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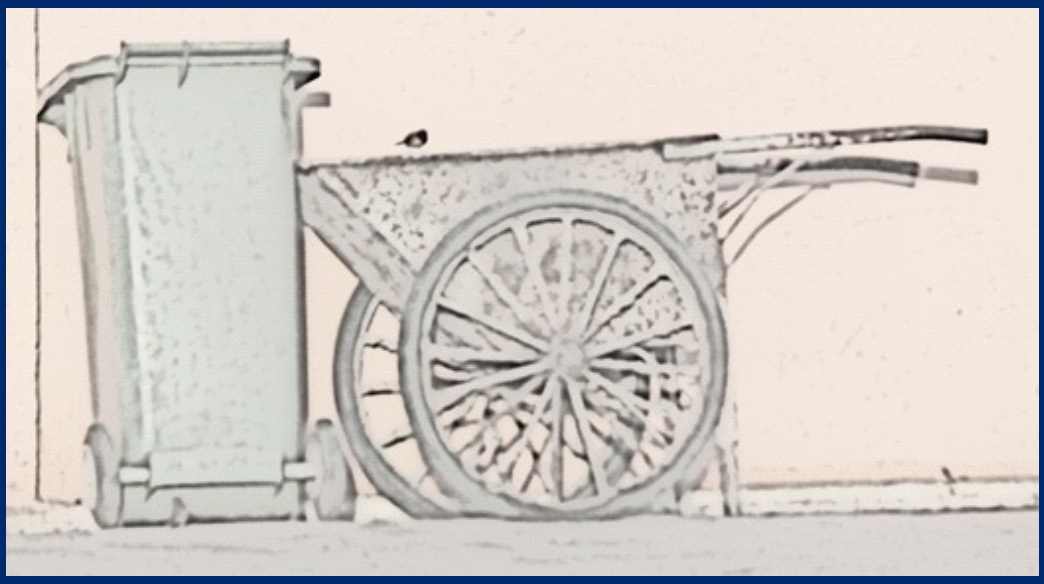
TA-8566 REG: Mainstreaming Integrated Solid Waste Management in Asia - Solid Waste Management Team (46248-001)

Report on Climate Change Vulnerabilities and Mitigation Options in Solid Waste Management

[The Philippines, Myanmar & Thailand]



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Executive Summary

Africa, East Asia & Pacific region, Central and South Asia regions are likely to experience relatively higher growth rate of waste generation and per capita MSW generation by 2025. The challenges in municipal solid waste (MSW) management are more acute in the developing countries of these region compared to the developed countries. On top of the anticipated higher solid waste generation, MSW management poses a severe challenge owing to various limitations such as technical and financial capacities, government regulations and policies, social perspective and institutional mechanisms, as well as lack of holistic and long term planning and strategies.

Asian Development Bank (ADB) has initiated a regional capacity development technical assistance (R-CDTA) project namely "Mainstreaming Integrated Solid Waste Management in Asia" which aims at supporting three shortlisted countries - the Republic of Philippines, the Republic of the Union of Myanmar and the Kingdom of Thailand. This project comprises (i) selection of five case study cities (CSCs), (ii) formulation of integrated solid waste management (ISWM) strategies, (iii) identification of feasible solid waste management (SWM) projects and delineating their structures and (iv) provision of recommendations on possible policy/regulatory reforms and institutional development to foster private-public partnership (PPP) in this sector.

This report is formulated based on the climate change actions and vulnerabilities which cause drastic changes than the normal routine of the three selected countries. This report details on the major vulnerabilities that these countries are bound to be exposed, due to the climate change. The impact of climate change on implementing SWM projects is discussed. The report also recommends the possible mitigation options for SWM as a preventive measure from climate change vulnerabilities.

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Abbreviations

3Rs	-	Reduce, reuse and recycle
ADB	-	Asian Development Bank
BAU	-	Business as usual
BOT	-	Build, own and transfer
CCAI	-	Climate Change and Adaptation Initiative
CRI	-	Climate risk index
CSC	-	Case study city
GDP	-	Gross domestic product
GHG	-	Greenhouse gas
GoM	-	Government of Myanmar
HVAC	-	Heating, ventilation and air-conditioning
IPCC	-	Intergovernmental Panel on Climate Change
ISWM	-	Integrated solid waste management
IUCN	-	International Union for Conservation of Nature
JTWC	-	Joint Typhoon Warning Centre
LGU	-	Local government units
MoNRE	-	Ministry of Natural Resources and Environment
MRF	-	Material recovery facility
MSW	-	Municipal solid waste
MT	-	Metric tons
MW	-	Mega Watt
NFSCC	-	National Framework Strategy on Climate Change
NSWMF	-	National solid waste management framework
OECD	-	Organization for Economic Co-operation and Development
ONEP	-	Office of national resources and environmental policy and planning
PEP SOA	-	Project Development Program Southeast Asia
PPP	-	Private public partnership
RA 9003	-	Regulation Act 9003
R-CDTA	-	Regional Capacity Development Technical Assistance
SLF	-	Sanitary landfill
SWM	-	Solid waste management
tpd	-	Tons per day
UNFCCC	-	United Nations Framework Convention on Climate Change

USAID - United States Agency for International Development

1. Introduction

The Earth's climate is a complex system consisting of atmosphere, land surface, snow, ice, oceans, other water bodies and living things. Climate is referred as the "average weather" with respect to the variation in temperature, precipitation and wind over a certain period in a defined region. Currently, climate change is the major environmental issue recognized by the countries globally. The risk associated with climate change is called vulnerability, a function of exposure, sensitivity to impacts and lack of ability to adapt. The communities across the globe are threatened not only by the climate change but also by the resulting environmental degradation leading to economic and social challenges.

1.1. Climate change

Climate change, global warming and the greenhouse gas effect, all refer to the same global environmental problem of increasing mean global temperature. Climate change will have significant impacts on every nation on the planet increasing the frequency of climate related catastrophes such as droughts, floods, storm surges, heat waves and wild fires.

The Intergovernmental Panel on Climate Change (IPCC) assessment (2014) revealed that the mean global temperature had increased by 0.85oCover the period from 1880 to 2012 and the sea level has risen by 19cmover the period from 1901 to 20101. IPCC has clearly stated that the developing countries will be affected the most by the climate change. IPCC has also stated that the climate related catastrophes had increased about five folds during the four decades of 1950-1992 and damages to economies had increased 10 fold during the same period.

1.2. Solid waste management (SWM)

The management of solid wastes has been considered as one of the most prominent challenges to the sustainable development worldwide, particularly, to the developing countries. The world development has undergone rapid urbanization in the past decades. The population residing in the urban areas, their living standards and the disposable income have been increasing. These, along with the change towards more urbanized lifestyle have led to the increase in solid waste generation.

According to a World Bank study2, there were about 2.9 billion urban residents generating 0.64 kg of municipal solid wastes (MSW) per person per day or 0.68 billion tons of MSW per year in total, during the decade of 1990s. The study estimates that the residents may have grown to 3 billion, with per capita MSW generation rate increased to 1.2 kg now. It also anticipates that the urbanized residents may increase to 4.3 billion generating 2.2 billion tons of MSW per year (~1.42 kg/capita/day of MSW generation rate) by 2025.In addition to the anticipated higher solid waste generation, MSW could be a severe challenge to the developing countries owing to various limitations such as technical and financial capacities, government regulations and policies, social perspective and institutional mechanisms, as well as lack of holistic and long term planning and strategies.

The summary of the World Bank study based on solid waste generation and population growth data for present and 2025 scenario from various countries around the globe is shown in Table 1-1.

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[1] IPCC 5th Assessment Report, 2014

[2] What a Waste: A Global Review of Solid Waste Management. 2012. The World Bank.

[2] What a Waste: A Global Review of Solid Waste Management. 2012. The World Bank.

[3] https://en.wikipedia.org/wiki/Philippines

[4] https://www.cia.gov/library/publications/the-world-factbook/geos/rp.html

Table 1-1 World waste generation by 2025

Region	Current available data			Projection for 2025		
	Total urban population (millions)	Urban waste generation		Projected urban population (millions)	Projected urban waste generation	
		Per capita (kg/capita /day)	Total (tons/day)		Per capita (kg/capita /day)	Total (tons/day)
Africa	260	0.65	169,119	518	0.85	441,840
East Asia & Pacific	777	0.95	738,958	1,229	1.5	1,865,379
Eastern & Central Asia	227	1.1	254,389	239	1.5	354,810
Latin America & Caribbean	399	1.1	437,545	466	1.6	728,392
Middle East & North Africa	162	1.1	173,545	257	1.43	369,320
OECD	729	2.2	1,566,286	842	2.1	1,742,417
South Asia	426	0.45	192,410	734	0.77	567,545
Total	**2,980**	**1.2**	**3,532,252**	**4,285**	**1.4**	**6,069,703**

1.3. Asian Development Bank project

Asian Development Bank's (ADB) Mainstreaming Integrated Solid Waste Management in Asia (hereafter "the Project") is a regional capacity development technical assistance (R-CDTA) project. The program aims to support the countries in selecting the case study cities (CSCs) and in supporting these cities to formulate integrated solid waste management (ISWM) strategies. The project will also identify feasible solid waste management projects, delineate their structures and provide recommendations on possible policy/regulatory reforms and institutional development to foster private-public partnership (PPP) in this sector.

This project plans for contribution towards the sustainable waste management. The holistic approach on various practices on SWM in the selected CSCs would help in dissemination and replication of the same in neighbouring countries and also would increase the investments in the SWM sector.

Under this project, ADB has shortlisted three developing Asian countries and will support in selecting the case study cities in each country, totalling to 5 case study cities, for developing international standard integrated SWM systems/practices. The three shortlisted countries are:

- The Republic of Philippines
- Republic of the Union of Myanmar
- The Kingdom of Thailand

1.4. Engagement of consultants

ADB has recruited professional experts in solid waste management (SWM) and related fields to carry out the study in the selected 5 CSCs. ADB have assigned the study to 21 consultants, both national and international. The consultants who are engaged in this project are:

- SWM Specialist - Technical
- SWM Specialist - Policy/Institutional
- Public - Private Partnership Specialist
- Finance Specialist
- Carbon Finance Specialist

The following are the roles and responsibilities of the carbon finance specialist:

- Assemble and review the country-level existing information on climate change vulnerabilities and mitigation & adaptation options towards addressing the projects in SWM sector in the CSCs
- Identify possible options and practices for reducing GHGs in the SWM sector, which can be integrated in the design of SWM
- Provide technical support and oversee the development of climate change related outputs and milestones, especially like, bringing in the sector-specific national/international cases and good practices
- Perform other tasks assigned by the team leader

This report is prepared in accordance with the role of carbon finance specialist to assemble and review (i) the country-level existing information on climate change vulnerabilities and (ii) possible mitigation & adaptation options for addressing the projects in SWM sector.

