Annex 3a

Economic Analysis Report

Contents

1. Overview

1.1 Introduction

This report provides a cost-benefit analysis (CBA) for the Green Climate Fund (GCF) project proposal “Enhancing Early Warning Systems to Build Greater Resilience to Hydro-meteorological Hazards in Timor-Leste” (henceforth “the Project”), which has been developed by the United Nations Environment Programme (UNEP) in consultation with the Government and stakeholders in the Democratic Republic of Timor-Leste. An early warning system (EWS) is defined by the UNDRR (2021) 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”. Timor-Leste currently lacks an end-to-end EWS and relies on a fragmented disaster risk management system, leaving local communities vulnerable to increasingly frequent or intense climate-induced disasters and without the capacity to coordinate their disaster risk management activities in a national system.

This Project seeks funding from the GCF, a fund that provides financial support to developing countries to induce a paradigm shift towards climate-resilient development and low emissions (GCF, 2018). The GCF and the United Nations Framework Convention on Climate Change (UNFCCC) have recognized the need to provide financial resources for activities that avert, minimize and address loss and damage in developing countries, specifically by providing support for EWS, weather insurance and infrastructure resilience to climate stresses (GCF, 2021). This Project aligns with these goals by firstly strengthening the delivery model and legislation for climate information and multi-hazard EWS, secondly strengthening the analysis and forecasting of the climate and its impacts, thirdly improving the dissemination and communication of risk information and early warning, and finally enhancing climate risk management capacity of Timor-Leste.

The World Meteorological Organization (WMO, 2015a) has shown that investments in National Meteorological and Hydrological Services (NMHS), defined as “weather, climate and hydrological information, forecasts and, more recently, remotely sensed data and early warnings to the public and private sector” (pg. xv) can both help vulnerable communities to prepare for and respond to extreme weather events as well as facilitate enhanced decision-making in weather-sensitive economic sectors. Improving NMHSs to reduce disaster losses in developing countries is shown to have benefit-cost ratios between 4:1 and 36:1, which suggests that every US$10 invested generates benefits between US$40 and US$360 in return (WMO, 2015a).

The remaining report is structured across two main sections. Section 1 will firstly provide an overview of Timor-Leste in terms of its country context, economic context and climate and hazard context, and secondly provide a summary of the Project in terms of its activities and results. Section 2 will discuss the CBA of the Project by firstly outlining the approach and methodology of the Project, secondly providing estimates of the total costs and benefits of the Project, and finally discussing the findings of the CBA according to the cost-benefit ratios and associated sensitivity analysis. This report provides a positive quantitative justification for the Project, which is estimated to generate a benefit-cost ratio of 5.7:1. This suggests that each US$10 invested in the Project will translate to benefits with a value of US$57.

1.2 Context

1.2.1 Country Context

Timor-Leste became independent from Indonesia in 2002 after decades of conflict and has since made significant progress in state-building and development (ADB, 2021a). Between 2002 and 2021, Timor-Leste's national GDP has increased from US$0.5 billion to US$2.2 billion and the country has made significant improvements in building water and sanitation systems, roads, ports, airports and government facilities. Despite improvements, the country remains fragile as it struggles with the legacies of recent conflicts (World Bank, 2021c). Doing business in Timor-Leste is challenging and Timor-Leste is therefore placed 181 out of 190 countries in the World Bank's (2020) 'Ease of Doing Business' rankings. Despite poverty rates having reduced by 50% since 2007, 42% of Timor-Leste's 1.3 million population still live below the poverty line (World Bank, 2021d). The majority of the population relies on subsistence farming as their main source of income and food, with 69% of the population living in rural areas, compared to the global average of 44% (World Bank, 2021b). Additionally, food insecurity in Timor-Leste is high, partly due to low agricultural productivity and partly due to high inflation rates from oil exports that limit the capacity to import food. As a result, child malnutrition is a prominent health concern arising from both food insecurity and the country's weak human resource capacity (CFE-DM, 2016). The low quality of life and vulnerability of the population in Timor-Leste has been exacerbated by the recent COVID-19 pandemic, where the extended state of emergency since 2020 reduced their GDP growth rate from 1.8% in 2019 to -7.9% in 2020 (ADB, 2021b).

The Government of Timor-Leste has laid out the country's long-term plan for sustainable development in its 'Strategic Development Plan for 2011-2030'. The plan specifically outlines the aim of transitioning from a low-income country to a middle-income country and to ensure a healthy, well-educated and safe population by 2030 (Government of Timor-Leste, 2010). The plan emphasises development across social capital, infrastructure development and economic development. Social capital refers to the development of education, health, environments and culture; infrastructure development includes the improvement of roads, water and sanitation, electricity and telecommunications; and economic development refers to the enhancement of rural development, key economic sectors and private sector investments. The plan sets out a path to ensure a peaceful and prosperous nation by 2030, with special reference to providing support to the local communities that are vulnerable to the effects of climate change and natural disasters. Priorities providing support to local communities and individuals who are at risk of starvation due to crop failures; strengthening recovery capabilities following a natural hazard; and developing disaster assistance packages for health, education, housing and employment.

1.2.2 Climate and Hazard Context

Timor-Leste is located in South-East Asia, 400 kilometres northwest of Australia, and is comprised of four islands: the eastern half of the Timor Island, the exclave of Oecusse in West Timor and the two islands of Atauro and Jaco (Timor-Leste, 2021). Timor-Leste is near the intersection of three continental plates, making it vulnerable to earthquakes and associated tsunamis. Although earthquakes are not frequently occurring, they can have disastrous effects by causing landslides, damaging livestock, roads, infrastructure and property. The islands' volcanic origins have given it a rugged terrain and mountainous topography, providing challenges for agriculture. Timor-Leste has a tropical monsoon climate, which is characterised by a wet season from December to March and a very marked dry season from May to October. The country is highly exposed to natural hazards and experiences recurrent disasters associated with droughts, floods, and landslides. Floods are the most frequently occurring and most deadly natural disaster in Timor-Leste, although both floods and cyclones jointly contribute to the most severe damage to infrastructure and food insecurity. Timor-

Leste has a medium exposure to natural hazards and has suffered from 470 disaster events between 2000 and 2010 according to UN estimates. However, the lack of coping and adaptive strategies makes it the 7th most disaster-prone country in the world (CFE-DM, 2016).

Climate change is a severe threat to the health, food security and overall development of Timor-Leste's population. The impacts from climate change have already been experienced in agriculture and food production due to hotter dry seasons, shorter and more unpredictable rain seasons and more extreme rainfall (CFE-DM, 2016). Air pollution is a growing challenge especially in Dili, the capital of Timor-Leste. Climate change and air pollution are interrelated; air quality is strongly dependent on weather and is therefore sensitive to climate change (Jacob and Winner, 2009). Notably, increasing temperatures and extreme heat can increase the concentration of fine particulate matter (PM2.5) and ground-level ozone (O_3) (Exhaustion.eu, 2020). Timor-Leste's contribution to climate change is negligible as one of the lowest carbon emitters in the world, leaving neighbouring countries predominantly responsible for the climatic changes experienced in Timor-Leste. The climate variability and change in Timor-Leste are predicted to worsen over the next decade, including projected warming of up to 1.1 °C by 2030, delays in the onset of the wet and dry seasons, higher frequency of extreme rainfall events, sea-level rise between 8-18 centimetres and increased impact of storm surges and coastal flooding (Australian BoM and CSIRO, 2014; CSIRO, 2010; CFE-DM, 2016).

