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In collaboration with
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WORLD ECONOMIC FORUM

Catalysing Business Engagement in Early Warning Systems

WHITE PAPER

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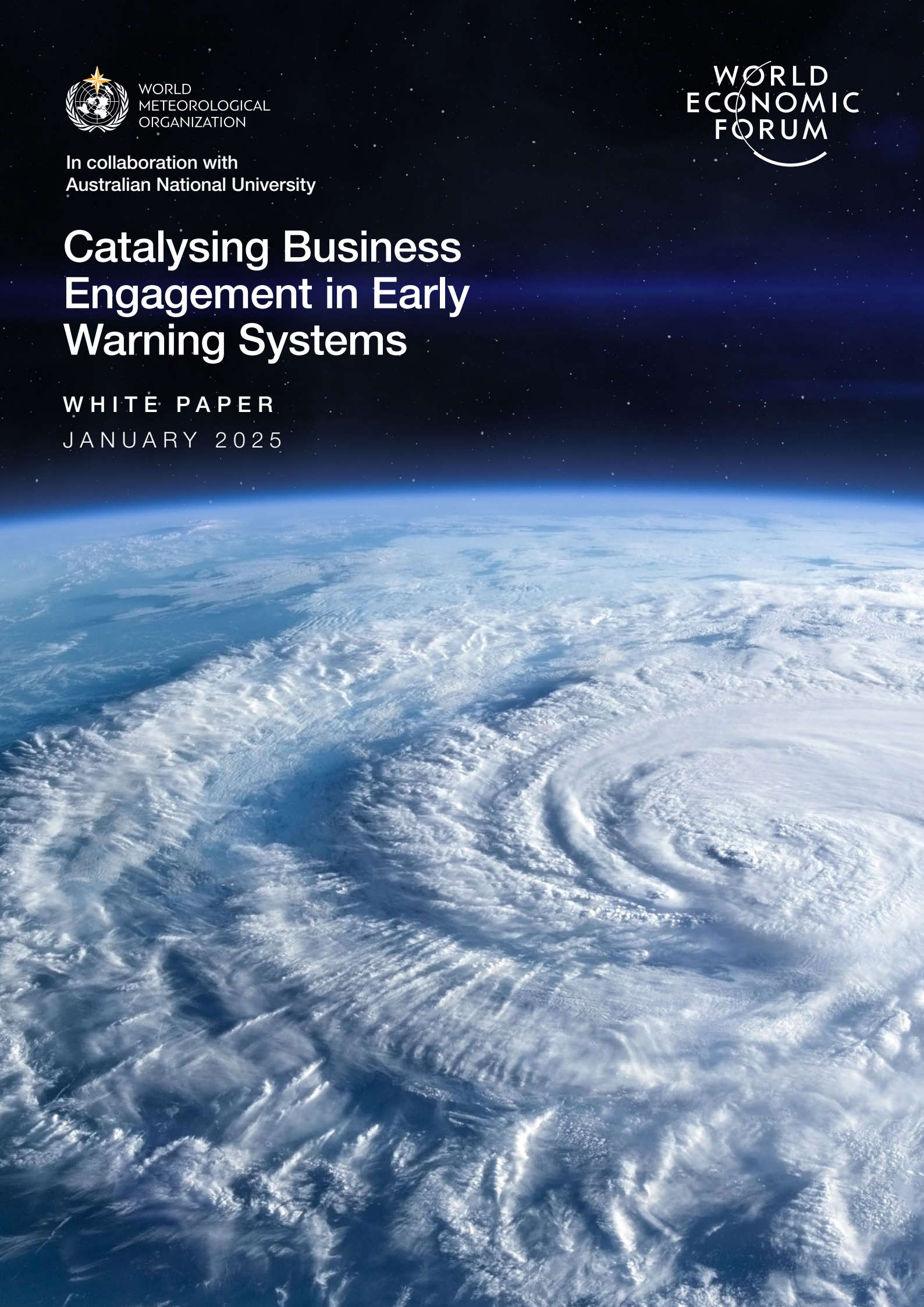

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Celeste Saulo
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Early warnings are crucial to save lives from extreme weather, water and climate-related events. In Bangladesh, in 1970 a tropical cyclone killed 300,000 people. In 2020, a storm of similar strength killed just 26 people. This reduction was due to the effectiveness of the Bangladesh Cyclone Preparedness Programme, a multistakeholder initiative, which ensured timely warnings reached vulnerable populations, as well as coordinated disaster preparedness and response.

