Ministry of Water Resources and Meteorology

Private Sector Engagement in Climate Information Services and Early Warning System in Cambodia

Feasibility Study

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Strengthening Climate Information and Early Warning Systems to Support Climate-Resilient Development in Cambodia

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Private Sector Engagement in Climate Information Services and Early Warning System in Cambodia

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List of Acronyms

ASMC	ASEAN Specialised Meteorological Centre
ADB	Asian Development Bank
BCC	Beijing Climate Center
CRC	Cambodian Red Cross
CCAP	Climate Change Action Plan
CCD	Climate Change Department
CCSP	Climate Change Strategic Plan
CIS	Climate Information Services
CCDM	Community Committees for Disaster Management
DRR	Disaster Risk Reduction
DCDM	District Committees for Disaster Management
ENSO	El Niño Southern Oscillation
EWS	Early Warning Systems
GIS	Geographic Information Services
GFCS	Global Framework for Climate Services
GFDRR	Global Facility for Disaster Reduction and Recovery
GCF	Green Climate Fund
GDP	Gross Domestic Product
ICT	Information Communication Technology
JICA	Japan International Cooperation Agency
JAG	Joint Action Group
LDCF	Least Developed Countries Fund

MRC	Mekong River Commission
MAFF	Ministry for Agriculture, Forestry, and Fisheries
MoE	Ministry of Environment
MIME	Ministry of Industry, Mining and Energy
MRD	Ministry of Rural Development
MoT	Ministry of Tourism
MOWRAM	Ministry of Water Resources and Meteorology
NCCC	National Climate Change Committee
NCDM	National Committee for Disaster Management
NHMSs	National Hydro-meteorological Agencies
NGO	Non-governmental Organizations
O&M	Operation and Maintenance
PDOWRAM	Provincial Department of Water Resources and Meteorology
PIN	People in Need
PSDSC	Private Sector Development Steering Committee
PCDM	Provincial Committees for Disaster Management
PPP	Public Private Partnership
RCCs	Regional Climate Centers
RGC	Royal Government of Cambodia
SCCSP	Sectoral Climate Change Strategic Plans
TCC	Tokyo Climate Center
TCFD	Task Force on Climate Related Financial Disclosures
UNDP	United Nations Development Programme
UNDRR	United Nations International Strategy for Disaster Reduction
UNDRR	United Nations Office for Disaster Risk Reduction
USAID	United States Agency for International Development
VTDM	Village Teams for Disaster Management
WHO	World Health Organizations
WMO	World Meteorological Organization

1. Introduction

1.1 Background and Purpose

The Global Environment Facility - Least Developed Countries Fund (LDCF) is supporting the Royal Government of Cambodia (RGC) through the “Strengthening Climate Information and Early Warning Systems in Cambodia” project. The project aims to bridge existing gaps in institutional capacity, inter-ministerial coordination, and infrastructure with respect to the provision of Climate Information Services (CIS) and Early Warning Systems (EWS). The project comprises three complementary outcomes:

1. Increased institutional capacity to assimilate and forecast weather, hydrological, climate and environmental information
2. Enhanced availability of climate and weather information for national, sectoral and sub-national planning as well as for transboundary communication in the region
3. Strengthened institutional capacity to operate and maintain EWS and climate information infrastructure, both software and hardware, in order to monitor weather.

A fundamental strategy for achieving these outcomes is through the creation of partnerships between the Ministry of Water Resources and Meteorology (MOWRAM) and other stakeholders, with the goal to generate resources that can sustain an adequate and effective climate and weather data collection network. Global experience has demonstrated that engaging the private sector in CIS and EWS can be an effective strategy for meeting budgetary, technical and human resource gaps by National Meteorological and Hydrological Services (NMHSs). In recognition of this, the project has commissioned this feasibility study to identify the existing and potential role of the private sector in the provision of climate and early warning products and services in Cambodia.

1.2 Methodology

This report has been prepared using a combination of primary and secondary research. Information has been gathered through three main avenues: 1) review of pertinent literature and documentation; 2) stakeholder interviews; and 3) case studies. Using these techniques and an analysis of global and regional trends in CIS; the report provides a landscape analysis, market review, and recommendations for private sector engagement.

Literature review included review of project documents, policy documents, websites of government, non-government and educational institutions as well as websites and reports produced by a number of global, regional, and local companies providing and using CIS. Please see the References page for further details.

Stakeholder interviews were conducted over Skype due to travel restrictions imposed during the conduction of this research due to the COVID-19 pandemic. Please see Annex 1 for a full list of planned and actual interviews along with interview questions. The planned interviews that were unable to materialize during the project timeframe will be conducted in the next phase of the project.

Finally, promising private sector actors were selected for follow-up interviews and case study development. Please see the Case Study boxes in this report for reference.

1.3 Climate Change and Disasters in Cambodia[1]

Cambodia is characterized by a humid tropical climate, heavily influenced by the annual monsoon season that typically occurs from mid-May to October and brings nearly 75% of the country's annual precipitation. Temperatures are generally consistent across the country, averaging 25 to 27°C throughout most of the year. The average annual maximum is 38°C in April and average annual minimum is 17°C in January.

Historical climate trends have shown an increase in temperature of approximately 0.18°C per decade since 1960, with the most rapid increase during the dry season (Nov-Apr). The frequency of "hot days" increased by 46 days per year. Future climate modeling indicates that average annual temperatures are very likely to increase by 0.8 to 1.6°C by 2030 and the frequency of hot days will increase by 4 to 49 percent (World Bank, 2020).

Rainfall has increased in some areas of the country whereas other regions have not experienced statistically significant changes. Projections indicate an increase in the intensity of heavy rainfall events of 1 to 15 percent by 2050 but the change in overall amount of rainfall remains uncertain. Climate changes are projected to result in a potentially shorter, or shifted, rainy season by 2085, with drier conditions in April and May and wetter conditions in October and November.

The implications of projected changes are wide-ranging but are especially significant for the agricultural sector. This is because agriculture represents the predominant livelihood in Cambodia. Rural areas comprise 98 percent of the country's total land area and is home to 77 percent of the population. 90 percent of the rural population is engaged in agricultural activities and 80 percent relies upon subsistence crop production (USAID, 2019). Agriculture is not only a source of livelihood for many people, but also essential for food security.

[1] Information for this section has drawn from the USAID Climate Risk Profile for Cambodia, Feb 2019 and the RGS Cambodia Climate Change Strategic Plan 2014-2023, and the WHO Health Risk Profile for Cambodia, 2015

Climate change is expected to reduce agricultural productivity as a result of rising temperature, erratic rainfall, more frequent droughts and floods, and sea-level rise. One study suggests that a failure to ensure optimal timing, cultivar, and fertilizer use in the face of shifting climatic conditions could result in as much as 9.9 percent losses in wet season yields and 7.7 percent loss in dry season yields by 2050 respectively (USAID, 2019).

Changing climatic conditions also leads to increased outbreaks in agricultural pests and diseases. For rice crops, pest cycles may speed up and phytosanitary conditions may worsen as a result of increased periods of rain and higher temperatures. Meanwhile, drought conditions could reduce plant resistance to pests such as grasshoppers, and strong winds could accelerate the spread of those pests. These increased threats may in turn result in the increased need for and cost of agricultural inputs (Costa, 2018).

Cambodia's NDC highlights agriculture, infrastructure, forestry, human health, and coastal zones as the most vulnerable sectors to the impacts of climate change. In upland forest systems, shifts in precipitation patterns and increased temperatures will accelerate degradation from agricultural expansion, illegal logging, and charcoal production. Extreme weather events, such as heavy rainfall and increased intensity of tropical storms, combined with upland deforestation could result in increases in downslope sedimentation of surface water bodies or increased risk of landslides for downstream populations.

Alterations in water flow, quantity, and quality will impact agriculture as well as human health. It is projected, that by 2030, an additional 69,800 people may be at risk of river floods annually as a result of climate change. In addition to deaths from drowning, flooding causes extensive indirect health effects, including impacts on food production, water provision, ecosystem disruption, infectious disease outbreak, and vector distribution. Longer term effects of flooding may include post-traumatic stress and population displacement (WHO, 2015).

Cambodia's 435 km of coastline is vulnerable to sea-level rise and the severe impacts of more frequent typhoons that are expected under future climate projections. This could affect tourism and human health in coastal areas. Safe drinking water along the coastal areas will be compromised due to saline intrusion resulting from sea level rise in combination with coastal erosion. Saline intrusion is also projected to increasingly impact inland waterways, which are integral for freshwater fish and rice production.

1.4 Climate Information Services and Early Warning Systems

According to the WMO's Global Framework for Climate Services (GFCS), climate services provide climate information to help individuals and organizations make climate smart decisions. Meteorological and non-meteorological data is collected and transformed into customized products such as projections, trends, economic analysis and services for different user communities. CIS equip decision makers in climate-sensitive sectors with better information to help society adapt to climate variability and change.

CIS is the provision of climate information to assist decision-making. It involves collating, analyzing, packaging and distributing climate data on variables such as temperature, rainfall, wind, soil moisture, ocean conditions and extreme weather indicators. Successful CIS/EWS must provide accurate, spatially resolved daily, ten-day, monthly, and seasonal forecasts and advisories in a timely and accessible manner as well as historical trends and monitoring products (Usher, Phiri, Lincare, O'Sullivan, & Qadir, 2018). The service must respond to user needs, be based on scientifically credible information and expertise, and integrate engagement between the users and providers. End-users include government decision makers, businesses, smallholder farmers and individuals.

The global weather forecasting systems market (an important sub-set of the CIS market) was estimated to be USD $2.3 billion in 2019 and is projected to reach USD $3.3 billion by 2025 (Markets and Markets, 2019). Increasing demand for weather forecasting using big data analytics and rise in climate change patterns resulting in uncertainties related to rainfall are major factors expected to drive the growth of the weather forecasting systems market globally.

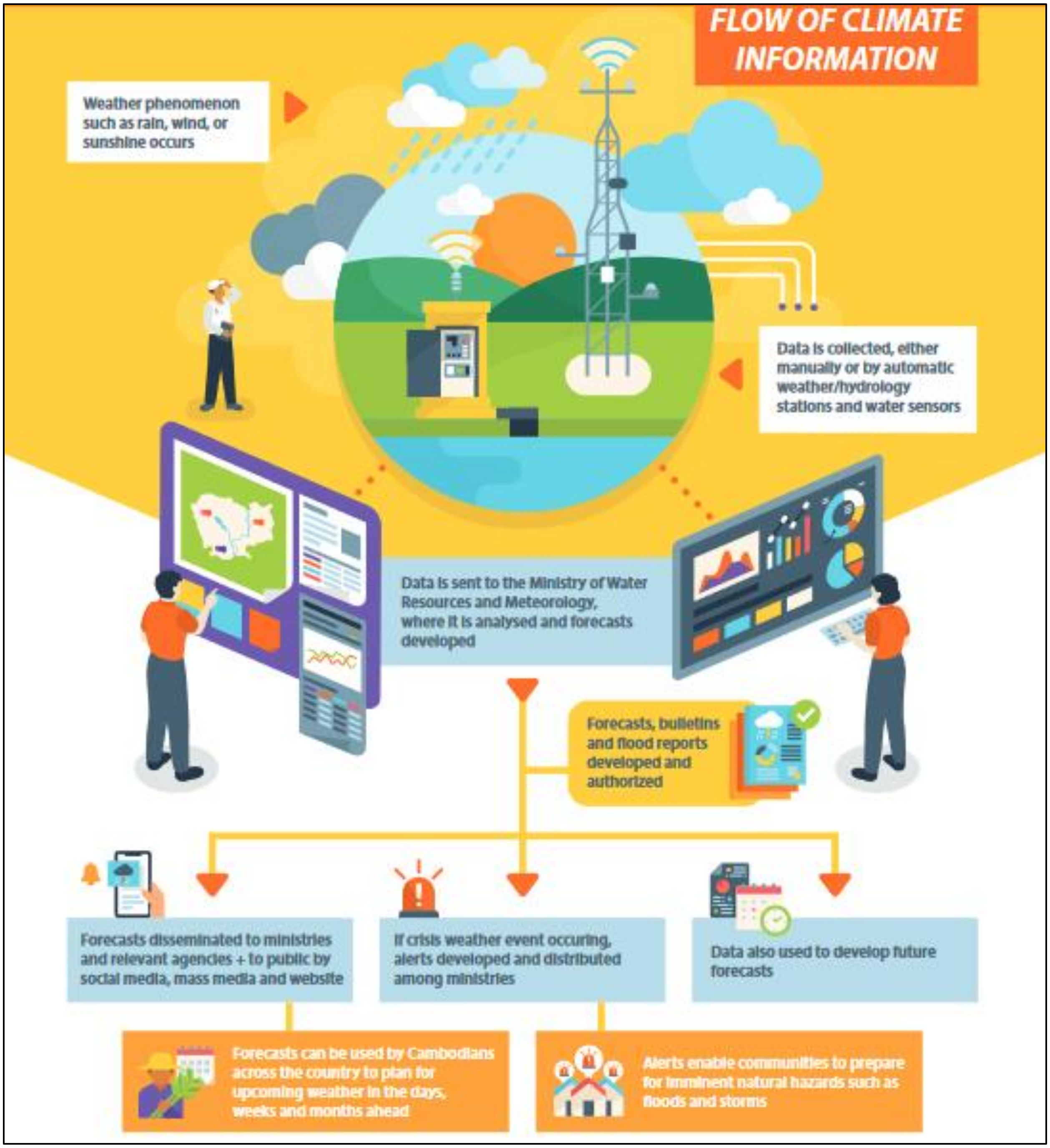
UN Office for Disaster Risk Reduction (UNDRR) defines an EWS as an integrated system of hazard monitoring, forecasting and prediction, disaster risk assessment, communication and preparedness activities systems and processes that enables individuals, communities, governments, businesses and others to take timely action to reduce disaster risks in advance of hazardous events. A complete and effective early warning system comprises of four elements as shown in the figure below.

Figure 1: Elements of an effective Early Warning System (adapted from UNISDR)

NMHSs commonly serve a national mandate to observe, forecast, and issue warnings for pending weather, climate and water threats. Accurate forecasting depends on a network of global, regional, and national remote and in situ observations of the atmosphere, oceans, and land that are conducted by NMHSs with multiple partners in most countries. Climate and weather observations are also often made by other agencies (e.g., agriculture, aviation, water, and energy) and increasingly the private sector, but these efforts are not often effectively coordinated. Sustainability of CIS is severely lacking in developing countries where constrained budgets do not prioritize meteorological services.

In Cambodia, the collection, analysis, and dissemination of CIS is the primary domain of the Ministry of Water Resources and Meteorology (MOWRAM). MOWRAM manages hydro-meteorological infrastructure, collects, collates, analyses and archives meteorological data, and provides CIS/EWS services and products. It currently provides city forecasts, radar animation, satellite animation, severe weather and safety warnings, and forecast products. Under its purview, MOWRAM has 24 meteorological stations and 114 hydrological stations. The general flow of information is depicted in the infographic on the following page.

