KINGDOM OF BHUTAN

THIRD NATIONAL COMMUNICATION TO THE UNFCCC

National Environment Commission
Royal Government of Bhutan

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Third National Communication from Bhutan to the UNFCCC

Coordinated and Edited by:
Tenzin Wangmo, Chief, CCD
Tshering Tashi, National Coordinator, TNC
Tashi Dendup, EO, CCD, NEC
Sonam Dagay, EO, CCD, NEC
Tshering Yangzom, CCD, NEC
Lobzang Tempa, CCD, NEC

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GLOSSARY OF ACRONYMS

ABI	*Association of Bhutanese Industries*
AFOLU	*Agriculture, forestry, and other land use*
BAU	*Business as usual*
BC	*Biological corridors*
BCCI	*Bhutan Chamber for Commerce and Industries*
BTFEC	*Bhutan Trust Fund for Environmental Conservation*
BUR	*Biennial Update Report*
C4	*Climate Change Coordination Committee*
CCA	*Climate change action*
CCD	*Climate Change Division*
CDM	*Clean development mechanism*
CGE	*Computable general equilibrium*
CH_4	*Methane*
CMIP	*Coupled model intercomparison project*
CNR	*College of Natural Resources*
CO	*Carbon monoxide*
COP	*Conference of the Parties*
CO_2	*Carbon dioxide*
CO_2e	*Carbon dioxide equivalent*
CRU	*Climatic Research Unit*
CSO	*Civil society organization*
CST	*College of Science and Technology*
CTCN	*Climate technology center and network*
CWP	*Country work program*
DDM	*Department of Disaster Management*
DHPS	*Department of Hydropower and Power Systems*
DNA	*Designated National Authority*
DoA	*Department of Agriculture*
DoFPS	*Department of Forests and Park Services*
DoI	*Department of Industries*
DoL	*Department of Livestock*
DRC	*Department of Revenue and Customs*
DRE	*Department of Renewable Energy*
EA	*Environment Assessment*
EC	*Environment clearance*
ECHAM	*European Centre Hamburg*
ECP	*Environment climate poverty*
EDP	*Economic development policy*
EF	*Emission factor*
FMU	*Forest management unit*
FRMD	*Forest Resources Management Division*
FYP	*Five-year plan*
GCF	*Green Climate Fund*
GCM	*General circulation model*
GDP	*Gross domestic product*
GECDP	*Gender, environment, climate, disaster risk reduction and poverty alleviation*

GEF	*Global Environment Facility*
Gg	*Giga gram*
GHG	*Greenhouse gas*
GIS	*Geographic information system*
GLOF	*Glacial lake outburst flood*
GNH	*Gross national happiness*
GNHC	*Gross National Happiness Commission*
GPG	*Good practice guidance*
HEC HMS	*Hydrological Engineering Center Hydrologic Modelling system*
HEROES	*Himalayan environmental rhythm observation and evaluation system*
HG	*High growth*
HWC	*Human wildlife conflict*
ICIMOD	*International Centre for Integrated Mountain Development*
INC	*Initial National Communication*
IPPC	*Inter-governmental panel on climate change*
IPPU	*Industrial process and product use*
KCA	*Key category assessment*
KM^2	*Square kilometer*
LCMP	*Land use classification mapping project*
LDC	*Least developed countries*
LG	*Low growth*
LG	*Local government*
LPG	*Liquified petroleum gas*
LULC	*Land use and land use change*
LULUCF	*Land use land-use change and forestry*
M^3	*Meter cube*
MASL	*Meter above sea level*
MAXENT	*Maximum entropy distribution modelling*
MME	*Multi model ensemble*
MoAF	*Ministry of Agriculture and Forests*
MoHCA	*Ministry of Home and Cultural Affairs*
MoIC	*Ministry of Information and Communication*
MoWHS	*Ministry of Works and Human Settlement*
MSTCCC	*Multi-sectoral technical committee on climate change*
MT	*Million tones*
MW	*Megawatt*
N_2O	*Nitrous oxide*
NAMA	*Nationally appropriate mitigation action*
NAP	*National adaptation plan*
NAPA	*National adaptation plan of action*
NBC	*National Biodiversity Center*
NCCC	*National climate change committee*
NCD	*Nature Conservation Division*
NCHM	*National Center for Hydrology and Meteorology*
NEC	*National Environment Commission*
NECS	*National Environment Commission Secretariat*
NEX GDDP	*NASA earth exchange global daily downscaled projection*
NGO	*Non-governmental organization*