There are similar recent success stories in other countries that are exposed to tropical cyclones – in low-lying South Pacific and Caribbean islands such as Fiji, Vanuatu, Barbados and Jamaica and in the coastal Southern African nation of Mozambique.

Unfortunately, only 50% of countries worldwide have reliable multi-hazard early warnings. The UN Secretary-General's Early Warnings for All initiative seeks to extend these life-saving services to all, especially the most vulnerable. This requires sustainable partnerships and clear guidance on how the private sector can contribute to, and leverage the benefits of, the early warning systems (EWS) value chain.

There is significant room for the private sector to create added value, with promising technologies and services ranging from cutting-edge AI-driven models for better risk knowledge to enhanced warning dissemination and communication. Business engagement also benefits society, allowing companies to enhance their corporate social responsibility.

It is essential for National Meteorological and Hydrological Services (NMHS) and businesses to reach a balance between delivery of authoritative and reliable warnings and services, and innovation. This will ensure the long-term sustainability and relevance of EWS. This partnership is vital to closing the global early warning coverage gap and protecting lives and economies from growing climate change impacts.

This paper aims to lay the foundations for partnership. It presents a framework for understanding the role of business in early warning and a first assessment of business engagement in the field.

Foreword

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Even as businesses seek to cut carbon emissions and mitigate the effects of climate change, there is an increasing need to adapt to the new normal and build resilience. One essential area to explore is early warning systems (EWS) – an ecosystem of sensors, analytical tools, communications chains and plans that can support swift, efficient and robust responses to weather events. Notably, EWS are growing in importance as climate change intensifies weather events in both frequency and severity.

Outside of specialist firms that support national hydrometeorological capabilities, EWS have traditionally been viewed as exclusively governmental domains. However, there are now increasing opportunities for businesses to explore EWS to optimize their operations or supply chains for climate and weather. They can potentially harness advancements in sensing, computational and communications technology, along with the availability of data, to inform decision-making.

This white paper seeks to illuminate how businesses can use EWS to strengthen their climate adaptation and resilience strategies, working in concert with government and other stakeholders to prepare and protect communities during extreme weather events.

Foreword

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Many parts of the world are experiencing increasing climate risks. This is partly due to climate change, which drives the increased intensity and frequency of extreme weather events, combined with decision-making processes that place people and infrastructure in harm's way. Managing these risks requires more effective discourse on what our societies value and greater emphasis on evidence-based decision-making to safeguard our environment, people, communities, culture, infrastructure and business operations. This latter group has not been adequately engaged regarding their emerging vulnerability to climate-driven impacts or their potential role in providing solutions. This white paper emphasizes the value of a transdisciplinary approach by engaging businesses in early warning systems (EWS). This can be achieved by bringing together scientific knowledge, advanced technological innovations and favourable policies to develop actionable solutions.

Aligning with the priorities of the Australian National University (ANU), this paper provides a comprehensive approach to engaging businesses in EWS. It focuses on integrating diverse strategies and collaboration models to achieve the goals of the Early Warnings for All initiative. The paper demonstrates that catalysing business involvement in EWS goes beyond financial investments or supporting National Meteorological and Hydrological Services (NMHS) communication of warnings. It also encompasses effective knowledge sharing and the co-creation of innovative solutions to enhance the accuracy and reach of real-time warnings linked with action plans.

Positioning businesses as partners and innovators in the EWS value chain enhances knowledge about hydrometeorological hazards and risk reduction, enabling businesses to make more informed decisions. This collaborative model also encourages businesses to explore market opportunities and cater to their operational needs while achieving broader societal goals. As we move forward, there will be substantial benefits from harnessing the knowledge, experiences and resources of different stakeholders to develop more effective and efficient EWS that protect people, the planet and the economy and hence contribute to the success of the Early Warnings for All initiative.

Executive summary

The world needs more early warning coverage, and businesses can help.

As the earth experiences anthropogenic climate change, weather events are becoming more extreme, frequent and variable. Each country must tailor its response to these growing threats based on its specific circumstances. Certain interventions, including early warning systems (EWS), have proven effective across many contexts.

EWS can provide preemptive warnings about upcoming hazardous events. They project probable impacts, efficiently communicate information and ensure that people know how to stay safe.[1] Central to EWS are the National Meteorological and Hydrological Services (NMHS) being the authoritative source of weather, water and climate information and warnings. EWS consists of a broad ecosystem of public and private sector players that work together to deliver timely and effective warnings to those at risk. Multi-hazard EWS have been proven to save lives and can reduce economic losses.