2. Climate change vulnerabilities

The existing climatic conditions of the country, potential climate changes and the vulnerabilities associated with those changes in each of the selected countries - The Philippines, Myanmar and Thailand, are explained in this chapter.

2.1. Republic of the Philippines

The Philippines is an archipelago consisting of 7,107[3] islands. The total coastal line covers 36,289[4] km, which also acts as the boundary length of the country. The total forest area accounts to 25.9%[4]of the total land area. The country is positioned in western part of the Pacific Ocean with 37 active volcanoes. Out of the 37, eighteen volcanoes are potentially active and could erupt at any time. Population of the Philippines is 100.09 million (2014)[5] and the density of population is approximately350people per sq.km of land area. Manila is the capital city of the Philippines. Currently, 17 administrative regions, one autonomous region and 81 provinces are governed by the Philippines government[6]. According to International Monetary Fund (2016), the country's Gross Domestic Product (GDP) is USD 299,314 billion which ranks 11th position among the Asian countries[7].

[3] https://en.wikipedia.org/wiki/Philippines

[4] https://www.cia.gov/library/publications/the-world-factbook/geos/rp.html

[5] http://www.worldometers.info/world-population/philippines-population/

[6] https://en.wikipedia.org/wiki/Administrative_divisions_of_the_Philippines

[7] https://en.wikipedia.org/wiki/List_of_Asian_countries_by_GDP

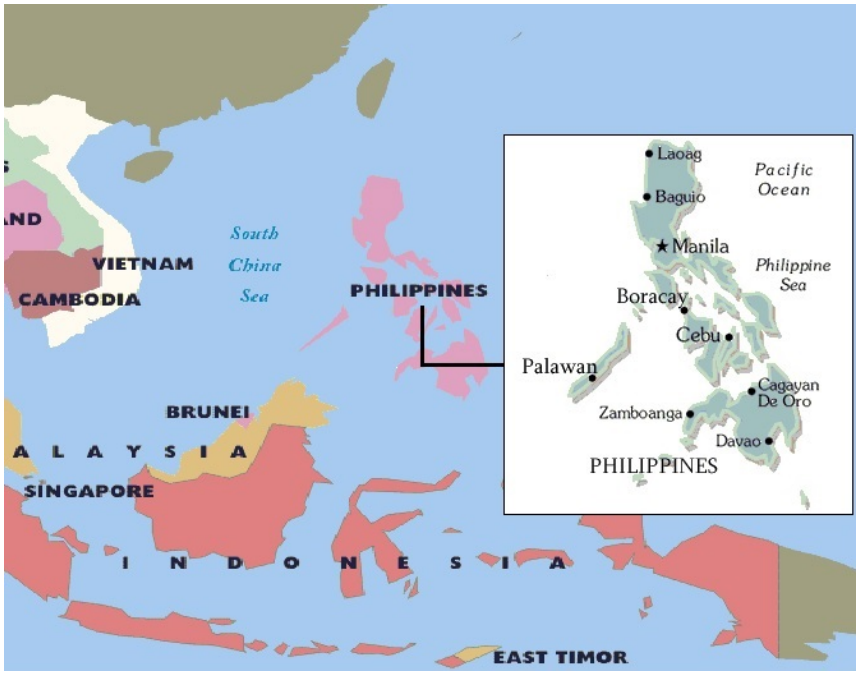

Figure 2-1 The Philippines location map

2.1.1. Existing climate conditions

The climate of the Philippines varies widely with high temperature, oppressive humidity and heavy rainfall. The Philippines has typical tropical climate with three seasonal variations namely summer (March to May), rainy season (June to September) and cool and dry monsoon (October to February). The annual average temperature of the Philippines ranges from 23 °C to 32 °C[8]. The annual average rainfall of the Philippines ranges from 96 cm to 406 cm[7]. The Philippines has 412 river basins, out of which, 19 are considered as the major rivers. Some of the major rivers of the country are Cagayan, Mindanao, Magat, Agusan and Pampanga rivers. Mount Apo is the highest peak in the Philippines and is one of the potentially active volcanoes in the country. Agriculture is the main industry in the Philippines with major crops being rice, sugar, coconut, pineapple, corn and rubber. Around 3,000 tree species and 210 mammal species are known to thrive in the country.

2.1.2. Climate change vulnerabilities

The climate conditions in the Philippines are vulnerable due to the increased occurrence of storm surges, cyclones and high tides, which result in significant soil and coastal erosions. An increase in the incidence of diseases such as malaria and dengue fever, are also projected as an effect of climate change. As per global Climate Risk Index (CRI) 2015, the Philippines ranks 5thin the list of countries which are worst affected by climate change. It was due to the extreme weather impacts, which prevailed in the country during 1994 – 20139.

The country is significantly affected by the impacts of human induced climate change and unsustainable coastal developments with dominant vulnerabilities of tropical cyclones, landslides, etc. The country wide climate change vulnerability factors are:

[8] http://www.nationsencyclopedia.com/geography/Morocco-to-Slovakia/The-Philippines.html

[9] https://germanwatch.org/en/download/10333.pdf

- Temperature
- Precipitation
- Sea level rise
- Access to water
- Migration
- Infrastructure
- Volcanic eruption

The above mentioned factors are detailed below.

- **Vulnerability to temperature**

In the Philippines, the average increase in temperature was recorded as 0.64°C[10] over the last decade. The projected increase in average atmospheric temperature is by 2˚C with 0.9 to 1.1 ˚C by 2020 and 1.8 to 2.2 ˚C by 2050[9].The increase in temperature directly influences the wind speed. Other impacts are, few or no rains in some parts of the country, shortened cold seasons and increased days of summer. This climate driven phenomena affects the major sectors of the country such as industrial sector (affected by the increased heat stress and energy demand), agricultural sector (increase in yield during hot seasons and decline in yield during cold seasons), etc. In addition, the increase in temperature causes increase in the number and severity of glacial melt-related floods, slope destabilization followed by the decrease in river flows due to disappearing glaciers. Outbreak of insects also increases over a period resulting in severe health risks such as malaria, dengue, etc.

[10] National Climate Change Action Plan (2011 – 2028), The Philippines

- **Vulnerability to precipitation**

Increase in precipitation depends on El Niño (surface water is warmer than the ocean temperature) and La-Niño (Ocean temperature is warmer than the surface water) conditions of the country.

Figure 2-2: Typhoon Haiyan[11]

The country is forecasted to experience an increase in both the frequency and intensity of the extreme daily rainfall event. According to Joint Typhoon Warning Centre (JTWC), 19 typhoons would have influence over the country, out of which six to nine typhoons would cause landfall, annually[12]. The impacts due to increase in precipitation are as follows:

- Reduction in agricultural productivity due to floods and storms
- Loss of vegetation
- Soil infertility, erosion and landslides
- Need for alternate cropping to adapt fluctuating seasons and rainfall
- Contamination of groundwater quality
- Disruption of settlements due to flooding
- Loss of property
- Changing patterns in the occurrence of disease vectors affecting the health
- Increase in endemic diseases and mortality due to diarrheal disease and increase in the abundance and/or toxicity of cholera

[11] http://www.news.com.au/world/typhoon-haiyan-more-than-100-reported-dead-in-philippines/story-fndir2ev-1226756265135

[12] http://www.dw.com/en/philippines-a-country-prone-to-natural-disasters/a-17217404

According to National Framework Strategy on Climate Change (2010-2022), the annual mean change of precipitation is expected to be from -0.5% to 17.4% in 2020 and -2.4% to 16.4% in 2050[13]. Luzon and Visayas regions are projected to receive high rainfall while Mindanao region will experience low rainfall or may experience dry atmosphere.

- **Vulnerability to sea level rise**

As stated by the World Metrological Organization in 2014, the Philippines posted the highest average increase in sea levels at 60 cm since 1901, against the global average of 19 cm[14].The river basins, coastal and marine systems are highly vulnerable due to sea level rise, consequently impacting the food security, water resources, human health, public infrastructure, hydropower plants and human settlement. Sea surface temperatures are likely to be 1°C to 4°C[15] by end of this century followed by sea level rise by 400cm to 600cm[16]due to the possibility of melting of the large land-based ice sheets in Antarctica and Greenland.

Figure 2-3: Sea level rise in the Philippines[17]

Extreme climate event will affect freshwater resources, especially, in the coastal areas through saltwater intrusion into the groundwater and incursion into the river bays. The movement of the saltwater to the river bays would affect the freshwater-pumping plants, brackish-water fisheries and agriculture. Mangrove forests, coral reefs and wetlands are increasingly threatened by the

[13] National Framework Strategy on Climate Change , 2010 - 2022

[14] http://www.interaksyon.com/article/84113/warning--ph-seeing-highest-sea-level-rise-in-the-world---thrice-the-global-average-in-fact

[15] http://wwf.org.ph/what-we-do/climate-solutions

[16] http://www.globalwarmingart.com/wiki/Special:SeaLevel

[17] http://6abc.com/weather/typhoon-hagupit-hits-philippines;-3-dead/426275/

severe climatic disaster and anthropogenic issues. Ocean acidification will lead to widespread coral reef death and will cause shrimps to become unable to develop skins, oysters unable to develop shells and fish larvae unable to develop bones.

- **Vulnerability towards access to water**

Watersheds and river catchments are highly sensitive to rainfall variations. In the Philippines, it is indicated that the rivers on volcanic and granitic islands have limited storage of water. In addition, rivers on porous limestone and low lying islands have minimal surface runoff and the water will rapidly percolate into the groundwater. Therefore, the projected changes in rainfall are expected to create severe water poverty and stress both in quantity and quality. Increase in the rainfall variability and longer dry periods will affect the amount of water in dams which provide irrigation services to the farmers, thereby limiting the agricultural production.

Figure 2-4: Loss of agricultural productivity[18]

These climatic conditions may result in severe drought affected by land degradation, increased livestock death, wildfire risk, water stress, water shortages for settlements, malnutrition risk, outbreak of water and food borne diseases, etc. The water scarcity will cause shortages in supply of water for drinking as well as domestic purposes to the human settlements. Domestic water supply will further be impacted by the poor infrastructure and poor governance in the Philippines.

- **Vulnerability on migration**

Migration and relocation are the important coping mechanisms for communities living in the disaster vulnerable areas. The impacts of climate change on agriculture and coastal resources will influence migration. Internal migration in the Philippines is driven by socio-economic factors. The general trends of migration show that poor people move from danger zones to safe zones, especially, into the cities where the services and infrastructure are developed. This pattern is

[18] http://www.vallartatoday.com/how-el-nino-will-change-the-world-s-weather-in-2014

likely to be intensified by the underdevelopment of the rural areas in the Philippines. Crop and livestock producers abandon agriculture because of the decreasing yields and migrate to the urban areas to seek new job opportunities. These shift in population results in additional pressures in already depressed urban areas, particularly in mega cities. These situations are likely to affect the overall GDP of the country.