1.2.3 Economic Context

The economic context of Timor-Leste is discussed according to the five key climate-sensitive economic sectors outlined by the WMO's Global Framework for Climate Services (GFCS), which includes agriculture and food security, health, energy, disaster risk management and water resource management (WMO, 2015a). The GFCS is a tool designed to strengthen the production, availability, delivery and application of science-based climate prediction and services. It aims to enable societies to better manage the risks and opportunities that arise from climate change, specifically for those countries that are most vulnerable to climate hazards, by developing and incorporating science-based climate information and prediction into planning, policy and practice (WMO, 2018).

Agriculture and Food Security

Agriculture is one of the most important economic sectors in Timor-Leste, contributing to 17.5% of non-oil GDP and 90% of the country's non-oil exports (World Bank, 2018). However, Timor-Leste's rugged terrain and varying rainfall pose chronic challenges to agriculture, leading to low agricultural productivity and yields. Despite the agricultural sector employing 65% of the population, about 70% of the rural population suffers from food insecurity (FAO, 2016). The high rate of food insecurity makes a large share of the population extremely vulnerable to food loss and exacerbated food insecurity as impacts from climate change increase (CFE-DM, 2016). A thriving agricultural sector is vital for Timor-Leste's ambitions to reduce poverty, enhance food security and promote economic growth across the country, and specifically in rural areas. The Government of Timor-Leste (2010) aims to improve national food security, reduce rural poverty, promote environmental sustainability of natural resources and support a transition away from subsistence farming towards commercial farming. However, the agricultural sector and food security remain threatened by the expected increase in frequency and/or severity of climate-induced natural disasters over the next decade. Specifically, the yields of some of the most common crops in Timor-Leste, such as maize, are vulnerable as the frequency of extreme rainfall events increases (FAO, 2016).

Key stakeholders in Timor-Leste's agricultural and food security sectors specifically include the Ministry of Agriculture and Fisheries (MAF) and the Food and Agricultural Organization of the United Nations (FAO). The MAF is the government department in Timor-Leste that has the responsibility to ensure development of the rural sector. The Ministry works to develop a sustainable, competitive and prosperous agricultural sector that subsequently can reduce poverty, ensure food and nutrition security, and promote employment and economic growth within the agricultural sector (Devex, 2021). FAO has been working in Timor-Leste since 1999. The organization is guided by its Country Programming Framework, which specifies five priority areas. Firstly, to support the improvement of institutions and coordination mechanisms for policies, laws and regulations, as well as programmes and plans to ensure 100% equitable access to food for all. Secondly, to strengthen the national capacity for agricultural data collection, analysis, management and publications. Thirdly, support improved farming livelihoods, food availability and diversity of household diets. Fourthly, to support smallholder fishing and agriculture households to become more resilient in the face of climate change. Fifthly, to support the renewal, realignment and development of TL's cash crop economy (FAO, 2021)

The agricultural and food security context can be improved using climate information and EWS, as demonstrated by several case studies in different countries. For instance, Adedeji *et al.* (2020) uses evidence from Nigeria, showing the economic benefits of drought monitoring based on Geographic Information Systems (GIS). The study shows that low-income countries with a high risk of natural disasters and weak institutions risk suffering from migration, loss of farmlands, famine and hunger following a drought. EWS based on GIS has shown to have positive impacts on the accuracy and access of climate information and data, reducing losses from droughts. Fakhruddin and Schick (2019) use evidence from Samoa, showing that economic benefits from EWS in the agricultural sector include reduced damages of 10% from natural disasters due to early harvesting, saving at least 70% of agricultural machinery and equipment by preventing their exposure to hazards, and avoiding at least 80% of damages by relocating harvesting to safer areas. EWS are also expected to have a direct impact on food security and food prices, as shown by Venton and Majumber (2013). Early warnings can prevent 14% of the expected increase in food prices following a natural hazard as EWS can reduce losses from crops and reduce losses from agricultural equipment.

Health

The overall health situation of Timor-Leste’s population is low, with 20% of children being chronically malnourished and over 50% of children under the age of five suffering from stunting. Communicable diseases such as respiratory diseases, diarrhoea and malaria are the most common source of death in Timor-Leste, accounting for 60% of total deaths (CFE-FM, 2016). Respiratory and diarrheal disease are also the primary factors causing the high rates of child mortality in Timor-Leste, where 4.4% of all children under five fail to survive (UNICEF, 2021). Air pollution poses further health risks. The annual mean concentration of PM2.5 in Timor-Leste is 19 $\mu g/m^3$, which exceeds the “safe” maximum of 10 $\mu g/m^3$ recommended by the World Health Organization (IAMAT, 2021). PM2.5 is a significant contributor to ill health, including cardio- and cerebrovascular disease, respiratory illnesses, and lung cancer (IPCC, 2014). The Government of Timor-Leste (2010) aims to achieve a healthier population by 2030, achieved through comprehensive, high-quality health services to all Timorese people. A healthier population is subsequently expected to reduce poverty rates, raise income levels and improve national productivity. However, the path to a healthier population is threatened and likely to become even worse by climate change. Climate change is expected to induce mortality rates due to higher frequencies of extreme weather events and increasing the risk of malnutrition and cardiovascular, respiratory and infectious diseases. Rising temperatures, higher flood risks and heat waves will further reduce agricultural production and subsequently increase the risk of child mortality and malnutrition (WHO, 2015).

Key stakeholders in Timor-Leste’s health sector specifically include the Ministry of Health, supported by the District Health Services, Community Health Centres, Health Posts and outreach activities, as well as the Cruz Vermelha de Timor-Leste (Timor-Leste Red Cross Society, CVTL), the International Federation and Red Cross and Red Crescent Societies (IFRC) and the World Health Organization (WHO). The IFRC, and CVTL as its National Society, have been proactively tackling the humanitarian needs of vulnerable people in Timor-Leste. Specifically, the CVTL aims to save lives and improve the quality of life for the most vulnerable by improving health, disaster risk reduction, community resilience to natural disasters, youth education and organizational development (IFRC, 2019). The Ministry of Health in Timor-Leste has also worked closely with the WHO. The WHO has been a part of developing policies and arranging health services required in the country. The WHO has played a catalytic role in Timor-Leste for the formation of the future direction of health development, health authorities and formulating health policy, planning and health regulations (CFE-DM, 2016)

The health context can be improved using climate information and EWS. Timely and actionable early warnings of potentially dangerous weather and climate conditions can improve health emergency preparedness, save lives and reduce negative impacts. For example, the establishment of a health EWS and heat preparedness plan in Ahmedabad, India, is increasing the resilience of its most vulnerable population groups to extreme temperatures, whilst also increasing the capacity of health professionals to care for patients with heat-related illnesses. This has been demonstrated to reduce loss of life during recent heat waves (WMO and WHO, 2016). Bai *et al.* (2018) show that rising air pollution has a direct effect on both human and environmental health, which are further induced by climate change and temperature rise. EWS for air pollution can prevent large scale human disasters, such as the 1952 Great London Smog that killed over 4000 people in 5 days. Kelly *et al.* (2012) showed that EWS systems for air pollution can empower individuals by giving them the information and data needed to make informed decisions regarding their own health, such as actions to reduce exposure to pollutants and/or increase medications to lessen the onset of symptoms from pollutants. EWS systems for air pollution has therefore shown to improve human health in both developed and developing countries, as exposure to air pollution increase globally as energy consumption and emissions from transportation and industry increase. EWS systems for natural disasters also have significant implications on human health. Teisberg and Weiher (2009) showed that an EWS for tornadoes increased the average lead time and the fraction of warnings, subsequently reducing fatalities by 45% and injuries by 40%.