Despite this, there is a coverage gap in EWS in some areas. To close this gap, businesses need more awareness of the opportunities, and governments must develop strategies to engage them further. Opportunities for businesses are manifold and can be found in areas such as data collaboration, climate services or risk analytics. Businesses can either provide these services or use them to create new forms of value for customers in many different domains. This paper presents a framework for understanding the various roles that businesses can play in EWS (users, vendors, partners or innovators) along each of the four steps in the EWS value chain – risk knowledge, monitoring and warnings, communications and dissemination, and response capability. Then, building on a survey of 19 businesses (20 responses provided) and a review of available literature, the paper presents the current state of business engagement in EWS.

Business activity has increased in the field, particularly in the use of EWS data to provide novel goods or services for weather-related optimization across industries. This rise is driven by greater awareness of weather and climate risks, increasing data availability and affordable computing, and heightened public focus on disaster resilience since the COVID-19 pandemic. These drivers are all expected to persist or intensify in the coming years.

Barriers to participating in EWS persist, ranging from technical to economic challenges. For example, some markets for non-traditional climate services are immature and present high entry costs with unclear returns. Some barriers are governmental, manifesting as challenges in accessing the necessary data or finding mutually beneficial arrangements with NMHS agencies.

To drive more business engagement in EWS, governments can focus on providing clarity and incentives and work to make meteorological data as accessible as possible. Businesses should be alert to the possibilities in a growing market and explore how their capabilities can create value as more industries and governments look to build stronger disaster resilience capabilities.

1 Context and purpose

Early warning is an effective tool for dealing with the impacts of extreme weather. But it is underprovided.

In recent years, the world has increasingly felt the impacts of hazardous weather events. These include (but are not limited to) floods, droughts, wildfires, heatwaves, cold waves, tornadoes and tropical cyclones, which can all result in death, damage to critical infrastructure and economic loss.[2] The increasing frequency, severity and unpredictability of these events have been attributed to anthropogenic climate change.[3]

According to the World Meteorological Organization's (WMO) analysis of the Emergency Events Database (EM-DAT) data, between 1970 and 2021, nearly 12,000 disasters, over 2 million fatalities and $4.3 trillion in economic losses were attributed to weather, climate and water extremes.[4] The reported economic impacts of extreme weather events have grown eightfold over the last 50 years[5,6] and pose a significant threat to businesses and economies worldwide. The World Economic Forum's *Global Risks Report 2024* listed extreme weather as the most likely global risk to trigger a major crisis in the next decade.[7]

1.1 Early warning systems as effective adaptation tools

The impacts of hazardous and extreme weather events necessitate a wide range of responses, from improved adaptation planning to stronger safety nets – each tailored to the local context. However, early warning systems are a strategy that has consistently proven effective.

EWS form an integrated value chain system that enables individuals, communities, governments, businesses and others to take timely action, reducing disaster risks in advance of hazardous events. National Meteorological and Hydrological Services (NMHS) provide essential services to national EWS through the provision of hazard monitoring, forecasting and prediction, disaster risk assessment, communication, and preparedness activities. National multi-hazard EWS (MHEWS) can issue warnings for various hazards, improving efficiency and consistency through coordinated, multidisciplinary systems and capacities.[8]

EWS have a significant impact. Analysis of disaster-related data reveals that countries with only "limited to moderate" MHEWS coverage have a mortality ratio almost six times higher than countries with "substantial to comprehensive" coverage.[9] Similarly, countries with limited to moderate MHEWS coverage have nearly five times more disaster-affected people than countries with substantial to comprehensive coverage.[10] According to a study by the Global Centre on Adaptation, EWS can reduce an event's damage by 30% just by giving a 24-hour notice.[11]

1.2 The EWS coverage gap

While evidence suggests that investing in multi-hazard EWS directly reduces the human toll of disasters, there is a large gap in coverage globally. The United Nations Office for Disaster Risk Reduction (UNDRR) and WMO's 2022 report, *Global Status of Early Warning Systems*, highlighted that only half of all countries have EWS in place.[12]

In March 2022, United Nations (UN) Secretary-General António Guterres announced the UN would spearhead new action to ensure every person on Earth is protected by EWS within five years. At the time, the UN estimated that filling this gap would require billions in investments.[13]

1.3 Closing this gap will require stronger engagement of private sector

Though early warnings are developed through a collaborative ecosystem of many types of partners, EWS are often seen as governmental. While governments must remain the issuing authority for warnings, the private sector can create value within every other aspect of EWS.[14,15] These opportunities are poorly understood outside the specialist companies that work closely with EWS. If done in a way that is appropriate and ensures continuity of services, expanding the number of involved companies and deepening their engagement could help close the EWS coverage gap.