- **Vulnerability to infrastructure damage**

Infrastructure facilities are threatened by climate change as they are directly exposed to prolonged and frequent rainfall, strong winds, cyclones and temperature variations that can lead to accelerated structural fatigue and material failure in the sectors of power transmission structures, roadways, public buildings, historical monuments, sea ports, dams, air ports and railway structures.

Figure 2-5: Damage caused by cyclone[19]

- **Vulnerability to volcanic eruption**

Volcanoes are the most catastrophic to the geology of the earth. In 1991, the Philippines experienced the world's second largest volcanic eruption at Mt. Pinatubo followed by earthquakes, cyclones, etc., causing explosion of hot gas, ash and giant mudflows. Mt. Pinatubo emitted billion tons of magma and million tons of sulphur-di-oxide spreading as an ash cloud all over the earth.

[19] http://www.huffingtonpost.com/2013/11/11/typhoon-haiyan photos_n_4256159.html?ir=India&adsSiteOverride=in

Figure 2-6: Eruption of Mount Pinatubo, Philippines (1991)[20]

This caused the global temperature drop by 0.5 ^{o}C[21] temporarily (1991-1993). The sulphur-di-oxide mixed with water and oxygen in atmosphere created sulphuric acid which caused acid rain. This had direct influence over the human health, causing skin diseases, cancer, respiratory diseases, etc. More than 200,000 people faced issues like infrastructure damage, unemployment, destruction of agriculture, migration and poverty due to this volcanic eruption.

[20] http://pubs.usgs.gov/fs/1997/fs113-97/

[21] http://pubs.usgs.gov/fs/1997/fs113-97/

Table 2-1Summary of Climate Change Vulnerabilities

Indicators	Current trends	Projections	Vulnerability
Temperature	The prevailing temperature is 23°C to 32°C. Average annual temperature increase by 0.64°C from 1951-2010.	Mean average temperature increase by 0.9°C to 1.1°C by 2020 and 1.8°Cto 2.2°C by 2050.	• Change in wind speed • Increased summer days • Increase in heat stress and energy demand • Melting of glaciers
Precipitation	No evidence of precipitation level increase or decrease over the period	Mean change in precipitation by -0.5% to 17.4% by 2020 and -2.4% to 16.4% by 2050.	• High intensity tropical cyclone • Land degradation • Loss in agricultural productivity • Contamination of groundwater
Sea level	Average sea level increase by 60 cm since 1901	Sea level increase by 100 cm[22]	• Salt water intrusion into water beds • Ocean acidification • Threat to aquatic life, coral reefs and mangrove areas • Threat to human and wild life • Infrastructure damage • Threat to agricultural productivity

2.2. Republic of the Union of Myanmar

Myanmar is the largest country in Southeast Asia and is bordered by China, Laos and Thailand in east, by India and Bangladesh in north and by Indian Ocean in west and south. Myanmar has a total land area of 676,578 sq.km,[23] extending 800 km east to west and 1,300 km north to south with a population of 53.44 million (2014)[24]. The population density is approximately 80 persons per sq.km of land area. The majority of the population is concentrated in the Sagaing, Magway and Mandalay regions. Myanmar is divided into 14 administrative units consisting of seven states and seven regions. Nay Pyi Taw is the country capital and Yangon is the largest city in the country. Myanmar is rich in natural forests which covers 49% (~ 317,730 sq.km) of

[22]National Framework Strategy on Climate Change , 2010 - 2022

[23]http://unstats.un.org/unsd/demographic/products/dyb/dyb2012/Table03.pdf

[24]http://data.worldbank.org/country/myanmar

the total land area[25]. According to International Monetary Fund (2016), the country ranks 23rd position among the Asian countries in terms of GDP growth of USD 65,775 billion[26].

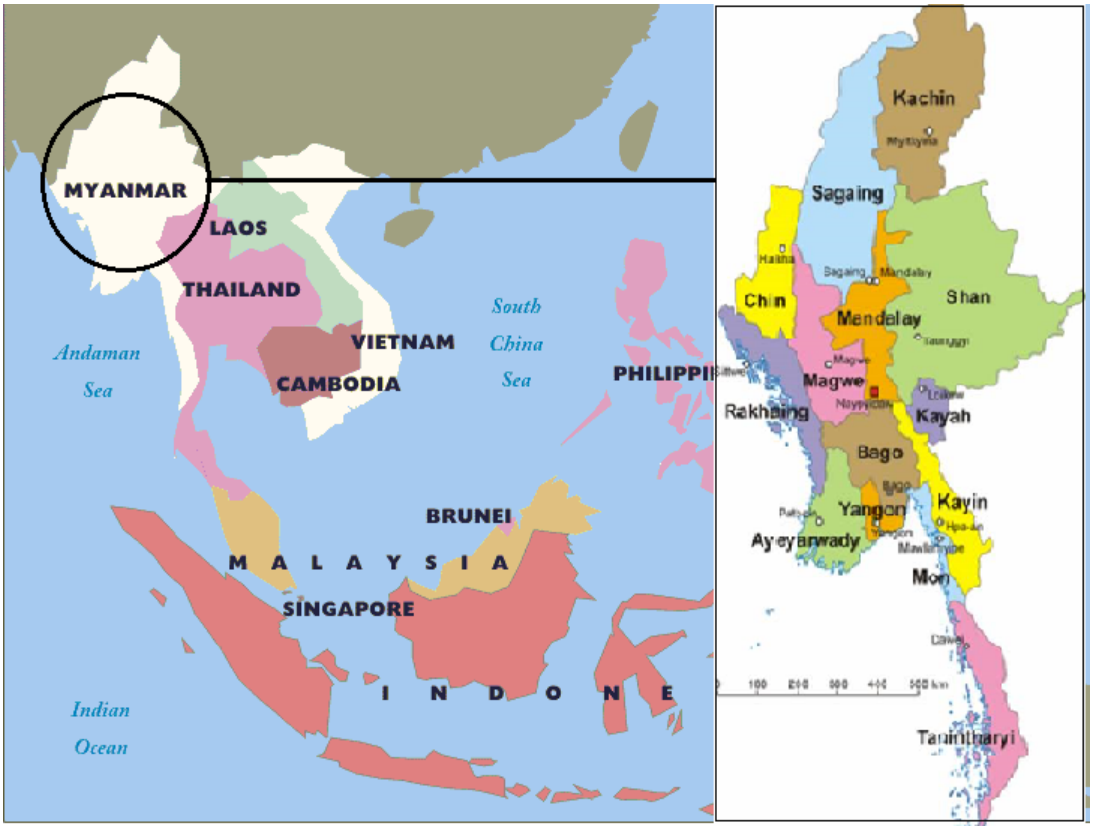

Figure 2-7: Myanmar location map

2.2.1. Existing climate conditions

Myanmar has a tropical to subtropical monsoon climate with three seasons namely dry season (mid-February to mid-May), rainy season (mid-May to late October) and cool relatively dry monsoon (late October to mid-February). The climatic conditions of Myanmar widely differ due to its different topographic conditions. Mean temperature ranges between 32°C in coastal areas and 21°C in northern lowlands. In the central zone, dry temperature is recorded at the maximum range of 40-43°C to 10-15°C in the cool relatively dry monsoon[27]. Highest mean annual rainfall of about 250 - 550 cm/year has been recorded in the coastal regions, whereas the lowest of about 50-100 cm/year has been recorded in the central dry zone[28].Frequent tropical storms and cyclones occur during October to December and April to May.

Myanmar has a variety of ecosystems namely plains, mountains, forests, wetlands, etc. Forest and wetland ecosystems include mangroves, swamp forest, lakes, marshes, etc. and important species of animals, including - tiger, leopard, elephant, wild boar, crocodile, freshwater fishes, etc. Myanmar has a wide range of plant species including teak, rubber, bamboo, oak, pine,

[25] World Bank. Myanmar country data. http://data.worldbank.org/country/myanmar.

[26] https://en.wikipedia.org/wiki/List_of_Asian_countries_by_GDP

[27] Myanmar's National Adaptation Programme of Action (NAPA) to climate change, 2012

[28] Myanmar's National Adaptation Programme of Action (NAPA) to climate change, 2012

coconut, banana, mango and guava. Agriculture is the predominant sector in Myanmar, with major crop being rice followed by wheat, maize and millets. Myanmar has three volcanoes namely Singu, Lower Chindwin and Mt. Popa, which are less active and it has been more than a decade since they have last erupted. The people of Myanmar are frequently affected by vector borne diseases such as diarrhea, cholera, influenza, malaria, dengue and yellow fever. Diarrhea is common throughout the year.

2.2.2. Climate change vulnerabilities

Myanmar's environment, people and society are at a significant risk due to climate change that results in reduced agricultural yields, spreading of diseases and loss of habitable land. Government of Myanmar (GoM) has identified the below as the priority sectors which are subjected to climate change:

- Agriculture
- Energy and industry
- Forest
- Public health
- Water resources
- Coastal zone
- Biodiversity

The country is significantly affected by the impacts of human induced climate change and unsustainable coastal developments with dominant vulnerabilities of tropical cyclones, landslides, etc. The country wide climate change vulnerability factors for Myanmar are listed below.

- Temperature
- Precipitation
- Sea level rise
- Intensity of disasters such as droughts, cyclone and landslides

The details of the above mentioned climate change vulnerability factors are furnished below:

- **Vulnerability to temperature**

During 1951-2007, the temperature in Myanmar had increased at an average rate of ~0.08^{0}C per decade. Kayin state had faced high temperature increase of about ~0.32^{0}C per decade. In addition, five regions of Myanmar had experienced decrease in temperature in the range of -0.23^{o}C to -0.16^{o}Cper decade. From 1951 to 2000, approximately 15 heat waves had occurred per year in Myanmar. In May 2010, the hottest temperature of 47.2^{o}C[29]has been recorded in Myinmu, Sagaing Division, which reported 260 heat related deaths[30].The temperature across Myanmar has been projected to increase by 0.8^{o}C to 1.4^{o}C by 2050 and by 2.8^{o}C to 3.5^{o}C by 2100[31]. Figure 8 shows the temperature projections for Myanmar from 2001 to 2100.

