to reach the most vulnerable**

Social protection is a set of policies and programmes aimed at preventing and protecting all people against poverty, vulnerability, and social exclusion, throughout their life cycle placing a particular emphasis on vulnerable groups.[[62]](#footnote-63)

The instruments that governments use for social protection commonly fall in three categories[[63]](#footnote-64):

* **Social Assistance**: financed either by taxes or international development aid. Examples of this type of assistance are in-kind or cash transfers, including Cash+ programmes.
* **Social Insurance**: programmes to protect people from potential financial losses linked to life-cycle events (e.g., old age), livelihood risks (e.g. illness) or climate-related shocks.
* **Labour market interventions**: protective policies and programmes for the working-age population designed to safeguard workers’ rights and entitlements.

Social protection is a policy and programmatic solution that has traditionally been used to address idiosyncratic risks, those experienced by individuals and households throughout their lives, such as disability, unemployment, and old age. Evidence across the world’s regions shows that social protection can generate a broad range of positive impacts: enhancing vulnerable households’ economic and productive capacity, smoothing consumption, fostering economic inclusion, safeguarding food security and nutrition, and building resilience to shocks and stresses[[64]](#footnote-65).

In recent years the increase in magnitude and frequency of extreme events, also caused by climate change, such as drought, floods, or conflict, that particularly hurt the most vulnerable[[65]](#footnote-66) has highlighted the need for comprehensive, inclusive, and more cost-effective disaster risk management systems. Indeed, the proportion of low- and middle-income countries vulnerable to climate extremes has climbed from 76% in 2000–2004 to 98% in 2015–2020. (FAO, IFAD, UNICEF, WFP and WHO, 2021). Climate extremes will undoubtedly worsen as the planet warms to 1.5°C and possibly beyond, with severe consequences on hunger and poverty.[[66]](#footnote-67)

As a reflection of the increased climate variability and extreme events, efforts during the past decade have been devoted to design national social protection systems that can be leveraged to address covariate risks. Particularly, two main approaches emerged that apply social protection as a platform to reduce climate risks by integrating climate and disaster response interventions among vulnerable households. First, adaptive social protection refers social protection systems and programmes that aim at promoting resilience of vulnerable households to withstand climate and disaster related shocks. This approach uses social protection systems to reduce climate risks and increase capacity to adapt to climate change. The second approach, shock-responsive social protection which focuses on leveraging social protection systems to prepare for, anticipate, respond, or recover from shocks by channelling disaster risk management activities in an inclusive and efficient manner, reducing the need for a separate/ad-hoc systems.

**Linking anticipatory action to social protection for a more timely and inclusive approach to hazards**

Strategies for the implementation of social protection measures can be a good platform to channel the development of anticipatory action plans.

When a predetermined level of probability for a specific shock is reached, anticipatory actions such as cash transfers or distribution of inputs to support at-risk livelihoods can be embedded in social protection systems through a range of operational considerations related to how, what, when, and where and to whom transfers can be targeted and delivered.[[67]](#footnote-68) Beneficiary information from social protection registries can be leveraged to forecast the impact of shocks to assess who would be hit the hardest and who require support. This would help inform targeting criteria based on the objective of the transfer (i.e., to compensate for lost wages due to unemployment or provide in-kind support to protect livelihoods.)

**Benefits to channel Anticipatory Actions to Social Protection mechanisms**

Social Protection registries information can be leveraged to forecast who would be hit the hardest

Social Protection disbursement systems can be used to (i) ensure the most vulnerable are supported and (ii) to use it in an efficient and effective way

Social Protection offers a key policy platform for the institutionalization of an Anticipatory approach.

Federico Spano, FAO, 2022

Implementing anticipatory actions through social protection delivery systems can be used to ensure the most vulnerable are supported and use resources in an efficient and effective way compared to using parallel mechanisms to deliver support. Indeed, all phases from assessment to management offers operational opportunities and entry point to use existing infrastructures and ensure institutionalization pathways for the anticipatory approach within national support systems.

To redesign the graphic below and add: adapted from" Lindert, K., T. G. Karippacheril, I. Rodriguez Caillava, and K. Nishikawa Chavez. 2020. Sourcebook on the Foundations of Social Protection Delivery Systems. Washington, DC: World Bank.

Timeline

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Anticipatory actions and social protection systems are interconnected.[[68]](#footnote-69) Furthermore, geographical targeting can be applied to identify high-risk locations exposed to hazards. Similarly, design tweaks can be made to modify social protection programmes to account for early payment of transfer benefits and modify the frequency of how often payments are made to minimize the impact of shocks.

Early warning systems can also be used to adopt targeting criteria that are sensitive to climate vulnerability and risks. For example, when social registries are utilized to gather beneficiary information, registries can consider the location of where vulnerable households reside overlayed with remote sensing to pre-identify households at risk of facing livelihood disruptions. These forms of operational considerations require partnerships in place to work together to ensure synergy between government programs and development and humanitarian actors.

**Integrated early action and social protection approaches have the potential to be a game-changer**

On one hand, well designed and ‘risk-informed’ social protection programmes can better take shocks into account and adapt to be ready to deal with them. This may include simple design adjustments to routine functioning (e.g. expanding routine coverage in shock-affected areas, or enhancing resilience-building and climate-mitigation measures), as well as preparations to accommodate expansions of adequacy and coverage in the face of increased demand. Further, well designed social protection systems can, in the appropriate circumstances and with prior planning, make their delivery mechanisms available as a ‘vehicle’ for responses of other actors – including government (e.g. DRM) or international early action and emergency response, provided this doesn't overload them. Strengthening of core social protection systems lies at the heart of this.

On the other, for early action actors and investors, building on existing social protection systems has the potential to provide timelier, more sustainable, and more appropriate assistance than a late humanitarian response – or indeed any humanitarian response at all. Economic analysis looking at the cost effectiveness of social assistance transfers as opposed to the ongoing humanitarian response in protracted crisis, found that billions could be saved by investing in routine social protection, and filling remaining humanitarian gaps using humanitarian systems and funds.

REAP Early Action and the Climate Crisis: could social protection be a game changer?

Given its inherent focus on the most vulnerable, social protection systems can ensure a more inclusive approach to anticipatory action. To pre-select beneficiaries at risk from a predicted hazard, for example, social protection information management systems can incorporate climate risk indicators to inform targeting criteria and include non-routine beneficiaries considered at risk of losing their livelihoods to forecasted hazards.[[69]](#footnote-70)

Governments can uptake national ownership of linking anticipatory action with social protection. Various stakeholders are involved to develop targeting criteria, which can be overlaid with climate vulnerability assessment. Through complementary capacity development of national stakeholders, targeting analysis overlaid with climate vulnerability assessments can be institutionalized by supporting national capacity and ownership to carry out relevant assessments to inform targeting criteria.

Similarly, social protection systems can be equipped with early warning information and triggers to act fast when needed. By exploiting important features of national social protection systems, such as delivery channels, financial service providers, or current partnerships, anticipatory actions can be delivered in a timely manner, without creating parallel support structures.

By assisting disadvantaged populations upon ahead of shocks, households can protect their assets and build their resilience rather than losing them in a crisis. It can also help national governments construct risk-aware social protection systems that can reduce or avert shocks.

|  |
| --- |
| Example practice  While linking social protection to anticipatory action holds potential in several context, it has yet to be applied at scale. An example of a social protection system that is linked to an early warning system that enables anticipatory action is Kenya’s Hunger Safety Net Program (HSNP). HSNP is a government-led social protection scheme aimed at reducing extreme hunger and vulnerability by delivering regular and unconditional cash transfers every two months to food insecure households in northern Kenya. The programme can scale up assistance before a drought turns into a food crisis by automatically triggering additional payments once the Vegetation Condition Index for extreme or severe drought crosses a pre-established threshold. In case of extreme drought, emergency payments can reach up to 75 percent of the population in the north of the country. |

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| **Integrating social protection and early warning for anticipatory action systems**  (To redesign the graphic below and add: adapted from FAO, 2019) |
| Chart, bubble chart  Description automatically generated |

* 1. **Establish Early / Anticipatory Actions mechanisms**

In recent years, humanitarian organisations have demonstrated the value of anticipatory action.[[70]](#footnote-71) [[71]](#footnote-72) The World Bank estimates that upgrading early warning and early action capacity in all developing countries could save some 23,000 lives and avert the destruction of between US$ 300 million and US$2 billion in assets every year[[72]](#footnote-73).