NIR	*National inventory report*
NKRA	*National Key Result Area*
NOx	*Nitrogen oxides*
NSB	*National Statistical Bureau*
NSSC	*National Soil Service Center*
NPPC	*National Plant Protection Center*
NTWG	*National thematic working group*
OPC	*Ordinary Portland cement*
ORC	*Outreach clinic*
PAs	*Protected areas*
PGR	*Population growth rate*
PHCB	*Population housing census*
PPC	*Portland pozzolana cement*
PSC	*Portland slag cement*
QA / QC	*Quality assurance quality control*
RCP	*Representative concentration pathways*
RDF	*Refuse derived fuel*
RGoB	*Royal Government of Bhutan*
RNR	*Renewable natural resources*
RUB	*Royal University of Bhutan*
SAR	*Second assessment report*
SLM	*Sustainable land management*
SLMP	*Sustainable land management project*
SNC	*Second National Communication*
SOC	*Soil organic carbon*
TACCC	*Transparency, Accuracy, Completeness, Comparability, Consistency*
tCO_2e	*Tones of CO_2 equivalent*
TERI	*The Energy Resource Institute*
TJ	*Terajoule*
TM	*Traditional medicine*
TNC	*Third National Communication*
TOE	*Tones of energy*
UNDP	*United Nations Development Program*
UNEP	*United Nations Environment Program*
UNFCCC	*United Nations Framework Convention on Climate Change*
UNGA	*United Nations General Assembly*
USD	*United States dollar*
UWICER	*Ugyen Wangchuck Institute for Conservation and Environmental Research*
V&A	*Vulnerability and Adaptation*
WHO	*World Health Organization*

Glossary of Dzongkha Terms

Dzongkhag	*District*
Dzongdag	*District Administrator*
Geog	*Smaller administrative unit comprising multiple villages*

MESSAGE FROM THE CHAIR, NEC

Climate change is now considered as one of the greatest challenges not only to the national and regional governments but also to the world community. The international scientific community has proven beyond doubt the impacts of global warming to our planet's climatic system.

Realizing climate change as one of the biggest threats to sustainable development and the livelihoods of the people, Bhutan is committed to taking all necessary measures to address climate change. In 2009, Bhutan pledged to remain carbon neutral at COP15, in Copenhagen. Our constitution mandates us to maintain 60% of our total land area under forest cover in perpetuity. This is a significant contribution towards carbon sequestration globally. Further, a policy decision to pursue green growth has also been made through the Economic Development Policy, 2016. In addition, we have recently adopted Climate Change Policy of the Kingdom of Bhutan, 2020 that aims to enhance climate resilience of the economy and carbon neutral development.

The Third National Communication from Bhutan to the UNFCCC elaborates the actions taken, which are required in addition to emission mitigation and address adverse impacts of climate change in Bhutan. According to the Bhutan's national greenhouse gas inventory, emissions from Bhutan are only third of what our forests sequester. However, emissions are growing especially from energy (fuel for transport and industries) and process emissions from industries. Mitigation measures that are already in place and options for further action are presented in this report. Building on Second National Communication, vulnerability and adaptation assessment in the key sectors of water, agriculture, energy (hydropower), human health, forest and biodiversity and an additional assessment in urban development sector was carried out. The adaptation actions needed to address the vulnerabilities and mitigation potentials identified will require the support of the international community to ensure their implementation.

On behalf of the National Environment Commission, I would like to extend our appreciation to all the key stakeholders, relevant agencies, national experts and all individuals involved in the process of formulating the document for their dedication and commitment in achievement of this important document. I would also like to thank all our national and international partners who have been supporting Bhutan in its development efforts and in combating climate change.

Dr. Tandi Dorji
Chairman, National Environment Commission &
Minister, Ministry of Foreign Affairs

MESSAGE FROM THE SECRETARY, NECS

Climate change is one of the most significant problems faced by humanity, which threatens our future extensively unless response measures are taken today. For this reason, urgent measures need to be taken at global, regional as well as local scale and cooperation should be enhanced in order to fight against climate change.

In 2015, the Royal Government of Bhutan, through the submission of Nationally Determined Contribution, reaffirmed Bhutan's commitment to remain carbon neutral declared in 2009. The commitment was made with the view that there is no greater need, or more important, then keeping the planet safe for life to continue. The coordinated climate actions have also been articulated in Climate Change Policy of the Kingdom of Bhutan that was endorsed in January 2020 by the National Environment Commission.