[29]https://en.wikipedia.org/wiki/2010_Northern_Hemisphere_summer_heat_waves#Burma_.28Myanmar.29

[30]Myanmar's National Adaptation Programme of Action (NAPA) to climate change, 2012

[31]Myanmar's National Adaptation Programme of Action (NAPA) to climate change, 2012

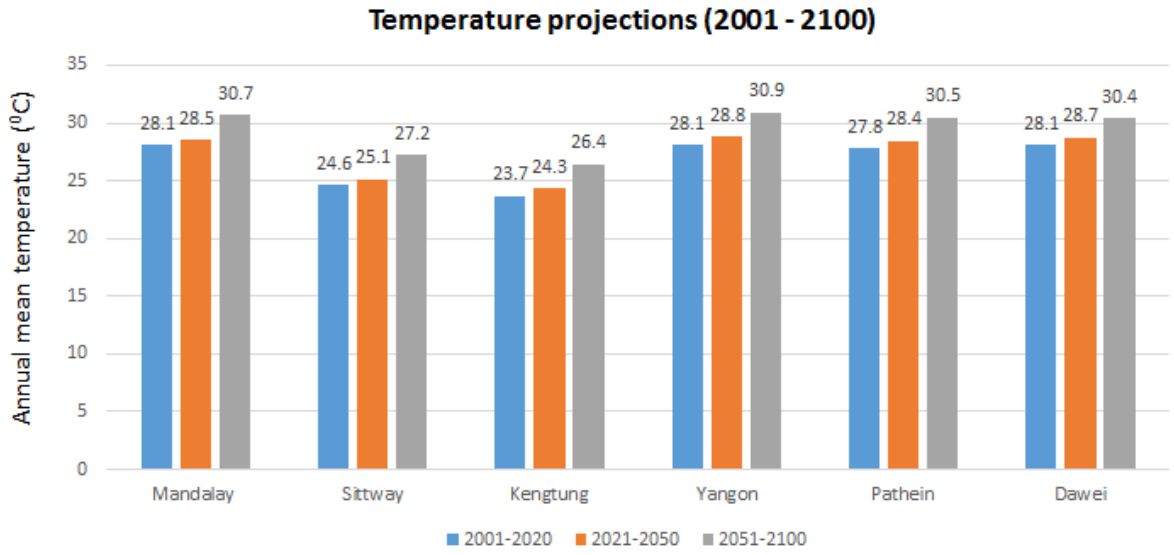

Figure 2-8: Myanmar temperature projections (2001-2100)[32]

The extreme high temperatures would result in situations like decreased agricultural production, outbreaks of disease, occurrence of wildfires in forest covers, decline in water storage, etc.

- **Vulnerability to precipitation**

Rainfall pattern of Myanmar becomes unpredictable due to vulnerable climate change. However, the annual rainfall is forecasted to increase between March and November and to decrease between December and February. The annual rainfall in Myanmar ranges from50 - 100 cm in dry zone and from 200 - 600 cm in coastal and delta regions[33].Over the period of 1951-2007, the average annual rainfall in Myanmar has increased by 2.9 cm per decade[34]. The projections of average annual rainfall indicate that there will be an increase in rainfall across the country by ~158.2 cm per year in the coastal region and by ~20.9 cm in the hilly regions by 2100[35].

The change in rainfall will increase the demand of water for drinking, irrigation and food production. The projected rainfall changes will reduce the forest vegetation cover and will increase the runoff, erosion and sedimentation of rivers. In July 2009, 43.4 cm of rainfall was received in a single day in Launglon breaking the highest 24 hour rainfall record in the country. Similarly, Bago division received 24 hours continuous rainfall in August 2009 which resulted in severe flooding. Figure 9 shows the annual rainfall variability of Myanmar from 2001 – 2100.

[32]Myanmar's National Adaptation Programme of Action (NAPA) to climate change, 2012

[33]http://bytelife.altervista.org/monsoon.htm

[34]Myanmar's National Adaptation Programme of Action (NAPA) to climate change, 2012

[35]Myanmar's National Adaptation Programme of Action (NAPA) to climate change, 2012

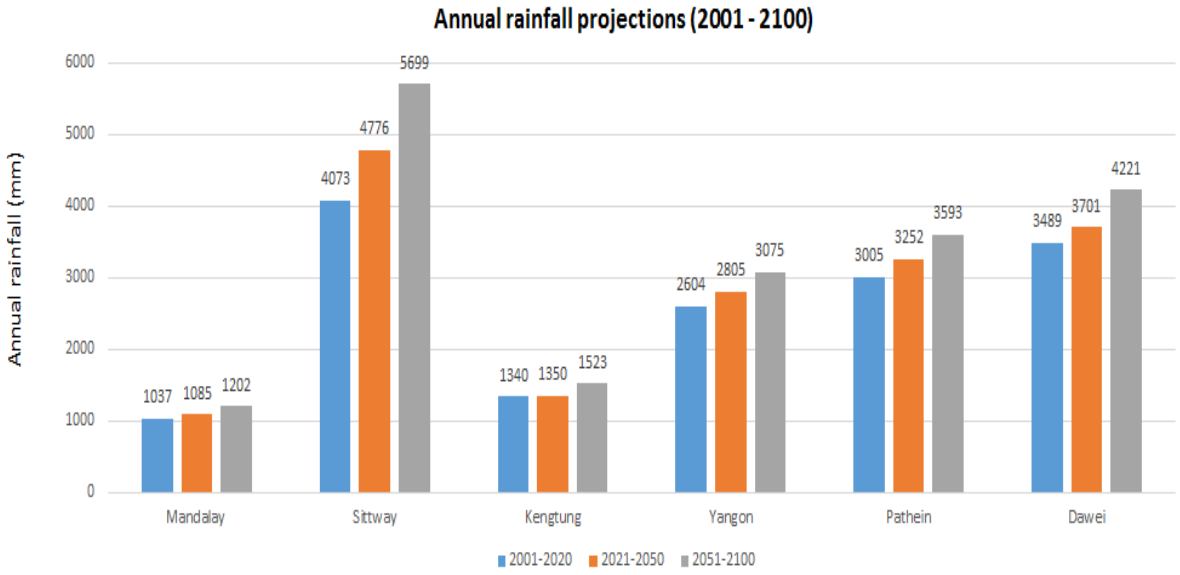

Figure 2-9: Myanmar annual rainfall projections (2001 - 2100)[36]

- **Vulnerability to sea level rise**

Myanmar is vulnerable to the rising sea level as a result of its highly populated, low-lying coastline mainly in Ayeyarwady delta region. A small increase in the sea level will inundate large part of the delta region. On 02 May 2008, a 12 feet height storm surge has inundated 4 major rice-growing divisions of Ayeyarwady region, which accounted for 58% of the national rice production. According to the study carried out by National Centre for Atmospheric Research in 2010, along the coasts of the northern Indian Ocean, the sea level has risen by an average rate of about 1.3 cm per decade[37]. The projection in 2012showed that 50cm of sea level rise will cause advancing of the shoreline along the Ayeyarwady Delta by 10 km[38].The rising sea level will lead to intrusion of sea water, coastal erosion, high demand of freshwater sources and threats to coral reefs, aquatic habitats, etc.

[36]Myanmar's National Adaptation Programme of Action (NAPA) to climate change, 2012

[37]http://www.colorado.edu/news/releases/2010/07/13/sea-levels-rising-parts-indian-ocean-according-new-study

[38]Myanmar's National Adaptation Programme of Action (NAPA) to climate change, 2012

Figure 2-10: Sea level rise in Ayeyarwady Delta[39]

- **Vulnerability to droughts, cyclone and landslides**

The intense changes in the temperature and rainfall patterns in Myanmar result in increased drought and frequent cyclones and landslides. Cyclone Nargis was the most devastating cyclone that occurred in Myanmar during May 2008. The cyclone caused extensive damage to mangroves, increased salinity in agricultural lands as well as freshwater sources, loss of livelihoods and infrastructures (3.2 million people affected), including 138,373 deaths.

Since 2011, severe droughts have occurred due to an extended dry season and extreme temperatures mainly in the central region of Myanmar (e.g., Mandalay, Magway, etc). The conditions of these areas are worst hit in past five years, where people have been suffering due to water scarcity[40]. In February 2016, Myanmar meteorology department reported that Mandalay will face severe drought during March-May which will affect 40,500 ha. of farmland cultivation[41]. Researchers of Oxford University have predicted that climate change in Myanmar will have a severe impact on food production and may result in the underweight related deaths in adults by 2050[42].

Landslides often occur in the mountainous region of Myanmar especially, in the western ranges. In 1999, the landslide occurred along the western slopes of the Taninthayi ranges due to heavy

[39] http://www.voanews.com/content/myanmar-floods-thein-sein-evacuations/2904274.html

[40] http://frontiermyanmar.net/en/drought-the-dry-zone

[41] www.news.xinhuanet.com

[42] http://www.mmtimes.com/index.php/national-news/mandalay-upper-myanmar/19337-climate-change-could-cause-4450-deaths-in-myanmar.html

rainfall and caused damages to several villages. Some schools and households were also buried under the landslide[43].

Figure 2-11: Drought in Myanmar[44]

[43]Hazard profile of Myanmar, July 2009

[44]https://asiancorrespondent.com/2011/07/china-ignores-own-irrawaddy-dam-study/

Figure 2-12: Cyclone Nargis[45]

Table 2-2 Summary of climate change impacts

Indicators	Current trends	Projections	Vulnerability
Temperature	The prevailing temperature ranges between 10°Cand 43°C. Average annual temperature increase by ~0.08°C from 1951-2007.	Mean average temperature increase by 2.8°C to 3.5°C by 2100.	• Change in wind speed • Increase in summer days • Increase in heat stress and energy demand • Melting of glaciers
Precipitation	The mean rainfall increase by ~2.9cm per decade from 1951-2007.	Mean annual rainfall increase by ~ 20.9 cm to 158.2 cm per year by 2100.	• High intensity tropical cyclone • Land degradation • Loss in agricultural productivity • Contamination of groundwater • Reduction in the period of Southwest Monsoon

[45] http://www.collectivelens.com/blog/disaster-relief-photos

Indicators	Current trends	Projections	Vulnerability
Sea level	Average sea level increase by 1.3 cm per decade in north Indian Ocean	A 50cm of sea level rise would result in advancing of 10km shoreline in Ayeyarwady delta region.[46]	• Salt water intrusion into water beds • Ocean acidification • Threat to aquatic life, coral reefs and mangrove areas • Threat to human and wild life • Infrastructure damage • Threat to agricultural productivity

2.3. Kingdom of Thailand

Thailand is situated at the centre of mainland Southeast Asia with the total land area of approximately 513,120 sq.km[47]. The total population of Thailand is 67.96 million (2015)[48] with a population density of approximately 130 persons per sq.km of land area. The natural vegetation of Thailand is extremely diverse. 32.1% of the country's land area (~ 163,990 sq.km) is covered by biodiverse and dense forest[49]. Bangkok is the national capital of the Thailand. Thailand has 76 provinces and one special administrative district namely Bangkok. According to International Monetary Fund (2016), the country ranks 8th position among the Asian countries in terms of GDP growth of USD 373,536 billion[50].