Nowadays, with increasing climate related shocks and other crises, there is an exponential increase of humanitarian needs and limited humanitarian funding. Hence, there is even more the need to act early and try to reduce humanitarian needs even before they materialize[[73]](#footnote-74). Waiting for disasters to strike when science and risk assessments can predict its impacts has become unacceptable. Anticipatory action has been increasingly embedded within humanitarian and disaster risk management systems. Together with WFP, FAO, OCHA and START Network as key partners, anticipatory approaches are now being implemented in more than 60 countries. In 2019, the Risk-informed Early Action Partnership (REAP) was established by 50 countries and organisations with the goal of making 1 billion more people safer from disasters, including by reaching 1 billion people with financing and delivery mechanisms connected to effective early action plans, ensuring they can act ahead of predictable disasters.

Yet scientific and risk assessments’ progress over recent decades means that we can now make increasingly precise predictions about when and where extreme weather events such as hurricanes, drought, floods, and others are likely to occur, and what their likely impacts on people will be to avert and minimize the impacts of hazards. These advances mentioned in the previous chapter around impact-based forecasting together with effective early warning systems, pre-arranged plans and financing make anticipatory action possible.

Anticipatory action is *“a set of actions taken to prevent or mitigate potential disaster impacts before a shock or before acute impacts are felt. The actions are carried out in anticipation of a hazard impact and based on a prediction of how the event will unfold. Anticipatory actions should complement longer-term investment in risk reduction and should aim to strengthen people’s capacity to manage risks*.”[[74]](#footnote-75) Though anticipatory actions come in many forms and sizes, they always come before the shock has impacted people, are highly time-sensitive and connected to forecasts.

Some anticipatory actions can look like the provision of cash, waterproof silos, sanitation and hygiene kits and shelter toolkits to the at-risk population ahead of a flood or cyclone; the provision of resistant crop seeds, animal health support and animal feed ahead of drought; supporting the population with the evacuation of livestock, to save animals which are a key livelihood asset for the most vulnerable in some area, or to strengthen shelters ahead of a cyclone. Whatever the context, all anticipatory actions share the same goal: to save lives and livelihoods, whilst protecting the assets and agency of people at risk.

Based on a collective learning, some of the key elements of effective anticipatory action are:

* **Risk analysis**: identification of hazards and their historical impact in-country crosses with vulnerability mapping allows determining the risks to which a country is exposed and potential impact.
* **Impact-based forecasting and early warning systems**: establishment of multi-hazard EWS and formulation, access and usage of reliable forecasts is essential to act ahead of a shock. Oftentimes, there is a short window of time to respond from the time of receiving the alert to impact of a hazard. Determining the impact of a hazard allows setting triggers that would signal when the pre-determined anticipatory action should start. Effective forecasting is naturally linked to the establishment and well-functioning of early warning systems, able to reach up to the last mile. Therefore, predictive capacities of and coordination with national hydrometeorological institutions are central.
* **Identification of appropriate Anticipatory Action and development of Anticipatory Action Plans**: based on the risk analysis and pre-identified impact of the hazard in target location, it is possible to determine the most appropriate and effective anticipatory actions that would minimise the effects of the hazard and thus save lives and livelihoods. Anticipatory actions vary from distribution of cash or in-kind items, or actions as harvesting matured crops, strengthening shelters, evacuating assets and people before the disaster occurs, all based on pre-agreed triggers and plans.
* **Flexible financing: the** time-window to implement anticipatory action between the alert and the actual occurring of the event is generally small. Therefore, the existence of reliable, and pre-agreed funding mechanisms is critical to be able to implement these actions. To date, examples of financing mechanisms include the IFRC Forecast-based Action by the Disaster Relief Emergency Fund (DREF), the START Ready fund, the Anticipatory Action window of FAO's Special Fund for Emergency and Rehabilitation Activities (SFERA-AA). The UN Central Emergency Response Fund (CERF) has taken on an important role in supporting the set-up and financing of several anticipatory action pilots, led by the Office for the Coordination of Humanitarian Affairs (OCHA) in close collaboration with the broader humanitarian system.
* **Policies, institutional structures, and capacity** for anticipatory action to be sustained and successful, it needs to be anchored in national and local disaster risk management policies strategies and funding, as well as in Social Protection national strategies as a mean to channel the implementation of key and focalized anticipatory actions. Furthermore, it is essential that capacity of government officials as well as all other first responders is strengthened to be able to implement anticipatory actions.
* **Learning, monitoring, and evidence**: strengthening and mainstreaming anticipatory action in disaster risk management systems requires, continuous updating of risk analysis, forecast and reinforcement of EWS; building evidence and learning from experiences to determine what works best, how, and where; and make sturdy connections with social protection national strategies and/or systems to offer an institutionalized and sustainable channel to deliver and implement anticipatory actions.
* **Knowledge sharing** among all actors involved is also critical to concerted action and improvement of anticipatory actions, facilitate such exchange across humanitarian, climate, and development actors, whilst promoting and disseminating evidence and learning across anticipatory action stakeholders, for example through global working groups and Dialogue Platforms on Anticipatory Action. [Anticipation Hub](https://www.anticipation-hub.org/) facilitate such exchange across humanitarian, climate, and development actors, whilst promoting and disseminating evidence and learning across anticipatory action stakeholders, for example through global working groups and Dialogue Platforms on Anticipatory Action.[[75]](#footnote-76)

**Examples of anticipatory action in practice**

[**FAO: Philippines**](https://reliefweb.int/sites/reliefweb.int/files/resources/cb7145en.pdf)

In the Philippines, a country that faces major natural hazards such as typhoons and drought on a regular basis, FAO has been working with the Government and other partners to make anticipatory action a central part of the way the country manages disaster risk – in other words, to institutionalize the practice of acting early ahead of crises. In its 2018–2019 action in Mindanao, FAO supported families caught between escalating local conflict and a looming El Niño induced drought. People received vegetable gardening kits for their backyards and small community-run poultry farms set up close to evacuation centres. Both provided families with nutritious food before they were cut off from their farmland. Those who did still have acess to their rice paddies received drought-resistant rice seeds ahead of the dry spell, so they could plant, after having lost their crops and seeds in two previous droughts. In all, Mindanao farmers received USD 4.4 in benefits and avoided losses for every dollar FAO invested.

[**Ecuador Red Cross**](https://www.anticipation-hub.org/experience/anticipatory-action-in-the-world/ecuador)

On September 21st, 2020, the Ecuadorian Red Cross activated its Early Action Protocol for volcanic ash in response to the significant increase in the level of eruptive activity of the Sangay volcano. A couple of days after this increase the National Society had managed to timely reach 1,000 families in 7 different communities with health and livelihood kits and cash-based interventions. All these actions were implemented in a very challenging environment with the Covid 19 pandemic raging through the country. In 2019 Ecuador Red Cross had their Early Action Protocol (EAP) for volcanic ash approved to be funded by the Forecast based Action by the DREF. This protocol seeks to reduce health impact on vulnerable population and damage of crops and livestock arising from exposure to volcanic ashes. To be ready to implement their early actions in accordance with the seven days lead time, the National Society had pre-positioned shelter materials, health protection kits and awareness raising materials and conducted trainings for their volunteers and staff.

[**Bangladesh Red Crescent**](https://www.anticipation-hub.org/experience/anticipatory-action-in-the-world/bangladesh)

The Early Action Protocol (EAP) for cyclones covering 13 sea-facing coastal districts in Bangladesh was approved to be funded by the Forecast based Action by the DREF in 2018. Then in May 2020, their pre-agreed trigger was met giving them around 30 hours to reach the population and support their evacuation ahead of cyclone Amphan’s impact. The early actions were implemented in 10 districts and the National Society managed to reach 36,000 people with evacuation support, food, water and first aid services in the evacuation centres.  This was a number way above their initial plan to target 20,000 people.