Energy

Fossil fuels account for 90% of the total primary energy supply in Timor-Leste in 2017, with only 10% of the total energy supply coming from renewable sources (IRENA, 2017). However, 90% of the power requirements for rural communities are met using biomass fuels, such as wood fuel, for heating and cooling applications. The electricity sector in Timor-Leste is inadequate and of low quality, only providing electricity to a third of the population and only for approximately six hours per day. Only the central areas of Dili and Baucau have access to electricity most hours of the day, although there are regular outages. The Government of Timor-Leste (2010) aims to ensure electricity for all citizens 24 hours per day through investments in new power plants and improved transmissions and distribution systems, alongside expansions of renewable energy systems. Access to electricity is essential for the country’s development, supporting a healthy and well-educated society that is interconnected to the rest of the world. However, climate change and related impacts are linked to negative effects on Timor-Leste’s energy sector, with disruptions on both the demand and supply sides. Climate change is expected to increase the energy demand as the rising average global temperature will increase the need for heating and cooling appliances, which is the predominant use of energy in Timor-Leste. Climate change is also expected to reduce the capacity for energy supply as changing precipitation patterns will cause local floods that disrupt power transportation lines and distribution networks (World Bank, 2021a).

Key stakeholders in Timor-Leste's energy sector include a range of actors at various levels of society. At the national level, the Ministry of Petroleum and Mineral Resources is responsible for the design and execution of energy policies and management of oil resources in Timor-Leste, as approved by the Council of Ministers. The Ministry is also responsible for drafting and proposing policy and legislation for the sector (gpm.gov.tl, 2021). Additionally, at the national level, the Secretariat of State for Energy Policy is responsible for the national development of renewable energy in Timor-Leste. The Secretariat has already developed an action plan for renewable energy, which is expected to have a significant impact on the quality of life for the population, as well as have positive impacts on job sources and government revenue (Timor-leste.gov.tl, 2010). At the district level, the state-owned company 'Electricidade de Timor-Leste' (EDTL) has the monopoly of electricity supply in Dili and 11 district capitals (DLA Piper, 2015).

The energy sector can be improved using climate information and EWS. Hallegatte (2012) suggests that the energy sector benefits from EWS due to the ability to anticipate energy demand. Projections of energy demand allow producers to maximize energy supply from low-cost production units and reduce supply from high-cost production units. Similarly, IRENA (2020) show that short-term forecasts, up to 1 day, are useful for the optimal use of energy reserves and smoothing power production. Long-term forecasts, between 1 month and 1 year, are useful to support authorities in electricity generation planning and security operations, prepare for extreme weather events and improve the resilience of the system. Renewable energy is particularly vulnerable to extreme weather events, with evidence from North America and Europe showing that whether phenomena can cause up to 1020% variation in wind and solar generation. Roulston *et al*. (2003) show that weather forecasts can be valuable for wind energy producers as short lead times can double net income from energy production. The value from forecasts does not stem from the accuracy of weather predictions, but rather from the enhancement of decision making with forecast information.

Disaster Risk Management

Timor-Leste is the 7th most disaster-prone country in the world, predominantly impacted by droughts and floods, which exacerbates poverty and malnutrition in the country (CFE-DM, 2016). The vulnerability of Timor-Leste to climate-related disasters is evident from the devastating impacts of the recent tropical cyclone (Seroja), heavy rains, flooding and associated landslides that occurred between 29th March and April 2021, which affected a total of 33,835 households and caused at least 41 fatalities (UN RCO Timor-Leste, 2021). In 2015 and 2016, the El Niño-induced drought impacted over 120,000 people across the country, of which 400,000 people were directly and severely affected (UNSDG, 2016). Droughts in Timor-Leste have shown to harm the water and sanitation systems, food security, health and livelihoods of local communities. However, despite the negative impacts from droughts, many citizens reported a lack of response and recovery following the El Niño drought and few communities could access government or external actor assistance (Cook *et al.,* 2019). To address disaster risks, the Government of Timor-Leste has committed to various international treaties, such as the UNFCCC's Paris Agreement, and has developed a disaster risk management plan as a part of their National Adaptation Plan. However, government commitments are limited due to insufficient staff capacity and a lack of local acknowledgement regarding the need for climate risk management. Climate change is expected to exacerbate the risk and frequency of natural disasters in the next decades, directly affecting food and agriculture, with the greatest harms for coastal regions. Climate change is also expected to increase the risk of injury and deaths, damage to natural resources and displacements of local communities (CFE-DM, 2016).

Key stakeholders in Timor-Leste's disaster risk management sector includes a range of actors across various levels of the society. Specifically, at the national level, the National Disaster Management Directorate (NDMD) is responsible for providing disaster risk management coordination and technical support to the government and communities in Timor-Leste. At the district level, the District Disaster Coordinator (DDC) is responsible for disaster response decision-making, response observations and disaster risk reduction. At the sub-district level, the Sub-District Administrator (SDA) is responsible for emergency and disaster risk reduction activities, seeking assistance from the DDC or at national level as required. Within each village, there is a Suco Chief, as well as village leaders (elders, traditional leaders and village councils), who provide further support for emergency and disaster risk reduction activities. In addition, Timor-Leste Red Cross Society (Cruz Vermelha de Timor-Leste – CVTL) was legally recognized as an auxiliary to the Government in 2005. CVTL plays a key role in disaster risk management, including participating in national emergency planning and national and district-level disaster simulation exercises. Involvement of CVTL is key for the preparedness and response capacities of NDMD and District Disaster Management Committees. The International Federation of Red Cross and Red Crescent Societies (IFRC) supports CVTL through technical advice, coordination and knowledge sharing, as needed, working before, during and after disasters and health emergencies to meet the needs and improve the lives of vulnerable people (CFE-DM, 2019).

The context for disaster risk management can be improved using climate information and EWS. Venton and Majumder (2013) provide evidence for the success of a disaster risk reduction system in Bangladesh, particularly for cyclones, through the Cyclone Preparedness Programme (CPP). Prior to the implementation of CPP, fatalities associated with cyclones were high, with almost 500,000 fatalities resulting from one cyclone in the 1970s. After the implementation of the CPP, cyclone related fatalities dropped significantly. Although a cyclone in 1991 caused 140,000 fatalities, the programme managed to safely evacuate 350,000 people. Only 3,400 people died following a cyclone in 2007, and only 113 people died from a cyclone in 2009. Fekete *et al*. (2014) discuss disaster reduction programmes in high-income countries, such as the "Internal Security Strategy for the European Union", which was implemented to ensure a more climate-resilient Europe. Additionally, Villagran de León *et al.* (2007) shows that best practices for EWS systems for disaster risk reduction have four characteristics. Firstly, strong risk knowledge, achieved through comprehensive risk assessments and mapping. Secondly, a sound scientific basis for early warnings, achieved through constant monitoring of potential disasters. Thirdly, clear communication and dissemination of information, essential to ensure that local communities can respond properly to warnings. Finally, trust in early warning systems and the ability to react accordingly, which translates into enhanced preparedness and response capabilities. Finally, Forecast-based Financing (FbF) – an innovative mechanism that releases funding based on forecasts for pre-agreed activities that aim to reduce the humanitarian impact of a disaster – can bridge the gap between longer-term disaster risk reduction activities and post-disaster response measures. The Bangladesh FbF project, implemented by the Bangladesh Red Crescent Society and the German Red Cross, demonstrated that FbF activation saved lives and reduced the suffering of the population affected by severe flood events in July/August 2017. FbF activation was also shown to make the most efficient use of donors' funds and strengthened the government's capabilities to manage disaster risk (IFRC, 2017).