The National Committee for Disaster Management (NCDM) is the primary entity responsible for operating the EWS. NCDM was established by a sub-decree in 1995 for the purpose of leading the management of disasters in Cambodia and developing disaster management capacity at all levels. The NCDM communicates early warning messages to the Provincial Committees for Disaster Management (PCDMs), the District Committees for Disaster Management (DCDMs), the Community Committees for Disaster Management (CCDMs), and the Village Teams for Disaster Management (VTDMs), as appropriate for action and response. While NCDM has a clear mandate, the exact legal authority of NCDM to exercise its mandate and responsibilities has yet to be clarified, due in part to its status as a committee. This has resulted in its mandated activities being at times undertaken by member ministries, sub-national disaster management committees and non-governmental organizations (NGOs) — blurring the lines of accountability and weakening NCDM's leadership role (UNDP, 2014).



A notable player in EWS provision is the NGO, People in Need (PIN) Cambodia, who developed a user-centered alert tool, called EWS 1294. First created in 2013 for the NCDM, EWS 1294 delivers advance warnings to people in areas that frequently flood. The system has now expanded to national coverage. Users have free access through mobile phones to voice-based early warning messages upon registration. This EWS will be discussed in more detail in Section 4.3.2.

1.5 Economic Context

The CIS/EWS market analysis is predicated on an understanding of the economic context in Cambodia. Weather, climate and disasters touch every sector and economic activity, some more than others. There may be untapped opportunities in Cambodia to create tailored products and services for specific clients and sectors, or vice versa for private sector actors to participate in the production of hydro-meteorological information. This section examines key sectors in Cambodia vis-à-vis climate impacts. Section 4 will then look at existing and potential market actors, products, and services within these sectors.

Over the past two decades, Cambodia has undergone a significant transition, reaching lower middle-income status in 2015 and aspiring to attain upper middle-income status by 2030. Driven by garment exports and tourism, Cambodia's economy has sustained an average growth rate of 8% between 1998 and 2018, making it one of the fastest-growing economies in the world (World Bank, 2020).

Agriculture remains the most important sector of the Cambodian economy in terms of its share of the Gross Domestic Product (GDP), and it employs the vast majority of the workforce. Rice is Cambodia's major crop, its principal food and most important export commodity. Major secondary crops include maize, cassava, sweet potatoes, groundnuts, soybeans, sesame seeds, dry beans, and rubber. The principal commercial crop is rubber.

Around 700,000 people, the majority of whom are women, are employed in the garment and footwear sector. An additional 500,000 Cambodians are employed in the tourism sector, and a further 200,000 people in construction. Tourism has continued to grow rapidly with foreign arrivals exceeding 2 million per year in 2007 and reaching 5.6 million visitors in 2017. Mining also is attracting some investor interest and the government has touted opportunities for mining bauxite, gold, iron and gems (CIA, 2020).

The garment industry operates largely on the final phase of garment production as the country lacks a strong textile manufacturing base. This phase of the process is relatively robust to climate change related impacts as well as climate variability and will not be examined further in this report.

Agriculture

Cambodia is considered to be one of the most vulnerable countries in the world given the predicted changes in temperature and precipitation, its share of labor in agriculture, and the country's low adaptive capacity. Temperature increases, rising seas and changes in rainfall patterns and distribution will lead to substantial modifications in land and water resources for rice production as well as in productivity and yield. Farmers face the seasonal challenges of droughts in the dry season and floods due to heavy rains in the wet season. Rainfall patterns have been shifting, with longer droughts, short rainy seasons and occasional flash floods. Impacts include increased risk of poor yields or even crop failure, and greater incidence of pest and diseases.

Temperature regimes greatly influence growth duration and patterns. Variability in the amount and distribution of rainfall is the most important factor limiting yield of rainfed rice. In Cambodia the predominant growing environment is the rainfed lowland rice crop, which accounts for over 90 percent of total wet season crop area. Variability in the onset of the rainy season leads to variation in the start of the planting season in rainfed rice. Complete crop failure usually occurs when severe drought stress takes place during the reproductive stages.

Flooding is also a central constraint to rice production in low-lying areas. The agricultural sector in Cambodia has been battered by weather extremes in recent years. The major flood of 2013 caused GDP to decrease by two percent and the widespread 2015-16 El Niño droughts led to yields drastically falling[2]. Floods cause indirect damage to rice production through the destruction of property and farmers' production means, and to critical infrastructure supporting rice production (e.g. dams, dikes and roads).

Localized climate information products and services in agriculture could reduce the climate risks on rice as well as other crops, livestock, fisheries and management practices. This tailored information can assist farmers and businesses in making management decisions that are climate-responsive and lead to resilient practices. More discussion on this is included in the Section 4 of this report.

Tourism

The tourism sector is one of the largest and fastest growing global industries and is a significant contributor to national and local economies around the world. During the last decade the tourism industry of Cambodia was one of the fastest growing tourism sectors in the world (Hess J. S., 2012). The main tourism attractions of the country are the temple complexes of Angkor and Phnom Penh with its Royal Palace, National Museum and Wat Phnom. Other frequently visited sites are the Killing Fields and Toul Sleng. Sihanoukville and its surrounding islands have more recently developed into a tourist hotspot, with the shoreline and beaches becoming an alternative to the crowded beaches of Thailand. Other attractions are located among the Mekong and in the mountain and highland regions, though these are still largely undeveloped.

Nearly all tourism destinations experience disasters of one form or another at some point in their history, with the COVID-19 pandemic being the most recent and extreme disaster in recent history. Despite this, few destinations have adequate disaster management plans in place to help

[2] https://www.eco-business.com/news/how-can-cambodian-farming-survive-climate-change/

them cope with such eventualities. Minimizing losses of life, livelihood, and property during disaster is generally an indicator of the destination's capacity to adequately prepare for and effectively manage disaster events. For the tourism industry, cooperation between local disaster management agencies and industry actors is crucial. For many countries, this remains a challenge yet an imperative for creating a resilient industry, with a sound reputation for managing disasters (UNEP, 2008).

The interface between climate and tourism is multifaceted and complex, as climate represents both a vital resource to be exploited and an important limiting factor that poses risks to be managed by the tourism industry and tourists alike. All tourism destinations and operators are climate-sensitive to a degree and climate is a key influence on travel planning and the travel experience (Scott, 2010).

Climate is a determinant of the suitability of destinations for tourism and influences the seasonality in tourism. It also affects the operating costs, especially related to heating or cooling, food and water supply, and insurance, thus having a significant influence on the profitability of tourism enterprises. Indirect impacts can also influence tourism through ecosystem changes and transformation of the flora and fauna, change in resource availability (such as water), damage to infrastructure, increase of pandemic diseases, altered agricultural production, and increased natural hazards. These indirect effects are likely to be largely negative though some destinations may be favored by improved climatic conditions (Hess, 2012).

Construction

The construction industry in Cambodia has been booming with accelerated demand for hotels, shopping malls, real estate and other key infrastructure. Foreigners are permitted to buy and own condominiums which has helped attract real estate investors from Thailand, Malaysia, Singapore and other countries. In 2012 the construction sector attracted investment of $2.1 billion, a 72 per cent increase on 2011[3].

The construction industry is typically viewed through the GHG emission lens in climate change policy realms given the large emissions footprint of the sector. However, the construction industry is by its very nature dependent on weather. Project planning and design are determined in large part by the landscape, geography and local weather. Building strategies and materials are tailored to suit a particular climate. In addition to the effects felt by citizens and residents, extreme weather events can derail projects, endanger workers and increase construction costs considerably (CMiC, 2017).

Worksite safety is of particular concern. Unpredictable rain and flooding can lead to deteriorating wood and slippery surfaces, increasing the risk of recordable injuries and creating unsafe working

[3] https://en.wikipedia.org/wiki/Economy_of_Cambodia#Construction

conditions. Higher temperatures can cause heat stress and lead to heat stroke, heat exhaustion, and even death. Workers might have to be changed out more often due to risks of heat stress or the work would have to be performed during a different shift resulting in slowdowns and additional labor expenses. There could also be a total reduction of the days when construction is feasible altogether. Some construction companies are facing increased insurance costs due to project delays related to extreme weather (Grant, 2018).

Weather also affects the performance and wear and tear of construction equipment. Dry weather can increase the amount of dust on the job site, which can jam and clog machinery. Strong winds can strain equipment and cause breakage. Hot weather can reduce the efficacy of materials like sealants and mortar. Higher temperatures create longer curing times for concrete, which extends construction time and skyrockets costs. Extreme hot or cold conditions may require additional specialized equipment resistive to such conditions resulting in cost overrun (CMiC, 2017).

CIS/EWS services for the construction industry would certainly help in the preparation, management, and response to such risks. There are a number of international providers of software, analytics, and tools to provide the construction industry with tailored CIS products and services (See Section 4).

Mining

Mining in Cambodia remains largely in the exploration phase but the industry is expected to grow. As of now, there is no large industrial-scale extraction of minerals carried out, but many exploration licenses have been granted including 3 major projects and a number of smaller ones for mining gold, iron ore, limestone, bauxite and coal[4]. There are more than 90 companies (from Australia, China, Vietnam, Thailand, and domestic) licensed to conduct exploration projects (Sustainable Engineering Solutions for the Mining Industry, 2020). Significantly, there are a large number of artisanal miners running small operations recovering gold and gemstones, often on a seasonal or part-time basis.

Disasters, changes to precipitation patterns, and rising sea levels may damage infrastructure. Existing assets may no longer be able to meet original design parameters and resource scarcity may constrain operations or increase costs. Flooding from increased rainfall in some areas can interrupt production, disrupt land transportation routes, degrade roads, and curtail production and efficiency. Employee health and safety is also a key concern, which is threatened by rising temperatures.

Mine sites operators are already using CIS to track changing weather conditions, making sure that everything from road conditions and visibility, blasting safety distances to ore loading weight are

[4] https://opendevelopmentcambodia.net/topics/industrial-mining-2/

considered. In Cambodia, the limitation of CIS could impede the growth of the mining sector. Concurrently, partnership with the mining sector could support the improvement of services beneficial for the sector as well as the broader public.

2. Stakeholder Analysis

This section highlights the important government and non-government stakeholders in the provision and/or demand of CIS/EWS. Private sector stakeholders are not discussed here due to a more detailed analysis later in this report. Research institutions, local civil society organizations, media, and other stakeholders are also not included in this analysis. The involvement of these types of stakeholders is absolutely critical for effective CIS/EWS. However, the purpose of this report is to strategize how government can engage private sector and so the analysis is limited herein.

2.1 Government Stakeholders

MOWRAM: Serves as the NMHS in Cambodia with the mandate to supply CIS and EWS to all relevant stakeholders. MOWRAM is discussed throughout this report in detail.

National Committee for Disaster Management: Responsible for disaster management and EWS. They serve as an intermediary between MOWRAM and other stakeholders in the delivery of the EWS services. NCDM is discussed throughout this report in detail.

Ministry of Environment: MoE is the coordination body for environmental issues including climate change. The Climate Change Office was established by the MoE in 2003 and then upgraded to the CC Department (CCD) in 2009. The CCD was designated as the secretariat for the National Committee on Climate Change (NCCC). The CCD has five units: the Administration Office; the GHG Inventory and Mitigation Office, the Vulnerability and Adaptation Assessment Office; the Policy Coordination Office and the Education and Outreach Office.

The CCD is the latest institution responsible for the coordination of climate change related work in Cambodia. After several reorganizations and reform processes over the years the CCD is now under the National Council for Sustainable Development-General Secretariat (GSSD) which is mandated to promote sustainable development aimed at ensuring economic, environmental, social and cultural balance within the Kingdom of Cambodia.

Ministry of Agriculture, Forestry, and Fisheries: MAFF consists of five departments: Agriculture, Livestock, Fisheries, Forestry, Rubber and Economic Land Concession. The Department of Agricultural Extension (DAE) is charged with contributing to the improvement of food security, rural income and agricultural production in Cambodia. The DAE has the potential to provide the interface between farmers and CIS dissemination.

Ministry of Health: MoH has developed three guiding documents on climate and health; the National Climate Change Strategic Plan for Public Health [2012], the Climate Change Action Plan for Public Health [2014-2018] and the National Strategic Plan for Disaster Risk Management for Public Health [2015-2019]. Climate information is included in the Integrated Disease Surveillance and Response (IDSR) system, including development of early warning and response systems for climate-sensitive health risks.

Under its sectoral CCSP, the Ministry sets objectives to enhance emergency preparedness and response to cope with extreme weather and climate change related disasters and the development and implementation of surveillance of extreme weather and related diseases, including respiratory diseases, injuries, malnutrition, food safety/consumption in synergy or collaboration with the Cambodian Red Cross, NCDM, MOWRAM and other relevant agencies (Ministry of Health, 2013).

Ministry of Rural Development: MRD is a multi-disciplinary institution, working in the areas of social and rural infrastructure in rural areas of Cambodia. They are responsible for rural road improvement, irrigation rehabilitation and water well construction. Social infrastructure and activities managed by MRD includes sanitation and hygiene, community development and capacity building, micro-credit provision, gender protection and indigenous population protection. The MRD has prepared its sectoral CCSP – however it does not include actions explicitly related to the use of climate information or early warning.

Ministry of Tourism: MoT has a role in managing and developing the tourism industry of the Kingdom of Cambodia. Its functions include the formulation of programs in compliance with national policies and to coordinate activities of various agencies including from the private sector for the development and promotion of tourism in the country. MoT has also prepared a Climate Change Action Plan for Ministry of Tourism (2015-2018). This plan however does not include strategies for EWS or use of CIS for managing impacts and risks.

Ministry of Industry, Mining and Energy: MIME is the government ministry responsible for governing the mining industry. It does not currently have any climate change related planning documents or strategies.

2.2 Regional Stakeholders

Mekong River Commission (MRC): MRC works directly with the governments of Cambodia, Lao PDR, Thailand and Vietnam to jointly manage shared water resources and to promote sustainable development of the Mekong River. MRC researches the impacts of climate change and supports knowledge and capacity building on climate adaptation and resilience. It’s Climate Change and Adaptation Initiative is a collaborative effort among MRC Member Countries to demonstrate and share adaptation strategies. With its emphasis on a basin-wide approach, the Initiative ensures that climate change adaptation is harmonized with effective strategies and plans at various levels and is applied at priority locations throughout the basin.

Access to climate change information through databases and forecasting of climate change risks and impacts on the hydrology of the Mekong River Basin are important aspects to be able to assess impacts on the environment and livelihood of people. These activities are prerequisites for effective decision making and are supporting MRC specific Goal 2 (Mekong River Commission, 2011).

WMO Regional Climate Centers (RCCs): WMO designated Regional Climate Centers (RCCs) generate and deliver more regionally focused high-resolution data and products as well as training and capacity building. They are centers of excellence that create regional products including long-range forecasts that support regional and national climate activities, and thereby strengthen the capacity of WMO Members in a given region to deliver better climate services to national users.

There are two RCCs that are particularly useful resources for Cambodia – the Tokyo Climate Center (TCC) and the Beijing Climate Center (BCC). TCC provides six key resources that MOWRAM and others in Cambodia can draw upon. These include: 1) iTacs, a web-based application that is interactive and helps to analyze extreme climate events and to monitor climate status; 2) Long-range forecasts using Japan's ensemble projections; 3) Monthly seasonal climate outlooks; 4) El Niño Monitoring; 5) ClimatView tool which enables viewing and downloading of monthly global climate data; and 6) TCC News, a quarterly newsletter on significant climate disasters and events, forecaster's commentaries on seasonal outlooks, and other relevant topics.