As crises - both natural and human induced - are on the rise, anticipatory action should become the new normal to allow effective reduction of the impact of shocks on vulnerable people. Over the last decade, anticipatory action has been increasingly recognised as a key solution to reduce the impacts of climate change and extreme weather events across humanitarian, development and climate communities and has gained a significant political momentum and commitments from key member states. In fact, many governments have recognised the role of anticipatory action, and for instance the release of the [G7 Famine Prevention and Humanitarian Crisis Compact](https://www.gov.uk/government/publications/g7-foreign-and-development-ministers-meeting-may-2021-communique/g7-famine-prevention-and-humanitarian-crises-compact) on May 5th 2021is an important milestone in scaling up anticipatory action. The G7 Members agree to avert the deterioration of acute hunger worldwide and curb the growth of humanitarian needs and support scaling up anticipatory action as a solution to do so.

Notwithstanding all this progress, anticipatory financing remains only the 3% of overall humanitarian and development funding[[76]](#footnote-77). For anticipatory action to become truly *the* modus operandi to mitigate the impact of crises, it needs more flexible and predictable funding and to be further scaled up to more countries, covering more people and a wider range of hazards. It also needs to improve cross-sectoral and multi-stakeholder collaboration across governmental, humanitarian-development actors and with the scientific community and academia. As the foundations have been set, we need to continue to move forward such discourse from words into action.

* 1. **Forecast based financing (FbF)**

Forecast-based financing (FbF) is a mechanism that enables access to humanitarian funding for ***Early or Anticipatory Action*** based on in-depth forecast information and risk analysis.[[77]](#footnote-78) The goal of FbF is to anticipate disasters, prevent their impact, if possible, and reduce human suffering and losses.

In 2014 the German Federal Foreign Office recognized the increasing need for humanitarian assistance after disasters linked to climate change and decided to launch the Action Plan for Humanitarian Adaptation to Climate Change. Within the framework of this action plan, and under the coordination of the German Red Cross, with partners such as the World Food Program, the Red Cross Red Crescent Climate Centre, the International Federation of Red Cross and Red Crescent Societies, the United Nations Office for the Coordination of Humanitarian Affairs, Welthungerhilfe and research institutes, the innovative methodology Forecast-based Financing (FbF) was jointly developed and tested in several pilot countries. Similarly, is also important to acknowledge some of the other FbF current mechanisms such as SFERA, Start Fund or CERF supporting strategies for Anticipatory Action.

Forecast-based Financing is linked to Early Action Protocols that determine the actions which will be taken when certain triggers are met. In 2018, the International Federation of Red Cross and Red Crescent Societies (IFRC) launched the Forecast-based Action by the Disaster Relief Emergency Fund (DREF) financing mechanism to support the implementation of approved Early Action Protocols.

A key element of FbF is that the allocation of financial resources is agreed in advance, together with the specific forecast threshold that triggers the release of those resources for the implementation of early actions. The roles and responsibilities of everyone involved in implementing these actions are defined in the Early Action Protocol (EAP). This ensures the full commitment of implementation among the involved stakeholders. As mentioned earlier FbF applies well for hazards that can be predicted days in advance.

* 1. **Impact-Based Forecasting (IBF) functions**

Understanding the impacts of a cyclone on critical infrastructures, -roads and public services in a community- in addition to the information regarding the cyclone current intensity and position, will enable authorities and people take appropriate actions to protect their lives and their livelihoods.

In recent years, MHEWS have begun to incorporate the notion of impact-based forecasting aiming to enhance the benefits of early warning efforts linking them with early actions. According the IFRC, impact-based forecasting (IBF) combines a forecast of a weather or climate hazard and an assessment of possible impacts, including when, where and how likely the impacts are[[78]](#footnote-79). This enables organizations and individuals to make critical decisions to ensure that resources and supplies are in place to anticipate and *take action* to mitigate the impacts of hazards responding as soon as it is safe to do so. If at-risk populations, authorities, and public institutions have the appropriate information about possible consequences in specific time and locations is more feasible the implementation of appropriate *early* *actions*.

This important change from the usual way of working with forecasts is producing a ‘paradigm-shift’ from *what the weather will be to what it will do,* enabling people to implement early actions, highlighting what people at-risk need to know to save lives and reduce losses of livelihoods and properties. This shifting of paradigm is offering the ‘capacity to predict the onset of specific meteorological and hydrological hazards and the subsequent impact based on the vulnerability of a society to those hazards, the ability to communicate and inform, and for the society to understand the threats and be able take appropriate mitigating actions.[[79]](#footnote-80)

In this way, Impact based forecasting benefits from the information compiled from risk assessment, specifically on the information on the vulnerability of exposed elements and livelihoods, and their degree of exposure to the hazard, as well as the analysis of the impacts of historical disasters.[[80]](#footnote-81) In summary, impact-based forecasting should be understood as a ‘structured approach for combining hazard, exposure, and vulnerability data to identify potential impacts and support decision-making, with the ultimate objective of encouraging early action that reduces damages and loss of life from natural hazards.’[[81]](#footnote-82)

**The benefits of impact-based forecasting**

* Impact-based forecast and warnings triggers anticipatory actions which saves lives and protects property and livelihoods.
* Impact-based forecasts and warnings communicate information that allows those at risk to make effective decisions to safeguard against the impact of forecast extreme weather or climate event.
* Developing impact-based forecasts and warnings builds strong, collaborative partnerships between national meteorological and hydrological services and sectors operating in disaster risk reduction and management.
* Impact-based forecasting communicates uncertainties. Decision makers can factor the uncertainties into choosing appropriate actions.
* Producers and users of Impact- based forecasting and warnings share data, best practice, and critical information before, during and after weather and climate events to improve the quality of forecast and warning information.

Box xx: The benefits of impact-based forecasting. Source: IFRC & UK Met Office, 2020

However, it should be noted that impact-based forecasting is limited and challenged in the context of very rapid onset hazards, for instance in its capacity to predict, in particular in the case of tsunami with just some minutes from generation to impact compared to days and months in the case of cyclones or droughts, however the global tsunami community are shifting from alert to threat level approaches, thus connecting better to effective decision making.

As IBF works well for certain hazards based on their predictability of occurrence, is important to consider as well as, the level of complexity related to socio-economic and political settings associated with IBF, as in the case of the major defies related to needed socio-economic policies when issuing impact-based forecasting during the Covid 19 pandemic.

While international actors are reinforcing initiatives to strengthen their programs including IBF some other challenges still need to be considered:

* The measurement of the impact (local, regional, national).
* The collection of available data that can be useful to design and impact evaluation.
* The interagency coordination enabling the timely exchange of appropriate data.
* The definition of roles and responsibilities of different agencies proving info about vulnerability and exposure of specific groups.

**Towards Multi-Hazard warning systems incorporating Impact-Based Forecasting (IBF) functions**

Impact-based forecasting is at the heart of people-centered early warning systems, as people will be more proactive when aware of the potential impacts as opposed to just being aware regarding the hazardous event itself[[82]](#footnote-83).

Scaling up the introduction of multi-hazard impact-based forecast and warning services should be viewed as a central part of the effort to modernize EWS. This requires a significant change in EWS’ operations, responsibilities, training, and partnerships with other national and international actors. IBFs require access to a wide range of new data including crowdsourced, behavioral and livelihood information, and the resilience of infrastructure systems and services. Thus, there are many more actors, including communities, which play a role through their response to impact-based forecasts and provide feedback to the forecasters. In effect “last-mile” connectivity between the communities affected and information providers becomes much stronger. Information users drive the requirements for information and therefore receive it in a form they are expecting and understand[[83]](#footnote-84).

**Traditional, technical, and centralized EWS** are the typical system operated by national observatories of hazards such as NMHS and Geological Surveys using sophisticated equipment and robust forecasting capacities. Traditional, technical, and centralized EWS include monitoring, forecasting, and warning phases, but do not include anticipatory response efforts. Monitoring and forecasting activities are carried out by specialized professionals in these scientific / technical agencies, and warnings are issued through mass media such as TV, radio networks and newspapers to inform the population of potentially catastrophic events.

Juan Carlos Villagran et all, 2006

Different available methodologies to scale up to IBF coincide with the general implementation of the following steps:

* An impact-based analysis about the vulnerability of a society/group/community to hazards
* The ability to communicate and inform about the hazard/s and its impacts
* The society to understand the threats and be able take appropriate mitigating actions.