Water Resource Management

Timor-Leste's water and sanitation infrastructure are of low quality following the damages suffered during the violence for independence, including damaged pumping stations, transmission pipes, valves and tanks. The low quality of water resource management makes diarrheal illnesses easy to obtain, putting the health of the population at risk of a major cause of death. Water and sanitation management systems are harmed by water shortages in dry seasons, as it reduces access to both drinking water and sanitation facilities. Water resource management systems are also increasingly harmed by extreme rainfall during wet seasons that, through flooding and damage to sewage systems, induces the spread of bacterial diarrhoea and typhoid fever (CFE-DM, 2016). Only 66% of the population has access to a clean water source, such as piped water, hand pumps, water tanks or water bottles. One-third of the population must walk over 10 minutes to access a water source and 96% of urban households outside Dili do not have access to safe water 24 hours per day (Government of Timor-Leste, 2010). The Government of Timor-Leste (2010) aims to build a water resource system that can provide the whole population with access to clean water and sanitation by 2030. However, climate change is expected to have negative impacts on Timor-Leste's water management as sea-level rise, projected increases in extreme rainfall events, and greater precipitation variability will increase the risk of flooding and droughts. Climate change also risks intensifying storm events and heatwaves, which will damage coastlines, freshwater and groundwater sources, thereby threatening the domestic water supply for urban centres (World Bank, 2018).

Key stakeholders in Timor-Leste's water resource management sector specifically includes the National Directorate for Water Supply (DNSA), the National Directorate for Basic Sanitation (DNSB), the National Directorate for Water Resources Management (DNGRA), the National Directorate for Meteorology and Geophysics (DNMG) and the National Directorate for Disaster Risk Management (NDMD). The DNSA and DNSB are responsible for the management, regulation, and oversight of activities related to water supply and sanitation systems (World Bank, 2018). At the sub-national level, the DNSA is responsible for ensuring piped water in urban areas (World Bank, 2015). The DNGRA has the mandate for hydrology and hydraulics and is responsible for monitoring and research on the quality and volume of water resources. The DNGRA is primarily focused at the national level on developing law and policy and implementing monitoring programs, for hydrometeorology and seawater intrusion. The majority of the Directorate staff work throughout the municipalities supporting the National Hydrometeorological Monitoring Program. Water Resources staff of the Municipal Water, Sanitation Service and Environment Services (SMASA) coordinates that program for their respective municipalities. Meanwhile, the responsibility for flood forecasting lies with DNMG. The NDMD is the main focal point to prevent water-related natural disasters and to provide assistance and protection to communities in the event of a natural disaster (World Bank, 2018). At the community level, community water management groups have the primary responsibility of securing water to communities, but with the oversight and technical input provided by the DNSA (World Bank, 2015). In addition, the GCF-funded UNDP project "Safeguarding communities and their physical assets from climate-induced disasters in Timor-Leste" (FP109) is addressing key elements of hydrology and hydraulics in Timor-Leste – including flood risk mapping, flood modelling and forecasting for major river basins.

The context for water resource management can be improved using climate information and EWS. The academic literature shows potential for economic benefits when installing EWS systems for water resource management. Kull *et al.* (2021) reviewed various academic studies and showed that weather forecasting can optimize water supply operations, leading to a 33% improvement in performance. Iglesias *et al*. (2007) show that EWS systems can enhance water management in the Mediterranean through managing both water quantities in periods of floods and droughts, as well as water quality. Adaptation strategies for water management have proved successful in the Mediterranean, such as through the European Water Framework Directive, providing an explicit link between legislation and management that in turn provides opportunities to integrate a range of stakeholders in decision-making.

1.3 Proposed Project

1.3.1 Project Summary

A dialogue of the Project started in 2015 after Timor-Leste expressed interest in the WMO's proposal for a multi-country programme in the Pacific region to strengthen EWS capacity for extreme hydro-meteorological events. A Concept Note was approved by the GCF in 2015 for five countries, including Timor-Leste. Since 2019, the development of the Project has been driven by UNEP in consultation and close collaboration with stakeholders in Timor-Leste.

The proposed Project will enhance the resilience of Timor-Leste's population to climate change impacts and climate-related hazards across four overarching results:

- **Result 1** – Strengthened delivery model and legislation for climate information and multi-hazard early warning services
- **Result 2** – Strengthened observations, monitoring, analysis and forecasting of climate and its impacts
- **Result 3** – Improved dissemination and communication of risk information and early warning
- **Result 4** – Enhanced climate risk management capacity

The Results will strengthen the implementation of the WMO Global Framework for Climate Services (GFCS) in Timor-Leste and are designed to align with the four elements of WMO's Multi-Hazard Early Warning Systems (MHEWS) Checklist: i) disaster risk knowledge; ii) detection, monitoring, analysis and forecasting of hazards and possible consequences; iii) warning dissemination and communication; and iv) preparedness and response capabilities. The Project Results also aims to directly contribute to the targets and indicators of the Paris Agreement, Sustainable Development goal 13 on Climate Action, Sustainable Development Goal 3 on Good Health and Well-being, and the Sendai Framework for Disaster Risk Reduction.

1.3.2 Partnership Approach

This Project is based on a partnership approach to achieve its Results, meaning that UNEP and the Government of Timor-Leste collaborate with a range of institutions and organizations with longstanding experience on-the-ground to ensure coherence and complementarity throughout the Project. UNEP is the Accredited Entity for the Project and will be responsible for the overall implementation, financial management, evaluation, reporting and closure of activities under the Project. The Secretary of State for the Environment in Timor-Leste will serve as the national Executing Entity, who is accountable to UNEP for Project execution at the national level. Technical Partners of the Project are important to maximise efficiency and effectiveness, drawing on their comparative advantages and expertise on-the-ground, including the Food and Agricultural Organization (FAO); Regional Integrated Multi-Hazard Early Warning System (RIMES); the Cruz Vermelha de Timor-Leste (Red Cross of Timor-Leste, CVTL); Indonesian Meteorological Climatological and Geophysical Agency (BMKG); and the Abdus Salam International Centre for Theoretical Physics (ICTP).

Long-term sustainability is one of the expected benefits of a multi-partner approach. For example, RIMES was created as a collective effort of 26 countries to provide early warnings of future natural disasters and weather hazards (Subbiah *et al.,* 2008; Teisberg and Weiher, 2009) and the Timor-Leste Red Cross Society (CVTL) was created in 2000 to save lives and improve the quality of life for the most vulnerable people in Timor-Leste (IFRC, 2021). This partnership-based approach will provide the Project with long-term stability as the partners are permanently located in Timor-Leste and have direct relationships with the Government and relevant entities, such as the DNMG and NDMD. Both organizations have experience with operationalizing disaster management in low-capacity countries, such as RIMES' 'Specialised Expert System for Agro-Meteorological Early Warning' in Myanmar between 2015 and 2016. Additionally, multi-partner collaboration has been found to have great success among climate change-related projects, by creating new knowledge to promote growth, reducing poverty and driving large-scale change (Cochrane and Cundill, 2018). For example, RIMES has found to show evidence of facilitating economies of scale and economies of scope. Firstly, economies of scale arise when countries merge resources, as individual investments are costly, to jointly protect themselves from natural disasters. Secondly, economies of scope emerge as RIMES includes a multi-hazard approach, integrating hazards such as floods, storms, cyclones and tsunamis (Subbiah *et al.,* 2008). RIMES show how, when countries come together to jointly protect themselves from natural disasters, benefits become greater than would have been the case if countries protected themselves individually. As a result, the Project will benefit from the support of local organizations with on-the-ground knowledge and widespread networks across the country.