Bhutan is highly vulnerable to impacts of the climate change and extreme weather events due to its location in fragile mountainous ecosystem, limited resources and technology to adapt and moreover our economy is heavily reliant on climate sensitive sectors like hydropower and agriculture. Additionally, climate change threatens the stride Bhutan made so far in socio-economic development front.

This report represents Bhutan's Third National communication required under the United Nations Framework Convention on Climate Change and is subsequent to the 2nd National Communication submitted in November 2011. This report presents, in compliance with the commitments made, the emission inventory of Greenhouse Gases, the strategies of adjustment undertaken to face the impacts of climate change, the actions taken to mitigate the emissions of Greenhouse Gas and includes updated information regarding the institutional, legal and political development since the submission of the 2nd National communication.

Bhutan's Third National Communication to the UNFCCC prepared through Global Environment Facility's enabling activity under the umbrella support of the United Nations Environment Program, Nariobi, is an outcome of joint coordinated effort of numerous agencies both governmental and civil society organizations, national thematic working groups, national experts, peer reviewers and individuals. I would like to thank everyone involved in preparation of this report right from inception to completion for their concerted efforts and unwavering support. I would also like to express our gratitude to the GEF and the UNEP for the financial and technical support provided towards formulation of this report.

Sonam P Wangdi
SECRETARY

EXECUTIVE SUMMARY

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Geography

Bhutan is a small, landlocked country with an area of 38,394 Km^2 situated on the southern slope of the Eastern Himalayas, bordering China to the north and India to its south, east and west. The country is almost entirely mountainous. With altitudes ranging from about 100 meters in the foothills to over 7,500 meters in the north, the country's north-south border spans over 170 km while the east-west dimension measures around 300 km.

Owing to its fragile mountainous ecosystem, Bhutan is highly vulnerable impacts of climate change and extreme weather events. The situation is further worsened by country's low adaptative capacity, poor economic status constrained by limited financial, technical and human capacity. Additionally, the country's economy is still predominantly dependent on climate sensitive sectors like agriculture (more than 60% of rural population depend for livelihood) and hydropower. The mountainous landscape makes communication and transport very fragile and expensive.

Climate

The climate of Bhutan is exceptionally diverse. Two main factors affecting the variation in climatic variation of mean temperature and precipitation are: the vast differences in altitude in the country and the influence of the North Indian monsoons. Bhutan's location at the northern periphery of the tropical circulation is an important feature that determines its climate.

Bhutan receives about 70% of the precipitation during monsoons, while pre-monsoon rainfall accounts for 20%. The annual precipitation ranges widely in various parts of the country. The northern region gets about 40 mm of annual precipitation, mostly in the form of snow. The temperate central valley receives about 1,000 mm of rainfall, while the southern region gets about 1,500 mm of rain annually (NSB, 2018). The monsoons last from late June through late September.

Natural Resources

Forest resources

Bhutan has a total of 70.77 % forest cover (2,717,161.64 ha) out of the total geographical area (3,839,400 ha) of the country (FRMD, 2017). Broadleaved forests constitute around 65% of the forested area, while conifer forests make up about 35%. The forest cover of Bhutan marginally increased from 70.46% in 2010 (LCMP, 2010) to 70.77% in 2016 (FRMD, 2017).
The total forest carbon stock of Bhutan is 645 million tonnes of carbon in the form of biomass carbon and soil organic carbon (SOC) (FRMD, 2020). The biomass carbon pool constitutes 457 million tonnes of total carbon stock and 188 million tonnes of carbon is stored in mineral soils/soil carbon pool (FRMD, 2020).

Protected Area Network

The protected area (PA) network of Bhutan consists of five National Parks, four Wildlife Sanctuaries, one Strict Nature Reserve, eight Biological Corridors (BC) and a Royal Botanical Park (RBP). The total PA, including BC and RBP, covers 51.44% of the country's area.

The PA system in Bhutan is unique. There are human settlements occurring within the PAs that play an essential role in our conservation efforts, unlike in other parts of the world, where communities in the PAs are relocated (MoAF, 2019).

Biodiversity

Due to the high forest cover, pristine environment, strong conservation efforts and good network of Protected Areas, Bhutan has flourishing populations of some of the rarest flora and fauna on earth.

The 2017 Biodiversity Statistics of Bhutan records 11,248 species of all biodiversity groups found in Bhutan, namely 5,114 species under the Kingdom Animalia, 5,369 species under the Kingdom Plantae, 690 species of fungus, 55 species under the Kingdom Chromista, 18 species of Eubacteria, and two species of protozoa under the Kingdom Protista.