Graphic: Process to implement IBF. Own elaboration based on the report of the Workshop organized by China Meteorological Administration, 2016.

As an increase on intensity and frequency of hydrometeorological hazards is expected due to climate change, the scaling up of forecasts to IBF is a critical shift to foster the implementation of anticipatory actions that can drive the reduction of losses, can promote the reduction of humanitarian funding for emergencies response and finally, strengthen resilience within communities.

A summary of a step-by-step methodology[[84]](#footnote-85), developed by the China Meteorological Administration and the GFDRR is presented in the graphic below as a suggested option to modernize EWS. Likewise, key elements to be considered on a scaling up process to IBF are listed below.

**The impact is Road Closures**

Graphic Overview of IBF. Own elaboration based on the report of the Workshop organized by China Meteorological Administration, 2016.

**Step 1: Develop the Risk Matrix[[85]](#footnote-86)**

The basic tool of an impact-based warning system is the *Risk Matrix*. The matrix relates the expected impact of a hazard to the likelihood of occurrence of the hazard. The likelihood is best determined from a probabilistic forecast using ensemble techniques. The level of the impact is determined from knowledge of vulnerability and exposure. Together, these determine the severity of the warning using a four-color system – green, yellow, orange, red. It is recommended that warnings should only be issued when the impact is expected to be *Medium* or *High*.

**Step 2: Identify Events and Hazards**

The identification of all events impacting the territory of the country, and the primary, secondary and tertiary hazards is required [cascading effect]. The primary hazards are caused directly by the event and cannot be mitigated to any significant extent (e.g., rainfall). The secondary hazards are related to the primary hazard and can often be partially mitigated (e.g., structural works can reduce the possibility of a sur-face flood in an urban area). The tertiary hazards, which are generally non-meteorological or hydrological, are caused by the primary and secondary phenomena or may be a consequence of human failure. The latter have the greatest scope for mitigation by either structural measures to reduce vulnerability or exposure or both.

**Step 3: Assess Vulnerabilities Related to the Identified Hazards**

Various tools exist to carry out vulnerability assessments. They should be infrastructure system and service specific. For example, the vulnerability of bridges and roads to inundation or destruction due to flooding should be estimated. Understanding the interdependencies of the infrastructure systems and services is essential – for instance, the vulnerability of transportation networks to flooding and to the destruction of bridges, roads, rail should be assessed. Food chain distribution blockages, educational services interrupted, etc.

**Step 4: Develop Impact Tables**

An impact table needs to be developed for each hazard and for each sector. It requires knowledge of the hazard and expert knowledge of the likely impact on a specific sector. This may or may not be informed by a formal vulnerability assessment. At its most basic it would rely on expert knowledge rather than quantitative data. In the case of flood risk, this may involve water resource managers, irrigation experts, dam operators as well as disaster managers.

**Step 5: Implement Advisory Tables**

A final component of the warning system is to provide advice on what actions to take. These messages will be tailored to specific needs of each key stakeholder. Typically, this will involve disaster management and other key stakeholders.

**Key elements of an Impact-based Forecast and warning Service**

The timely and appropriate consideration to the following elements should be taken into account for an effective transition to IBF.

1. **Partnerships**

A successful impact-based forecasting service will require close operational cooperation with the agencies responsible for meteorology, climatology, hydrology, disaster management, and first responders as well as other sectors with access to, and ownership of, data on infrastructure systems and services (e.g., energy, transportation, health, water resources). This would require a high-level agreement that describes the commitment of the agencies to work closely together to share data, information, expertise, and responsibility. The sectors with information on their own vulnerability will also be the ones that would benefit the most from impact-based forecast and warning services.

1. **Joint Development of Information and Services**

The partnership is a perquisite for the joint development of services. This would include using 24/7 operational forecasting capabilities of the NMHS, joint development of flood forecasting, and joint operations combining the expertise of meteorologists, hydrologists, disaster managers.

1. **Developing capacity of NMHSs’ and disaster management staff, partners, and users**

Frequent training is essential to increase and maintain the skills of different agencies working in EWS implementation. Such training should be viewed as a continuous process, in which all staff members are involved in a long-term program to improve their skills. As part of the twinning arrangements, study tours and familiarization visits should be organized to expose senior management and forecasters to specific advanced technologies that could be implemented to improve forecast production and delivery.

1. **Validation**

Validation and verification are important components of any forecasting system. However, impact-based forecasting and warning systems need different methods to those applied to objective forecasts. Here the emphasis is on the *utility* of the forecast, not just the *accuracy* of the underlying meteorological or hydrological prediction. This requires agreement among stakeholders and partners on what constitutes utility and cooperation to analyze and evaluate events to improve the warning system.

**Chapter 4**

**Monitoring access and measuring effectiveness of Early Warning and Anticipatory Action**

Monitoring the availability and access to multi-hazard early warning systems offer information on where and who is needing EWS coverage. This information, in addition to assessments of areas of greatest exposure to disaster risk, is critical for the design, implementation and reinforcement of EWS.

The UNDRR, through the monitoring of the Global Target G of the Sendai Framework, is working to have this information available for everyone. This information can help governments to reinforce their initiatives to reduce risks though the implementation of EWS.

As is no possible to envision an effective EWS without the implementation of *Early / Anticipatory Actions* this chapter will also offer some preliminary guidelines to evaluate the outcomes of AA and to assess the socio – economic benefits of EWS.

**4.1. Reporting on the Global Sendai Target G**

The Sendai Framework for DRR, 2015-2023, aims to “Substantially increase the availability of and access to multi-hazard early warning systems and disaster risk information and assessments to people by 2030” as one of its seven targets. It is supported by 38 indicators to track progress in implementing the seven targets of the Sendai Framework, as well as related dimensions in SDGs 1, 11 and 13. The Open-ended Intergovernmental Expert Working Group recommended the indicators, and the United Nations General Assembly endorsed them. The Sendai Framework Monitor (SFM) is the online reporting tool where countries enter, track, and submit official data under a reporting framework. Since its launch in 2018, more than 150 countries have reported on at least one of seven Sendai Framework targets. The aim of the SFM extends beyond compliance in reporting and assessing progress. It is also a means to provide an analytical and evidence base for risk-informed planning through garnering statistically rigorous and government-owned data. It also demonstrates applications in development and humanitarian spheres. It supports countries to develop DRR strategies, make risk-informed policy decisions and allocate resources to prevent new disaster risk.

Text, application

Description automatically generatedThe effectiveness of MHEWS is self-assessed by reporting countries by using metrics such as level of application of disaster risk knowledge (G-5), detection, monitoring, analysis and forecasting of hazards and possible consequences (G-2), dissemination and communication of warnings and associated information on likelihood and impact (G-3), and preparedness at all levels to respond to the warnings received (G-4).

[Sendai Framework Indicators (preventionweb.net)](https://www.preventionweb.net/sendai-framework/sendai-framework-indicators)

Supplementing the Target G global indicators, a set of optional MHEWS custom indicators have been developed that will allow key elements of MHEWS to be monitored and can be used to identify aspects of MHEWS which may require targeted support.

In addition to supporting Target G, the indicators can also be used as a stand-alone set of indicators for monitoring and evaluating the effectiveness of MHEWS in-country by any member state.

The [proposed custom indicators](https://ane4bf-datap1.s3-eu-west-1.amazonaws.com/wmocrews/s3fs-public/ckeditor/files/workdoc5_11th_Steering_Committee_CREWS_Effective_EWS_Project_1.pdf?uZFYqQsJ3IF_Pmy4Uz5LaY2h_eyoblEn), reflecting the four components of an EWS will not only facilitate the measurement of the effectiveness of hydrometeorological EWS, it is also applicable for those related to geo-hazards and biological hazards, among others; therefore, securing coherence and a holistic reporting to SFM. A learning package was developed which will facilitate reporting.

**4.2. Evaluating efficacy and effectiveness / measuring the outcomes**

Confidence in early warning systems is a determining factor for the implementation of Early / Anticipatory Actions which reduce the impact of disasters. Demonstrating the effectiveness of (MH)EWS could be an important factor in increasing confidence and ultimately implementation of early actions. Knowing about the effectiveness of such systems increase the understanding of the capabilities of EWS, allow to make informed decisions to protect life and livelihoods, and promote the development of resilience of groups at risk.