1.3.3 Proposed Interventions

Result 1 will be achieved through the development of institutional and policy frameworks, legislation and delivery models for climate services. One major component of Result 1 is the development of a National Framework for Climate Services (NFCS) for Timor-Leste's meteorological service, the National Directorate for Meteorology and Geophysics (DNMG). The NFCS will develop coordination mechanisms across the five key climate-sensitive sectors: agriculture, health, energy, disaster risk management and water resource management. Result 1 will also be achieved through the establishment of a User Interface Platform (UIP), a platform for interaction between the DNMG, the provider of climate services, and the end-users of climate services. Additionally, other components of Result 1 include the enhancement of data management and governance and to mainstream climate risk knowledge into the five key climate-sensitive sectors.

Result 2 will strengthen the technical capacity and modernize Timor-Leste's national meteorological and hydrological services by installing new infrastructure and equipment and by providing targeted training. This Result will be achieved by the development of three components. Firstly, the Project will upgrade and expand the surface-based observations and monitoring networks in Timor-Leste to comply with the WMO Global Basic Observing Network (GBON) standards. Secondly, the Project will strengthen climate modelling and impact-based forecasting. The former will be achieved by establishing a national Forecasting Centre and building capacity of DNMG to improve weather, water, climate and ocean forecasting and prediction. The latter is based on establishing a multi-hazard impact-based forecasting approach that translates weather and climate-related hazard information into sector and location-specific impacts. Thirdly, the Project will establish climate services for health by addressing the need for timely, relevant and useable climate information. Improved climate information will be achieved by strengthening the National Climate and Health Working Group, introducing an air quality monitoring network and health impact advisory, and delivering tailored forecasting and decision-support systems for the health sector.

Result 3 focuses on improving the dissemination and communication of climate risk information and early warnings, which will be achieved by building the capacity needed to deliver clear messages with straightforward, practical and actionable information. Result 3 will build capacity by regularly convening with a working group to reach community-level actors, co-developing socially inclusive and gender-responsive communication strategies, collaborating with the Timor-Leste Red Cross Society to establish community-based early warning systems, providing training on disaster risk management to integrate forecasts and early warnings into farmers operations, and disseminate sector-specific early warning information for the agriculture sector.

Result 4 is designed to increase coherence and mutual reinforcement between disaster risk management and climate information and early warning services. Result 4 will partly be achieved by building capacity to enable the Timorese population to better prepare for climate risks and hazards, and partly be achieved by the establishment of a Roadmap for Forecast-based Financing (FbF). Firstly, the Project will build capacity support in Timor-Leste through interventions including collaborating with the Timor-Leste Red Cross Society to build disaster preparedness capacity from national to community level; enhancing capacity of Timor-Leste's National Disaster Management Directorate (NDMD) to utilise EWS; and by raising public awareness and education regarding climate hazards. Secondly, the Project will establish a Roadmap for implementing and building capacity for FbF, also known as Early Warning Early Action (EWEA). FbF is an innovative system that increases resilience in disaster-prone countries by triggering the release of disaster funds and issuing reliable disaster alerts prior to climate hazards, with lead times that are long enough to implement effective preparedness actions (Bischiniotis *et al*., 2019).

1.3.4 Rationale for Interventions

The various interventions and Project Activities have been selected according to evidence and research of their effectiveness as well as according to the most recent developments of EWS and weather, water and climate information systems. Three prominent elements introduced the Project include compliance with the standards of the WMO Global Basic Observing Network (GBON), Impact-based Forecasting and Forecast-based Financing.

WMO Global Basic Observing Network (GBON)

GBON is a landmark agreement that offers a new approach to how basic surface-based observation networks are monitored, designed and defined (WMO, 2020a). Under Result 2, the Project will expand and upgrade the meteorological observation network in compliance with GBON and enable DNMG to achieve WMO Category 2 (Essential Services) status. GBON will significantly increase the availability of surface-based observations, improving weather forecasts and climate services. This is achieved by both improving the timely and spatial availability of observational data, as well as increase the functionality and application of satellite data. As a result, the Project will facilitate that the effective implementation of GBON standards results in filling the gaps in surface-based observations in Timor-Leste, a data-sparse area.

The Project will substantially and effectively expand the geographical coverage of weather and climate observations in Timor-Leste and its coastal waters by modernising observation and communication equipment, refurbishing and upgrading weather stations and installing additional observation equipment in compliance with GBON requirements. The Project will make the additional data available as information to government sector agencies and other relevant platforms (such as cloud computing).

By focusing on GBON, the Project is expected to facilitate Timor-Leste to qualify for ongoing technical and financial support from the Systematic Observations Financing Facility (SOFF) beyond the implementation period. The SOFF is envisaged to ensure the provision of basic systematic observations as a global public good by providing equitable, predictable, sustainable and performance-based finance as well as technical assistance to developing countries for the provision of foundational observations data as per the GBON standard adopted by the WMO Congress. This is an important element in the exit strategy and sustainability of the Project.

Better access to high-quality observation, analysis and predictions have proved to be successful in disaster-prone countries around the world. The Philippines, which ranks third for their exposure to disaster risk, has undertaken improvements in surface-based observations in line with the GBON standards. Evidence suggests that disaster managers have been successful in using these improved weather forecasts in cyclone-prone areas in the world, saving millions of lives and avoiding negative economic impacts (WMO, 2020b)

Impact-based forecasting

Impact-based Forecasting (IbF) is defined as the process of "turning forecasts and warnings from descriptions of *what the weather will be* into assessments of *what the weather will do*" (510.global, 2021). The Project will support Timor-Leste to establish an efficient multi-hazard IbF approach that translates information on weather and climate-related hazards into sector- and location-specific impacts. IbF fills the gap between adequate forecasts of weather and natural hazards, and insufficient forecasts of the impacts following the weather and/or natural disaster. Specifically, the difference between general weather warnings and impact-based warnings is the inclusion of vulnerability of people, livelihoods and property with consideration of hydrometeorological hazards (WMO, 2015b).

IBF is a subset under the decision support system (DSS)[1] framework to be introduced by this Project that estimates the potential impacts of hazards with different intensities. It uses data and information on extreme weather or climate events (such as floods, droughts and heatwaves) and estimates the socio-economic impact. Whereas the IBF will generate potential impacts in the extreme of extreme weather/climate events, the DSS will generate information throughout the year for both resource management (e.g., for the agriculture sector – application of fertilizers, changing irrigation schedules or harvesting crops) and for risk management as and when an extreme event occurs, utilizing IBF for disaster management purposes.

On a national level, IbF plays a vital role for the DNMG, NDMD and NGOs supporting disaster risk management. Although scientists prefer to make statements that they know to are current and avoid making speculative statements, speculative information can play an important role for the decision-makers in Timor-Leste. There is always some level of uncertainty with a forecast, and it is difficult to explain degrees of confidence. Therefore, the national organizations and authorities of Timor-Leste need to have access to impact-based forecasts to make decisions on the most cost-effective and efficient approaches to prepare for weather, water and climate-related hazards.

On a community level, individuals need to get timely reliable forecasts, particularly for extreme weather events and climate-related hazards. This includes clear statements on the probable impacts and specific advice on how to prepare, in their own language. The information delivered to the Timorese population can be as detailed as advice to avoid fishing or travel, to secure items that could be lifted by cyclonic winds or to check guttering and water tanks before a drought.

Impact-based forecasting has successfully been implemented across the world, whereof one example of successful implementation can be seen in Mongolia. Mongolia implemented impact-based forecasting to address the large-scale livestock mortality following the *Dzud*, a period of extreme cold following the summer drought. In 2009/2010, more than 10 million livestock died from starvation, affecting over 220,000 households and with estimated damages of US$345 million. Various authorities in Mongolia, including the Red Cross society and FAO, used impact-based forecasts to trigger release funds in areas where impacts of the *Dzud* was experienced. In 2018, the IbF interventions effectively reduced livestock mortality by 50% and increased offspring survival for various species (IFRC, 2020).