BCC organizes and coordinates research efforts on regional climate, operational predictions and climate application and services, among others. It provides climate services to China and other Asian countries for disaster prevention and mitigation and for socio-economic development. Services include operational long-range forecasts, climate monitoring, data services, use of regional climate products and training on service delivery and research on climate change. BCC is also engaged in climate data management and rescue for the Asian region and involved in the International ACRE (Atmospheric Circulation Reconstructions over the Earth) Initiative to facilitate the recovery of historical surface data in Asia.

ASEAN Specialised Meteorological Centre (ASMC): The concept of a specialized regional center to support the ASEAN region was initiated by the ASEAN National Meteorological Services in 1985. ASMC was officially established in January 1993 and is hosted by the Meteorological Service Singapore (ASEAN Specialized Meteorological Center, 2020). It provides a wide range of operational and regularly updated information and products on the weather, climate and smoke haze situation in the ASEAN region that can be used by meteorological experts and end users from different sectors (such as environment, forestry, agriculture, etc.). It also provides 1-month and 3-month seasonal outlooks, ENSO forecasts, and regional weather reports and updates.

Regional Integrated Multi-Hazard Early Warning System (RIMES) is an international and intergovernmental institution, owned and managed by its Member States, for the generation and application of early warning information. RIMES evolved from the efforts of countries in Africa and Asia in the aftermath of the 2004 Indian Ocean tsunami. The goal was to establish a regional early warning system within a multi-hazard framework for the generation and communication of early warning information, and capacity building for preparedness and response to trans-boundary hazards. Their role has expanded since then to broader support for NHMSs. RIMES is active in Cambodia, working with MOWRAM, UNDP, and other stakeholders to strengthen CIS/EWS.

2.3 International Development Partners

UNDP: UNDP has been working alongside various line departments including the MOWRAM, MAFF, and NCDM to address current barriers to CIS and EWS through three complementary outcomes: (1) installing automatic weather stations and automatic hydrological stations for climate data and information, as well as developing / proposing hydro-meteorological platform for climate modelling, (2) increased institutional capacity to assimilate and forecast weather, hydrological and climate information, and (3) dissemination of climate information for national, sub-national, and sectoral planning.

ADB: ADB's Greater Mekong Sub-region Flood and Drought Risk Management and Mitigation Project (2013–2019) has a component that supports the development of design criteria for flood and drought risk mitigation schemes and water control infrastructure in the Mekong Delta and elsewhere, the assessment of cross-border flood management options in Vietnam and Cambodia, and the strengthening of the National Flood Forecasting Center (ADB 2012).

The Climate-Friendly Agribusiness Value Chains Sector Project also funded by ADB and the Green Climate Fund (GCF) includes a component on Information and Communication Technology (ICT) tools that will help provide weather, market, and agronomic information to create a more effective environment for climate risk management and reduce the agriculture sector's carbon footprint.

JICA: The Japan International Cooperation Agency (JICA) provides assistance for the improvement of hydrological and meteorological services to enhance DRR capacity and climate change adaptation capacities. They work with MOWRAM to develop projects, support modernization of MOWRAM and equipment, and capacity building of MOWRAM staff.

2.4 NGOs/CSOs

People in Need (PIN): PIN is a Czech NGO that has been working in Cambodia since 2008. It has ongoing disaster risk reduction programs including a major initiative to create an EWS for the country in partnership with MOWRAM and NDC. They have developed a user-centered alert tool called EWS 1294 which is a phone-based EWS. Using sophisticated hazard-detection technology, data-storage tools and warning-dissemination software, EWS 1294 sends voice-based alerts and instructions to registered users when rivers and streams reach dangerous levels. This is further explored in Section 4.3.2.

Dan Church Aid (DCA): In Cambodia, DCA works with partners and the private sector by introducing innovative solutions to improve food security and disaster preparedness and response, with a strong focus on climate change adaptation. DCA has installed an AWS and launched the Khmer Smart Farming app which provides weather and climate advisories. DCA's work is further discussed in Section 4.3.3 on visualization and decision-support tools.

Joint Action Group for Disaster Risk Reduction (JAG): JAG is a non-formal group of civil society organizations (CSOs) working in Cambodia on Disaster Risk Reduction (DRR) and Disaster Management. Members coordinate relevant activities and share information, knowledge, skills and experience.

Cambodia Red Cross: The CRC is the largest humanitarian organization in Cambodia. It is officially recognized by the Royal Government as the primary auxiliary to the public authorities in humanitarian services. CRC mostly serves as a response organization but has piloted some EWS work in the country. For example, they implemented a two-way radio communication system that allowed Red Cross volunteers to send river level data to the MRC as well as to receive forecasts. Thirty-eight villages were chosen based on pre-established criteria including historic vulnerability to annual and flash floods, proximity to MRC water-level gauging stations, the presence of Red Cross volunteers and the level of interest among local communities and authorities. The forecasts are generated by the Department of Hydrology and River Works. Alarm levels and corresponding responses have been developed with the involvement of local communities. This EWS has been recognized as a positive example and has been incorporated into National and Cambodian Red Cross Society DRR strategies but has faced difficulties since the end of the externally funded project period (IFRC, 2012).

Monsoon Forum: Monsoon Forums were originally devised by RIMES and are now conducted in more than half a dozen countries around the world. It is a seasonal forecast-based planning mechanism aimed at optimizing both resource and risk management in various sectors. In Cambodia it is a regular platform for dialogue between Department of Meteorology and stakeholder institutions, including line ministries and sectoral departments. The Department of Meteorology convened Cambodia's first forum in January 2011, with the support of RIMES and the Food and Agriculture Organization of the United Nations (FAO). Subsequent forums have received the ongoing support of RIMES, FAO and the United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP) and UNDP.

3. Enabling Environment for CIS

3.1 Climate Policies

The Climate Change Strategic Plan (CCSP) 2014-2023 is the overarching climate policy underpinning climate change efforts in Cambodia. It is a coordinated strategy that provides a framework for action and is shepherded by the National Climate Change Committee (NCCC). The NCCC has as its Honorary Chair the Prime Minister of Cambodia and the Minister of Environment as its Chair.

The Mission of the CCSP has been to provide a national framework for engaging the public, private sector, civil society organizations and development partners in a participatory process for responding to climate change to support sustainable development. Amongst the various objectives, Objective 5 focuses on the improvement of capacities, knowledge and awareness for climate change responses. Under this objective, the key strategies related to CIS and EWS include the following:

- Strengthen the capacity for collection, analysis, modelling and interpretation of climate data and information dissemination to various end-users, including seasonal forecasting for adaptation and community early-warning facilities for disaster risk management;
- Improve the national weather monitoring and forecasting systems and develop partnerships for creating downscaled models of future climate;
- Develop early-warning systems and programs for climate-related disaster management and recovery.

3.2 Development Policies

The RGC in 2004 adopted the **Rectangular Strategy** for Growth, Employment, Equity and Efficiency (RGC 2004) as the framework for the country's socio-economic development. The strategy is now in its fourth phase. Founded on the platforms of good governance, peace, political stability, social order, macroeconomic stability, partnership and economic integration, the Rectangular Strategy focuses on critical development issues such as the enhancement of the agricultural sector, rehabilitation and construction of physical infrastructure, private sector development and employment generation, and capacity development and human resource development.

Rectangle four which deals with inclusive and sustainable development is where climate change issues are situated in this framework. Side 4 of the rectangle is focused on ensuring the environmental sustainability and preemptive response to climate change with the goal to minimize environmental impacts, enhance the capacity to adapt to climate change, and contribute to reducing global climate change to ensure sustainable development. The strategy does not address the need for basic observational and monitoring systems of weather and climate as a path toward greater adaptive capacity.

The **National Green Growth Roadmap** was created to conserve and restore the natural capital base while promoting economic growth within the limits posed by the environmental carrying capacity of the country. The roadmap proposes possible paths for short, medium, and long-term implementation of green growth in Cambodia. In doing so, it suggests win-win-win situations between economy, environment and society to show that economic growth, environmental sustainability and human well-being can be achieved (Kingdom of Cambodia, 2009).

The roadmap addresses the need for hydro-meteorological services in the context of agriculture. MAFF's role is discussed in terms of conservation of soil and water resources, integrated pest management, and reduction of non-point source pollution. However, the strategy neglects to mention the importance of CIS as a prerequisite. Without the effective delivery of information by MOWRAM, MAFF cannot achieve its goals. Promotion of sustainable irrigation infrastructure, effective and efficient management of water catchments, rivers, lakes, streams and other water sources and mitigation of flood impacts is all dependent upon good CIS/EWS.

3.3 Disaster Management Policies

The NCDM is responsible for disaster risk management and communicating related information. NCDM developed the Strategic National Action Plan for Disaster Risk Reduction (2008-2013). While this document mentioned the risks of climate change, it did not mainstream climate change into its strategic planning and rather suggested this as a future outcome. As per this recommendation as well as the directives of the CCCSP, NCDM developed a Climate Change Strategic Plan for Disaster Management Sector to mainstream climate change into its role. This was followed-up by a National Action Plan for Disaster Risk Reduction (2014-2018). This has most recently been updated with the National Framework for DRR (2019-2030) and National Action Plan for DRR (2019-2023).

The Strategic Plan addresses EWS explicitly through its Action Fiche 5 whereby it aims to set up or strengthen sub-national early warning system and communication mechanism in cooperation with concerned ministries, agencies, mobile phone companies, and commune/Sangkat councils. Specially, it calls for the establishment of the EWS in partnership with MOWRAM along with personnel and equipment for 171 district and provincial offices.

As mentioned previously in this report, the lack of clear legal authority and directives have hampered the NCDM in delivering effective services it is mandated to provide, including EWS.

3.4 Sectoral Policies

Alongside the CCCSP, line ministries have developed their Sectoral Climate Change Strategic Plans (SCCSP) to guide the integration of climate change into their sectoral planning. While the CCCSP provides a national perspective and framework for addressing climate change, the SCCSPs of the line ministries focus on sector-specific responses to climate change.

Most relevant to CIS and EWS aspects of climate change include 1) Climate Change Action Plan for Agriculture, Forestry, and Fisheries; 2) Climate Change Action Plan for Water Resources and Meteorology (2013-2017); and 3) Climate Change Action Plan for Ministry of Environment. These are all now out of date, and no new plans or strategies have replaced these at this time. However, it is useful to assess progress against the CIS and EWS targets.

The CCAP for Agriculture, Forestry and Fisheries deals mostly with the impacts of climate change and how the agricultural sector can respond. It also integrates into its plan some CIS related actions including:

- Collection of agro-climatic data which is interpreted according to agro-ecological zones and disseminated to farmers
- The development of climate change scenarios specific to the agriculture sector
- Promotion of relevant weather forecast at the provincial level through telecom services

3.5 PPPs and Private Sector

A public-private partnership (PPP) is a long-term contract between a private party and a government entity for the purpose of providing a public asset or service, in which the private party bears risk and management responsibility and payment is linked to performance (World Bank, 2017). Historically, PPPs have focused on infrastructure development, particularly in the transportation and energy sectors. Today, PPPs are expanding to encompass a wide variety of industries and services. Although PPPs are not commonly used for the provision of CIS or EWS, they do show a promising model for how public finance can be used to leverage private capital. In addition to attracting financing, PPPs allow the public sector to leverage private-sector technical expertise to fill capacity gaps.

The Private Sector Development Steering Committee (PSDC) is responsible for PPPs in Cambodia. Expectedly, these are exclusively focused on large capital development projects and infrastructure. Learning from PPP frameworks and adapting them to the provision of CIS, particularly the data infrastructure, could prove useful. A PPP in the CIS/EWS sector could have several components including shared initial investment, shared operational responsibilities and data rights, and revenue sharing from ongoing data services. This model is worth exploring further in the future and is discussed more in Section 5 on Recommendations.

4. CIS/EWS Market Analysis

Although MOWRAM is nationally mandated with the responsibility to observe, forecast, and issue public warnings for pending weather, climate and water threats, they do not operate in isolation. A wide range of additional actors can and should be involved in the provision of CIS including academic institutions, private sector companies, civil society and non-governmental organizations, and other public-sector institutions with mandates to provide CIS to their stakeholders. By combining assets and resources through partnership, a more cost-effective and sustainable way forward for the sector can be devised.

For example, a partnership between a private provider of Geographic Information Services (GIS) and MOWRAM to deliver CIS to a community of rice producers would be more cost-effective than if each institution chose to independently develop the skill or capacity of its potential partner. Public-private-academic partnerships can also increase the utility of services to end users while also providing more cost-effective CIS by accessing the expertise and assets from each partner and reducing the duplication of effort and expense.

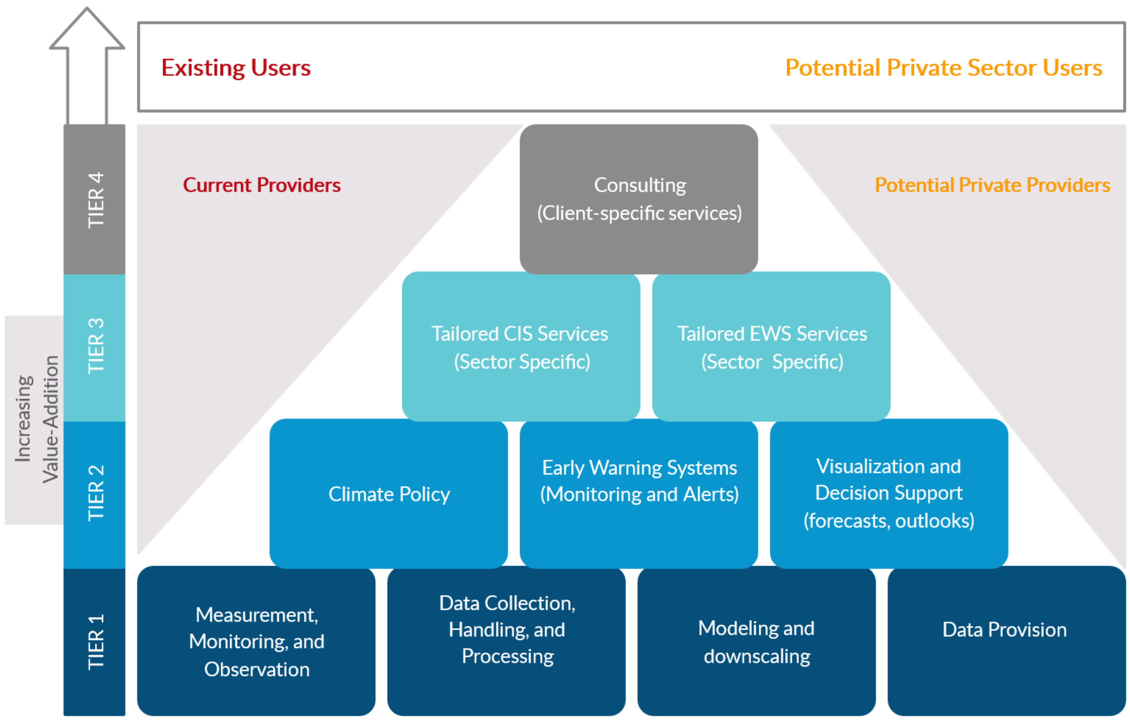
This report is focused on the engagement of private sector in the delivery of CIS and EWS and this section seeks to analyze the opportunities for engaging the private sector in both delivery of CIS as well as demand and willingness to pay for services.