Moreover, knowing the socio-economic value/benefit of the (MH)EWS allow authorities and decision-makers, among other possibilities, define, and negotiate the budget allocation associated with the implementation, maintenance or updating EWS. To support decision maker’s management, this section presents guidelines for the implementation of a methodology, based on the Information Value Chain framework,aiming to evaluate/asses the socio-economic benefits of the EWS and evaluate the results of the implementation of Anticipatory Actions.

**4.2.1. Evaluating socio economic benefits of EWS**

Studies confirming that the benefits are greater than the costs when we measure the effectiveness of EWS implementation are becoming more and more frequent. In 2015, a study commissioned by the WMO indicated that the cost-benefit ratios were greater than one, specifically mentioning the case of improvements in the national meteorology and hydrology systems, generating a range of ratios from 4 to 1 to 36 to 1[[86]](#footnote-87).

To offer alternatives for carrying out contextualized measurements, this section presents a basic sequence of 3 steps to carry out an analysis of the benefits associated with the implementation of EWS. If a full benefit-cost analysis is conducted, is strongly encouraged to review the Lazo & Mills (2021:12) excerpt at the end the this section and consult the guidance and detailed steps provided in the WMO 1153 guide[[87]](#footnote-88).

Applying the concept of the knowledge or *Information Value Chain* (IVC) is a useful tool to guide assessments of the socioeconomic value of warning systems. The IVC framework can support the understanding, discussion, and analysis the socio-economic value of the entire process of information, creation, communication, and use of early warning services.

Such an evaluation involves a series of steps each requiring some degree of reflection, data collection, analysis, and interpretation. These have been grossly synthesized into the three general tasks below.

1. **Clearly define the purpose(s) of the evaluation of socio-economic benefits**

* Articulating the ‘why’ and ‘for whom’ are the benefits of the EWS sets the broad scope of the investigation.
* For example, it may be to develop evidence for a specific agency, enterprise or organization that may be used to evaluate and justify past and current program investments or changes (e.g., integration of multiple warning systems); assess and compare potential future investments or changes; or to prioritize or reallocate limited resources.
* The program, investment or change and its rollout (i.e., timeline, milestones, sequence, etc.) should be described as granularly and thoroughly as possible.
* Often the largest reward is increased awareness and understanding of the various actors, complex linkages, constraints, opportunities, and assumptions involved in the process of realizing value.

1. **Construct and populate a working MHEWS Information Value Chain (IVC) that captures the main features of the warning cycle to be evaluated**[[88]](#footnote-89)

* Start simple and add complexity as needed, e.g.

Diagram

Description automatically generated

Source: Modified from WMO (2015:xvi)

* Basic IVC framework consists of nodes, flows and actors[[89]](#footnote-90) describing the components of the above graphic.
* Building from purpose/scope of evaluation, specify types of hazards (geo-hazards, hydro-met or biological), important risk outcomes to value could include: health/safety, population dislocation, critical infrastructure damage/disruption), impacts on food chain, and details regarding the specific information (MHEWS attributes) relative to what was already in place, the latter in order to draft a baseline.
* Add nodes where information/knowledge is produced, translated, transformed, disseminated and/or used in decision-making (nodal functions).
* Specify actors (e.g., individuals, enterprises, organizations, agencies, communities…) that operate/perform the node functions and attendant dynamic qualities/characteristics
* Identify and label flows depicting communication and movement of knowledge, resources and relations among actors and nodes.
* Prescribed set of methods to develop and populate the framework. Options could include one or more of: workshops, focus groups, interviews, and surveys of experts or subsets of actor population; content analysis of reports, web sites, planning documents, traditional media, electronic communications (e.g., social media), published literature; formal analysis of secondary data (e.g., risk analysis), scenario-based, simulation, or quasi-experimental approaches.
* Best if it’s iterative in nature, building out or ‘snowballing’ from those internal to the agency leading the warning program/service to further out in the chain.

1. **Develop and conduct an economic valuation**

* The aim is to obtain snapshot impression of the value chain at a minimum of two points (i.e., before and after implementation of the new or improved service/information/system) to facilitate comparison and attribution of changes in outcomes and benefits. If the evaluation is for possible or planned changes, then ‘expected’ values would be sought (as opposed to recalled information, data). Depending on the overall purpose, as explained previously, it may be sufficient for the lead agency to report only on important risk outcomes (e.g., one expects XX lives to be saved, XX injuries or damage avoided, etc.) and rely on those making investment decisions to infer or judge implied relevance and value[[90]](#footnote-91).

The idea that should be present during the whole evaluation process is that the benefits of EWS services result from groups at risk taking decisions or implementing early actions, at least in part based on the information provided by the EWS.

*Economic values are the result of the complex process of information creation, communication, interpretation, use, and decision-making. Ultimately VOI [value of information] is a function of the ability of decision-makers to receive, understand, and act on information on uncertain future events. To derive valid benefit estimates, the research must be able to tell the story of the [MHEWS] information chain end to end or explain explicitly how the information relates to decisions, outcomes, and values. The value is measured as a difference between two states of the world—with the impact or information compared to some “baseline” or “counterfactual.” Thus, the researcher needs to be able to characterize both states of the world to measure the impact of [the hazard(s)] (usually done implicitly by assuming “normal” [conditions] as the nonimpact state) or the value of the [hazard state] information (often done assuming continuing of the current information regime compared to an improved or different information context).*

* + 1. **Assessing the outcomes of Anticipatory Action**

International organizations are using a range of methods to assess the outcomes of Anticipatory Action (AA). Most AA analyses focus either on system level analysis estimating how EWEA/AA can reduce response costs, time, or humanitarian needs; or empirical studies directed toward individuals or households, estimating what impact EWEA/AA approaches have on protecting lives and livelihoods and strengthening resilience. While there are a growing number of analytical methods estimating the benefits of AA, there is still a significant gap in analytical standards, methods, and uniformity across agencies.

Analytical approaches can be divided into two categories: modelled outcomes based on theories of change or constructed scenarios, or empirical studies that provide evidence on the outcomes of AA impacts. A recent report by WFP that assessed 25 AA studies conducted in 16 countries, noted that cost-benefit analysis (CBA) was the main analytical method used to measure AA project benefits[[91]](#footnote-92). Other analytical methods used comprised comparing beneficiary groups to control groups, including quasi-experimental approaches, while traditional evaluation methodologies assessing food security or resilience scores, as well as gathering qualitative information via key informant interviews (KII) and field group discussions (FGD) were also used in several studies. Because each method has its limitations (data, capacity, time, counterfactuals, etc.), a mixed method approach is essential to deliver a comprehensive picture of the outcomes of AA programs.

FAO has greatly used CBA approaches within its mixed methods evaluations. CBA results show a significant return on investment (ROI) in most cases. According to seven studies published by FAO, all but one project delivered a ROI above 1, with the 2017-18 Mongolia project reaching as high as 7.1[[92]](#footnote-93). Further, traditional evaluation techniques, including index scoring for resilience and food security, as well as KIIs and FGDs, are also extremely useful in bringing detailed qualitative evidence to support technical quantitative approaches. FAO’s evaluation in Madagascar found that only 16 percent of AA beneficiary households were classed as having a poor diet, as opposed to 40 percent for households who did not benefit from AA programming[[93]](#footnote-94). In Colombia, 97 percent of families who participated in AA interventions had an acceptable food consumption score and children under the age of five within participant households drank 0.5 liters more milk per day[[94]](#footnote-95) than those in non-participant households[[95]](#footnote-96). Further, the use of KIIs brought significant understanding on the behavioral changes AA outcomes may have on a household. This includes how individuals have changed consumption patterns to improve the economic wellbeing of the household, or purchased assets to increase the household’s economic output or improve efficiency in their daily routines[[96]](#footnote-97).

Recently, studies have used more sophisticated techniques including quasi-experimental techniques such as controls, matching techniques, propensity score matching, and other forms of statistical modelling based on outcomes between control and beneficiary populations. Quasi-experimental techniques are more robust in establishing the statistical differences between groups (control and treatment) and linking impacts to the program intervention.