[46] Myanmar's National Adaptation Programme of Action (NAPA) to climate change, 2012

[47] https://www.cia.gov/library/publications/the-world-factbook/geos/th.html

[48] http://www.worldbank.org/en/country/thailand

[49] http://www.fao.org/3/a-i4808e.pdf

[50] https://en.wikipedia.org/wiki/List_of_Asian_countries_by_GDP

Figure 2-13: Thailand location map

2.3.1. Existing climate conditions

The climate of Thailand is tropical under the influence of two monsoon winds namely southwest monsoon and northeast monsoon. Thailand's landscapes vary from low mountains to fertile alluvial plains dotted with rice paddies to sandy beaches set amid the equatorial latitudes of the Asian monsoons. The three distinct seasons of the country are summer from March to May, monsoon from June to October and winter from November to February. The annual temperature of Thailand varies from extreme minimum of -1.4 ^{0}Cto extreme maximum 44.5 ^{0}C[51]. The annual average rainfall ranges from 120cm to 160 cm[52].Rice is the major crop and other crops are rubber, sugarcane, cassava, fruits, cashew nuts, corn, tobacco, cotton, cocoa, peanuts and soybeans.

2.3.2. Climate change vulnerabilities

As per global Climate Risk Index (CRI) 2015 ranking, the Thailand is placed 11thfor the extreme weather impacts in the country during 1994 - 2013[53]. This is the indication that Thailand is one of the most affected countries in the world due to climate change given its geography, economy and level of development. The country wide climate change vulnerability factors for Thailand are listed below:

- Temperature

[51] The climate of Thailand.pdf

[52] The climate of Thailand.pdf

[53] https://germanwatch.org/en/download/10333.pdf

- Precipitation
- Sea level

The details of above list of climate change vulnerability factors are furnished below:

- **Vulnerability to temperature**

Thailand is experiencing severe impacts of global warming. Thailand meteorological department has reported that the annual mean temperature in Thailand rose by approximately 10C from 1981 to 2007.The average temperature of Thailand generally varies from minimum of 13 0C to maximum of 35 0C, approximately54.

In 2004 to 2005, Thailand faced severe drought due to high temperature, which resulted in rapid evapo-transpiration and water shortage. The cultivated crops were affected by these changes and resulted in very low yield, which was not sufficient for the country. The economy of the country declined due to the reduced number of tourists owing to the temperature change. The human settlements also suffered a lot due to the surface warming and break out of severe epidemic diseases.

- **Vulnerability to precipitation**

The number of rainy days and the level of precipitation in Thailand have decreased over the last 50 years. The decline in annual precipitation has an impact on water resources of Thailand. The annual rainfall in Thailand generally ranges from 102 cm to 380 cm[55].The estimated scenario shows that high intensity rainfall over a short duration results in heavy flooding and coastal erosion. The amount of precipitation is dispersed differently among the regions of Thailand. Precipitation level in north of the country remains constant, while it is increased by 40% in south. The rest of the country receives 20% high precipitation than the actual.

[54] http://www.nationsencyclopedia.com/Asia-and-Oceania/Thailand-CLIMATE.html

[55] http://www.nationsencyclopedia.com/Asia-and-Oceania/Thailand-CLIMATE.html

Figure 2-14: Ubon Rattana dam in Thailand[56]

Flood causes(i) deforestation, (ii) soil erosion, (iii) increased water level in waterways, (iv) overflow of water from the reservoirs when exceeding their holding capacity, (v) increased pressure in drainage of water, etc. Infrastructure of the human settlements is endangered due to flooding and as a result, frequent migration of people takes place. The flood also declines the quality of fresh water, causing deterioration of oxygen content, increased production of aquatic biomass and decreased biodiversity of species.

Figure 2-15: Flood in Thailand 2011[57]

- **Vulnerability to sea level rise**

The country is also extremely vulnerable to sea level rise. Bangkok, the capital city, which lies at an elevation of just 5 feet above the sea level, is under threat due to sinking land and rising global sea levels. The land area of the city is already sinking at the rate of 2 cm every year. It is projected if the same rate continues, and then Bangkok will be submerged in water in the next 15 years[58]. According to the study conducted by Thailand-EC Cooperation on 2013, the sea level change in the bays of Bangkok and Mekong delta is 0.5 to 0.6 cm/year, which is much faster than the global sea level rise[59]. Rising sea levels and coastal erosions are also threatening the coastal cities of Thailand that are vulnerable to sink into the sea by 2030. Salt water intrusion from the sea has contaminated the groundwater and fresh water resources, increasing the salinity of water and salt deposition leading to soil erosion. This climatic change has increased the intensity and frequency of severe tropical storms causing damage to the

[56] http://www.bangkokpost.com/photo/photo/347210/drought-in-northern-and-northeastern-thailand

[57] http://sites.psu.edu/vxp5086/2014/03/06/flood/

[58] https://weather.com/science/environment/news/bangkok-sinking-subsidence-warming-15-years

[59] http://eeas.europa.eu/delegations/thailand/documents/thailande_eu_coop/geo2tecdi/naeije_en.pdf

coastal areas and low lying areas. Changes in ocean currents, salinity, temperatures, wind directions, as well as the vertical circulation of ocean water will affect the nutrients, the species composition and the population dynamics of the ocean ecosystems and fish production.

Figure 2-16: Thai temple influenced by sea water inland invasion in 2008

Table 2-3 Summary of climate change impacts

Indicators	Current trends	Projections	Vulnerability
Temperature	The prevailing temperature is 13^0C to 37^0C. Average annual temperature increases by 1^0Cfrom 1981-2007.	Mean average temperature increase by 1.4^0C to 5.8^0C[60] by 2100.	• Water scarcity • Increased summer days • Increase in outbreak of diseases • Melting of glaciers • Extinction of species • Loss in agricultural productivity
Precipitation	The annual total precipitation decreases by 0.77 cm/decade during 1955 – 2007[61].	Change in average precipitation is 10% - 20% by 2100.[62]	• High intensity tropical cyclone • Land degradation • Loss in agricultural productivity • Contamination of groundwater
Sea level	Sea level rise by 0.5-0.6 cm/year[63]	Global mean level rise is 26cm to 98cm by 2100.[64]	• Salt water intrusion into water beds • Ocean acidification • Threat to aquatic life, coral reefs and mangrove areas • Threat to human and wild life • Infrastructure damage • Threat to agricultural productivity

[60] http://www.meteo.gov.lk/index.php?option=com_content&view=article&id=14&Itemid=133&lang=en#future-scenarios-of-temperature

[61] http://onlinelibrary.wiley.com/doi/10.1002/joc.1979/pdf

[62] http://www.climatechange2013.org/images/report/WG1AR5_SPM_FINAL.pdf

[63] http://eeas.europa.eu/delegations/thailand/documents/thailande_eu_coop/geo2tecdi/naeije_en.pdf

[64] https://www.ipcc.ch/pdf/assessment-report/ar5/wg1/WG1AR5_Chapter13_FINAL.pdf

3. Climate change priorities and SWM practices

SWM is one of the most vulnerable sectors rapidly influenced by climate change. Urbanization, changes in the lifestyle of an individual and increasing population lead to the generation of large quantity of solid wastes. The generated solid wastes are not being processed appropriately due to the lack of advanced technology and efficient management in the developing countries. The developing countries, especially Asian countries are struggling to implement efficient SWM practices due to insufficient capital funds. In addition to this crisis, climate change plays a tremendous role in SWM in terms of disruption or disaster. Solid waste is the major contributors of greenhouse gas (GHG) emissions accounting to 60% of the total global emissions.

In this context, the current solid waste generation and management in the selected 3 countries is explained in this chapter.

3.1. Republic of the Philippines

In the Philippines, rapid increase in solid waste is an indication of urbanization. Cities usually generate more wastes compared to the rural areas. SWM remains to be one of the biggest challenges that the country faces today. The total waste generation of the country is estimated to be 35 tpd or 13.1million tons/year. The national capital region posted the highest solid waste generation rate of 0.71 kg/capita/day whilst for the rest of the country, it ranges from 0.30kg to 0.684 kg/capita/day, depending upon the socio – economic status of each region[65].

The Philippines conducted second GHG emission inventory survey in 2000 for different sectors and found that the country's emission was totaling to126.877 million tCO2e. It was reported that the emissions from the waste sector was 11.6million tCO2e backing 9% of the total country's GHG emissions[66]. According to the National SWM Strategy, the emission from waste sector has increased to 10.4% in 201267.

The Philippines has already enacted effective waste management laws towards sustainable environment. The objective of the framework is to enhance implementation of proper waste management and the priority should be given in promoting the best practices in waste management, involving all categories of waste. The Philippines government has implemented two nationally approved frame works, one for the climate change and the other one for SWM strategy as given below:

- National Framework Strategy on Climate Change 2010-2022
- National Solid Waste Management Strategy 2012-2016

[65] National solid waste management strategy 2012-2016

[66] National Framework Strategy on Climate change 2010-2022

[67] National solid waste management strategy 2012-2016

Figure 3-1: Payatas dumpsite in The Philippines[68]

3.1.1. Second national communication to the UNFCCC

The Philippines' second national communication to the UNFCCC was submitted on 29 December 2014[69]. The Philippines took an inventory of GHG emissions for the year 2000 and it showed that the country emitted a total 126.877 milliontCO_2e. The biggest contributor to the GHG emission was the energy sector, followed by agriculture, and to a lesser degree was the waste and industrial processes sector.

Waste sector:

For the year 2000, the waste sector had released 11.6 millionCO2e to the atmosphere. Approximately 47% of the total emissions came from solid wastes which generated 5.45 millionCO2e.This amount only accounted for the wastes that were brought to the solid waste disposal sites. Municipal, industrial wastewater and human sewage were considered to be under the sector of wastewater handling, which collectively accounted for 6.15 millionCO2e or 53% of the emissions.

The Philippines is aggressively formulating programs and projects to address the barriers and to promote the GHG emission reduction technologies in the waste sector. The following technologies are needed to reduce emissions from the waste sector:

- Technologies for wastewater treatment or sewage treatment
- Landfill technologies

[68] http://www.dailymail.co.uk/news/article-3148193/Beneath-poverty-line-Children-Philippines-risk-lives-sifting-floating-rubbish-filthy-rivers-material-sell-survive.html

[69] http://unfccc.int/essential_background/library/items/3599.php?rec=j&priref=7784#beg

- Technologies for recycling
- Waste to energy technologies
- Methane capture from disposal facilities, hog farms, etc.
- Waste heat recovery

3.1.2. National INDC communication to the UNFCCC

The Philippines' "Intended Nationally Determined Contributions" (INDC) is communicated to UNFCCC on October 2015[70]. The Philippines is highly vulnerable to the impacts of climate change and natural hazards. Climate change and natural hazards will progressively impact sectors that are strategically important for the growth of the economy, e.g., agriculture, fisheries and water resource management. Increase in temperature, coupled with changes in precipitation patterns and hydrological regimes, can only worsen the country's existing vulnerabilities, threatening its sustainable development and the survival of future generations of Filipinos.

The Philippines intends to undertake GHG emission reduction of about 70% by 2030 relative to its business as usual (BAU) scenario of 2000. Reduction of CO_2e emissions will come from energy, transport, waste, forestry and industry sectors. The mitigation contribution is conditioned on the extent of financial resources, including technology development & transfer and the capacity building that will be made available to the Philippines.