[1] The DSS is an overarching framework that encompasses different data layers and logic information to support an effective decision-making process.

Forecast-based Financing

Forecast-based Financing (FbF) is a system spearheaded by the International Federation of Red Cross and Red Crescent Societies that enables access to humanitarian funding for early action based on in-depth forecast information and risk analysis. The goal of FbF is to anticipate disasters, prevent their impact, if possible, and reduce human suffering and losses (IFRC, 2021b). The Project will introduce FbF to facilitate timely and sustainable early action in Timor-Leste. In the longer term, the innovative mechanism will enhance the impact of early warning systems by catalysing pre-planned early actions based on forecast triggers, supported by pre-allocated funding. The Project will seek to incorporate FbF into the overarching financial framework for climate services to maximise coordination between the climate and disaster risk management sectors. The Project will partner with the IFRC and FAO, which have already successfully implemented pilot projects that demonstrate FbF is a sustainable and effective mechanism.

On a national level, FbF is a mechanism that can reduce harm for the local, disaster-prone communities as well as be economically efficient for the public entities funding the FbF system. Early action for natural hazards in low-income countries is found to be significantly more cost-effective when compared with late humanitarian response. Building resilience can represent the best value for money for disaster interventions when considering the wider development implications from investments (Chadburn *et al*., 2013). It is important to consider the main risk from early responses, which is that that large-scale investment may render unnecessary in the event of a false alarm. However, research shows that early action funding could be funded twice in Kenya, and seven times in Ethiopia, before equalling the cost of one single late response (Venton *et al.,* 2012). The implementation of FbF has also shown to improve the quality of information used by decision-makers in the event of an incoming natural disaster, specifically when EWS improve lead times between the warning and the natural disaster (Bischiniotis *et al*., 2019).

On a community level, the value of an FbF system goes beyond quantitative benefits. For example, the FbF can ensure that temporary flood measures, such as sandbags, are installed to protect critical infrastructures; buildings can be evacuated to reduce fatalities; or chlorine tablets can be distributed to ensure that more people have access to clean water which prevents the spread of disease (Bischiniotis *et al*., 2019). Most importantly, FbF saves lives (IFRC, 2017).

FbF has been used around the world since 2008 and there are numerous success stories associated with their implementation. For example, as India and Nepal were hit with cyclone Hudhud in 2014, there were zero causalities associated with the direct impact of the natural hazard since the local FbF system warned fishermen at sea and called them back to land. Although cyclone Hudhud took the lives of 59 people and injured 175 people, these impacts were the result of heavy blizzards and avalanches across various trekking routes, despite warnings from the official warnings regarding cyclone risks. In 2013, the FbF system prevented large-scale fatalities associated with cyclone Phailin India. The total death toll of 23 individuals was low as a result of 800,000 successfully evacuating buildings before cyclone Phailin arrived, possible due to timely weather predictions using state of the art climate models (Bhandari *et al.,* 2021)

2. Cost-Benefit Analysis

2.1 Approach and Methodology

This section discusses the cost-benefit analysis (CBA) of the proposed Project by comparing the costs and benefits of the suggested interventions with the counterfactual of a no-project scenario. Monetary estimates of the Project’s costs and benefits are identified in the year in which they arise and a discount rate is used to translate future costs and benefits into present values (ADB, 2017). The costs and benefits are used to estimate the economic net present value (NPV), defined as "the sum of the differences between the discounted benefits and cost flows" (pg. 48), and the economic internal rate of return (IRR), defined as "the discount rate at which the NVP becomes zero" (pg. 48). The following CBA will consider the Project efficient if the NPV of the project is greater than one and if the IRR is greater than the discount rate used to estimate the NPV, which also can be seen when the cost-benefit ratio being larger than one.

This CBA will discount future costs and benefits into present values using a social discount rate of 10%, in line with the best practice for Small Island Developing States and low-income developing countries. The discount rate reflects the inter-temporal value of the opportunity cost of investment from a societal perspective. A positive discount rate is higher than a zero social rate of time preference which places an equal value of future and current consumption, and thereby indicates a stronger preference for current consumption over future consumption. This assessment will undertake a sensitivity analysis to explore the robustness of the results. Sensitivity analyses test the sensitivity of the NPV estimates by altering the assumptions and parameters used to estimate the costs and benefits (OECD, 2018). The sensitivity analysis in this CBA will challenge the assumption of a 10% discount rate by comparing the findings when the NPV is estimated with an 8% and 12%, the 12% discount rate represents a conservative scenario that places a further negative bias on the NPV estimates. The sensitivity analysis will also challenge the uncertainty of findings by estimating the NPV across three scenarios where costs and/or benefits are increased and/or decreased by 10%, estimated at an 8%, 10% and 12% discount rate.

2.1.1 Data

The costs, benefits and counterfactual estimates in this report are based on data from the Pacific Catastrophe Risk Assessment and Financing Initiative (PCRAFI, 2011), PreventionWeb (2014) and DesInventar (2017). PCRAFI (2011) presents country risk data on Timor-Leste based on catastrophe risk models and is one of the first comprehensive assessments of cyclones, earthquakes and tsunamis in countries across the Pacific Ocean (Noy and Edmonds, 2016). PreventionWeb (2014) provides systematic data that inform policy decisions regarding disaster risks and building resilience. It is managed by the UNDRR and draws its data from various sources including EMDAT and DisInventar (PreventionWeb, 2021). DesInventar (2017) sources its disaster data for Pacific countries from the Secretariat of the Pacific Community and from national governments. However, the DesInventar data is commonly found to be underestimated as not all loss and damages are recorded following a natural disaster (Noy and Edmonds, 2016). The data used in this analysis is measured and/or translated into real terms using the base year of 2020. The analysis estimates costs and benefits over a 10 year period, which reflects the lifetime of the proposed early warning equipment. However, it is important to acknowledge that although the costs of the Project can be estimated over 10 years, the many benefits of the Project are non-quantifiable and go beyond the 10-year timeframe.

It is important to acknowledge that data available for Timor-Leste across all sources remain limited and of low quality, which can be attributed to the historical political instability and newly independent status of Timor-Leste. Therefore, the quantitative analysis on the costs and benefits of the Project in Timor-Leste is subject to incomplete datasets and limited access to all relevant variables. However, in order to ensure a high-quality analysis on the impact of the Project, this report has drawn on data from other SIDS in the Pacific as a solution. Specifically, the benefits articulated in this CBA partly draw on data from Fiji, a country with a similar surface area and asset replacement costs (PCRAFI, 2011). However, as the available data suggest that Fiji is almost twice as prone to natural disasters as Timor-Leste, this has been adjusted for in the calculations. Additionally, the issue of limited data on weather and natural hazards in Timor-Leste will be addressed as one of the objectives of the proposed Project. The Project will address the data gap by facilitating greater data collection in Timor-Leste and by delivering comprehensive capacity building to enhance capabilities to collect data on weather, water and climate-related disasters and climatic changes.

2.2.2 Assumptions

This section summarises all assumptions made in this economic analysis, outlined in two categories: general assumptions made for all cost-benefit calculations; and specific assumptions for estimating the benefits of the Project (see Section 2.4 Total Benefits of Project).

Firstly, general assumptions for this CBA:

i. **Period of analysis** – The NPV of the project are calculated over a 10-year period.
ii. **Discount rate** – The NPV is calculated with a discount rate of 10%.
iii. **Sensitivity analysis** – The sensitivity analysis assumes four alternative scenarios: a) 10% discount rate; b) benefits decrease by 10%; c) costs increase by 10%; and d) both reduced benefits of 10% and increased costs of 10%. Scenarios b, c, and d are calculated at an 8%, 10% and 12% discount rate.