Nevertheless, agencies face significant limitations when implementing evaluation methods in AA. Estimated outcomes are usually measured at one point in time. Consequently, cost-benefit approaches likely yield conservative outcomes as they do not fully consider the long-term benefits of protecting livelihoods ahead of shocks. Time constraints also significantly limit the ability to develop data collection methods for quasi-experimental techniques. This is especially the case for collecting baseline data, which can greatly influence possible evaluation approaches. Establishing counterfactuals is also a challenge, making it difficult to assess what the AA approaches should be compared to. Further, funding and internal capacity also limit agencies’ ability to develop and refine their measurements, as more advanced techniques require more investment in human capital, analytical design and data gathering. The lack of data collected to assess outcomes may also be due to the current small scale of AA initiatives. This may be alleviated in the future, as AA approaches expand and sharing of data and models between agencies increase, enabling a common framework for comparisons.

Overall, there is more and more solid evidence that acting early prevents suffering, is cost effective, and more dignified. Some findings from recent AA interventions are encouraging: a study published by the Centre for Disaster Protection on anticipatory cash transfers implemented by WFP ahead of floods in Bangladesh found that, for those who received cash earlier than others, marginal yet significant increased levels of welfare were observed[[97]](#footnote-98). There is also significant qualitative evidence, as during interviews beneficiaries often highlight the importance of having received assistance before rather than after the shock[[98]](#footnote-99). With a growing evidence base, the case for AA interventions is more solid, and this is resulting into increased commitments by governments and donors towards a system wide shift from reactive to anticipatory approaches to shocks.

As new approaches to AA evaluation are incorporated into program design and evaluation, it is important that agencies implementing AA programs try as much as possible to unify evaluation techniques and agree to minimum standards that can be operationalized across the sector to ensure outcomes of AA/EWEA programmes are being correctly measured. There is still a need to further expand knowledge and incorporate new methods into analytical frameworks, conduct joint studies and engage with local communities to better understand and measure AA outcomes. It would be also valuable that programs routinely integrate a component dedicated to evaluating the program itself and collect lessons learnt, with specific funding and capacity.

**Appendix A**

**Supportive platforms for early warning systems**

Supportive platforms for early warning systems include several aspects. Supportive action on early warning system to increase the quality the forecasting, increase the reach out of the alerting information to last one mile, and to ameliorate the preparedness of stakeholders on the existing early warning system. These include scientific research on the phenomenon and algorithms of the forecasting, learning from other practices through sharing data and experience, support on technical and policy development, and advocacy. The modality of the supportive actions would be implemented by from single institution itself to network or platform of the institutions, countries, and regional bodies. In this section we focus on Information and knowledge sharing platform and networks for multi hazards and single hazard early warning system.

**Information, Knowledge Sharing Platforms and Networks**

Following are the examples of network to share information and knowledge including advocacy on early warning systems. There are global to local initiatives including multi-hazards to single hazards.

1. **Global level**

One important and notable supportive global level Platform for MHEWS is the creation of the *International Network for Multi-Hazard Early Warning Systems* (IN-MHEWS). The network was announced at the Third United Nations (UN) World Conference for Disaster Risk Reduction (WCDRR) in Sendai, Japan, in March 2015 to facilitate the sharing of expertise and good practices for MHEWS as a national strategy for DRR, climate change adaptation, and building resilience. The platform is co-chaired by WMO, UNOOSA and UN-SPIDER and include major actors, namely FAO, IAEA, IOC-UNESCO, ITU, UNDP, UNESCAP, UNESCO, UNISDR, UNITAR/UNOSAT, WFP, WHO, CREWS, World Bank/GFDRR, EU (EC/JRC), IFRC/Red Cross Red Crescent Climate Centre, ISC/IRDRБ.

The IN-MHEWS partners work together to promote a holistic and integrated approach to early warning, building on their respective programmes, activities, and institutional mechanisms for cooperation in EWS. The network supports the strengthening of user-interface platforms as a contribution to the DRR Priority of the Global Framework for Climate Services (GFCS).

At the Second Multi-Hazard Early Warning Conference (MHEWC-II) in Geneva, 2019, the [International Network of Multi-Hazard Early Warning System (IN-MHEWS)](https://riskfinder.climatecentral.org/caribbean) demonstrated its value by committing to continue advocating for the implementation and strengthening of MHEWS and developing actions to support countries in building their national systems and to contribute to achieving [Target G](https://riskfinder.climatecentral.org/caribbean) of the Sendai Framework. There are several global MHEWS knowledge platforms, some of them will be listed below.

* The Global Disaster Alert and Coordination System (GDACS) is a cooperation framework between the United Nations, the European Commission and disaster managers worldwide to improve alerts, information exchange and coordination in the early phase following major sudden-onset disasters. Over the past decade, GDACS has drawn on the collective capacity of disaster managers and information systems worldwide to facilitate information sharing and decision-making.
* The Global Earth Observation System of Systems (GEOSS) and its GEO-Portal is an online map-based user interface which allows users to discover and access Earth observation data and resources from different providers from all over the world. The portal is implemented and operated by the European Space Agency and provides a single point of internet discovery and access to the growing quantities of heterogeneous collections of Earth observations from satellites, airplanes, drones and in-situ sensors at global, regional and local scales through the GEOSS.
* The Global Sea Level Observing System (GLOSS) is a global endeavor requiring coordinated participation of an international group of agencies. GLOSS sea level data centers provide complimentary data streams while helping to shape the future of the global in situ sea level observing network, which is essential for flooding warning and tsunami monitoring.
* The International Platform on Earthquake Early Warning Systems (IP-EEWS) is a new initiative launched by UNESCO to create a space for enhanced collaboration and knowledge sharing within the scientific community and among scientists, decision- and policymakers to promote the development of EWS in earthquake-prone regions and countries.
* The Global Flood Awareness System (GLOFAS) is an early warning service provided by the Copernicus programme of the EU and provides forecasts of the levels of floods in various segments of channels of rivers classified into four categories according to the level of the potential flood[[99]](#footnote-100).
* The Global Drought Observatory, also under the umbrella of the Copernicus programme of the EU, provides information on the status of droughts worldwide. The use of the same algorithms worldwide allows this service to homogenize the information on the status of droughts worldwide[[100]](#footnote-101).
* The *Global Wildlfire Information System (GWIS)* launched by the Copernicus programme, NASA and GEO, provides information on the status of wildfires worldwide, and includes a database of historic forest fires that can be consulted for analysis of historical trends at the country and lower levels[[101]](#footnote-102).

Similarly, other alliances and partnerships are working together strengthening efforts to increase the efficacy and the implementation of EWS worldwide, among them:

* [CREWS](https://www.crews-initiative.org/en): Climate Risk and Early Warning Systems was established as a mechanism that funds Least Developed Countries (LDC) and Small Island Developing States (SIDS) for risk informed early warning services, implemented by the World Bank/GFDRR, the WMO and UNDRR, based on clear operational procedures.
* [SOFF](https://library.wmo.int/index.php?lvl=notice_display&id=21769#.Ynoh2y8RoSJ) as a new way of financing surface-based observations. The Systematic Observations Financing Facility (SOFF) will support countries to generate and exchange basic surface-based observational data critical for improved weather forecasts and climate services. SOFF has three novel design features to provide long-term financing and technical assistance in an effective way. It has a unique focus and complements and supports existing funding mechanisms
* [The Risk Informed Early Action Partnership – REAP](https://www.early-action-reap.org/), creates a space in which partners and aligned organizations use their targets to drive a systemic shift towards acting earlier to reduce the impacts of disasters, mobilize commitments and inspire action. Based on advocacy mechanisms, REAP seeks to enable coherence, alignment, and complementarity of existing initiatives, while learning together what new initiatives are needed to make 1 billion people safer.
* [The Anticipation Hub](https://www.anticipation-hub.org/) is a platform to facilitate knowledge exchange, learning, guidance, and advocacy around anticipatory action both virtually and in-person. The Anticipation Hub brings together partners across the Red Cross Red Crescent Movement, universities, research institutes, (i)NGOs, UN agencies, governments, donors, and network initiatives.