It is essential for business leaders and NMHS to recognize the need for a balance between innovation and stable service delivery. By working together with NMHS, private sector innovations can be more effectively integrated into established and mandated public services, supporting the long-term sustainability of EWS. Such partnership is vital to sustainably closing the global early warning coverage gap and protecting lives and economies from the growing impacts of climate change.

This paper identifies ways to grow business participation in EWS, such that closing the coverage gap becomes a more manageable task. It starts by articulating a framework for businesses' engagement in EWS. Then, relying on academic literature and a survey of 20 businesses conducted by the Forum and WMO, it describes the current contours of business action on EWS. Based on survey responses, follow-up interviews and further references, it then discusses drivers and barriers to business participation in early warning and closes with recommendations for increasing engagement.

> **"While governments must remain the issuing authority for warnings, the private sector can create value within every other aspect of EWS.**

2 The state of business engagement in EWS

A growing number of businesses are providing new and innovative products or services linked to EWS.

This chapter explores the current level and characteristics of business engagement in EWS. First, it outlines a framework for understanding the various roles that businesses can play in relation to the EWS system. Then, based on a survey and literature review, it presents headline findings that describe the overall state of business engagement on the issue.

2.1 Framework for business engagement in EWS

The framework for understanding businesses' role in EWS starts from the EWS value chain – the four interrelated elements of EWS that work together to produce and disseminate warnings. The steps in the EWS value chain are as follows:[16]

- **Risk knowledge**: Understanding and quantifying hazards, exposure and vulnerability of persons, communities, organizations and assets
- **Detection, monitoring, analysis and forecasting of hazards and possible consequences**: Hazard monitoring through effective and operational forecasting and warning services, with clear institutional mechanisms in place
- **Warning dissemination and communication**: Decision-making processes, communication systems and equipment, and targeting approaches
- **Preparedness and response**: Developing, operationalizing and regularly testing and evaluating disaster preparedness measures, including response plans, public awareness and educational campaigns

Across each of these steps in the value chain, a business's relationship with EWS can be defined as one (or more) of four types. Businesses can relate to EWS as users, vendors, partners or innovators. These terms are defined below, along with illustrative descriptions of how each type of relationship manifests within each step of the EWS value chain. Case examples of many of these types can be found throughout the rest of this document.

Users: Businesses integrate EWS data to mitigate risks, identify opportunities and refine long-term strategies. While users typically consume EWS data, they also have the potential to become more engaged by enhancing and contributing to the system.

- **Risk knowledge**: Users rely on EWS data to identify and assess risks, enabling proactive measures such as adjusting operations in high-risk areas. They also use this data to develop products and services to help others mitigate risks.
- **Monitoring and warning**: Companies use real-time EWS alerts to modify operations, such as rerouting logistics or pausing activities in affected areas.
- **Communication and dissemination**: Businesses receive warnings through internal and external communication channels and can play a larger role by helping disseminate critical information to supply chains, customers and local communities.
- **Response capability**: Businesses develop emergency plans to safeguard their employees and infrastructure based on authoritative EWS warnings.

> Vendors offer state-of-the-art tools, such as smart sensors, internet of things (IoT) devices, satellite monitoring systems and non-traditional data to support hazard detection.

Vendors: As vendors, businesses supply key technology and infrastructure, playing a crucial role in improving EWS performance.

- **Risk knowledge**: Vendors provide advanced analytics platforms, including tools powered by artificial intelligence (AI) and non-traditional data sources that enhance the ability to collect and process risk data more efficiently than traditional methods.
- **Monitoring and warning**: Vendors offer state-of-the-art tools, such as smart sensors, internet of things (IoT) devices, satellite monitoring systems and non-traditional data to support hazard detection.
- **Communication and dissemination**: Vendors provide scalable communication infrastructures (such as satellite, mobile networks and cloud-based systems) that rapidly disseminate warnings.
- **Response capability**: Vendors develop emergency management tools, automated response systems and disaster simulation platforms that improve coordination and response times during crises.

Partners: These businesses collaborate directly with EWS to improve products or services or develop new capabilities.

- **Risk knowledge**: As partners, businesses collaborate with public agencies by sharing data and co-developing tools that enhance collective risk knowledge.
- **Monitoring and warning**: Businesses contribute through partnerships by developing and improving monitoring and forecasting systems.
- **Communication and dissemination**: Partners help scale warning systems, providing infrastructure and platforms for the broader distribution of critical alerts.
- **Response capability**: Businesses partnering with public agencies can enhance real-time threat management and strengthen response plans.