Secondly, specific assumptions made for calculating the total benefits of the Project:

i. **Total benefits** – The benefits from the Project are assumed to be the sum of: a) total annual avoided damages and losses; and b) improved productivity in key sectors.
ii. **Total annual avoided damages and losses** – The total annual avoided damages and losses calculated as the sum of a) avoided costs or damages; b) avoided environmental damages; and c) avoided indirect economic losses. The three components are calculated according to the following assumptions:
    a. **Avoided costs or damages** – assuming reduced damages of 30% through extended lead time (see below).
    b. **Avoided environmental damages** – assuming avoided damages of 3%.
    c. **Avoided indirect economic losses** – assuming avoided losses of 5%.
iii. **Lead time** – The Project is assumed to reduce damages by 30% by extended lead time. The improved lead time is derived from calculations of avoidable damages from EWS according to Subbiah *et al*. (2008). The estimates suggest that the baseline EWS achieves a damage reduction of 6% following a natural hazard and the installation of a new EWS is estimated to achieve a damage reduction of 36% following a natural hazard, thereby improving damage reductions by 30% through an extended lead time.
iv. **Improved productivity in key sectors** – assuming an increase in productivity of 2%.
v. **Effectiveness** – The effectiveness of capital investments, referring to the benefits derived from the implemented project, is expected to be 10% in Year 1, 30% in Year 2, 60% in Year 3, 70% in Year 4 and 100% between Years 5 and 10.

2.2 Baseline - in the absence of the Project

Timor-Leste has a national meteorological service (DNMG) that only can provide basic weather services, with almost no capacity for forecasting and early warnings, which is not sufficient to protect communities from recurring natural disasters and climate change. Therefore, there is a need for climate services that increase lead time and produce more localised weather data information (Subbiah *et al.,* 2008). The specifics regarding the baseline of Timor-Leste's meteorological services can be outlined according to the four elements of the Multi-Hazard Early Warning Systems (MHEWS) Checklist (WMO, 2018). Firstly, the current state of disaster risk knowledge in Timor-Leste is characterized by traditional knowledge held by local communities, with a lack of systematic information dissemination regarding the trends and impacts of extreme weather events and climate-related disasters. Secondly, the current system for detection, monitoring, analysis and forecasting of climate hazards and possible consequences in Timor-Leste is of low quality. There is no systematic and established EWS for Timor-Leste and none of the DNMG's automatic or manual weather stations are currently reporting to the WMO Integrated Global Observing System (WIGOS). Thirdly, the warning dissemination and communication of extreme weather events have limited means and channels. Information on natural hazards and climate variability is mostly based on local knowledge as formal weather information is limited to those with televisions. Fourthly, the current state of preparedness and response capabilities in Timor-Leste is reasonably well developed for earthquakes and tsunamis but lacking for floods and drought. Current response methods for floods are based on traditional knowledge, which relies on estimating water levels at river-banks.

The baseline scenario is based on the estimated costs from damages incurred from natural hazards and climate impacts and presents the counterfactual to which the Project costs and benefits are compared. The baseline scenario is quantified in terms of Average Annual Losses (AAL) of natural disasters which is defined as "the expected loss per annum associated to the occurrence of future perils assuming a very long observation timeframe" (PreventionWeb, 2014). Data from PCRAFI (2011) suggests that the AAL for Timor-Leste is US$5.9 million when only considering earthquakes and tropical cyclones. Until 2060, Timor-Leste has a 50% chance of experiencing a total loss exceeding US$88 million with over 300 casualties, and a 10% chance of experiencing a total loss exceeding US$530 million with over 2,100 casualties.

2.3 Total Costs of Project

The total cost for the Project is estimated according to the four Project Results and 'Other' costs including Project Management Costs (PMC), Monitoring and Evaluation costs (M&E) and Contingency costs. The costs are categorized into capital and operational costs and are estimated over a 10-year period. Most equipment is estimated to be installed within the first 5 years of the project, have an average lifetime of 10 years and to be replaced after that period.

Table 1 shows the total capital and operational cost of the Project, which amounts to a total of US$23.51 million over 10 years. The total capital costs for the Project amounts to US$10.83 million and total operational costs amounts to US$11.68 million. Table 2 shows the distribution of total costs between the Government of Timor-Leste and GCF funds. The Government of Timor-Leste has agreed to provide co-financing of US$748,400 and US$20.98 million is requested as a Grant from the GCF. A detailed breakdown of all total costs can be found in Annex 3b.

	Capital Cost	Operational cost	Total cost
Result 1	-	491.25	491.25
Result 2	9,800.48	4,758.29	14,558.76
Result 3	436.81	2,095.83	2,532.64
Result 4	560.38	3,182.37	3,742.75
Other	32.47	2,157.06	2,189.53
	10,830.14	11,684.79	23,514.92

Table 1. Total cost of the Project (US$'000)

	Capital Cost	Operational cost	Total cost
GCF funding	8,895.64	12,084.79	20,980.43
Government of Timor-Leste	1,934.50	600.00	2,534.50
	10,830.14	12,684.79	23,514.92

Table 2. Distribution of funding (US$'000)

2.4 Total Benefits of Project

2.4.1 Quantitative Benefits: Total Benefits of the Project

The overall aim of the Project is to increase resilience to climate change and enhance the livelihoods of the population in Timor-Leste. This will be achieved by catalyzing a paradigm shift towards evidence-based decision making, strengthened preparedness to climate risks, and by ensuring the provision of timely, credible, impact-based and actionable climate and weather information. The Project will reach the "last-mile" by improving communities use and understanding of actionable climate information products and targeted early-warning alerts. As a result, the Project is estimated to reduce the negative impacts from climate-related hazards of 1,293,119 beneficiaries, representing 100% of the population, including a direct impact on 1,034,495 beneficiaries, representing 80% of the population.

The total benefits of the Project accrued over 10 years, as shown in Table 3, are estimated according to two components: the total annual avoided damages and losses and the improved productivity in key sectors. The first component – total annual avoided damages and losses – is the sum of (a) avoided costs or damages; (b) avoided environmental damages; and (c) avoided indirect economic losses. Firstly, the avoided costs and damages are calculated according to the AAL from all natural disasters in Timor-Leste, estimated at US$52.45 million. The Project is projected to improved lead-time and reduce damages by 30%, thereby avoiding costs and damages of US$122.1 million over 10 years. Secondly, the Project is assumed to increase the AAL by additionally 3% through avoided environmental damages, amounting to US$3.7 million over 10 years. Thirdly, the Project is also assumed to increase the AAL by additionally 5% though avoided indirect economic losses, amounting to US$6.1 million over 10 years. In sum, the total benefits derived from total annual avoided damages and losses is $131.9 million over 10 years. The second component of total benefits is calculated according to the benefits arising from improved productivity in key economic sectors. The Project is assumed to improve productivity in key economic sectors by 2%, generating benefits of US$2.4 million over 10 years. Additionally, the total benefits of the Project are calculated according to the assumption that the benefits from investments are realised with an efficiency of 10% in year one, 30% in year two, 60% in year three, 80% in year four, and 100% in year five and for following years. As a result, over 10 years, the total benefits derived from the total annual damages and losses avoided and from improved productivity across key economic sectors amounts to US$134.3 million. A detailed breakdown of all total benefits can be found in Annex 3b.