1. **Regional level**

At the regional level, for instance in Europe, there is considerable experience with EWS, especially for flood and flash-flood risk, storms, forest fires, heatwaves, and droughts. EWS are directly relevant for various sectors that are primarily affected by climate-related risks, including public health, disaster risk reduction, agriculture, forestry, transport, and energy. As part of its European Scientific Partnerships initiative, the European Commission has established the European Natural Hazard Scientific Partnership (ENHSP), which is led by the Italian National Institute of Geophysics and Volcanology (INGV) and the German Central Institution for Meteorology and Geodynamics (ZAMG) and currently involves sixteen partners across Europe, bringing together scientific and operational experts on natural hazards. The partnership covers earthquakes, tsunamis, severe weather, floods, volcanoes, and forest fires both at European and global levels. In the future it will be extended to cover man-made hazards.

The [Copernicus Emergency Management Service (CEMS)](http://www.rimes.int/), managed by the Joint Research Centre of the European Commission, provides access (among others) to major European EWS, in particular the [European Flood Awareness System (EFAS)](https://en.unesco.org/disaster-risk-reduction/science-technology-resillience/REL), the [European Forest Fire Information System (EFFIS)](https://en.unesco.org/disaster-risk-reduction/science-technology-resillience/REL), and the [European Drought Observatory (EDO)](https://en.unesco.org/disaster-risk-reduction/science-technology-resillience/REL). In addition, the Copernicus programme offers access free-of-charge to satellite imagery collected by the fleet of European Sentinel satellites. The higher resolution and visit frequency allow applications in specific types of EWS. Additional satellite image repositories can be found on the data sources page of the UN-SPIDER Knowledge Portal.

European and Global Forest Fire Information Systems forecasts dangerous weather conditions up to 10 days ahead and provide near-real-time information on active fires and burnt areas. The systems analyze the severity and risk posed by each forest fire to the local population and the environment. This allows informed decisions on the deployment of EU firefighting capacity. The European and Global Drought Observatories provide information on droughts risks in Europe and worldwide, including meteorological indicators, soil moisture anomalies, vegetation stress and low river flows.

[EUMETNET](https://www.eumetnet.eu/) is a grouping of 31 European National Meteorological Services that provides a framework to organize co-operative programmes among its members in the various fields of basic meteorological activities. These activities include observing systems, data processing, basic forecasting products, research and development and training.

[The European Centre for Medium-Range Weather Forecasts (ECMWF)](https://www.ecmwf.int/) is a research institute and a 24/7 operational service, producing global numerical weather predictions and other data for Member and Co-operating States and the broader community. The Centre has one of the largest supercomputer facilities and meteorological data archives in the world.

[Meteoalarm](https://meteoalarm.org/en/page/about?z=3&lon=4.3499850533743825&lat=50.84498694827824) provides the most relevant information to prepare for extreme weather, expected to occur somewhere over Europe. The website integrates all important severe weather information originating from the official National Public Weather Services across a large number of European countries.

**In Latin America and the Caribbean (LAC),** there are number of platforms available for citizens, scientists, and authorities to understand local and regional vulnerabilities, both historically and in real time. These platforms and the information they provide serve to enable local and national governments to collect geological and hydrometeorological data and disaster information to enhance national EWS and better prepare citizens for disaster events.

In relation to earthquakes and volcano eruptions the CERESIS: [Regional Seismology Center for South America (CERESIS).](http://www.ceresis.org/) is an international organization, created in 1966 through a bilateral agreement between UNESCO and the Government of Peru. The main objective of the organization is to promote all kinds of seismological studies and activities in the South American region and to assist in their realization, as well as to liaise between regional seismological stations and institutions and with international seismological centers.

Concerning hydro-meteorological hazards, the [Risk finder for rising Caribbean Sea levels](https://riskfinder.org/caribbean) portal was developed for the Caribbean islands by Climate Central and the IDB. The portal includes maps, projections of sea levels and flooding, population, connectivity, and other variables such as Coastal DEM elevation data generated by Climate Central. Hydrometeorological information can be also obtained for LAC through other international platforms, such as the portals of the National Oceanic and Atmospheric Administration (NOAA), and El Niño Southern Oscillation and Global Sea Level Trends.

Relatedly, the [Index of Governance and Public Policy in Disaster Risk Management (iGOPP)](https://riskmonitor.iadb.org/en) has been developed by the Inter-American Development Bank to evaluate the existence of legal, institutional, and budgetary conditions that are considered essential for the implementation of disaster risk management (DRM) processes in each country. The iGOPP is made up of six subindexes pertaining to each DRM component: General Framework of Governance for DRM (GF), Risk Identification and Knowledge (RI), Risk Reduction (RR), Disaster Preparedness (DP), Post-Disaster Recovery Planning (RC), and Financial Protection (FP). Within the Disaster Preparedness indicator (DP-1B-2), the iGOPP collects information regarding the existence of norms and regulations for disaster preparedness which foresee the development and implementation of early warning systems[[102]](#footnote-103).

|  |  |
| --- | --- |
| |  | | --- | | [The Coordination Center for Natural Disaster Prevention in Central America](https://www.sica.int/consulta/entidad.aspx?IdEnt=802&Idm=2&IdmStyle=2) (CEPREDENAC), promotes and coordinates the international cooperation concerning emergencies: -Facilitate the sharing of experiences between the institutions and the countries of the region; -Provide technical and technological assistance in order to reduce the socio-natural disasters in the region. | |

[The Caribbean Disaster Emergency Management Agency (CDEMA)](https://www.cdema.org/) is a regional inter-governmental agency for disaster management in the Caribbean Community (CARICOM). The Agency embrace the principles and practice of Comprehensive Disaster Management (CDM) seeking to reduce the risk and loss associated with natural and technological hazards and the effects of climate change to enhance regional sustainable development.

**In Africa and Asia**, the [Regional Integrated Multi-Hazard Early Warning System (RIMES)](https://dipecholac.net/sites/caribe/contenido/30-caribe.html) provides regional early warning services and builds the capacity of its Member States in the end-to-end early warning of tsunami and hydro-meteorological hazards.

[ASEAN Disaster Monitoring and Response System (DMRS)](https://www.unisdr.org/we/coordinate/sendai-framework) integrates data and information from numerous sources, including national and international hazard monitoring and disaster warning agencies, into a single platform. The DMRS can issue alerts of potential disaster and significant impacts from multiple hazards in the region. It reports imminent hazards, incidents of disaster occurrence and updates on disaster parameters. AHA Centre Flash Alerts are generated from the DMRS. All ASEAN Member States’ NDMOs have access to monitor and contribute to the DMRS.

[DisasterAWARE](https://www.eumetnet.eu/about-us/) provides multi-hazard monitoring, warning, decision support and risk intelligence tools for disaster management agencies and I/NGOs around the globe. DisasterAWARE is fully customizable and feeds the regional and national warning systems of ASEAN's AHA Centre in Indonesia.

[The Climate Prediction and Applications Centre (ICPAC)](https://www.icpac.net/about-us/) is a Climate Center accredited by the World Meteorological Organization that provides Climate Services to 11 East African Countries. Our services aim at creating resilience in a region deeply affected by climate change and extreme weather

The [African Center of Meteorological applications for Development (ACMAD)](http://acmad.org/index.php/mandates/) aims is to improve understanding of atmospheric and climatic processes over Africa, collect, analyze and disseminate meteorological and hydrological information, provide a meteorological watch and early warning system over Africa and promote the training of African scientists and technicians in the application of meteorology for development.

The [African Risk Capacity (ARC) Group](https://www.arc.int/) is a specialized agency to support African governments improve their capacities to better plan, prepare, and respond to extreme weather events and natural disasters. Through collaboration and innovative financing, the ARC Group enables countries to strengthen their disaster risk management systems and access rapid and predictable financing when disaster strikes to protect the food security and livelihoods of their vulnerable populations.