3.1.3. National Framework Strategy on Climate Change 2010-2022

National Framework Strategy on Climate Change, 2010-2022 (NFSCC) was framed by Climate Change Commission functioning under the Office of the President of the Philippines. The main objective of this framework is addressing the adaptation needs, capitalizing on the mitigation potential and complying with the UNFCCC obligations, systematic analyzing, strategic planning and determined implementation. The vision of this framework is "a climate risk-resilient Philippines with healthy, safe, prosperous and self-reliant communities, and thriving and productive ecosystems."

Programmes under NFSCC

National Renewable Energy Program (2011 – 2030) was launched in 2010 by Climate Change Commission under the guidelines of NFSCC for increasing the electricity generation capacity of renewable energy systems to 15,304 MW and for reducing the fossil fuel based emissions. The main vision of this program is efficient and effective climate change adaptation and mitigation of GHG emissions. The target of this programme is to implement at least 264.7 MW biomass power (like wood, forest residues, solid waste, etc.), 5,408 MW hydro power and 284 MW solar power by 2030[71].

GiZ joined together with Climate Change Commission in the implementation of NFSCC action plans. GiZ engaged itself in NFSCC by developing renewable energy technologies mainly, solar, hydro and biomass powers, biogas, energy efficiency and emission trading in the Philippines. GiZ has developed two main programmes for the implementation of NFSCC in the Philippines namely,

- Support to Climate Change Commission (Support CCC)

[70] http://www4.unfccc.int/Submissions/INDC/Published%20Documents/Philippines/1/Philippines%20-%20Final%20INDC%20submission.pdf

[71] http://www.eria.org/events/6.%20Mr.Mario%20Marasigan%20%20Renewable%20Energy%20Development%20in%20the%20Philippines.pdf

- Project development program Southeast Asia (PEP SOA)

The programmes established reflects the NFSCC's active operation that would extent the support towards the implementation of new emission reduction projects and also the encouragement towards establishing renewable power generation technologies in the Philippines.

3.1.4. National Solid Waste Management Strategy 2012-2016

National SWM Commission launched the National Solid Waste Management Framework (NSWMF) under Regulation Act (RA 9003, 2000) in 2004. This policy emphasizes on the measures that encourage the waste avoidance, reduction and recycling with mandatory segregation at source and also the waste diversion target of at least 25%. NSWMF encourages local government units (LGU), particularly the barangay or village-based political subdivisions, to compost the biodegradable wastes and to establish materials recovery facilities (MRFs) which would improve the resource recovery. According to the RA 9003, all the dumpsites should have been closed by 2016. Thus, the residual waste should be mandatorily managed at the sanitary landfills (SLFs) or at the integrated eco-centers for final processing and safe disposal.

Action plans for SWM

Philippines development plan 2011-2016 adapts a framework that intends for sustainable growth and development. This plan identifies solid wastes, as the major source of pollutants, are to be managed and streamlined within the proposed period. The plan points towards the actions that are eligible under NSWMF. Some of them are as follows:

- Reduce the waste generated and improve the waste disposal in compliance with RA 9003
- Reduce the land based pollution
- Immediately close or rehabilitate the dumpsites
- Implement environmentally sound management practices
- Promote clean production and infrastructure development
- Encourage public-private partnership and Build, Own and Transfer (BOT) mechanisms

SWM project implemented in the Philippines

Cebu is the second largest business city of the country influenced by increased urbanization. 15% of city land area is flat terrain upland, which is highly vulnerable to cyclones and sea level rise. The average total waste generated from the city is 450 – 500[72]tpd and is disposed in piles at the uncontrolled open dumpsites. During cyclones, the piled wastes undergo landslides and create massive disasters in the city. To prevent such disasters, Cebu City Solid Waste Management Board has established an ordinance for ISWM in compliance with RA 9003 and NSWMF to treat the solid waste and reduce the emissions generated. Cebu community based SWM is in operation since 2011 with composting and waste to energy technologies. Apart from Cebu, the Philippines government has established more number of SWM projects under RA 9003 and NSWMF in the country.

The existing scenario of SWM in the Philippines shows the support of the government and the policy framework in establishing the ISWM. The policy and action plans help in upgrading the ISWM and reducing the increasing solid wastes in the country. It also encourages bringing down various financing mechanism for ISWM.

3.2. Republic of the Union of Myanmar

Myanmar is currently facing serious environment issues mainly due to the solid waste generation. The solid waste generation is linearly increasing because of rapid urbanization, population growth, economic growth, change in consumption patterns, public unawareness, etc. Solid waste collection in Myanmar is labour intensive and relies on manual collection with non-

[72] http://pcieerd.dost.gov.ph/images/downloads/presentation_materials/gmi_04242012/07%20challenges%20on%20msw_artajo.pdf

specialized vehicles, ranging from pushcarts to garbage trucks. The common practice of waste disposal prevailing in Myanmar is open dumping.

The total waste generation in Myanmar is 5,616 tpd. The solid waste generation rate is 0.44 kg/capita/day depending upon the socio-economic status of the country[73]. It is projected that the total waste generated will increase to 21,012 tpd and the per capita per day generation of solid waste will increase to 0.85 kg/capita/day by 2025[74]. The per capita generation of solid waste in Yangon[75] and Mandalay[76]is 0.53 kg/capita/day. The solid waste generated is mainly composed of 73% organic waste, 18% paper, 4% wood waste, 2% plastic, 2% textile and 1% other wastes. The GHG emission of the Myanmar is 239 million tCO_2e (2011)[77].

Figure 3-2: Solid waste in Myanmar

The SWM in Myanmar is under the responsibility of,

- Yangon city development committee
- Mandalay city development committee
- Nay Pyi Taw development committee and
- Township development committee

[73]What a Waste : A global review of solid waste management, 2012

[74]What a Waste : A global review of solid waste management, 2012

[75]http://www.uncrd.or.jp/content/documents/RT1_03_Myanmar.pdf

[76]http://www.iges.or.jp/en/archive/wmr/pdf/activity100728/6_Myanmar_Day1_Session2.pdf

[77]http://www.lse.ac.uk/GranthamInstitute/wp-content/uploads/2015/05/MyanmarIndicators.pdf

Figure 3-3: Dumpsite at Yangon

Myanmar Agenda 21 (1997) identified four programme areas in Environmental Quality Management and Enhancement. The general aim of Myanmar Agenda 21 is to facilitate the integration of environmental and sustainable development considerations into the daily activities and decisions of individuals, households, communities, corporations and the government.

Waste related laws for effective management of solid waste in the country are,

- The Yangon Water-Work Act (1885)
- The City of Yangon Municipal Act (1922)
- The Water Power Act (1927)
- The Underground Water Act (1930)
- The City of Yangon Development Law (1990)
- The Development Committees Law (1993)
- The City of Mandalay Development Law (2002) and
- The Nay Pyi Taw Development Law (2009)

3.2.1. First national communication to the UNFCCC

Myanmar's first national communication to the UNFCCC was submitted on 26 December 2012[78].GHG emission in Myanmar for the year 2000 was estimated to be 41.6 million tCO_2. The trends for CH_4 and N_2O emissions in agriculture sector clearly highlighted a sharp increase during 2000-2005. Waste sector showed an increase in CH_4 emission due to the population growth. Myanmar is under no obligation to quantify reduction of GHG emission. However, GHG emission mitigation options assessment has been made and the strategies were developed for

[78] http://unfccc.int/essential_background/library/items/3599.php?rec=j&priref=7764#beg

the key socio-economic sectors namely, (1) Energy; (2) Waste; (3) Agriculture and livestock; and (4) Land use change and forestry.

Myanmar has not submitted its second national communication to UNFCCC yet.

Waste sector:

CH_4 emissions from the waste sector have been worked out from two different sources;

(1) disposal of solid wastes and

(2) treatment of domestic and commercial wastewaters

For the year 2000, the disposal of solid waste contributed 133,310tons (99 %); domestic and commercial wastewater contributed 1,198 tons (1 %) of CH_4 emissions.

In order to mitigate the GHG emissions and adapt to the increasing global warming, policy measures have been identified for integrating into the national and sectoral development plans and programs as follows:

Policy:

(i) strengthen “Green and Clean Cities “campaign for making the city green and clean
(ii) reduce GHG emissions and environmental pollution

Strategies:

(i) minimize per capita waste generation
(ii) recycle the wastes
(iii) generate heat and electricity from wastes
(iv) advocate self-cleanliness and public hygiene
(v) enforce “Polluter Pay System”

Mitigation actions:

(i) Reduce the volume of waste per capita
(ii) Categorize the waste and dispose it properly at designated landfills
(iii) Collect fees for the waste disposal
(iv) Fine heavily those who throw wastes recklessly
(v) Eliminate the use of polyethylene bags
(vi) Expand the waste treatment facilities
(vii) Produce biogas for electricity generation at the sewage treatment facilities
(viii) Encourage the waste recycle and waste reuse
(ix) Promote market opportunities for the recycled waste products
(x) Enforce regulations and standards for the waste management
(xi) Raise public awareness on waste generation and disposal

3.2.2. National INDC communication to the UNFCCC

Myanmar's "INDC" is communicated to UNFCCC on August 2015[79]. Myanmar is one of the most highly vulnerable countries in the world to the adverse impacts of climate change facing threats from extreme weather events, sea level rise, flooding and drought. In 2015, for the third consecutive year, Myanmar was ranked globally by studies, as the second most vulnerable country in the world to extreme weather events over the last 20 years.

Myanmar would undertake mitigation actions in line with its sustainable development needs, based on the availability of international support, towards its contribution to global action of reducing future emissions of GHGs. In addition to the mitigation actions, Myanmar will implement a number of climate change mitigation policies and strategies, which will not only make the mitigation contributions identified above feasible, but also helps to identify other mitigation actions for future implementation.

- **National Climate Change Strategy and Action Plans** are under development and is expected to be adopted in 2016. The strategy will devise the means to achieve the overall vision and will set out a detailed implementation framework to address climate change in each sector.
- A **National Climate Change Policy** is expected to be developed in 2016.
- The **National Environmental Policy, Framework and Master Plan (2030)** is also currently being developed with UNDP support and will update the National Environmental Policy (1994).
- The **National Waste Management Strategy and Action Plans** are currently being developed and are expected to be completed in 2017.

3.2.3. The City of Mandalay Development Law (2002)

The city of Mandalay Development Law was enacted in 2002. The Chairman of the committee is the Mayor and the Head of Office is the Joint Secretary of the committee. The functions and duties of the committee under this law include,

- carrying out environmental conservation works
- carrying out sanitation and public health works
- prescribing conditions in respect of food businesses, restaurants and roadside stalls,
- building slaughter houses and granting permission to slaughter cattle for consumption, etc.

3.2.4. The Environmental Conservation Law (2012)

The Law has eight objectives, including conserving natural and cultural heritage for the benefit of current and future generations, reclaiming ecosystems that are starting to degenerate and disappear, promoting international, regional and bilateral co-operation focused on environmental conservation, etc.