Innovators: These businesses push the boundaries of the traditional landscape of the EWS value chain. They expand the impact of EWS capabilities by broadening their reach, often focusing on novel approaches.

- **Risk knowledge**: Innovators create cutting-edge tools, like AI-driven models and predictive analytics, that offer faster and more accurate risk assessment.
- **Monitoring and warning**: Businesses lead innovation in forecasting by developing real-time monitoring tools, smart sensors and advanced IoT-based systems, potentially aimed at areas where such monitoring has not previously been feasible.
- **Communication and dissemination**: Innovators develop multi-channel platforms for personalized alerts, integrating user-generated data for greater accuracy.
- **Response capability**: Innovators further advance automating response systems, virtual disaster simulations and platforms that enable better coordination and analysis during emergencies.

2.2 Current state of business engagement in EWS

95%

of businesses in the US rely on weather information.

The following insights emerge by analysing the survey of 20 businesses, reviewing relevant literature and conducting interviews.

Insight 1: Most businesses engage with EWS primarily as users

The role of businesses as users of weather, climate and water data has expanded significantly in recent years. A joint survey by the IBM Institute for Business Value and Oxford Economics, which included 1,000 executives across 13 industries in 15 countries, revealed that most executives view better weather insights as a key factor in reducing operating costs and ensuring business continuity.[17] Nearly 50% of respondents recognized weather insights as a source of competitive advantage. In the US alone, 95% of businesses rely on weather information.[18] However, while businesses increasingly understand the value of weather-related insights, they are not generally sophisticated users of this information. This means they elect to work with tailored third-party insights derived from weather data rather than directly with the weather data itself.

The fact that many businesses use EWS data is consistent with several recent findings (including by the World Economic Forum[19]) that most businesses do not invest in minimizing their physical climate risk exposure. Weather data used to optimize routine operations (e.g. ship routing) is not seen as risk mitigation. Neither are risk assessments, which require weather data, or data used for developing or refining new products or services. The use of weather data seems to be aligned with these cases.

Insight 2: Businesses have multifaceted relationships with NMHS

Businesses that engage in EWS often develop diverse and bespoke relationships with NMHS. They sometimes function simultaneously as users, partners, vendors and innovators. This means they not only provide products and services to NMHS, but also rely on NMHS data to develop customer-facing solutions. Businesses often collaborate with NMHS by offering feedback, helping to refine the quality and utility of weather data, which improves both their commercial offerings and public sector services.

Businesses often grow into these relationships, realizing that as vendors or innovators, they can work towards becoming partners and further harness the EWS value chain to drive innovation, capitalize on new market opportunities and position themselves as leaders in climate risk management.

For instance, a weather information and service company exemplifies the multifaceted relationships businesses can have with NMHS. The company operates across the hydrometeorological value chain. As partners, they collaborate on projects such as installing high computing capabilities in EWS networks and integrating weather data in EWS. As vendors, the company supplies advanced weather monitoring equipment, station networks and software solutions.

Insight 3: There are a growing number of "innovators", as defined in section 2.1

The global weather industry is experiencing substantial growth. The integration of EWS data across industries is helping companies manage operational risks while creating opportunities for innovative services that improve resilience and reduce costs. As demand for these solutions grows, businesses across multiple sectors are increasingly using weather-related data to drive profitability and long-term sustainability.

In the past 5 to 10 years, entirely new categories of products and services have been created by combining weather data with other data and sophisticated technology. Agriculture has been a particular focus – companies are providing sophisticated, real-time added value assessments of the impacts of weather, climate and water risks on agricultural production.

In insurance, the understanding of natural disaster risk has become much more precise, enabling the development of novel products. This is particularly evident through the growth of "parametric" products, i.e. those that issue payouts after certain objective indicators are reached rather than after a loss-adjustment procedure.[20]

While agriculture and insurance may see the most innovation, the opportunity cuts across industries. One company has developed an offering to help communities improve their standing within the Federal Emergency Management Agency's (FEMA) Community Rating System (CRS), a voluntary incentive programme that rewards communities for reducing flood risks.[21] Another example refers to the advanced wildfire detection systems that are being used by forestry and electricity companies, among others.

3 Drivers and barriers of business engagement in EWS

Major global trends are driving the growth of business opportunity in EWS.