The country's biodiversity includes several plants and animal species listed as vulnerable, endangered, or critically endangered in the International Union for Conservation of Nature Red List of threatened species. The country is home to 15 vulnerable, 20 endangered and 13 critically endangered seed plants.

Bhutan hosts 13 vulnerable, 11 endangered and two critically endangered mammal species. Likewise, the country has 22 vulnerable, four endangered and four critically endangered bird species. There are also eight vulnerable and three endangered fish species, 11 vulnerable, five endangered and two critically endangered amphibians, and one vulnerable butterfly (MoAF, 2018).

Water resources

Most of the major rivers in Bhutan originate from glaciers and are recharged by watershed. The river system is generally distinguished by main rivers that flow from north to south, with tributaries flowing in an east-west direction. The main rivers are Amochhu, Wangchhu, Punatsangchhu and Manas. Two large rivers, Mangdechhu and Drangmechhu, converge into one river and make up the Manas just before crossing the Indian border. The Manas river covers about half the country.

Most of the river discharge results from rainfall, supplemented by an estimated 2-12% glacial melt and another 2% from snow melt. The combined outflow of the rivers is about 70,576 million m^3, or 2,238 m^3/s, which corresponds to a flow of 109,000 m^3 per capita per year, the highest in the region.

Population

Bhutan is one of the least populated countries in Asia with a total population of 727,145 in 2017 and Population Growth Rate (PGR) of 1.3% per annum as per Housing and Population Census of Bhutan, 2017 (NSB, 2017). As a result of the gradual increase in the population size, the population density of Bhutan increased from 17 persons per km^2 in 2005 to 19 persons per km^2 in 2017. The distribution of the population over the land area is not uniform throughout the country. While the capital, Thimphu, has the highest population density at 67 persons per km^2, Gasa Dzongkhag has the lowest with just 1.3 persons per km^2.

Since the commencement of the planned socio-economic development in the 1960s, Bhutan has developed from a nascent health system to a closely-knit network of health facilities catering to its people's health needs. As of 2018, there are 211 Basic Health Units, 52 sub posts and 551 ORCs at the primary level, 26 hospitals at the secondary level and three referral hospitals at the tertiary level, spread across the country. Furthermore, the provision of traditional medicine (TM) services from 61 TM units and one national TM hospital has enhanced the health service delivery in the country. Health services are delivered free of cost, mainly financed by the government (MoH, 2018).

The 2017 Population and Housing Census of Bhutan (PHCB) reported the literacy rate of 71.4% and the adult (aged 15 years and above) literacy rate of 66.6%. There is a marked difference in the literacy levels between the male and female populations, with 78.1% of the male population literate compared to 63.9% of the female population. Overall, the literacy rate is significantly higher in urban areas (84.1%) than in rural areas (63.6%).

Macroeconomy

Bhutan is one of the world's smallest economies, with Gross Domestic Product (GDP) in 2017 recorded at NU 164.6 billion or approximately

USD 2.4 billion. However, growth has been remarkable, with the economy growing at an average rate of seven percent over the past decade, mainly due to investments in the hydropower sector. GDP per capita increased from USD 2,464 in 2013 to USD 3,438 in 2017 (GNHC, 2019).

Bhutan was categorized as a Least Developed Country (LDC) by the United Nations General Assembly (UNGA) in 1971. However, over the decades, Bhutan has made remarkable socio-economic advancements, qualifying the country for graduation from this category for the first time at the 2015 triennial review of the list of LDCs (GNHC, 2019). Bhutan's economic freedom score is 62.9, making its economy the 74th freest in the 2019 index and ranked 16th among 43 countries in the Asia-Pacific region. Its overall rating is above the regional and world averages.

The public sector has long been the primary source of economic growth, but the government now recognized the significance of private-sector growth. Economic diversification is now a higher priority, and Bhutan has made progress in modernizing its economic structure and reducing poverty. Constraints on private-sector development include an inefficient regulatory framework, significant nontariff barriers to trade, and a rudimentary investment code (The Heritage Foundation , 2019).

Bhutan's economic development policy continues to be guided by the overarching philosophy of Gross National Happiness (GNH) based on the four pillars of sustainable economic development; preservation and promotion of culture and tradition; conservation of the environment; and good governance. However, sustainable economic growth remains a major challenge as it is financed mainly by external aid (RGoB, 2016). The GNH Commission (erstwhile Planning Commission), is the apex body for planning in Bhutan that emphasizes the importance of using GNH as the guiding philosophy for all the country's plans and programs.