The figure below depicts the framework for analysis developed for this purpose. It groups CIS/EWS in terms of tiers of value-addition. The tiers consist of services that can be provided by an NMHS, with the tiers moving from predominantly generic at the bottom of the pyramid to more customized service delivery at the top. Tier 1 comprises available services from mostly public providers to an increasing share of commercial provision and highly customized services from private businesses moving toward Tier 4 of service delivery.

Each layer however holds the opportunity for private sector engagement and partnership, but as the market analysis will illustrate – some areas are better suited than others for private actors to be involved. The left side of the diagram represents the baseline situation in Cambodia with existing users and current providers in the value-chain, whereas the right side represent the potential for private sector engagement from both demand and supply perspectives.

The following sub-section will describe both the left and right sides using the Tiers of Service as the lens for analysis and will describe the current supply and demand and the potential private sector entities to engage as suppliers and consumers in the future. Demand and willingness to pay will also be explored.

FIGURE 2: FRAMEWORK FOR ANALYSIS OF PRIVATE SECTOR ENGAGEMENT IN CIS/EWS IN CAMBODIA



4.1 Demand and Willingness to Pay for CIS/EWS

As governments and industries are prioritizing climate change more and more, climate services are emerging for a broad range of actors and for multiple purposes. CIS/EWS offer huge societal benefits, the value of which is not always well-understood. Costs are incurred by NMHSs for human resources, infrastructure, energy and other natural resources to cater to demand from a diverse customer base of citizens, government departments, aviation, agriculture, tourism, and other sectors. Yet these services are often provided for free or well below cost, despite indirectly generating market-based economic activity in transportation, agriculture and tourism. The World Bank Group estimated in a study that improved weather, climate, and water observation and forecasting could lead to a global increase in productivity amounting to US$ 30 billion per year and up to US$ 2 billion per year in reduced asset losses (WMO, 2015). A thorough review of the demand and benefits derived from CIS/EWS in Cambodia may encourage policymakers to mobilize and allocate adequate financing and budgets for improved service delivery.

Fundamental to identifying the potential for growth is identifying and actively building the demand for CIS/EWS. A lack of willingness to pay for CIS/EWS is a clear obstacle to private sector engagement in this sector. Many end-users believe that climate and weather information should be a free public good or do not understand the value of timely, reliable CIS/EWS. However, research and experience from around the world show that when the services are tailored to the needs of end-users, they are willing to pay for them. Thus, an essential element to growing demand and a concurrent willingness to pay by users is through demonstration and promotion of the value that is added through CIS/EWS.

An end-user is generally an individual or organization that makes decisions in a climate-sensitive context and to who some form of climate information is delivered. However, often it is difficult to have a clear-cut differentiation between users and providers. As the value chains that are built up in the generation of climate services are typically multi-stage and can take different routes, many organizations in intermediate positions are both providers and users (Cartecar, Lamich, Otto, & Pawelek, 2017). For example, an airport that hosts a weather observation station is both supplying information to the NMHS as well as using it for managing their own operations.

Knowledge varies dramatically from sector to sector and from user to user. It is clear that the current demand and willingness to pay for climate services in Cambodia is less than what is required to deliver effective services. It is vital for MOWRAM to shift from being supply-driven and toward a user-informed service model. This would include an understanding of the drivers that encourage the use of climate services such as economic benefits accrued, protection of workers, responding to policy, etc. An analysis of constraints in using CIS is also needed (e.g., integration into existing decision framings and processes, and translating implications into economic terms) and attributes and modes of required services (e.g., reliability, fit-for-purpose, usability, trust, and the balance between freely available services and services for a fee) (Street, 2016).

The table on the next page presents the types of end-uses that are typically derived from CIS/EWS in various industries.

Table 1: Examples of CIS/EWS User Needs

Sector	CIS/EWS Needs
Aviation	- Reducing wait times on runways - Accident reduction through in-flight hazards (e.g. icing, lightning, wind shear) - Aircraft route forecasts - Aerodrome forecast
Agriculture	- Crop management (e.g., timing of planting/harvesting, selection of crops) - Irrigation decisions - Input use (e.g. fertilizer application) - Herd management - Predicting commodity prices - Developing index-insurance for crops - Early warning for food security - Climate risk management
Insurance and Reinsurance	- Modeling of crop production - Early warning for extreme events - Pricing risk for insurance products - Understanding risk exposure
Telecom	- Early warning for clients - Bundling weather information with other services
Fisheries	- Preparedness for algal blooms - Harvest management - Vessel operations and hazard warnings
Water Resources	- Storage/release decisions - Water pricing/allocation - Adoption of conservation measures - Design of infrastructure
Energy	- Managing emergency response - Managing capacity and resources (grid/distribution management) - Optimizing reservoir/hydropower operations - Commercial/residential consumption decisions
Construction	- Management of heat stress-related risks - Scheduling according to weather conditions - Assessing insurance needs
Tourism	- Event management - Reducing long-term climate risks - Early warnings for tourists
Mining	- Road access - Slope stability - Construction of mine infrastructure - Safe working environment - Dispersion of hazardous gases

4.2 Tier 1 Services

Tier 1 Services serve as the backbone of the CIS/EWS sector and is often the sole responsibility of the NHMS in a country. Services in this tier include: 1) measurement, monitoring and observations; 2) data collection, handling, and processing; 3) modeling and downscaling; and 4) data provision. Each service function within this Tier has varying actors involved and so each one is analyzed accordingly in the following sections.

4.2.1 Measurement, Monitoring, and Observation

Current Providers

The measurement, monitoring and observation systems comprise include two subsystems—the global data system and the national data system. This includes all of the data available through the WMO and other global and regional service providers that is accessible by MOWRAM as well as the national observational systems managed by MOWRAM and other agencies in Cambodia.

UNDP has conducted one of the most recent and comprehensive reviews of MOWRAM's measurement, monitoring and observations network as part of the project development process for the *Strengthening climate information and early warning systems in Cambodia to support climate resilient development and adaptation to climate change* project – the same project under which this study is being produced. The following information is referenced from the Project Documents submitted to the Global Environment Facility.

As a WMO member, DOM currently accesses meteorological data and information (i.e. satellite data, storm information, ground and atmospheric meteorological parameters) from various meteorological agencies in the region and globally, namely Japan, China, Korea, Thailand, France, and the United States. DOM uses SYNERGIE software to generate forecasts and models, and has access to run weather research and forecasting (WRF) models online via the Regional Integrated Multi-Hazard Early Warning System for Africa and Asia (RIMES) (UNDP, 2014).

In 2012, MOWRAM installed and put into operation, a Doppler Rainfall radar (C band) with a range of 480km, which was expected to improve weather and rainfall forecasting. However, it still faces many difficulties, mainly the lack of experienced and dedicated meteorologists to operate the system, including conversion software.

DOM's meteorological observation network consists of 24 synoptic stations, 1 in each of the 24 provinces in Cambodia and 200 rainfall stations. There are also 114 hydrological stations managed by the Department of Hydrology and River Works (DHRW) within MOWRAM. DHRW is tasked with the installation, monitoring and O&M of hydrological stations on the main streams to serve water resources development and EWS.

An assessment conducted in 2013 as part of a UNDP study indicated that most stations are not fully functional and require repair, upgrade or replacement. With different brands and models at different sites, the assessment further revealed that there did not appear to be a standardized approach to procurement of equipment in the past.

Outside of government, there are some small scale investments in monitoring stations such as the installation of two Automatic Weather Station (AWS) by DanChurchAid/Christian Aid (DCA/CA) in the Samaky Meanchey district of Kampong Chhnang province and another in the Lumphat district of Ratanakiri province. The project is community-focused, and the data collected from the stations does not yet get fed back to DOM for national use and analysis. These stations were not procured with standardization needs of the national network as the selected brand is not currently used in the country. Another example is the installation of AWS by Earth Networks and Smart Telecom. These are also not integrated into MOWRAM's systems. PIN also operates sensors across the country for flood and drought warning.

An AWS is installed at the Phnom Penh airport as per requirements of the International Civil Aviation Organization (ICAO). It needs to be explored whether other airports in the country have any weather monitoring capabilities. ICAO is a UN specialized agency established in 1944 to manage the administration and governance of the Convention on International Civil Aviation (Chicago Convention). ICAO works with the Convention's 193 Member States, including Cambodia, and industry groups to reach consensus on international civil aviation standards and Recommended Practices (SARPs) and policies in support of a safe, efficient, secure, economically sustainable and environmentally responsible civil aviation sector (ICAO , n.d.). While ICAO establishes the requirements for meteorological services to international aviation, the WMO establishes how to meet these requirements and sets standards for service delivery. The aviation sector and CIS are very closely linked and the box below highlights how they can be mutually supportive and lead to sustainable CIS services and cost-savings for the industry.

BOX 1: Potential for Aviation to Support Sustainable CIS

Aviation is highly sensitive to weather conditions and aviation is a major consumer of climate services across the world. NMHSs typically provide the data, products and services that contribute to the safety and economic operations of the sector. Aviation meteorological services provide a major contribution to many NMHS budgets through cost recovery through the imposition of on-route and landing charges on airline operators (Shun, LIsk, McLeod, & Johnston, 2009). In this way, the private sector is indirectly financing weather services in many countries, particularly in the developing world where other sources of cost recovery are negligible.

In many countries the charges are set by regulators who tend to apply discounted pricing for CIS. Moreover, many commercial aviation companies purchase CIS from the government and the government does not always allocate the funds back to the NMHS. Greater allocation of aviation fees toward NHMS has the potential to create more sustainable and effective CIS/EWS capabilities.

This is particularly important in the context of the growth of the aviation industry whereby global air traffic is doubling every 15 years (ICAO 2014). As the industry grows and evolves, cutting-edge aeronautical meteorological services, which need to be seamless and coordinated at the regional level are necessary. The implementation of a quality management system (QMS) comprising procedures, processes and resources necessary to facilitate quality management of the meteorological information is of paramount importance (WMO, 2014).

There is mounting evidence of the economic value of CIS that can help in advocating for cost-recovery models that reflect actual expenditures by NHMSs. Some studies have demonstrated this value, examples of which include[1]:

- 58 million in annual benefits to U.S. aviation sector in reductions in accidents and flight delays with NOAA's GOES (NOAA, 2002).
- $580 million in annual delay reductions at U.S. airports with use of Federal Aviation Administration's Terminal Convective Weather Forecast (6% of U.S. weather delay costs in 2001) (Sunderlin and Paull, 2001).
- Annual benefits of terminal wind information for reducing flight delays: $25.7 million at Los Angeles, $16.7million at Seattle, and $119 million at San Francisco airports (Evans et al., 1999).

Potential Private Sector Engagement

There has been a global rise in the installations of personal and professional weather stations by non-governmental entities. However, this is less often observed in low and middle-income countries. Private sector engagement in the investment into hardware and software elements are limited to pilot projects in the Cambodian context as the market for services is underdeveloped. This reduces the viability and Return on Investment (ROI) on hardware and measurement systems.

Nevertheless, it is worth exporting opportunities, particularly with advancements in technology and systems occurring in the meteorological observational systems sector. Weather satellites, AWS, airborne hardware such as weather balloons and drones, LiDAR, and other hardware and software solutions can all be part of a modernization effort that MOWRAM can undertake in partnership with the private sector.

As discussed in the previous section, the aviation sector is an important user of real-time observational data. There are two potential paths for engaging the aviation industry in the improvement of observational systems. Firstly, and commonly, is the operation of airport weather stations which are automated sensor suites designed to serve aviation and meteorological operations, weather forecasting and climatology. Automated airport weather stations have become part of the backbone of weather observing in the United States and Canada and are becoming increasingly more prevalent worldwide due to their efficiency and cost-savings.

Cambodia currently has a weather station at the Phnom Penh International Airport. There are 2 other major airports in the country (Siem Reap and Sihanoukville) but it is unclear during the time of this study whether they currently have any observation stations. The State Secretariat of Civil Aviation oversees the operations of all airports in Cambodia and should be involved in further development of the private sector engagement strategy for CIS/EWS.

The second path worth exploring is the Aircraft Meteorological Data Relay (AMDAR) system. AMDAR is a program initiated by the WMO in cooperation with aviation partners and has led to the development of the AMDAR observing system. The AMDAR system utilizes predominantly existing aircraft onboard sensors, computers and communications systems to collect, process, format and transmit meteorological data to ground stations via satellite or radio links. Once on the ground, the data is relayed to NHMSs, where it is processed, quality controlled and transmitted on the WMO Global Telecommunications System (GTS).

The data collected is used for a range of meteorological applications, including public weather forecasting, climate monitoring and prediction, early warning systems for weather hazards and, importantly, weather monitoring and prediction in support of the aviation industry. Perhaps one of the most important attributes of AMDAR data is their cost: a vertical sounding of temperature and wind derived from an aircraft on ascent or descent produces a profile that is typically less than 1 per cent of the cost of a radiosonde sounding. In addition, in some areas of the world, AMDAR soundings provide the only information available on the detailed vertical structure of the atmosphere (Grooters, 2008).

Real-time use of high-quality vertical profiles of AMDAR temperature and wind in Australia, Canada, Hong Kong (China) and the USA has proved to contribute significantly to the improvement in short-to medium-term forecasting applications. They are particularly useful for nowcasting situations, where conditions are changing rapidly and are therefore of special use to the aviation industry[5].

AMDAR provides an opportunity for special collaborative programs to be developed between countries operating long-haul flights into countries in data sparse regions that are unable to

[5] Ibid

develop local programs of their own. For example, the European AMDAR program has commenced providing AMDAR data for the "Agence pour la Sécurite de la Navigation Aérienne en Afrique et à Madagascar" (ASECNA) group of countries in Central and West Africa using long haul aircraft operating from Europe. Optimization systems are also being developed that will provide targeted data to better define the atmosphere in areas of special meteorological interest (International Amdar Program). These systems will be used operationally to provide improved lead-time and quality of forecasts of major weather events.

In WMO's Region II (Asia) there are several airlines that participate in the AMDAR program including Air Nippon Airways, Asiana Airlines, Cathay Pacific, China Southern Airlines, Dragon Airlines, Japan Airlines, Korean Air, and Shandong Airlines. Moreover, many long-haul carriers from North America, Europe and Asia are participants.

Another innovative strategy for leveraging the private sector for measurement and observational infrastructure is to engage the telecom industry. A new but promising area that is being explored in Africa and Asia is the installation of all-in-one AWS on mobile phone towers. Cell-phone networks are rapidly spreading and offers several opportunities for CIS/EWS provision. One is to leverage local cellular telephone networks to develop/expand national observation networks. As for-profit ventures, the telephone companies (or their supporting cell-tower service companies) have strong incentives for maintaining the functionality of equipment supporting the services they provide. They have the cash flow to provide security, reliable electrical service, automatic rerouting during outages of links, and wide bandwidth connectivity at each cell tower. The companies also have trained electronics and mechanical staff to install and maintain the equipment at each cell-tower site (frequently trained in-country and paid wages that allow for retention) (Snow, et al., 2016).