This chapter explores what drives businesses to engage with EWS, and what prevents them from doing more. These drivers and barriers are the basis of strategies for increasing business engagement in EWS, which are explored in the following chapter.

3.1 Drivers of business engagement in EWS

Driver 1: Businesses are focusing more on hydrometeorological hazard risks

Many businesses understand that their operations, supply chains, distribution and workforce are impacted by weather. However, two recent trends have increased their focus, the first of which is reporting. Since the adoption of the Corporate Sustainability Reporting Directive (CSRD) in 2024, companies operating in the European Union (EU) have been required to report on climate risk. Similar measures have been adopted in the UK, Canada, the State of California and other important business jurisdictions. Furthermore, voluntary disclosures, which ask companies to consider their impact on the natural world, have become increasingly popular. Both CRSD and voluntary disclosures require increased engagement with related data.

The second trend is the increase in extreme weather incidents. Companies in industries that are directly exposed to weather, climate and water effects (e.g. agriculture, extractives and companies that either own or have financial exposure to valuable outdoor physical assets) have developed robust plans based on highly localized predictions. One electricity company even invested in developing an internal climate scenario group that collects its own site-level weather data from across its global operations and informs the company's strategic decision-making. Beyond these primary industries, others are starting to consider impacts, even if many are not ready to make large investments in mitigating them. For instance, several are integrating real-time weather data into supply chain management systems to optimize logistics, reduce costs and improve operational resilience amid more frequent extreme weather events.

Driver 2: Disaster resilience is high on the public agenda

Though disaster resilience has been in public debate for some time (as noted by the 2015 Sendai Framework), COVID-19 changed the nature of the global conversation on resilience, exposing the "vulnerability of our society to global systemic risks".[22] In the context of a changing climate, this has especially included resilience to weather disasters, which, since around 2021, have become a more prominent part of the international agenda. This is clear through the development of major global programmes and initiatives that explicitly reference disaster resilience as a concern, including Early Warnings for All and the Bridgetown Initiative to reform the international financial system. It is also evidenced in funding allocations. For example, in 2021, the World Bank committed to a plan to increase its climate financing to 35% of its total portfolio, with half of climate financing from the International Development Association (IDA) and the International Bank for Reconstruction and Development (IBRD) being allocated to climate adaptation. A similar emphasis on resilience is clear at the national level. For example, in 2023, the White House held the first US national climate resilience summit.

Companies are increasingly choosing to enhance their corporate social responsibility (CSR) by aligning with important disaster resilience initiatives. For example, a company in the survey emphasized its commitment to sustainable development by mitigating risks through EWS, enhancing its reputation and aligning with CSR objectives. Similarly, another company noted that partnerships with government agencies and research institutions, developed through EWS collaborations, drive innovation and reinforce its growth strategy.

> Companies involved in climate resilience projects are seen as socially responsible, which resonates positively with customers, stakeholders and investors.

Participation in disaster resilience initiatives also helps businesses comply with national adaptation frameworks, which are increasingly being incorporated into regulatory systems. Regulatory bodies are demanding greater transparency and accountability, as evidenced by the Forum's 2023 stocktake report, which identified voluntary disclosures as a key driver of corporate engagement in climate adaptation.[23] Businesses have found that compliance with such frameworks can act as both a risk management tool and a driver for climate action. For instance, some companies accelerated their participation in EWS due to government-enforced regulatory changes.

Moreover, a proactive approach to disaster preparedness can enhance brand image. Companies involved in climate resilience projects are seen as socially responsible, which resonates positively with customers, stakeholders and investors. For instance, multiple survey respondents noted that their support of EWS elevates their reputation as responsible and innovative entities. These efforts also enable businesses to credential their technologies, potentially mitigating concerns related to other social or environmental issues.

Driver 3: Increasing data, information and technological advancements

The exponential growth of data and technological advancements in recent years presents two key opportunities for businesses. Firstly, it creates new avenues to sell or provide data, information and technologies to EWS. Secondly, it opens up new opportunities for applying weather-related optimization across a broader range of industries, driving efficiency and operational improvements.

Many businesses are focusing their efforts on harnessing cutting-edge technologies like AI, big data analytics, cloud computing, IoT networks, satellite monitoring and sensor development to gain a competitive edge in the expanding EWS market. A leading technology company, for example, uses AI-powered risk assessments and IoT to deliver tailored early alerts to its customers, strengthening its position in the market.