The law enables the formation of an Environment Conservation Committee and the establishment of an Environmental Management Fund to enable environmental conservation works. The law also identifies several duties and powers of the Ministry of Environmental

[79] http://www4.unfccc.int/Submissions/INDC/Published%20Documents/Myanmar/1/Myanmar's%20INDC.pdf

Conservation and Forestry, one of which is to create guidance related to mitigation and adaptation of climate change. Others include stipulating environmental quality standards (e.g. noise, water quality, solid waste, etc.) and establishing monitoring programmes for the conservation and enhancement of the environment.

The duties and powers of the Ministry of Environmental Conservation and Forestry are as follows,

- Implementing the environmental conservation policies
- Planning and implementing national or regional work plans relating to environmental management
- Establishing monitoring programs for conservation and enhancement of the environment
- Prescribing environmental quality standards on emissions, solid wastes, effluents, etc.
- Prescribing categories of hazardous substances that may significantly affect the environment
- Promoting and establishing stations for treatment of solid wastes, effluents, hazardous wastes, etc.
- Collaborating and implementing the international, regional and bilateral agreements accepted by Myanmar for environmental conservation and enhancement of environmental quality
- Carrying out functions and duties assigned by the Union Government

3.2.5. Environmental Conservation Rules (2014)

The Environment Conservation Rules reflects objectives similar to the Environmental Conservation Law. The rules are adopted by the committee and are assigned to the respective ministry and department for the conservation of the environment.

The environment conservation activities suggested under the waste management are as follows,

- specify categories and classes of hazardous wastes generated
- promote the establishment of necessary facilities for the treatment of solid waste, liquid waste, gaseous emissions, hazardous wastes, etc.
- prescribe the terms and conditions relating to effluent treatment in industrial estates, special economic zones, etc.
- adopt efficient solid waste systems, cleaner production methods, recycling method for wastes, etc.
- assign respective departments to inspect and report the treatment activities of wastes

3.2.6. Myanmar Action Plan for Disaster Risk Reduction (2012)

The Action Plan, developed by the Relief and Resettlement Department within the Ministry of Social Welfare, Relief and Resettlement, describes the institutional framework for disaster preparedness in Myanmar and details the regional and global commitments made by Myanmar.

The overall goal of the action plan is to “make Myanmar safer and more resilient against natural hazards, thus protecting lives, livelihood and developmental gains” and it lists down numerous projects to achieve this goal such as multi-hazard early warning systems and public awareness, education and training.

The action plan notes that the climate change is likely to increase the incidence of floods and droughts (in both the coastal and dry zones of the country), as well as the intensity of windstorms in Myanmar, and that the disaster risk planning must therefore take these factors

into account. The action plan also specifically identifies linkages with climate change adaptation to be important in the development of a Forest Fire and Haze Monitoring System.

The action plan has seven project components for disaster risk reduction as follows:

- Policy, institutional arrangements and further institutional development
- Hazard, vulnerability and risk assessment
- Multi-hazard Early Warning Systems
- Preparedness and response programs at national, state/region, district and township levels
- Mainstreaming of disaster risk reduction into development
- Community based disaster preparedness and risk reduction
- Public awareness, education and training

Each component has 4 to 13 sub components/projects and in total, 65 priority projects have been identified.

3.2.7. National Environment and Health Action Plan (2010)

The National Environment and Health Action Plan (NEHAP), developed by the National Commission for Environmental Affairs and the Department of Health within the Ministry of Health, aims to increase the capacity in the environmental health management. The NEHAP lists six priority areas of environmental concern:

- Air quality
- Water supply, sanitation and hygiene
- Solid and hazardous waste
- Toxic chemicals and hazardous substances
- Climate change, ozone depletion and ecosystem changes
- Contingency planning, preparedness and response in environmental health emergencies

3.3. Kingdom of Thailand

Thailand's MSW generation shows an increasing trend parallel to the development of economic condition, urbanization and rapid growth of population. Huge amount of wastes are generated daily and the waste management is a considerable task that encompasses various strategies such as recycling and reuse, efficient waste collection and disposal system, financial capability and effective participation of government, public and private sectors.

More than 60% of the solid waste disposal system in Thailand has been carried out by open dumping. According to the survey conducted in 2004, there are 425 disposal sites (95 landfills; 330 open dumps) in Thailand. The unmanaged wastes aggravate the emissions of methane, which is 21 times more lethal than carbon-di-oxide. The total emissions emitted from the 425 disposal sites is accounted to 0.12 million tons/year. Moreover, the disposal sites in Bangkok metropolitan has the highest methane emissions of 0.06 million tons/year (x 21 times of tCO2e) among all the regions in Thailand. The methane emission from 425 disposal sites alone is predicted to be 0.34 million tons/year (x 21 times of tCO2e) by the year 202080.

[80] http://www.thaiscience.info/Article%20for%20ThaiScience/Article/4/Ts-4%20municipal%20solid%20waste%20management%20in%20thailand%20and%20disposal%20emission%20inventory.pdf

The total GHG emissions from waste management sector of the country in 2011was11.43 million tCO2e. Of the total GHG emissions, 56.07% was contributed by wastewater treatment followed by 43.10% from solid waste disposal and 0.83% from waste incineration81.

Figure 3-4: Phuket landfill site in Thailand[82]

Total quantity of solid waste generated in the year 2010 was 15.2 million tons of which approximately 3 million tons of waste was produced in the city of Bangkok. The per capita generation rate in Bangkok is 1.5 kg/capita/day, which is more than twice that of other municipalities of Thailand, which is around 0.6 kg/capita/day41. Furthermore, tourist areas in Thailand, for example in Patong beach (Phuket), exhibit the highest amount of waste generation rate of around 5 kg/capita/day compared to that of Bangkok and in other urban areas.

Thailand has developed policies for upgrading the existing SWM and enhancing the efficiency of management process. On behalf of the environmental concern, Thailand has also developed a policy on climate change to mitigate the GHG emission from the anthropogenic activities.

- National Integrated Waste Management Policy
- National Strategy of Climate Change (2013-2017)
- Thailand Climate Change Master Plan (2012-2050)

[81] http://unfccc.int/resource/docs/natc/thabur1.pdf

[82] http://www.thephuketnews.com/phuket-seeks-b670m-for-garbage-problems-36026.php

3.3.1. Second national communication to the UNFCCC

The second national communication of Thailand was submitted to UNFCCC on 24 March 201183. In 2000, Thailand emitted 210.23 milliontCO2 and absorbed 52.4million tCO2. Thus, Thailand's net emission in 2000 was 157.86 million tCO2. Of the total emission in 2000, 90% of the emission was from power generating sector and the remaining was from the industrial sector, while an insignificant amount was emitted by the waste management sector.

Thailand emitted a total of 2.8 million tCH4(x 21 times of tCO2e) in 2000. Of the total, more than 70% came from agriculture, with rice accounting for a major proportion. Another 15% was emitted by the energy sector and 14% by waste management. The total emission from the waste sector in the year 2000 was 0.0233 million tCO2 from waste incineration and 0.39 milliontCH4(x 21 times of tCO2e) from solid waste and waste water handling.

3.3.2. National INDC communication to the UNFCCC

Kingdom of Thailand's "INDC" was communicated to UNFCCC on October 201584.Thailand's national GHG emissions represent only 0.84% of the global emissions in 2012. The country's share of cumulative emission from 1990-2012 was around 0.75%.At COP20 in Lima, Thailand pledged for a contribution of 7-20% GHG emission reduction by 2020 below the business-as-usual (BAU) in the energy and transport sectors.

According to a preliminary analysis, Thailand has already achieved 4% of the GHG emission reduction from the projected 2020 BAU and is well on track towards achieving the 7% target pledged as voluntary domestic efforts by 2020.

In its recent communication to UNFCCC, Thailand intends to reduce its GHG emissions by 20% from the projected BAU level by 2030. The level of contribution could increase up to 25 %, subject to adequate and enhanced access to technology development and transfer, financial resources and capacity building support through a balanced and ambitious global agreement under the UNFCCC.

3.3.3. National Strategy of Climate Change (2013-2017)

National Strategy of Climate Change has three key strategies that determine the principles and operational guidelines for coping with the effects of climate change which are as follows:

- Adaptation for coping with the negative effects of climate change
- Mitigation of GHG emissions and increase of GHG sinks
- Strengthening the capacity of human resources and institutions to manage the risks from the effects of climate change and cross cutting issues.

Change in temperature, rainfall, etc. cause major threats to livelihoods and economic growth of the country. Thailand collaborated with the neighboring countries and launched a Climate Change and Adaptation Initiative (CCAI) to put an effort to create awareness on climate risks to the people, initiate activities and develop mitigation tools for sustainable life in the Lower Mekong river basin.

[83] http://unfccc.int/essential_background/library/items/3599.php?rec=j&priref=7460#beg

[84] http://www4.unfccc.int/Submissions/INDC/Published%20Documents/Thailand/1/Thailand_INDC.pdf

Thailand united with USAID to develop an adaptation programme namely "USAID Mekong Adaptation and Resilience to Climate Change project (2013-2016)85". International Union for Conservation of Nature (IUCN) Thailand and USAID has identified hot spot provinces of Thailand to implement the project. The objective of the project is to understand climate risks, priority identification, implementation of adaptation activities and monitoring the activities.

The series of initiatives taken by the Thailand government on climate change and its interest to stand as an environment friendly country among others will help to propose a new climate change mitigation projects to the country.

[85] http://www.iucn.org/asia/thailand/countries/thailand/usaid-mekong-adaptation-and-resilience-climate-change

3.3.4. Thailand Climate Change Master Plan (2012-2050)

Thailand Climate Change Master Plan (2012-2050) is proposed by the Office of National Resources and Environmental Policy and Planning (ONEP), Ministry of Natural Resources and Environment (MoNRE). This framework comprises integrated policies and action plans relating to the climate change.

The target of this plan is that "Thailand is able to continue its economic, social, and environmental developments in accordance with sufficient economic philosophy and to cut GHG emissions by 2050, without impeding the country's GDP or reducing its growth of developmental capability and competitiveness".

Thailand has framed several action plans to support adaptation and to establish mechanisms for evaluating and alleviating climate change impacts. However, as yet, Thailand has not passed any concrete adaptation legislation.

3.3.5. National Integrated Waste Management Policy

SWM, with no exception has to move towards the national SWM policy. The policy is developed for integrated solid waste and waste water management. The policy aims to minimize the waste generation by promoting the 3Rs hierarchy including promotion of source reduction and separation, waste stream recovery for composting, material and energy uses. Biogas, heat and electricity generated in the processes can be used for internal consumption at the waste water treatment plant.