This strategy is currently being pioneered in Cambodia in a partnership between Earth Networks and Smart Axiata. The information from the AWS is packaged and disseminated through the Smart Weather App which provides CIS/EWS services to Smart users. More information on the application interface and services is provided in Section 4.3. Earth Networks decided to work in Cambodia as part of its expanding footprint in Asia and an analysis of where CIS has the potential for large impact. Identification of a reliable, widespread, and interested telecom was also a necessary prerequisite for investment. After identifying Smart as a partner and conceptualizing the project – Earth Networks has invested in 16 stations that include an AWS as well as lightening sensors that are used for severe weather early warnings. They have also trained Smart technicians in the installation and O&M of the equipment and provide continuous support services to ensure the sustainability of the equipment. The business model and ROI in this case is not fully clear, but interviews suggested a time horizon of 5-10 years to recoup costs and generate revenues through multi-user fees.

A parallel area of development in the use of telecoms infrastructure for weather monitoring is the so-called passive weather monitoring approach of analyzing radio spectrum propagation and degradation. This approach exploits the fact that the strength of electromagnetic signals is weakened by certain weather conditions, especially rain. Rainfall monitoring using microwave links has proved to provide accurate mapping and measurements. This technology/method is not currently used in Cambodia but may be further explored with Smart and other telecommunication providers.

Operations and Maintenance of the hydro-meteorological observation network is a major impediment in Cambodia due to lack of resources and capacities. MOWRAM is responsible, through its departments, for the collection of data as well as the O&M of the stations. The annual budget allocation from MOWRAM is estimated $25,000 for O&M of the country's meteorological stations and $12,500 for the hydrological stations. A more appropriate level would be approximately $2,500/per meteorological station/per year and $2,000 per hydrological station/per year or $60,000 for meteorological stations and $228,000 for hydrological stations. While MOWRAM acknowledges that the current budget is insufficient, it has faced difficulty in securing the necessary budgetary approvals for the required amount (UNDP, 2014).

Private sector engagement in O&M could prove a useful strategy. The key would be to identify partners/sectors that are a good fit for this type of engagement. Key characteristics of partners should include some or all of the following: 1) direct impacts on their businesses due to poor CIS/EWS services; 2) in-house technical capacities that can be directed toward O&M of stations; and 3) demand for tailored weather products. A partnership arrangement may entail tailored CIS for the client in return for assistance in O&M either financially or in-kind. Potential partners may include tourism operators (hotels, attractions, etc.), hydropower developers, agribusinesses and cooperatives, and large construction companies. Even public buildings facilities could be engaged – in Kenya, for example, weather stations were installed in schools and operated and maintained by students and teachers as part of their curriculum.

4.2.3 Data Collecting, Handling and Processing

Current Providers

The data obtained from the observational networks described above are brought to a central point where they are subjected to rapid QA/C and merged with similar data from surrounding countries, followed by analysis and assimilation. DOM's data collection, handling and processing capacities have been grossly under resourced in the past and rely on donor funding. Data transmission from the provincial stations used to be manually operated using HF single side band radio, public telephone, and fax which was then compiled into the prepared format for transmission to the GTS link. They continue to use manual readings for older equipment, but AWS now dominate their system and are thus no longer require manual data assimilation for majority of their data.

Potential Private Sector Engagement

Though DOM has been gradually building its ICT capacity for analysis, assimilation, product generation, and archiving required for CIS/EWS, there remains a need to continue developing this capacity and regularly updating DOM systems. Private sector engagement may provide additional needed expertise, technological solutions, and investment to support this essential step in CIS provision.

DOM's observational network and central network processing system should be very well coordinated. Private sector expertise can be leveraged for developing a database and information management system, back-up systems, development of data QC methods, use of cloud computing, etc. A key consideration here is to create an information management system that can integrate all meteorological data into one place so that it can be combined, analyzed, and shared easily.

Cloud computing in particular is growing as a means to parse, store, query and analyze data. NHMSs can use cloud distributed storage to store and query meteorological data in real time, utilize big data computing services to analyze and process meteorological data, and finally use various app services to set up meteorological platforms and apps. These types of cloud computing services provide a viable and relatively inexpensive alternative to the implementation and maintenance of in-house IT infrastructure. In addition to more effective CIS services, cloud computing can decrease expenses and limit the impact of unstable power and air conditioning systems in computer rooms at DOM. International providers of this services include IBM, Amazon Web Services, Google Cloud, and Alibaba's Tablestore.

4.2.4 Modeling and Downscaling

Current Providers

The DOM currently uses SYNERGIE software for modeling and forecasting. SYNERGIE has been developed by Meteo France International (MFI), a for-profit subsidiary of Météo-France, the French National Meteorological Service. It is a workstation that includes functionality for general forecasting as well as more tailored products for weather sensitive sectors such as agriculture and aviation. DOM also has access to the Weather Research and Forecasting (WRF) model through RIMES (UNDP, 2014). WRF is a next-generation mesoscale numerical weather prediction system designed for both atmospheric research and operational forecasting applications. WRF serves a wide range of meteorological applications across scales from tens of meters to thousands of kilometers.

In addition to operational forecasting, demand is growing for long-term climate information at the national to local scale. Global level projections are widely available and produced through Global Climate Models (GCMs), among which the most widely used is the Coupled Model Inter-comparison Project, Phase 5 (CMIP5) models included in the IPCC's Fifth Assessment Report

(AR5). GCMs however do not provide information at a sufficient resolution to fit the needs of sub-national adaptation planning.

Downscaling information consists of two general approaches, dynamic and statistical. Dynamical downscaling involves the use of Regional Climate Models (RCMs) that better represent local terrain and climatic processes over a region. Statistical downscaling uses statistical methods to relate large-scale climate features to local climate. The advantage of using dynamical downscaling is that a regional model can simulate local fine-scale feedback processes not anticipated with statistical methods. However, RCMs require robust input data and are thus computationally more complex.

In Cambodia, downscaling long-range climate projections to finer resolutions is not currently under the purview of the DOM, who play only a data provision role in this service. Rather, this function is primarily fulfilled by the Ministry of Environment and the Department of Climate Change under the National Council for Sustainable Development (NCSD). Several academic and research institutions, nationally and regionally, are also involved in downscaling activities.

Cambodia’s Initial National Communication, prepared in 2002, contained one of the first attempts to build climate change scenarios using CCSR and CSIRO GCM models. The uncertainty was significant and significant deviation from observed and modelled precipitation were noted. Subsequent efforts to downscale climate information has included the use of Regional Climate Scenario Generator (MAGICC–SCENGEN) and for the preparation of the Second National Communication (SNC).

In the SNC, regional climate models in combination with GCM models were run by the Climate Risk Assessment Division, Center for Global Environmental Research, National Institute for Environmental Studies (NIES) with a resolution of 100 × 100 kilometers. To address the scarcity of historical climate data, long time historical climate data was reconstructed using PRECIS. The PRECIS climate model (stands for "Providing Regional Climates for Impacts Studies") is an atmospheric and land surface model of limited area and high resolution which is locatable over any part of the globe.

Another effort was the creation of future climate projections on a daily basis for the two IPCC Special Report on Emission Scenarios (SRES) scenarios (A2 and B2) provided by the Southeast Asia System for Analysis Research and Training Regional Center (SEA START Regional Centre). These were based on the European Centre Hamburg for Medium Range Weather Forecast (ECHAM4) GCM from the Max Planck Institute for Meteorology, Germany and downscaled to the Mekong region using the PRECIS system.

Another supplier of downscaling capacities is the CORDEX project, which provides global coordination of Regional Climate Downscaling. Cambodia is involved in this program with the Paññāsāstra University of Cambodia as a key focal point.

Potential Private Sector Engagement

The private sector is already engaged globally through consulting companies that provide customized and downscaled climate information. Most of these products and services are in the form of forecasts and tailored information. The potential for this kind of engagement is discussed in more detail in following sections as there is more utility with greater value-added then just downscaled climate information. This information needs to be contextualized and packaged to create revenue-generating activities.

A potential option for enhancing modeling capabilities is to upgrade DOM workstations to the new web-based platform called SYNERGIE Web. Given that DOM is already familiar and has developed capacities to use this platform, an upgrade may provide an efficient path toward improved capabilities. The benefits discussed in the previous section on data handling and processing would also be covered under this arrangement. SYNERGIE-WEB precludes the need for specific software required on visualization, no IT maintenance / administration, and low deployment and operating costs. It has multiple functions including general, aviation and marine forecasting, severe weather monitoring, now-casting and specialized tools for weather sensitive end-uses.

In terms of long-range climate projections and scenarios, many industries have short planning horizons and are less interested in climate change impacts on their work. However, this is not true of all sectors. The insurance industry, for example, is a potential partner for advancing downscaled climate change projections. For insurers, engaging on climate risk management is a business prerogative given the inherent nature of the industry. The core competencies of the insurance industry lie in the assessment and management of risk and this area is becoming increasingly essential given global trends toward risk-based regulatory regimes such as the Task Force on Climate Related Financial Disclosures (TCFD) in Europe. Important to note that this impetus also drives institutional investors who are also expected to disclose and account for climate risks.

As part of this policy shift, insurance companies may be expected to evaluate all types of foreseeable risks including climate risks and allocate sufficient capital to assume the risks. These companies have traditionally used catastrophe models based upon historical statistics, but these are proving insufficient in capturing climate change-induced variability. It is thus in the interest of the insurance industry to have finer scale and accurate climate models. Moreover, the insurance industry is uniquely positioned to further scientific understanding of the risks of climate change on societies and their livelihoods. This is because insurers play a dual role where they are both managing risk by insuring assets while also being long-term investors in the economy. The insurance industry's societal mandate is to devise innovative risk-transfer solutions that minimize the financial consequences of uncertainty. In the face of climate change, such a mandate is now more relevant than ever (Geneva Association, 2018).

Cambodia’s insurance industry is relatively small but expanding. The International Monetary Fund (IMF) puts the insurance sector’s contribution to Cambodia’s gross domestic product (GDP) of $24.5 billion at 0.8 percent. Policy and legislation allow of 100% foreign direct investment in the insurance industry resulting in both domestic and foreign insurance companies being active in the country. According to a study, the top four general insurers together account for 84.2% of the country’s gross written premium. Manulife (Cambodia) Plc, among the first foreign insurance firms to establish themselves in Cambodia, serves some 90,000 people and insures over $2 billion (Chan, 2019). Other key players include Forte Insurance Company, Infinity General Insurance Plc, Campu Lonpac Insurance Plc, Asia Insurance (Cambodia) Plc, Cambodia – Vietnam Insurance Company Plc, Cambodian National Insurance Company (Caminco), People & Partner Insurance (PPI). In addition to large insurance providers, the micro-insurance providers also hold potential for supporting downscaling efforts to enable the provision of parametric insurance.

A partnership between Manulife, 19 other institutional investors, and Swiss climate modelling firm Carbon Delta provides a unique example of collaboration. They developed a common methodology for assessing climate risk that builds on the TCFD recommendations. It uses climate scenarios to create a database that enables managers to test their portfolios for risk (Burgess, 2019). Consultation and collaboration between various institutional investors and insurance companies in Cambodia could support engagement with government stakeholders on climate change risk modeling.

4.2.5 Data Provision

Current Providers

DOM currently provides data to other agencies and non-governmental and private stakeholders. The data sharing modalities are unclear and should be further explored and articulated in a strategy. While sale of data can raise revenues to support the operations of an NHMS, they may also constrain the growth of private sector. Therefore, a data policy is an important consideration that must be taken into account when defining a path toward sustainability of CIS/EWS.

Potential Private Sector Engagement

Global experience has demonstrated that when national agencies provide observational data and basic climate products freely, they become the backbone of the climate enterprise. When raw data is free and open, NMHSs are able to provide a "first layer service" regime which can in turn trigger the growth of the private sector. Specialized companies can add proprietary data and intelligence to the raw data to provide customized services to a variety of specific users (European Commission, 2014).

An entrepreneurial approach however is only possible when the NMHS is able to provide a foundation of good quality data. This enables private weather companies to improve both the quality and the quantity of their products and services, and thereby develop new market and provide tailored products (Mills, et al., 2016). An indirect but important benefit of providing data is the improvement of perceptions and trust in the NMHS, which can in turn lead to increased budgetary allocation.

NHMS decision-makers may have concerns related to their sustainability when they make data freely available. However, experience demonstrates that NHMSs can maintain a competitive advantage and an essential role in delivery of CIS even when the private sector is an active participant. This is due to the competitive advantage of an NHMS in its ownership of broad observation networks and in its ability to influence government, display neutrality and commitment to public safety, have dedicated public budgets, maintain formal links with aviation, and be supported by WMO and other international mechanisms and institutions. These all provide definitive advantages over the private sector and solidify the role of a NHMS while still attracting private sector actors to engage in other value-added services.

4.3 Tier 2 Services

Tier 2 Services are also an essential layer in any CIS market. Without this level of value-addition, the data and observations collected are of limited utility to end-users. Tier 2 represents the most basic of translation of climate data into information that can be used for decision-making purposes. This includes support for the development of climate policies, a national EWS system, and forecasts for the general public. All three of these services are generally considered a public good and in most cases are not revenue generating services. While Tier 2 services could benefit from private sector engagement, the business case may not be attractive enough to pull investment partners. On the other hand, Tier 3 and 4 services (i.e. tailored products and services) may be better suited for PPP arrangements.

Private sector engagement may be possible but would require government subsidy or other non-monetary incentives to make such partnerships viable. For example, NHMSs may partner with media and telecom companies to deliver early warnings to the country in return for tax incentives or other benefits. Tier 2 services are discussed further below.

4.3.1 Climate Policy Support

Current Providers

Every government ministry in Cambodia is required to take into account the impacts of climate change on their respective mandates. Since ratifying the United Nations Framework Convention on Climate Change (UNFCCC) in 1995, the Royal Government of Cambodia approved of the Kyoto Protocol in 2002 and has submitted two national communications to the UNFCCC, most recently in 2015. The Cambodia Climate Change Strategic Plan 2013-2023 (CCCSP) was developed to provide an overall framework for climate change response and integration of climate change issues into development planning at national and sectoral levels. Additionally, the Strategic National Development Plan 2014-2018 (NSDP) has made climate change a cross-cutting issue as an essential part of development efforts in Cambodia. Sectoral Climate Change Action Plans are being developed to support the goals outlined in the CCCSP. Other policies include the Initial and Second National Communication to the UNFCCC (2015), National Adaptation Programme of Action (2006), Royal Government of Cambodia Climate Change Strategic Plan (2013), Royal Government of Cambodia Climate Change Action Plan (2016), Climate Change Financing Framework (2015).

MOWRAM provides the data and information to various ministries to assist in the development of these climate policies which will continue to be updated and monitored in the future.

Potential for Private Sector Engagement

There is limited potential or need for private sector engagement in this function as it is part of the government mandate and the policy development process is relatively well-funded through government funding and development assistance. One potential opportunity is to employ consulting companies specialized in climate change for research and preparation of these studies. These companies support the overall CIS/EWS enterprise by being technical resources for deepening Cambodia’s overall adaptation capacities.

4.3.2 Early Warning Systems

Current Providers

MOWRAM is mandated to produce and disseminate forecasts for the entire country. It disseminates information through daily bulletins, emails and faxes to relevant line agencies to be disseminated further to the public by radio, newspapers and public media networks. The Provincial Department of Water Resources and Meteorology (PDOWRAM) at the local level further disseminates the warnings to communities (communes) through its networks by phone and radio-communication.