BOX 1

The competitive edge of AI, IoT and big data

The integration of AI, IoT and big data technologies is transforming how businesses engage with EWS. By using AI-driven analytics and real-time data from IoT networks, businesses can automate and optimize weather-driven decision-making across various sectors. For instance, AI-powered platforms can disseminate early warnings faster and tailor them to a specific client's needs.

Opportunities to sell or provide data into the EWS value chain

With the surge in commercial satellite imagery, IoT networks and AI capabilities, businesses are now in a prime position to offer valuable weather-related data to the EWS ecosystem. The volume of commercial satellite imagery has grown significantly. In 2010, the average number of satellite launches per year went from under 200 to over 1,200.[24] As of 2020, approximately 100 terabytes (TB) of earth imaging data were being collected every day, and the value of the earth imaging market is expected to quadruple between 2023 and 2030.[25] These developments provide an unprecedented wealth of high-resolution data that can be integrated into EWS.

Additionally, AI-powered analytics enable businesses to process vast amounts of satellite and sensor data in real-time, generating actionable insights for governments, industries and customers. Private IoT networks increasingly provide localized, real-time weather data that can enhance the precision and accuracy of official meteorological systems. For example, companies that develop satellite technology or IoT-based sensors are uniquely positioned to sell (or otherwise provide) their data streams to NMHS or other stakeholders involved in EWS. By offering this data, businesses can create new revenue streams while contributing to improved forecasting and risk management for the public and private sectors. For example, a company specializing in the aerospace and defence sector acts as an upstream provider of near real-time satellite data and related services. The company showcased its ability to assess mountainous region risks effectively by providing high-resolution topographic information.

Technological advancements in data integration and forecasting

Technological advancements in data assimilation have led to significant improvements in weather forecasting models. Over the past five decades, the global observing system, which includes surface observation stations and satellite-based data, has dramatically expanded. Deriving insights from this data is facilitated by the continued progress in computational power and AI witnessed in recent years.

As businesses tap into these technological advancements, they can enhance the precision of their weather-related services and offer more reliable insights to their customers. For example, a business using ECMWF's enhanced model forecasts could offer tailored risk assessments for industries such as insurance or agriculture, where precise weather predictions are crucial for managing climate risks.

3.2 Barriers to business participation in EWS

> A significant barrier to private sector engagement in EWS is the lack of clear governance, guidance and enabling policies from governments.

Barrier 1: **Gaps in data granularity, quality and usefulness**

Despite significant advances in weather data collection and forecasting, businesses still face challenges when applying weather insights to their specific operational needs. Many companies require highly granular data to make decisions (e.g. for individual facilities or supply chain nodes) rather than relying on broader city- or region-level insights. However, the high cost of obtaining data and the lack of compelling evidence to demonstrate a strong return on investment limit widespread adoption. Businesses are hesitant to invest heavily in asset-specific insights until the business case is clearer.

In many regions of the world, even city- or regional-level data is sparse or unavailable. Global disparities in weather observation capabilities, particularly in developing regions, pose a significant challenge to accurate weather modelling. Gaps in weather observations weaken forecasting models' ability to provide precise, localized predictions and reduce the accuracy of hydrometeorological forecasts. The latter are critical for effective decision-making, especially for industries that rely on real-time weather data to protect assets and ensure operational continuity. Globally, closing these gaps and improving forecasting precision will require significant investment.

Barrier 2: **Regulatory and policy barriers**

A significant barrier to private sector engagement in EWS is the lack of clear governance, guidance and enabling policies from governments. In many countries, the private sector's role in contributing to or using the EWS value chain remains unclear. This is due to restrictive or poorly defined policies developed without adequate consultation with key stakeholders – such as NMHS in its role as the authoritative voice on weather, climate, water and related environmental services and warnings. In turn, this contributes to overlapping responsibilities and reduces the private sector's ability to use EWS outputs fully, ultimately impeding the long-term development and sustainability of national EWS initiatives.

For instance, a major telecommunications company highlighted that regulations developed without consulting mobile network operators failed to create cohesive national EWS frameworks. These overly complex policies discourage private sector investment and hinder collaboration between businesses and governments.

4 Strategies for business engagement in EWS

Governments can play a major role in bringing more businesses into EWS.

Strategy 1

4.1 Focus on providing businesses with clarity and incentives

> Outside of the more established business lines providing equipment to NMHS, there is uncertainty about how markets will develop.

The costs of entering a technical industry like disaster resilience are high. Given the relatively rapid and recent expansion of the early warning ecosystem, the maturity of certain climate information and services markets is relatively low. Outside of the more established business lines providing equipment to NMHS, there is uncertainty about how markets will develop. In this context, steps to provide certainty or incentivize market participation could be effective. Companies in the survey highlighted both of these points.