The main strategies of the policy are:

- Promote 3Rs hierarchy (Reduce, Reuse and Recycle)
- Promote participation between public and private sector, and also public awareness/education
- Encourage the establishment of central solid waste disposal facilities with appropriate technology
- Promote privatization of SWM
- Revise the existing laws and regulations as well as emphasize on law enforcement regulations in order to make efficient SWM

Thailand successfully implemented numerous SWM projects in the country to reduce the solid wastes and recycle/reuse the waste end products. Thailand has high profile of successful completion of waste to energy and landfill projects in the community based dumping sites. Some of the projects on SWM are,

- Organic waste compost and energy production plant, Rayong
- Biogas plant at Samchuk, Supanburi
- Organic composting plant in Nonthaburi
- Mechanical biological waste treatment plant in Phitsanulok municipality
- 700 TPD incineration plant, Phuket
- 300 TPD waste to energy plant, Ayutthaya (proposed)

Increase in urban population and tourism population along with climate change impact is giving serious alarm to the country to focus more on solid waste management. Advanced technologies, effective treatment and space constraints are the areas to be addressed for addition of new solid waste management projects.

4. Climate change impacts on SWM

In the developing countries, solid waste is frequently dumped and accumulated in canals, waterways and in areas otherwise intended for water runoff or flood control. These conditions make the cities vulnerable to floods and contaminate the water even from moderate rainfall. The conditions may worsen with intense precipitation and potential storm surges expected with climate change. Areas of uncollected waste can spread existing sources of environmental pollution and health hazards as well as expand breeding grounds for water and vector-borne diseases. Informal settlements near or on top of dumped waste can also experience landslides as a result of flooding and can catch fire as a result of temperature increase.

4.1. Impacts across the solid waste sector

Climate change could result in change in temperature, cloud cover, rainfall pattern, wind speed and storms, i.e., all factors that could impact future waste management facilities' development and operation. The time scales for climate change and waste management are similar. For instance, landfill sites can be operational for decades and still remain active for decades following their closure. Therefore, there is a need to consider potential changes in waste management over significant timescales and respond appropriately. The summary of impact of climate change across the SWM sector is given in table below:

Table 4-1: Climate change impacts across SWM sector

Climate variable	Potential change	Potential impacts on solid waste management
Temperature	Annual warming	Increased risk of combustion at open sites and composting sites.
	Melting of permafrost or soils	Over time, may disrupt drainage and surface water flow around landfill sites.
	Increase in mean sea level and more intense rainfall events	• Flooding of facilities and basement/underground-level equipment • Floating waste may wash away with high precipitation or storm surges.
Precipitation	More intense rainfall events	Saturated soils and decreased stability of slopes and landfill linings (if clay or soil based) at waste management sites.
		Flooding in areas with untreated, dumped waste carries the risk of groundwater contamination.
		Disruptions in the removal and transportation of solid waste.

4.2. Impacts across the solid waste infrastructure

Flooding poses the biggest threat to solid waste infrastructure. Without proper water catchment systems around a landfill, heavy rain events can degrade the landfill, causing breakage in the containment structure that allows the debris and leachate to escape from the landfill and contaminate the local resources. Flooding from extreme storms may undermine the landfill foundations, releasing leachate into the groundwater or block the collection routes, sweep the waste into waterways, and cause the waste to clog other infrastructure. Landfills near the coast or in low-lying areas are vulnerable to sea level rise and storm surge. Water infiltration of the pit can lead to an overflow of waste from the landfill. Saltwater infiltration from below can deteriorate the impermeable lining of sanitary landfill facilities.

Table 4-2: Climate change impacts across SWM infrastructure

Infrastructure/ Component	Climate variable	Potential change	Potential impacts on waste management
Closed and open disposal sites	Temperature	Increase or decrease	• Altered chemical composition of contaminants below the surface, • Changes in evaporation rates.
	Precipitation	Increase	Unexpected leaching of contaminants in surface areas of closed landfills.
Marine transfer stations	Sea-level rise	Increase	Impacts on coastal docking and transfer facilities.
Path or roadside refuse	Precipitation	Increase or decrease	Damage to waste containment facilities or structures.
	Storm surges	Increase	• Inundation of waste releases contaminants to waterways, pathways and low-lying areas. • Potential for pools of stagnant contaminated water that promote water and vector-borne diseases.

5. Mitigation and adaptation measures of climate change impact on SWM

Climate change impacts on SWM infrastructure and surrounding environment may be temporary or long-lasting and also the impacts may occur both directly and/or indirectly. The climate change issues can be mitigated by enacting the policies on solid waste related development goals that must be the priority of the country, community or sector. The goals must consider the impact of climate change on SWM and adaptation methods to lighten the risks involved. Properly sited, constructed and maintained disposal facilities can minimize the risks of water and soil contamination from the consequences of climate change impacts.

5.1. Priority setting for adaptation measures

Through a screening process, adaptation action priorities can be selected based on the assessment of the local decision-makers on the following four key factors:

- Criticality – How important is the infrastructure to the community or region? How large is the population served by the waste management system? Are any backup services available?
- Likelihood – Given climate projections, what is the probability that the collection, processing, or disposal infrastructure will be affected?
- Consequences – How significant is the impact? Will the impacts complicate SWM? Will the impacts have health implications?
- Resources available – Can changes be made to the collection, processing or disposal using a reallocation of the existing time and resources? Are additional resources, such as additional workers, required?

By understanding the answers to these questions, adaptation actions can be integrated into the upfront design, construction, operation and maintenance of the SWM systems. Integrating adaptation can prevent misinformed decisions that would increase the vulnerability of the infrastructure and the people they are trying to serve.

5.2. Adaptation/mitigation measures

The consideration of adaption and mitigation measures at each stage of the SWM system is an effective way to fight against the climate change impacts. The general climate change-related adaptation measures are provided in Table 5-1 below.

Table 5-1: Climate change adaptations/mitigation steps

No.	Project stage	Climate change adaptation/mitigation steps
1	Definition of the project scope	Consider the impacts of climate and non-climate stressors on SWM project goals
2	Assessment of project feasibility	• Assess climate threats, vulnerabilities, impacts to solid waste collection, processing and storage to understand the adaptation needs • Evaluate climate-related risks in the light of all existing risks to solid waste
3	Project design	• Properly site the landfills away from floodplains, wetlands or areas with high water tables • Site the landfills away from drinking water supplies • Develop the sites large enough to accommodate projected population growth and corresponding waste generation • Design the sites with facilities for sorting, recycling and composting to reduce waste storage needs • Update the design standards to elevate and strengthen the containment walls to accommodate future sea level rise and high winds • Design the water catchment systems that can keep pace with the projected rainfall patterns • Update the equipment design standards to increase the efficiency and reduce the maintenance costs in changing climate, particularly for complex heating, ventilation and air-conditioning (HVAC)dependent equipment • Plan for the secure landfill closure and/or relocation • Plan for the extreme event evacuation
4	Construction, operation and maintenance	• Increase the financial and technical resources for more frequent maintenance and repairs • Train the waste sorters and educate the public about separating recyclable and compostable material from other wastes • Maintain the collection vehicles to minimize disruptions due to mechanical failures • Prevent the erosion of landfill slopes, covers and roads into and

		around the landfills • Maintain the storm water catchment systems to ensure proper functioning • Cover the threatened landfills and develop new sites in more secured locations
5	Monitoring and control	• Regularly inspect the integrity of water catchment systems and the containment walls, particularly after extreme rains or storm events • Continue to monitor the landfills for groundwater contamination and cover erosion

5.3. Recommendations for project planning

The starting point for any mitigation or adaptation measures will be a detailed assessment of the selected waste management technology with respect to the potential impacts of climate change by including expert knowledge from the policy regulators, service companies and field experts. The assessment shall indicate the scale of weather related risks on waste management sectors and specific technology. Other recommendations include:

- Development of tools and techniques to assess the site specific impacts including those of hydrology, leachate and gas yield
- Assessment of any operational change needed in the short, medium and long term to address the impacts. This shall include full range of issues from site engineering, management, health and safety of workers, biodiversity and the community.
- Development of a robust set of climate change indicators for waste management, e.g., temperature, precipitation, wind speed, atmospheric pressure, flooding incidences, site damage, occupational health and safety, etc. This will help in monitoring the climate change at the site level and to assess the possible consequences.
- Identification of engineering, operational, investment, timescale, technology, costs and land use impacts on the selection of adaptation/mitigation measures

5.4. Country level mitigation options for SWM

Based on the data collection and review of various factors of climate change vulnerabilities, the mitigation options for SWM projects in the three countries are summarized. The country level mitigation options for the problems faced by SWM due to climate change vulnerabilities are detailed in the Table 5-2.

Table 5-2: Country level mitigation options for SWM

Country	Vulnerability indicator	Effects in SWM	Mitigations
Philippines	Precipitation	• Increased leachate flow • Increased flooding of surface water and ground water • Erosion of soil • Dispersal of waste due to high intensity cyclones and wind speed	• Separate pipelines for leachate collection • Drainage pipelines for external run off • Protective layer to control waste dispersion
	Sea level rise	• Salt water intrusion in the site • Scale formation on the treatment equipment • Non operation of equipment • Weakened surrounding walls	• Appropriate storm water management system • Alarming the systems for disasters • Water proof cover to all equipment •
	Temperature	• Rapidly increased decomposition rate • Reduced water availability • Increased heat stress • Possibility of wild fire • Increased disease transmission	• Artificial liner to cover the waste. • Insulated protective layer to avoid heat stress • Avoiding mass burning of waste • Protective accessories for workers
Myanmar	Temperature	• Rapidly increased decomposition rate • Reduced water availability • Increased heat stress • Possibility of wild fire • Increased disease transmission	• Artificial liner to cover the waste. • Insulated protective layer to avoid heat stress • Avoid mass burning of waste • Provide protective accessories for workers
	Precipitation	• Increased leachate flow • Increased flooding of surface water and ground water • Erosion of soil • Dispersal of waste due to high intensity cyclones and wind speed	• Separate pipelines for leachate collection • Drainage pipelines for external run off • Protective layer to control waste dispersion

	Sea level	• Salt water intrusion in the site • Scale formation on the treatment equipment • Non operation of equipment • Weakened surrounding walls	• Appropriate storm water management system • Alarming systems for disasters • Water proof cover for all equipment •
Thailand	Precipitation	• Increased leachate flow • Increased flooding of surface water and ground water • Erosion of soil • Dispersal of waste due to high intensity cyclones and wind speed	• Separate pipelines for leachate collection • Drainage pipelines for external run off • Protective layer to control waste dispersion
	Temperature	• Rapidly increased decomposition rate • Reduced water availability • Increased heat stress • Possibility of wild fire • Increased disease transmission	• Artificial liner to cover the waste. • Insulated protective layer to avoid heat stress • Avoiding mass burning of waste • Protective accessories for workers
	Sea level rise	• Salt water intrusion in the site • Scale formation on the treatment equipment • Non operation of equipment • Weakened surrounding walls	• Appropriate storm water management system • Alarming systems for disasters • Water proof cover for all equipment

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