Agriculture

The agriculture sector comprises of farming, livestock and forestry which continues to be a major player in the country's economy. With only 2.75% of the total land area used for agriculture (DoFPS, 2016), the sector accounted for 17.37% of GDP in 2017 (NSB, 2018) and employed about 58% of the total population in 2015 (RGoB, 2016).

Governance structure

The government of Bhutan is a democratic constitutional monarchy with the executive power vested in the Cabinet (Lhengye Zhungtshog) headed by the Prime Minister (RGoB, 2008).

At the central level, the 10 different Ministry is headed by the Cabinet Ministers and at the local level, Bhutan is administratively divided into 20 *Dzongkhags* (districts), each governed by a district administrator or *Dzongda.* The Dzongkhags are sub-divided into small blocks or *geogs.* There are 205 *geogs* in the country, grouped under 47 constituencies.

Coordination Mechanism on Climate Change

The institutional arrangements for climate change coordination in Bhutan have evolved over the years since the establishment of the NEC and Bhutan's signing of the Rio Conventions in 1992.

Bhutan ratified the United Nations Framework Convention on Climate Change (UNFCCC) on 15 August 1995, and the National Environment Commission Secretariat (NECS is the national focal point for all the multilateral environmental agreements.

The National Environment Protection Act 2007, Section 20, mandates the National Environment Commission (NEC) as an independent authority and the highest decision-making body on all matters relating to the environment and its management in the country.

The Commission is supported by the Secretariat and is responsible for implementing the policies, regulations and directives issued by the National Environment Commission, and for administering the provisions of the National Environment Protection Act, 2007.

The erstwhile Multi-Sectoral Technical Committee on Climate Change established in 2010 was revamped as Climate Change Coordination Committee (C4) to serve as a forum to discuss and coordinate matters related to climate change in Bhutan and make recommendations for consideration by the Commission and ensure smooth implementation of climate change policies, projects and programs in the country.

National Greenhouse Gas Inventory

The main sources and sinks of greenhouse gas (GHG) emissions and removals have been divided into the four sectors, Energy, Industrial Processes and Product Use (IPPU), Agriculture, Forestry and Other Land Use (AFOLU), and Waste following the Inter-governmental Panel on Climate Change (IPCC) 2006 Guidelines. Total GHG emissions in Bhutan in 2015 was 3814.09 Gg CO_2 equivalent (CO_2e) excluding removals by forest, which represented a 120.75% increase from the 1994 level of 1727.74 Gg CO_2e and a 0.92% increase from the 2000 level of 3779.27 Gg CO_2e.

The carbon sequestration capacity of Bhutan in 2015 was 9386.59 Gg CO_2e, which showed an increase of 2.47% and 4.57% from the year 2000 and 1994.

Net GHG emissions in 2015 was -5572.50 Gg CO_2e, which represented a decrease of 23.11% from 1994 levels and an increase of 3.55% from 2000 levels. In general, emissions and removal from all sectors increased in 2015 compared to the base year, as shown in Figure 1 and Figure 2 shows the percentage contribution of each of the GHG inventory sectors for 1994, 2000 and 2015 (inventory year of INC, SNC & TNC), respectively.