However, the information is often not presented in a manner that can be easily understood or applied and SOPs defining roles, responsibilities, and accountability are lacking. Similarly, SOPs are lacking for the communication of advisories related to potential natural hazards and extreme weather events.

In Cambodia, NCDM has a coordinating function that is generally limited to disaster preparedness and emergency relief. During a disaster, NCDM is responsible for the immediate actions and coordinating role between the different line ministries and the donor community. On the other hand, the sectoral line ministries have responsibility for the implementation of specific structural interventions for flood risk reduction and restoration of damaged infrastructure.

NCDM was established by a sub-decree in 1995, for the purpose of leading the management of disasters in Cambodia and developing disaster management capacity at all levels. It is also the responsibility of NCDM to communicate early warning messages to the Provincial Committees for Disaster Management (PCDMs), the District Committees for Disaster Management (DCDMs), the Community Committees for Disaster Management (CCDMs), and the Village Teams for Disaster Management (VTDMs), as appropriate for action and response.

While NCDM has a clear mandate, the exact legal authority of NCDM to exercise its mandate and responsibilities has yet to be clarified, due in part to its status as a committee. This has resulted in its mandated activities being at times undertaken by member ministries, sub-national disaster management committees and non-governmental organizations (NGOs) — blurring the lines of accountability and weakening NCDM’s leadership role.

In fact, Cambodia’s only EWS is currently operated by an NGO through an innovative partnership with government, development partners, and the private sector. This system is called EWS1294. It is a free mobile phone service developed by Czech NGO People in Need (PIN). Individuals register by dialing 1294 and following the prompts. In the event of an emergency, such as a flood or storm, users in the affected area receive an audio message issued by NCDM warning them of the risks and steps to take to protect themselves, whether it be evacuation to the nearest safe site, staying indoors or securing their livestock. Since being piloted in 2013, EWS1294 has been integrated into NCDM’s disaster management strategy and all of the country’s 25 provinces are covered by the service. The project is currently in the handover phase, whereby NCDM will take full ownership.

PIN has developed a flood detection unit to detect dangerous water levels at the source called Tepmachai. It is a solar-powered, GSM-enabled, sonar-based stream gauge, built on open-source technology. At predetermined intervals, the device uses sonar detection to measure the height of the water at its location and sends this data over the cellular phone network back to a centralized web dashboard. If dangerous water levels are detected, the system automatically sends out a mobile alert message to people in the affected areas.

An innovation by PIN to reduce costs was to procure 3D printers to produce the hardware while outsourcing the software and hard drive components. This has enabled the organization to quickly and economically produce the required number of river gauges. The gauges run between 250 and 500 per unit; there are currently 20 installed and 20 additional in stock. Another central cost is the server fee which currently costs 750 USD/month. It is envisioned that the in the future MOWRAM, NCDM, or another ministry could host this server for free as the project is transferred to the government from PIN.

Maintenance is relatively inexpensive as these are not highly complex machines. However, capacity to repair the units is unlikely to exist within the government and should be contracted to tech companies with the requisite capacities. PIN uses several companies currently including Arrowdot, a local tech firm. These companies have the knowledge on how to install and maintain the equipment for the EWS in the future.

The PIN EWS runs both on this sensor technology and an open-source IVR solution using a number of Amazon Web Service. With the assistance of Open Institute, the EWS has become more customized and PIN has been working with a local developer on a custom-built, hosted, open-source IVR platform called Somleng, which—when used with RapidPro, an open source call-flow manager—can be used to transmit recorded voice messages to preselected groups of mobile phones, such as all of those in an area threatened by a weather-related emergency. In addition to these partnerships, the EWS also includes third-party, open-source software such as FreeSWITCH telephony software and the Adhearsion telephony application framework (Amazon Web Services, 2019).

IVR allows all provincial committees and NCDM to record alerts using a microphone that is provided through laptops. This is critical because it means that EWS1294 is not just for alerts related to floods detected by the PIN units, but any hazard information can be communicated. For example, recently the PCDMs have been using EWS1294 to communicate alerts related to the Covid-19 pandemic. MOWRAMs alerts that are passed to NCDM are also disseminated using the EWS1294 platform. The EWS Facebook page is also successfully delivering information to the population on hazards and has more than 112,000 followers.

The service is completely free for the user as per a sub-decree that mandates all telecommunication companies to support EWS. However, it does cost users a small fee to send the alerts. This cost may be considered in the future to also be provided free of cost, either through policy or incentives.

Potential Private Sector Engagement

Private sector engagement in reducing disaster risks is a key strategy for more effective and sustainable DRR, an essential part of which is EWS. Disasters affect businesses severely and they are incentivized to contribute to well-functioning EWS to ensure their own business continuity during and after disasters and to prepare for a wide range of disruptions before they happen. In addition, the private sector can contribute further through the development of their core business models and by exploring business opportunities that respond to the DRR needs of society.

In terms of provision of risk and hazard mapping and building the knowledge base – professional consulting companies may be useful to leverage. They can both help build the capacities of MOWRAM and other ministries as well as develop vulnerability assessments, risk maps, etc. Some key players in Cambodia include international firms such as KPMG, ARUP, and EY as well as local firms.

Sectors of particular interest to EWS include ICT and telecommunications, as demonstrated by the PIN model and the Insurance and Reinsurance sector. The PIN model may benefit from crowding in additional telecom providers, especially Smart Axiata, which is already engaged in the EWS space. They are demonstrating how a paid service, at nominal rates, can be structured to deliver EWS services. They currently charge 15 cents/month for the service and are working in partnership with Earth Networks. See Box 1 for more details.

BOX 1: Smart Axiata and Earth Networks Partnership

Smart Axiata announced a partnership with Earth Networks, a global leader in weather forecasting and reporting, to introduce a new weather intelligence service called "Smart Weather" – another first-of-its-kind digital service for Cambodia. Earth Networks operates weather observation and lightning networks around the globe and provide a range of value-added weather and environmental services in over 90 countries. They provide services to aviation, media, education, energy and utilities, insurance, parks and recreation, and many other industries. They provide products for improving public safety and emergency management, business continuity, data analytics, and risk management.

Smart Weather is designed to accommodate both individual users and intuitional customers such as businesses in sectors like aviation, agriculture or tourism, as well as government institutions and NGOs. Smart Weather can give information to mobile users even if they are not connected to the internet or using a smartphone. Smart Weather can also provide users with weather alerts for rain, storms, lightning and other key weather-related information through SMS and in future, Interactive Voice Recording. At 15 cents per month, individual users receive a weather update via SMS every morning, which provides them with a 10-day advanced forecast. Mobile users also receive SMS storm alerts two hours before a thunderstorm is expected to happen around their area. Users can also dial *559# or call 559 for an instant report on current weather conditions.

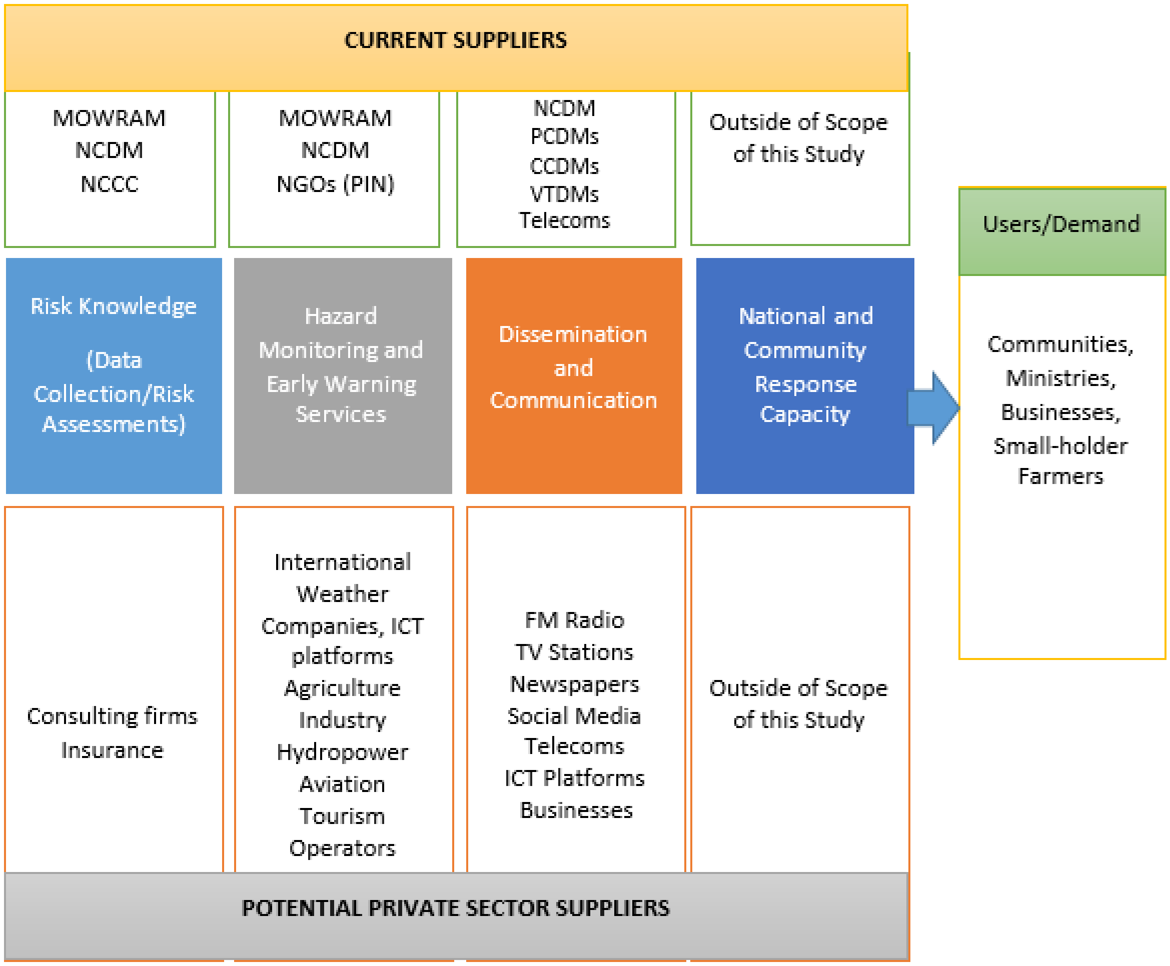
The insurance sector is directly affected by severe weather and disasters and is incentivized to both understand risks for pricing purposes as well as reduce risk to mitigate claims. Many insurance providers use their own proprietary risk assessment software and methodologies to understand climate risk, which could be extremely useful for public sector knowledge enhancement.

Index insurance is a relatively new but innovative approach to insurance provision that pays out benefits on the basis of a predetermined index (e.g. rainfall level) for loss of assets and investments, primarily working capital, resulting from weather and catastrophic events. Index insurance shows great promise in terms of building the capacity to respond and adapt to droughts and floods and other disasters. It also can play an important role in monitoring and observation systems for EWS.

Index insurance is primarily used in agriculture. Because of the high cost of assessing losses, traditional insurance based on paying indemnities for actual losses incurred is usually not viable, particularly for smallholders in developing countries. With index-based insurance, payouts are related to an “index” that is closely correlated to agricultural production losses, such as one based on rainfall, yield or vegetation levels (e.g. pasture for livestock). Payouts are made when the index exceeds a certain threshold, often referred to as a “trigger”. Index-based insurance is not therefore designed to protect farmers against every peril, but only where there is a widespread risk that significantly influences a farmer’s livelihood. Many such indices now make use of satellite imagery in combination with observational data. Index insurance providers may be willing to pay for services and generate a revenue stream for DOM/MOWRAM for investment in observational infrastructure as well as enhance their capacity in developing forecasts.

At the moment, there is no index insurance provision in Cambodia, but in the future this could likely change. For example, a primarily German-funded project in Cambodia called DE-RISK South East Asia is exploring innovative insurance solutions to climate risk management in the agriculture sector in SE Asia including Cambodia. The project will develop insurance products that will shield smallholder farmers and businesses engaged in producing coffee, sugar, rice, cassava, rubber, dairy, and grazing across the agricultural value chain in key SE Asia countries from physical and financial disaster associated with climate change. MOWRAM/DOM should engage with this project as there is potential opportunity to engage with the insurance industry in a meaningful way through this dialogue.

Another common partnership in early warning projects is with private-sector media, such as television, radio channels, and newspapers. This collaboration offers opportunities for expanded distribution of early alerts. When creating Public Private Partnerships (PPPs) with media, it is important to have a clear response matrix that assigns roles and responsibilities like when, how, and who does what to interrupt broadcasts for the issuance of early warnings. A good example of such early warning collaboration is the Asia-Pacific Broadcasting Union (ABU) that makes sure that warnings reach those in danger. The Cambodian media sector is vibrant with numerous radio, television and print media outlets. The two major national broadcasters, National Television of Kampuchea (TVK) and National Radio of Kampuchea (RNK) are departments within the Ministry of Information (MoInf). FM broadcasters are very popular in Cambodia with at least 65 stations. According to the Telecommunications Regulator of Cambodia (TRC), internet users – including both mobile internet and fixed internet - covers about 98.5% of the population. The approach to emergency broadcasting is unregulated and ad hoc. A strategy for engaging public and private sector media outlets in EWS in a systematic way has significant potential for improving EWS delivery.



4.3.3 Visualization and Decision Support

Current Providers

Climate information does not become a service until it is translated into visual products and tools that can support decision-making. In Tier 1 services, data has been collected, managed, analyzed and modelled. Tier 2 services is creating a number of forecasts and presenting information in understandable ways to end-users. Tier 2 services are provided by DOM and DHRW and are general products that target the general public, government departments, and businesses with basic information including the following:

- 3-day hourly forecasts for temperature, precipitation, and wind for 25 cities
- Very basic visualization products targeting fisheries, roads, and tourism sectors
- 3-day marine forecast for sea surface temperature and wave height
- 3-day outlooks for hazard warnings including 15 hazards
- Early Warning alerts

Agrometeorological services are handled by the Ministry of Agriculture, Fishery and Forestry (MAFF). DOM and DHRW provide hydro-meteorological data in addition to the rainfall data from the MAFF rainfall stations. Based on seasonal forecasts (onset of rainy season, drought or flood) and tropical cyclone warnings, the agriculturists advise the farmers on crop varieties and the proper time to plant or harvest.

The ability to make better decisions through climate services leads to the generation of more value for farmers. It is estimated that improved weather, climate, water observations and forecasting could lead to up to USD$ 30 billion per year in increased global productivity and up to USD$ 2 billion per year in reduced asset losses. The benefit-cost ratios are estimated to be in the order of 10 to 1 and in some cases, even higher (WMO, WBG, GFDRR, USAID, 2015; GCA, 2019).

Potential Private Sector Engagement

Visualization, decision-support and tools and products that translate data into information that is meaningful to users is critical to creating services. However, attracting private sector to partner in this field is hinged upon some baseline capacity within the national bodies. Forecast products that benefit the general public but are produced by private sector actors is unlikely without grants and subsidies given limited return on investment for such general services and products.