Total annual avoided damages & losses	Avoided costs or damages	122,094.44
	Avoided environmental damages	3,662.83
	Avoided Indirect economic losses	6,104.72
Improved productivity in key sectors		2,441.89
Total benefits		134,303.89

Table 3. Total benefits of the Project (US$'000)

The primary limitation to the quantitative analysis of benefits realised from the Project is the limited capacity of CBAs to incorporate the qualitative benefits which cannot be estimated in monetary terms (WMO, 2015a). Non-quantified benefits from EWS include social and environmental benefits, such as positive impacts on gender equality and ecosystem services, suggesting that the total benefit calculated in Table 3 are underestimated relative to the actual benefits derived by Timor-Leste. Further discussion on non-quantified benefits is provided in Section 2.4.2.

2.4.2 Qualitative Benefits: Social and Environmental Impacts

Social Benefits

The Project interventions are expected to have inherent social benefits for the population of Timor-Leste, as the climate and health are inextricably linked. Early warning systems can affect human health in three prominent ways: firstly, through the reduction in avoided losses and damages, there is a reduction in premature mortality; secondly, through the improvement of physical health among the individuals living with diseases, such as respiratory disease, relating to morbidity benefits; and thirdly, by reducing stresses and impacts on living, thereby improving mental health (OECD, 2018). Specifically, the value of a statistical life (VSL), which relates to the marginal value to prevent one additional mortality, has not been estimated in this CBA. VSL estimates have been omitted due to their ethical implications and complicated estimation processes. However, it is important to acknowledge that the value from reduced mortality, morbidity and mental health concerns are significant and their omission from the quantitative estimates results in a significant underestimation of total benefits from the Project.

Social benefits arising from the Project can also be observed within the health sector. The Project will work with DNMG and the Ministry of Health to co-develop tailored forecasting and sector-specific decision support systems, together with a mobile app, to extend the reach of health-related forecasts and advisories to the general public. Continuous engagement of multi-sectoral and multi-disciplinary stakeholders along the 'climate services for health' value chain will enable identification of health priorities and development of the most appropriate services to address these priorities; increase participation and ownership; improve perceptions towards the value of climate services; build in-country capacity; and align stakeholders' objectives and expectations.

At the community level, the Project will conduct targeted awareness-raising and education on climate-related health risks as a key trigger in encouraging protective behaviours and increasing collective local capacity to prepare for climate impacts. Moreover, the Project will build capacity to understand and use weather, water and climate forecasts and identify climate risks. This will enhance local knowledge and empower communities to increase their resilience to climate change impacts. Avoided loss of assets and livelihood sources will help to alleviate poverty in beneficiary communities by reducing the loss of income. Social cohesion will be promoted through community-based interventions and the co-development of a localised climate risk management plan. Additionally, the Project activities will create employment opportunities for national employees, particularly through hiring local consultants who will be employed by civil society organisations and government institutions. Local businesses will also benefit, as catering services, conference venues and interpreters will be employed as part of the workshop activities.

Environmental Benefits

The long-term environmental benefits of the Project are expected to be significant. The Project will support Timor-Leste's national meteorological service (DNMG) to generate and deliver impact-based forecasts, decision-support systems and advisories tailored to natural resource-dependent sectors, such as agriculture and fisheries. These activities will facilitate the rapid identification of weather, water and climate hazards that pose environmental risks and consequently inform the safeguarding of natural resources and biodiversity. Strengthened data sharing and inter-institutional coordination with the Water Sector, as well as the provision of data inputs to enhance the accuracy of flood hazard mapping and modelling, will contribute to improved water resource management. In addition, the establishment of marine forecasting will enable better management of coastal habitats and inform sustainable fisheries practices to minimise environmental impacts. The Project will also establish a high-resolution air quality monitoring and alerting framework that will provide multiple pathways for the Government of Timor-Leste to reduce climate change and air pollution impact through evidence-based mitigation policy and interventions.

At the local level, the Project will raise awareness on climate hazards and related risks, including environmental health, and will build preparedness capabilities for effective early action in response to early warnings. Moreover, training on the use of climate forecasts will sensitise communities to the value of climate information and early warnings towards reducing the impact of climate-related hazards, including on natural resources, ecosystems and biodiversity. This will contribute to enhanced local ownership for environmental protection and resilience building of natural environments.

2.5 Summary

The economic viability of the Project proposed in this CBA is determined according to the economic NPV and the IRR, estimated by comparing the costs and the benefits of the Project as found in sections 2.3 and 2.4. This CBA finds that, when estimating the NPV over 10 years with a 10% discount rate, the NPV is US$56.01 million and the IRR is 104.3%. As a result, the Project is considered efficient as the NPV is greater than one and the IRR is greater than the discount rate. The Project is also considered efficient according to the benefit-cost ratio of 5.7:1, which suggests that each US$10 invested generates benefits worth US$57.

This report tests the robustness of findings by conducting a sensitivity analysis by calculating the NPV and IRR across a range of assumptions and parameters. The sensitivity analysis has adopted conservative assumptions by estimating the economic NPV and IRR using an 8% and 12% discount rate. A 12% discount rate represents a relatively stronger preference for current consumption than future consumption, relative to an 8% discount rate, which has a relatively weaker yet positive preference for current consumption over future consumption. The sensitivity analysis also considers three conservative scenarios that challenge the uncertainty of the costs and benefits of the Project, including one scenario which reduces the benefits by 10%, one scenario that increases the costs by 10%, and one scenario which both reduces benefits by 10% and increases costs by 10%. All four scenarios of the sensitivity analysis have been calculated at an 8%, 10%, and 12% discount rate as shown in Table 4. All scenarios have NPVs are greater than one and the IRRs greater than the discount rates. This indicates that both the base results and the sensitivity analysis provide support for the effectiveness of the Project.

Scenario	NPV 8%	NPV 10%	NPV 12%	IRR (%)
NPV	63.76	56.01	49.36	104.3%
Reduced Benefits of 10%	55.49	48.61	42.71	90.2%
Increased Costs of 10%	61.87	54.21	47.64	91.5%
Reduced Benefits of 10% + Increased costs by 10%	53.60	46.81	40.99	79.4%

Table 4. Sensitivity Analysis (US$ million)

3. Conclusion

In conclusion, this report has reviewed costs and benefits following the proposed GCF Project on "Enhancing Early Warning Systems to build greater resilience against hydro-meteorological hazards in Timor-Leste" and provides a positive economic assessment of the Project.

As the climate changes and extreme weather events are projected to increase in frequency and/or intensity, the negative impacts on the lives and livelihoods of communities in Timor-Leste are likely to worsen, specifically increasing the risk of climate-induced fatalities and damages. The proposed GCF Project in this CBA aims to build resilience for the local communities in Timor-Leste to protect themselves against natural hazards through four result areas. Firstly, by strengthening the delivery model and legislation for climate information and MHEWS; secondly, by strengthening observations, monitoring, analysis and forecasting of climate and its impacts; thirdly, by improving the dissemination and communication of risk information and early warning; and finally, by enhancing climate risk management capacity.

The Project is estimated to have a lifespan of 10 years and have transformative impact on 1,034,495 beneficiaries, representing 100% of the population. The total net benefits of the Project are estimated to be US$56.01 million, calculated with a 10% discount rate. There is uncertainty in the findings of the CBA, with the total net benefits ranging between US$63.76 million and US$40.99 million, depending on various assumptions and parameters used. The sensitivity analysis provides support for the Project across all scenarios considered, as scenarios show a positive economic NPV and an IRR greater than the discount rate, which are the criteria used to determine the efficiency of the Project. However, the net benefits are likely to be underestimated due to conservative assumptions used in calculations in addition to the omission of the qualitative benefits excluded from the quantitative analysis, such as social and environmental benefits derived from the Project interventions. Most importantly, effective EWS save lives and this is arguably impossible to translate to dollar terms. As a result, this cost-benefit analysis provides quantitative support for the implementation of this Project which aims to enhance the EWS and build resilience against hydro-meteorological hazards in Timor-Leste.

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