**Appendix B**

**Table X: Uses of space-based technologies in tsunami early warning systems** **(Source:  UN-SPIDER)**

|  |  |  |
| --- | --- | --- |
| **Type of space technology** | **Sub-type of space technology** | **Applications / comments** |
| Earth observation from satellites | Moderate resolution optical satellite imagery (pixel size up to 10 meters resolution) | Location of urban and rural areas exposed to tsunamis |
| High resolution optical satellite imagery (down to 1-meter resolution or less) | Location of critical infrastructure, road network on coastal areas, other types of infrastructure exposed to tsunamis, as well as industrial, commercial, touristic, educational, health, housing, financial, religious, and cultural facilities in areas exposed to tsunamis |
| Identification of potential evacuation routes and safe areas |
| Moderate resolution digital elevation models | Used in combination with tsunami modelling to model tsunami propagation inland for national-level purposes and rural areas |
| High resolution digital elevation models | Used in combination with tsunami modelling to improve models of tsunami propagation inland for local- or urban-level purposes like ports and coastal cities |
| Satellite telecommunications | Data transmission | Used for the transmission of data from sensors deployed in remote areas and from buoys at sea to Regional Tsunami Watch Centres. |
| Transmission of texts | The World Meteorological Organization has allowed for the use of meteorological satellites to transmit information about tsunamis within continents and from one continent to another one. |
| Global Navigation Satellite Systems | Global Positioning System (GPS, United States), GLObal NAvigation Satellite System (GLONASS, Russian Federation) | Geographic location of critical infrastructure, road infrastructure (bridges), buildings, industrial facilities.  Assessment of the magnitude of strong earthquakes. |

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22. # For further reference see Inclusive and accessible multi-hazard early-warning systems: learning from women-led early-warning systems in the Pacific https://www.undrr.org/publication/inclusive-and-accessible-multi-hazard-early-warning-systems-learning-women-led-early

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23. Concrete recommendations will be included here [↑](#footnote-ref-24)
24. Multi-Hazard Early Warning Systems: A Checklist. World Meteorological Organization, Geneva, 2018. [↑](#footnote-ref-25)
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26. Section developed by Olaf Neussner, 2022 [↑](#footnote-ref-27)
27. Juan Carlos Villagrán De León, 2022. Head UN-SPIDER, Bonn Office [↑](#footnote-ref-28)
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29. Disaster Risk Preparedness: The Role of Risk Governance, Multi-institutional Arrangements and Polycentric Frameworks for a Resilient Tsunami Early Warning System in Indonesia. Ph.D. Thesis, Denis Chang Seng, UNU-EH, 2012. [↑](#footnote-ref-30)
30. Early Warning Principles and Systems, J. C. Villagran de Leon; in the Routledge Handbook of Hazards and Disaster Risk Reduction, ed. B. Wisner, J.C. Gaillard, and I. Kelman, Routledge, 2011. Pp 481 - 491 [↑](#footnote-ref-31)
31. (PA, 2020) [↑](#footnote-ref-32)
32. IFRC, 2012 [↑](#footnote-ref-33)
33. Sustainable Development Goals. https://sdgs.un.org/goals/goal3 [↑](#footnote-ref-34)
34. Paris Agreement, United Nations, Paris, December 2015 [↑](#footnote-ref-35)
35. The Routledge Handbook of Hazards and Disaster Risk Reduction. Edited by B. Wisner, J. C. Gaillard and I. Kelman. Routledge, 2012 [↑](#footnote-ref-36)
36. Sustainability of early warning systems. J. Twigg, 2021 [↑](#footnote-ref-37)
37. 36 As stated by the UNDDR there are the four key and interrelated components in an effective EWS

    1. Disaster risk knowledge based on the systematic collection of data and disaster risk assessments.
    2. Detection, monitoring, analysis and forecasting of the hazards and possible consequences
    3. Dissemination and communication, by an official source, of authoritative, timely, accurate and actionable warnings and associated information on likelihood and impact; and
    4. Preparedness at all levels to respond to the warnings received.

    [↑](#footnote-ref-38)
38. Based on inputs from Jeanique Serradinho (IFRC), 2022. [↑](#footnote-ref-39)
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40. Based on IFRC, Geneva, 2019. The Checklist on Law and Disaster Preparedness and Response [↑](#footnote-ref-41)
41. Adapted from UNDP, 2018. Five approaches to build functional Early Warning Systems [↑](#footnote-ref-42)
42. Adapted from UNDP, 2018. Section 2.1.1 [↑](#footnote-ref-43)
43. UNESCO/IOC, 2015 [↑](#footnote-ref-44)
44. Adapted from UNDP, 2018. Five approaches to build functional Early Warning Systems. [↑](#footnote-ref-45)
45. Elizabeth Riley, E., Cooke, A., Collymore, J. (2020) Model National Multi-Hazard Early Warning Systems (MHEWS) Policy, Caribbean Disaster Emergency Management Agency [↑](#footnote-ref-46)
46. [↑](#footnote-ref-47)
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51. ITU Facts and Figure 2021  [↑](#footnote-ref-52)
52. Copernicus programme Open Access Hub (https://scihub.copernicus.eu/)  [↑](#footnote-ref-53)
53. USGS Global Visualization Viewer (GloVis, https://glovis.usgs.gov/)  [↑](#footnote-ref-54)
54. See for example: Copernicus/JRC: Global Flood Awareness System (GLOFAS, https://www.globalfloods.eu/) - Copernicus/JRC: Global Drought Observatory (GDO, https://edo.jrc.ec.europa.eu/gdo/php/index.php?id=2001) - Copernicus/NASA/GEO: Global Wildland Information System (GWIS, https://gwis.jrc.ec.europa.eu/)  - ECMWF/GEO: GEOGloWS ECMWF Stremflow Hydroviewer  (https://tethys-staging.byu.edu/apps/geoglows-hydroviewer/) - NASA, US: Fire Information for Resources Management System (FIRMS, <https://earthdata.nasa.gov/earth-observation-data/near-real-time/firms>) - CONABIO, Mexico: Sistema de Alerta Temprana de Incendios (SATIF, http://incendios.conabio.gob.mx/)  [↑](#footnote-ref-55)
55. See for example: Copernicus: Digital Elevation Model (DEM, <https://land.copernicus.eu/imagery-in-situ/eu-dem/eu-dem-v1.1>) or Airbus Defense and Space, World Digital Elevation Model  (World DEMTM, <https://www.intelligence-airbusds.com/en/8703-worlddem>  [↑](#footnote-ref-56)
56. See for example: Copernicus Global Land Service (https://land.copernicus.eu/global/products/lc)   [↑](#footnote-ref-57)
57. For example: National Hurricane Centre, NOAA, US. Information on hurricanes (<https://www.nhc.noaa.gov/>)   [↑](#footnote-ref-58)
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70. <https://www.anticipation-hub.org/experience/evidence-database/evidence-list> [↑](#footnote-ref-71)
71. <https://www.wfp.org/publications/evidence-base-anticipatory-action> [↑](#footnote-ref-72)
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87. See previous footnote. [↑](#footnote-ref-88)
88. Several case study examples of information value chain construction and application are provided in Lazo & Mills (2021) [↑](#footnote-ref-89)
89. These and other elements are described by Lazo & Mills (2021:11) as part of the VOICE (Value of Information Characterization and Evaluation) approach in: Jeffrey Lazo and Brian Mills. 2021: Weather-Water-Climate Value Chain(s): Giving VOICE to the Characterization of the Economic Benefits of Hydro-Met Services and Products American Meteorological Society, Washington, DC. [↑](#footnote-ref-90)
90. If economic benefits are sought or a full benefit-cost analysis is conducted, then the reader is strongly encouraged to review the Lazo & Mills (2021:12) excerpt below and consult the guidance and detailed steps provided in WMO (2015). [↑](#footnote-ref-91)
91. <https://www.wfp.org/publications/evidence-base-anticipatory-action> [↑](#footnote-ref-92)
92. <https://www.fao.org/resilience/resources/resources-detail/en/c/1161388/> [↑](#footnote-ref-93)
93. <https://www.fao.org/emergencies/ressources/documents/ressources-detail/fr/c/1186991/#:~:text=Working%20with%20national%20governments%20and,translates%20warnings%20into%20anticipatory%20actions>. [↑](#footnote-ref-94)
94. equivalent to 21 and 54 percent respectively of daily calorie and protein requirements [↑](#footnote-ref-95)
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97. <https://static1.squarespace.com/static/61542ee0a87a394f7bc17b3a/t/616ad24fdbfca62188f8e614/1634390614711/FINAL%2BAnticipatory_Cash_Transfers_in_Climate_Disaster_Response%2B%28for%2BWP%29%2BF3.pdf> [↑](#footnote-ref-98)
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100. Ibid [↑](#footnote-ref-101)
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