Of course, the above discussion precludes the numerous, widely available and free weather services that include weather.com, AccuWeather, and many regional and global meteorological agencies that provide free information that is retrieved and packaged from various sources. Apps that are frequently downloaded in Cambodia for Android include[6]:

- Weather Forecast published by KUCAPP
- Khmer Weather Forecast published by Rotha Apps
- Weather Forecast published by Accurate Weather Forecast & Weather Radar Map
- Weather forecast published by smart-pro android apps
- Weather Forecast - local weather app published by KUCAPP

There are also a number of applications that have been developed to support farmers with decision-support tools. For example, Angkor Salad – a project funded by the Netherlands Space Office (NSO) - is focused on incorporating satellite-derived data to inform and improve agricultural production in selected developing countries. The overall aim of Angkor Salad is to reduce inputs, specifically water, while increasing productivity of vegetable production by approximately 20%. This is to be achieved through a commercial partnership with a leading input supply company in Cambodia, Angkor Green. This project aims to develop a client management and decision support tool that combines best practice vegetable production advice with near

[6] Source: Similar Web: https://www.similarweb.com/apps/top/google/store-rank/kh/weather/top-free

real-time information on soil moisture. It is envisioned that this tool will be commercially viable through the incorporation of package expenses into products bought by farmers or through a direct subscription model.

Another effort is through the DCA project that was discussed previously with respect to the installation of an AWS as a pilot project in one province of Cambodia. DCA has developed the Khmer Smart Farming (KSA) application for iOS and android which uses data from the DCA-installed AWS and crop information to provide CIS to farmers in the area. More information is provided in Box 2.

BOX 2: Case Study: Khmer Smart Farming App

As part of the *Agricultural Information for Livelihood Enhancement* (AGILE) project implemented by DCA, the Khmer Smart Farming (KSF) app has been developed as a tool to assist farmers in Cambodia in climate-informed agricultural decision-making. It makes use of an AWS installed on a SMART telecom tower. DCA has financed the equipment, maintenance, and the application development and hosting fees. Maintenance and repair is carried out by SMART technicians as part of an annual fee paid to SMART. The equipment was purchased from Earth Networks who have also provided training to SMART employees on installation and maintenance. KSF provides 10-day daily and hourly forecasts and information related to 12 different crops. With all of these various partners, KSF is demonstrating an innovative model for partnership between the non-profit, government, and private sector.

DCA has been actively engaging end-users in an iterative design process and feedback has been generally positive. One user who communicated the information to her community reported being labeled as the "fortune teller for the village." Others reported that they wanted more customized information rather than automated information and prefer multi-media learning materials that enable them to make better farming decisions.

While the impact of KSF is still being evaluated, lessons are being learned already and DCA and partners are addressing challenges. Key amongst these include:

- **Sustainability**: Given that DCA is a non-profit with a project timeframe, a sustainable business model and partner is required. The application is currently offered for free, but in the future a subscription model could be considered but market demand needs to be explored further. In addition to the initial capital expenditures, there are operational costs including web hosting fees, research and development, O&M of equipment, and value-added services such as training materials and guidelines.
- **Compatibility**: The application could potentially use information from any AWS installed by MOWRAM. This is currently not happening due to heterogeneous hardware and software. In particular, the Application Programming Interface (API) is a major barrier for the KSF app to utilize data from MOWRAM's observational network.
- **Decision-support**: User feedback has indicated that the forecasts are sufficiently accurate. The significant barrier is how to translate the information into crop-specific advice. In order to achieve impact in agricultural productivity, the app has potential to evolve into a farming knowledge hub and partner with agricultural stakeholders including MAFF, agricultural cooperatives, input suppliers, and farmers.

4.4 Tier 3 and 4 Services

Tier 3 and 4 have significant potential for private sector engagement. The private sector is both a consumer of data, which is essential for economic sectors ranging from transport to agriculture, as well as an onward provider to the general public, for example through the media, or technology firms that run popular weather apps for smartphones. Forecasts have no intrinsic value and their power lies in how they influence decisions, which in turn lies in how information is tailored and communicated to them.

Companies that provide tailored CIS are innovating rapidly, using state-of-the-art technologies, and generating demand for their products through intensive marketing targeting specific user groups. By contrast, MOWRAM and other government providers of CIS/EWS are focused on providing public goods such as basic weather forecasts to the general public, an accurate national climate record, and early warnings of hazardous weather events. As a result, they do not yet have the business skills required for developing and marketing cutting edge products. By providing accurate data and working closely with the private sector to improve the quality of climate and weather information MOWRAM can potentially share, through royalties or fixed fees, the revenues generated from products that incorporate their primary data. Such business deals are – as has already been demonstrated in some countries – likely to generate far greater income streams for the NMHSs than from the simple sale of primary weather data (Mills, et al., 2016).

4.4.1 Tailored CIS and EWS and Consulting Services

Current Providers

Tailored services would target entire sectors/industries such as agriculture, tourism, power, aviation, etc. or specific clients through consulting contracts. These services are developed through co-production whereby the end-user's needs drive the design and delivery of the service. Engaging the private sector in this part of the CIS value-chain is necessary because of the comparative advantage of private weather companies compared to MOWRAM to provide such services.

Some agrometeorological services are currently provided by the MAFF. Based on seasonal forecasts (onset of rainy season, drought or flood) and tropical cyclone warnings, the agriculturists advise the farmers on what variety of crop and the proper time to plant or harvest. For rice production, it is very sensitive to change in wet season rainfall and advance information on rainfall forecast is important. Advance planning of planting activity is made based on long range forecast i.e. forecast of El Niño/La Niña.

Currently, the only private sector company providing weather services in Cambodia is Earth Networks through its partnership with Smart Axiata which has been discussed elsewhere in this document.

In terms of private industry as end-users of tailored climate services, there is currently no evidence of this occurring, though it is likely that businesses do use climate information but are not labeling it as such. Tourism, agriculture, hydropower, and mining are likely using available information to create their own tailored tools/decision-making processes.

Potential Private Sector Engagement

Tailored information also includes sector-level or client level vulnerability and risk assessments due to climate change. This is a growing area of concern and private sector consulting firms may fill this gap effectively.

Moreover, private sector users could also be engaged in the co-production and dissemination of climate information. For example, rice exporters could provide agro-meteorological information to its producers, hotels and tourism operators could provide information to tourists and surrounding communities.

As Table 1 earlier in this report illustrates, nearly all sectors of the economy can benefit from CIS/EWS. The key to the private sector engagement strategy is fully understanding demands and creating products that provide value in real financial or socioeconomic terms. There are a number of local and global studies that attempt to value the impact of CIS. These should be supplemented with Cambodia specific information and used to grow market awareness and for government advocacy. See Box 3 below for examples of monetary gains accrued from CIS in other developing countries.

BOX 3: Creating Demand through Demonstrating Value

An important study produced by USAID reviews the global literature on valuing of climate services. The examples below are taken from this study to demonstrate the impact that CIS can have in economic terms. Such facts and valuations are useful in engaging private sector and should be explored in the Cambodian context.

- $17.7 – 41.9 per hectare for farmers in Southern Kenya with use of global circulation model-based seasonal precipitation forecasts for maize planting and fertilizer management (Hansen et.al., 2009)
- $0.44 –0.85 in willingness-to-pay by households in Zimbabwe for improved seasonal forecasts (Makaudze, 2005)
- $9-35 in benefits per acre by adjusting crop mix to ENSO phase in Argentina (Jones et al., 2000)
- $20 per hectare for Chilean potato farmers with use of perfect sea surface temperature anomaly (SSTA) information (Meza and Wilks, 2004)
- $1.80 (landowners) and $15 (tenants) per hectare for Argentinian farmers with use of ENSO forecasts (Letson et al., 2009)
- 2% reduction in losses for rice producers in the Ebro River Basin in Spain with use of water management strategies based on drought forecasts under climate change (Quiroga et al., 2011).

Digging deeper into the key economic sectors of interest in Cambodia can also help to highlight the specific private sectors entities that are best suited for an engagement strategy.

For agriculture, tailored information and products will support on-farm decision-making. Seasonal weather outlooks are especially useful for this purpose. High resolution information is often required that uses long-term historical data and local observations. Data and forecasts on evapotranspiration, temperature, humidity, wind speed and precipitation are needed. Crop specific forecasts are also used for planning.

For example, aWhere, an international provider of tailored CIS to the agriculture sector based in the US provides information and analytics to the agriculture market[7]. aWhere offers software and analytical tools to produce hyper-local agricultural intelligence targeting global development and agriculture with evidence-based decision-making tools that can be applied across value chains, from the field-level to corporate and policy-level. aWhere processes and analyzes billions of data points a day in a cloud-based platform and a number of value-added services are offered. The company initially focused on supporting sustainable development in developing countries but is now also providing services to the private sector including large agricultural companies and start-ups that are driving innovation in the agricultural sector around the world.

Given the importance of the construction industry in Cambodia, companies specializing in CIS for climate information should also be explored. Weather is one of the top reasons for missed milestones in the construction industry. Accurate and reliable weather data for construction sites play a pivotal role in increasing site safety and managing resources more efficiently. Tailored climate information can include details on site-specific conditions, as well as weather warnings specifically tailored to each location and its associated topography.

The mining sector may also benefit from tailored information in a similar way to the construction industry. Mine sites operators need to be constantly aware of changing weather conditions, making sure that everything from road conditions and visibility, blasting safety distances to ore loading weight are considered.

The insurance industry has been discussed in previous sections. This industry can benefit largely from CIS especially before, during, and after severe weather events. The insurability of risks and the calculation of risk-adequate premiums are one of the central challenges in risk management for insurers and reinsurers, especially in times of climate change and an increasing number of damaging weather events. CIS can enable agricultural insurance and index-based insurance that can be used during crop cycles and establishing weather-driven dynamic pricing models.

[7] https://www.awhere.com/

;

The international weather service UBIMET, with headquarters in Vienna, Austria, provides an interesting case of a CIS focused business providing services to the range of sectors discussed including insurance, events, agriculture, aviation, construction and mining.[8]

The types of climate services offered by CIS information providers can be more or less tailored. As an example, the IBM owned The Weather Company provide visualizations of weather and climate data, such as forecasts, explicitly for broadcast media. Many companies also combine weather and climate data with other information to create more customized services. Examples of tailored CIS providers are listed in the table on the following page. These are just a few examples to highlight the types of services that are offered. For more information and listings of CIS providers there are several resources that can be accessed for further information[9].

[8] https://www.ubimet.com/en/

[9] Resources for listings of CIS providers: https://wcdirectory.ametsoc.org/; http://marco-h2020.eu/results/#climate_service_providers; https://www.cmcc.it/wp-content/uploads/2013/05/rp0134-serc-06-2012.pdf;

Table 2: Sample of Global CIS Providers

Company	General Description/Services Provided
AerisWeather	Customized solutions for weather-sensitive businesses and media properties.
ClimSystems	Software systems for assessing impacts and adaptations to climate variability and change.
IBM	Tailored forecasts and information spanning a large number of industries.
Earth Networks	Operates a comprehensive weather network including hyperlocal real-time observations, lightning detection and trace gas monitoring that helps schools, government agencies and companies with weather intelligence data to help automate decision-making and optimize operations.
OTT HydroMet	OTT HydroMet provides valuable insights for experts in water and weather applications to help protect lives, the environment and infrastructure.
Prescient Weather Ltd	Provides information and strategies to manage weather and climate risk. The latest scientific understanding, data sets, and advanced technology are combined to create weather and climate products that confer advantage to industries and activities sensitive to atmospheric events and trends.
Weather Trends	Forecasting year-ahead weekly temperature and precipitation trends for millions of locations covering the globe and quantify how that affects thousands of seasonal categories and weather sensitive businesses.
Baron	Weather radar, visualization software, hydrological and roadway modeling, digital solutions, and value-added weather data through multiple distribution channels.
Panasonic	Launches weather satellites and run their own weather models. Operating the world's most advanced global weather forecasting platform, Panasonic Global 4D Weather.
Weather Decision Support Systems (WDSS)	Provides severe/hazardous weather detection and prediction tools, meteorological displays, and numerical modeling solutions. Provides professional tools and displays designed to aid users in real-time decision-making. It has a turnkey Numerical Weather Prediction (NWP) service or system that uses a proprietary version of the community Weather Research and Forecast (WRF) model to provide high resolution, accurate weather forecasts from an hour out to 10 days.
Weather Decision Technologies, Inc.	Provides organizations with weather decision support on a global scale. WDT offers specific expertise with big data as it applies to hazardous weather detection and prediction, forecast modeling, decision analytics, GIS, mobile apps and interactive mapping.

5. Recommendations for Engaging the Private Sector

Based on the analysis of the policy environment, current market and potential areas for private sector engagement, a number of recommendations emerge. Global experience and trends in the provision of CIS/EWS demonstrates that the private sector can play a critical role. However, it is important to recognize that there are key enablers to crowding in these actors and engendering an enterprise approach. Several global studies have looked at the key barriers and best practices in engaging the private sector in CIS provision. The figure below is from a very recent and comprehensive study undertaken by the World Bank and the International Bank for Reconstruction and Development titled *The Power of Partnership: Public and Private Engagement in Hydromet Services* (2019). Good practices are highlighted in the areas of governance, funding, capacity building, infrastructure, and donor support. This table should be consulted when developing any CIS strategy in Cambodia.

Good Practices	Area
Prioritize hydromet services as strategic public service by government	Governance
View the role of NMHS as an enabler for a well-functioning hydromet market	
High awareness in the government of the benefits of public hydromet services	
Recognizing the need for a clear legal frame	
Investment project controls are scaled adequately for the hydromet domain	
Sufficient and sustainable budget	Funding of public service
Realistic expectations of what a low-maturity NMHS can deliver outside its core competencies	
Minimize non-public service by NMHS	
NMHS is empowered to hire its own staff	Capacity building
Create attractive career paths	
Provide sufficient training	
Build fit-for-purpose infrastructure	Infrastructure
Create a standard for lower-cost weather stations	
Focus development activities on the entire hydromet value chain instead of just the NMHS	Development support
Keep the investment budget at an appropriate level and include an appropriate maintenance and operations budget that covers transition to sustained operations	
Flexible development project design with adequate technical specification capacity	

Figure 2: Good practices that foster the development of a sustainable hydromet value chain and successful public-private engagement. Source: The Power of Partnership: Public and Private Engagement in Hydromet Services, World Bank, 2019.

While all of these best practices are relevant, some key recommendations have emerged in the context of Cambodia and this study. The following considerations should be integrated into a phased approach to private sector engagement:

1. MOWRAM to provide the backbone of a CIS/EWS market

Historically, the private sector CIS market has been established by leveraging the baseline data provided by governments upon which additional products and services can be developed. NMHSs create this backbone of data in order to catalyze private sector investments and products. Furthermore, the NMHS must have sufficient and stable budgets that can support the ongoing operation and maintenance of their infrastructure as well as continuous capacity building of staff.

2. Modernization of MOWRAM for catalyzing private sector

Allocating public expenditures toward modernization of MOWRAM would not only improve CIS/EWS service provision by the DOM/DRHW but may also lead to a crowding-in of private sector entities. With competing demands on resources, the capacity for the RGC to invest in upgrading and adequately funding meteorological and hydrological services is limited, as is often the case in developing countries. In 2013, the World Bank estimated the financing shortfall in developing countries to be between US$1.5 billion and US$2 billion just to cover the cost of high-priority modernization requirements. An additional US$400-500 million per year would also be required for maintenance and operational support (Rogers & Tsirkunov, 2013).