One approach is to invest in strong public-private partnerships (PPPs) that provide structured funding mechanisms through bilateral agreements, engagement in government-to-government cooperation and/or tied-aid soft financing. A data analytics company in the survey emphasized the importance of PPPs for the joint development of data storage and management. They noted that "public-private collaboration on the joint development of data management, storage and distribution solutions would enable significant cost savings for NMHS and reduce deployment time for EWS".

In some EWS markets, these partnerships are well developed. For example, a meteorological equipment manufacturer in the interview sample has effectively established bilateral, government-to-government cooperation with tied-aid soft financing in Asia and Africa. This clear structure promotes the company's engagement in sustainable meteorological infrastructure and capacity-building projects, ensuring financial backing and government support for investments in EWS solutions. In other countries, however, governments may not be used to working with the private sector in this way.

Another possible approach is to strengthen consultative processes or develop public-private expert communities. The WMO has succeeded in this approach by accepting private sector participation in its expert discussions under technical commissions and establishing the Open Consultative Platform – an open, multistakeholder dialogue platform.

This feedback also comes from the interviewed companies. One mentioned that "mechanisms for sharing more information on where there is interest for private sector participation is key". Another mentioned that workshops on flood forecasting and machine learning to develop technical capacity and showcase best practices are helpful. Another asked for the public-private consultations that happen in the Early Warnings for All initiative at the global level to also happen at the national level. They added that private companies should be invited to follow-up processes and initial dialogues.

Finally, as countries build EWS capabilities, they should align policy with international standards. For example, adopting the Common Alerting Protocol (CAP) can standardize the dissemination of early warnings across different media, ensuring consistency and accuracy. Such standardization across the EWS value chain makes it easier for businesses to participate and enhance national EWS capabilities.

Strategy 2

4.2 Focus on open data

Data availability is a key driver of innovation in EWS, to the extent that private companies are beginning to offer weather data aggregation as a business-to-business service. For example, a major technology company in the sample has created open platforms that aggregate and standardize hydrological data sets, making it easier to access and understand the data. This supports businesses in customizing various EWS outputs for their use.

A core strategy for encouraging stronger business engagement in EWS is to make as much data open and easy to work with as possible. Open data platforms offer free and standardized data, democratizing access to critical information and enabling businesses to develop tailored solutions specific to their needs.

The WMO facilitates the free and open exchange of meteorological and environmental data through its 2021 Unified Data Policy, ensuring that comprehensive data (including weather) is accessible to all countries. Central to this is the WMO Information System 2.0 (WIS 2.0), a cutting-edge framework that enables data sharing across all WMO domains and disciplines. Supporting the Unified Data Policy and the Global Basic Observing Network (GBON), WIS 2.0 simplifies and lowers the cost of international, regional and national data exchange. At its core, WIS 2.0 embraces open data principles, adopting open standards and web technologies to facilitate the sharing of increasing volumes and varieties of real-time data, ensuring equal access to all.

Progress continues to be made in this area. For example, in 2019, the EU listed meteorological data as a "high-value dataset".[26] This required it to be made available via an application programming interface (API) to the public for reuse, free of charge. This approach has been implemented across the EU. It is progressing into states of the European Economic Area, with, for example, the Swiss NMHS MeteoSwiss scheduled to make its data freely available to the public as of 1 April 2025. Efforts to accelerate this trend globally would help bring more businesses into the early warning ecosystem.

Conclusion

Though they have always been important, early warning systems are becoming ever more so as people deal with the impacts of more frequent, severe and variable extreme weather events. Given that the primary way people will experience climate change in the near term is through extreme weather, EWS can be considered an effective climate adaptation solution.

Like most climate adaptation efforts, EWS suffers from a funding gap that limits its reach. However, there are opportunities for businesses to help close this gap and create value for both society and themselves. These opportunities arise from a combination of technological advancements and increased awareness of extreme weather issues in both the public and private sectors. They include the opportunity to supply new technologies, data or services into EWS directly, to provide weather or climate optimized products or services across a range of industries, or to partner with NMHS to help customers prepare for the impacts of extreme weather.

Doing this requires a mindset shift by both businesses and governments. Businesses need to look for opportunities in areas where they may not have historically been found. Governments need to do more to make it easy for businesses to get involved, which includes making data open, incentives available and processes clear.

Like many other climate adaptation domains, there is an opportunity to close coverage gaps by facilitating the development of markets that businesses can serve.

Annex: List of contributors

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