The US and Europe recognized the benefits of investing in the modernization of its NHMS and began this process for the National Weather Service with its Weather Service Modernization Act of 1992 and a $4.5 billion investment. This investment drove additional private sector growth and technological innovation within the CIS sector leading to a thriving market economy grossing more than USD $7 billion (National Weather Service, 2017). A blend of finance from public sector investment and ongoing operational support, along with private sector revenues, has created a sustainable set of CIS services for end users.

As a first step, a modernization strategy should be developed that assesses and quantifies the financial needs of DOM/DRHW to become an effective CIS/EWS provider. This strategy should include a component to target specific sectors and actors, drawing from this analysis of this report. For example, the private sector is efficient in raising and deploying private (venture) capital particularly for high-tech developments in measurement and computing/data technology. If providing a data service, the private sector would also enable a transfer of risk, such as that associated with building, launching and operating satellites, from the public sector. Using its resources, the private sector could also assist in technology transfer to developing countries, for example, through World Bank funding (Thorpe, 2016).

3. Demand Creation - Valuing CIS/EWS

One strategy to enhance government spending in MOWRAM and CIS/EWS in general is to broaden public understanding of what is at stake and to conduct socioeconomic studies that quantify the value of the public services resulting from strengthening and modernization. Such studies can also identify gaps in the current system and help prioritize elements of a modernization program. Following an understanding of the costs of modernization, it is essential to identify the value of this modernization in both monetary and human terms. Socio-economic benefits studies can help in advocacy efforts and create greater demand.

Moreover, public willingness-to-pay studies are also useful in identifying products and services that can be developed to enhance the sustainability of CIS through revenue generating opportunities.

4. Further Market Mapping

It is important to follow-up this feasibility study with further analysis using a market lens. Stakeholder workshops and consultations that include private sector participants from construction, agriculture, fisheries, aviation, tourism, mining, and telecoms, as well as CIS providers such as Angkor Salad, RIMES, DCA, and local consulting firms specialized in climate change and ICT. This will help identify areas for growth, define the needs of the end-users, highlight opportunities for partnerships, and attract private investors.

Demand for climate services should be understood in terms of current users and non-users. The detailed analysis should explore the specific needs of all end-users, as well as the decision-making processes that trigger a shift to the consumption of climate services. Granularity on the types of information being used or demanded will be critical.

In terms of the supply side of the market, this feasibility study has likely covered this information as there are little to no Cambodia-based private sector suppliers of CIS with the exception of Smart. There may be others providing CIS/EWS on a limited scale, which is worth exploring further. It is clear that the supply-side is rather undeveloped in Cambodia. However, identifying and collating best practices and challenged for suppliers in their business model design would be useful. Moreover, a deeper look into suppliers in neighboring countries, regionally, or globally that could address the demand identified through the consultations would be useful for developing a business case and attracting these companies.

5. Considering an Open Data Policy

When data is free and open, NHMSs provide the "first layer service" regime which triggers the growth of the business sector which, by adding proprietary data and intelligence, may provide customized services to a variety of specific users. In other words, Tier 1 and partially the Tier 2 services discussed in the analysis of this report provide the backbone upon which the market can grow. End users and markets would be sustainably served if RGC required MOWRAM to provide core infrastructure and observations but empowered the private sector to innovate and provide services using that backbone. It has been observed in Africa that NHMSs that charge for data only manage to recover marginal costs for the production of the data and the revenues generated are not always reinvested into the NHMS, but subsumed into the general exchequer. In this context, charging for data is an inadequate strategy for sustainability. On the other hand, when private sector suppliers have access to free and open data, and cooperate closely with the NHMSs, the general public perception of the NHMS improves, which in turn can lead to greater public financing.

6. Compatibility, Interoperability, Collaboration

Due to piecemeal investments in MOWRAMs observational network and data management infrastructure, a project-based approach has been employed and resulted in (a) a lack of equipment standardization, (b) difficulties related to operations and maintenance of different equipment at different sites, and (c) burdens in centrally synchronizing and analyzing data from different observational platforms. All of these overly complicate the process of climate and weather data collection, and challenge limited capacity and resources (UNDP, 2017). When new equipment is provided, it can actually be counter-productive if not done with consideration of requirements for integration within existing MOWRAM systems. Uncoordinated and piecemeal approaches result in multiple observing networks using different equipment and various observing/communication protocols. For example, a UNDP analysis found that AWSs installed in the past by vendors from USA, Japan, Russia (long time back) are often incompatible and have burdened MOWRAM staff with the task of homogenizing the information. It is essential that donors and other partners are aware of this consideration and that MOWRAM has the capacity and protocols in place to communicate their needs to their partners.

MOWRAM should also employ APIs for sharing of information with government, non-government, and private sector partners. APIs help systems talk to each other better. Using APIs makes it much easier to connect systems and to do so in a consistent, standard way. They can offer scalability by using a third-party cloud provider. Partners are enabled to utilize real-time meteorological products in a variety of formats and also be able to contribute to MOWRAMs database. For example, DCA's AWS and information from the PIN flood gauges should be compatible with MOWRAMs existing systems. Private sector entities can also create value-added products such as agrometeorological information and tailored information for industries such as construction, mining, tourism, and aviation.

7. Public Private Partnerships

Given the nature of CIS/EWS services whereby they provide a public good, it is highly unlikely that a purely private or purely public model will be sufficient in the future. Therefore, PPPs should be explored that formalize partnerships in a regulated way. There are many different forms a PPP can take. Some examples include[10]:

- **Customer-supplier relationship**: This is the current form of partnership that MOWRAM engages in whereby it procures hardware and software from the private sector.
- **Financial partnerships for infrastructure projects**: Co-financing of infrastructure through classic PPPs (e.g. investment projects for roads and airports) is not yet very common in the hydromet domain. One example of such a PPP is in Indonesia. The private company

[10] These examples are derived from *The Power of Partnership: Public and Private Engagement in Hydromet Services, World Bank, 2019*

pre-finances infrastructure investments, while the NMHS runs the instrumentation, receives education and training, and pays back the private company over a certain period.

- **Exchange or sharing of infrastructure**: MOWRAM could work with private sector to provide observations by: (i) building up separate but coordinated infrastructure and then exchanging observation data (e.g. cooperation between the private and public sectors in Japan); or (ii) sharing a part of the infrastructure (e.g. in Indonesia, the NMHS receives space to install its automatic weather stations on private offshore platforms, cell towers, or plantations and provides data in return).
- **Support for new products and services**: MOWRAM could support the development of new products and services in the private sector. For instance, in Indonesia, the NMHS is supporting the development of weather index-based micro-insurance by local companies. The insurance industry should also be consulted in Cambodia to explore this potential. A high potential area that already exists in Cambodia is in the agriculture sector. However, current models are supported by NGOs or subsidies. All participants in the agriculture value-chain should be explored as potential partners from input suppliers, producers, traders, processors, to retailers.
- **Dissemination of Warnings**: The private sector, such as mobile operators or transnational weather service companies, distribute warning messages on behalf of the NMHS or a public emergency service organization. This is already happening in Cambodia through the EWS 1294 model. However, this partnership needs to be formalized, strengthened, expanded and evaluated for long-term sustainability.

PPP models are being explored for CIS throughout the world. Japan's experience has been rich and offers some insights on lessons learned including:

- Legal and regulatory frameworks should clearly define the roles and responsibilities of the NMHS, public and private sector stakeholders in the provision of meteorological, hydrological and early warning services.
- Effective early warning systems require good coordination among stakeholders, clarification of their roles and responsibilities and procedures to ensure timely delivery of actionable messages to all residents at risk.
- National law(s) should clearly define the NMHS as the single authoritative voice for warning services.

Earth Networks has also been leading on the development of PPP models in the CIS space. See Box 4 for an example in Myanmar (World Bank/GFDRR, 2019). The information provided in the box is taken from a report from a workshop organized by the World Bank on PPPs in the CIS sector.

BOX 4: Exploring PPP Models – Earth Networks in Myanmar

Earth Networks and the Department of Meteorology and Hydrology (DMH) in Myanmar are implementing a pilot project aimed at demonstrating opportunities for public-private engagement in CIS delivery. The pilot aims to explore the adoption of innovative software services and transfer of technical skills to DMH and the development of a sustainable public-private engagement business model. It includes a network of total lightning sensors and mesoscale automatic weather stations. Products include severe weather warnings delivered in the Common Altering Protocol (CAP), rainfall estimates and hourly forecasts. There are a wide range of government beneficiaries and commercial opportunities.

The model envisaged involves co-investment in infrastructure with a guarantee of ongoing operations from the private investor and joint go-to-market shared cost recovery. Earth Networks have developed a similar approach in Philippines and India with the respective NMHSs. Issues that are highlighted for analysis in these projects include:

- How to develop a co-investment
- Potential for shared cost recovery and limitations based on government regulation
- Support from the government partner to a private sector consortium for selling data services to government and the private sector
- How to formalize a public-private partnership model, which demonstrably benefits both parties

8. Review Operating Model of DOM/DRHW

There are several types of operating models adopted by NHMSs globally with differing levels of autonomy and flexibility. With more autonomy comes more responsibility to generate income and become sustainable, but more flexibility and effectiveness. However, too much autonomy can push NHMSs into competition with the private sector and weaken their capacity and/or incentives to deliver their mandated services that protect the citizens of the state. There are five typical operating models that NMHSs adopt in order of increasing autonomy (Rogers & Tsirkunov, 2013):

1. Departmental unit (government department);
2. Contract agency;
3. Public body;
4. State-owned enterprise and;
5. Privatized company or private company.

Regardless of the model, it is imperative that government financing remains an integral part of the model. This requirement is critical for 1) ensuring the safety of the public by maintaining CIS services that contribute to the public good (e.g. early warnings), 2) maintaining an operational NHMS as it is highly unlikely they can generate enough revenues from non-government sources, and 3) supporting sustainability of the CIS enterprise through the provision of observational data and basic climate products that form the backbone of a thriving private sector in the CIS domain.

The current model of Cambodia, the departmental unit, may remain a suitable model even with the intent to attract private engagement. It is a straightforward model to implement if public sector financing is sufficient. However, the risk of this approach is that, because there are no alternative sources of revenue, services are insufficient or poor quality due to lack of public spending either historically or in the future.

Many developing countries with constrained public budgets and a need for more effective CIS/EWS are transitioning toward public agency models for their NMHSs. Public agencies operate at arm's length from the central government and they face less political and hierarchical influence and have more operational and managerial freedom. Public agency models provide the NHMSs with the ability to engage in commercial activities and catalyze a CIS market. Once the market is more developed and producing tailored CIS, it has proven to become a sustainable enterprise when the government institutions step back to fulfill their core infrastructural and public service responsibilities and avoid distorting markets (Rogers & Tsirkunov, 2013).

Annex 1: Interview Questions

MOWRAM (To be carried out in next phase)
- Can you provide details on the infrastructure in place for CIS and EWS, from the observation network, to computing infrastructure, to buildings? - Can you provide details on annual expenditures and SOPs for O&M? - How often are stations inspected annually? - Do you have a climate data base management system (CDMS)? - Is there a backup copy of the climate data? - How often have you made a backup copy of the data over the last year? Do you collect and archive station metadata? - Do you integrate observations from other national sources/agencies into your database? - Do you perform homogenization of climate data? - How many years of rainfall and temperature data have been digitized? - How often are monthly and seasonal forecasts issued? - Can you provide details on HR in terms of size and capacities? How many staff and in which departments? - Where are the biggest gaps in terms of human resource capacity and technical capacity? - What is your current revenue/cost-recovery model? What are the sources of income? - How often are you approached by users for tailored products? Are you able to provide? - Which private sector end-users are most interested in CIS in Cambodia? - Which private sector actors do you currently engage with in terms of ICT, modeling, visualization, dissemination, or other functions? - Are there any specific private sector actors you are interested to specifically engage with? - What are the key policy barriers for engaging with the private sector for delivery of CIS?
Smart Axiata
- Can you provide details on the motivation and major factors leading to your decision to provide weather services through the Smart Weather app? - What is the business model behind Smart Weather? Do you gain other non-monetary advantages or indirect benefits by offering this service? - Have you been evaluating user feedback and/or impact of the service on agricultural productivity? - Do you engage with MOWRAM or any other government agency? What is the relationship? - Would access to the existing hydro-meteorological observational network strengthen your product or is the Earth Networks partnership sufficient? - Is the business enabling environment conducive to expanding this service, and if not, why not? - What changes would help alleviate the difficulties of growth? Are they regulatory, capital, cultural, technological? - Have you considered investing further in the hydro-meteorological network?

- What other public or private partners would make Smart Weather an effective service? Are there any areas you wish to expand or specialize in the future?
Manulife Insurance (To be carried out in next phase)
- Does Manulife in Cambodia account for risks arising from climate change to its insurance portfolios? - Is climate risk considered in the calculation of premiums? - Is index-based insurance for farmers something that has been considered in the past? What are the barriers to introducing index insurance in Cambodia? - What kind of risk assessment tools do you currently use?
State Secretariat of Civil Aviation (To be carried out in next phase)
- Who is the designated meteorological authority? What is the legal document that designates this authority? - Are there regular meetings with users of the information and the providers? - Are quality management systems implemented? Do operational procedures and practices follow WMO regulations and guidelines? - Can you describe the meteorological information that is currently being used by the aviation sector? - Does the aviation sector pay for any services provided by DOM or to other agencies or private entities? - Is AMDAR system used in Cambodia? Which carriers are using it? Can this program be expanded? - Do airports own and operate their own weather stations? How are these linked to MOWRAM? - Is the information from MOWRAM fit for purpose for the aviation sector? If not, what specific services and products are needed? - What is Cambodia’s relationship with ICAO and is the industry involved in any weather-related programs with them?
Cambodia Rice Federation (To be carried out in next phase)
- How is CIS currently accessed and used by the rice sector? - Who are the major players in the sector from the private sector perspective? - What kind of services are or would be most useful? Is it seasonal forecasts, daily/weekly forecasts, historical data or is it information that is translated into decision-making tools such as advice on when to plant, harvest, etc.? - Which actors along the rice value chain have the most to gain from tailored weather and climate information? - Are there cooperatives or large companies that would pay for improved services?
PIN
- Can you describe the EWS system in detail? - What is the relationship between the project and DOM – is data shared?

- How sustainable is the project? Can you describe the handover plan and sustainability plan? - Is user-feedback incorporated into the design of the system? - What are the key cost drivers of the system? - What improvements are needed? - Which private sector entities do you engage with? - Which private sector entities do you think have potential to further engage with EWS provision?
DCA
- Can you describe the background and main project outcomes of the CIS related projects you are implementing? - What is the relationship between the project and DOM – is data shared? - What is the relationship with MAFF? Are you working with their extension workers? - How sustainable is the project? Can you describe the handover plan and sustainability plan? - Is user-feedback incorporated into the design of the system? - What are the key cost drivers of the system? - What improvements are needed? - Which private sector entities do you engage with? - Which private sector entities do you think have potential to further engage with EWS provision?
OTT Hydromet
- As a private sector provider of hardware and software solutions – can you describe the working relationships with various government entities in Cambodia? - Do you provide support in terms of capacity building, training etc.? - Can you describe in terms of quantity and type the infrastructure you have provided in Cambodia? - What opportunities do you see for further engagement for the private sector in CIS in Cambodia?

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