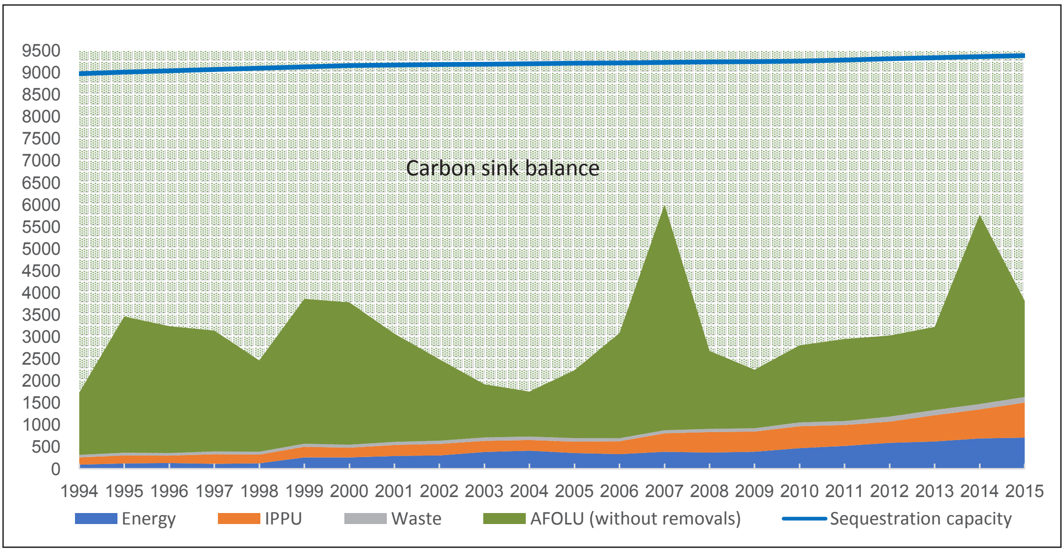

Figure 1. GHG Emissions and Sequestration (1994-2015)

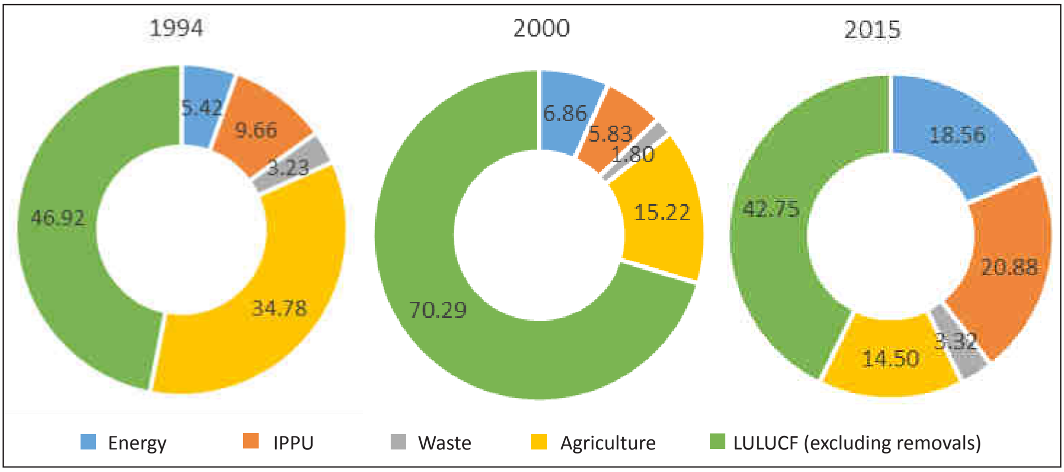

Figure 2. sectoral % contribution of GHG emissions to national net emissions excluding removalsby forest (1994, 2000 & 2015)

As shown in Figure 2, the waste sector's contribution to net national emission has remained more or less constant from 1994 through 2015. However, in terms of absolute figure of Gg CO_2e, the emission from this sector has more than doubled.

Percentage contribution of energy and IPPU sectors increased while the contribution of the LULUCF has been fluctuating based on the sector's level of activities. Emission from agriculture sector has been decreasing gradually over the same period. This pattern indicates that emissions associated with development and industrialization increased over time while the emissions associated with subsistence agriculture and livestock remained relatively stable.

Mitigation Assessment

Three scenarios of GHG trends are described and analyzed based on the gross domestic product (GDP) growth in Business as Usual (BAU), High Economic Growth (HG) and Low Economic Growth (LG) scenarios using a Computable General Equilibrium Model of Bhutan's economy.

In the High Growth Scenario (HG), the emissions of GHGs reach 6.4 Million tonnes CO_2e in 2041 and then increase to 8.431 Million tonnes by the year 2050 crossing the sink capacity in the 2051 - 2053 period.

In the Low Growth Scenario (LG), the emissions peak to 6.4 Million tonnes CO_2e in 2044 - 2046 and decrease to 6.258 MT CO_2e by 2050. This projection is significant because Bhutan has committed to femain carbon neutral for all times to come (Royal Government of Bhutan, 2009). The carbon neutrality pledge is at risk in the HG scenario. Energy (Transport, Industry and Air Transport), IPPU (heavy industries) and Waste sectors heavily contributes to GHG emissions.

The mitigation options formulated with the policy goal of Bhutan remaining carbon neutral for all times are chosen from a range of activities identified in the Low Emission Development Strategies and from the sectoral plans. The emissions projected use the different mitigation actions and GHG mitigation potentials calculated.

The implementation of the mitigation options would result in the mitigation of close to 1,400 Gg CO_2e, as depicted in Figure 3.

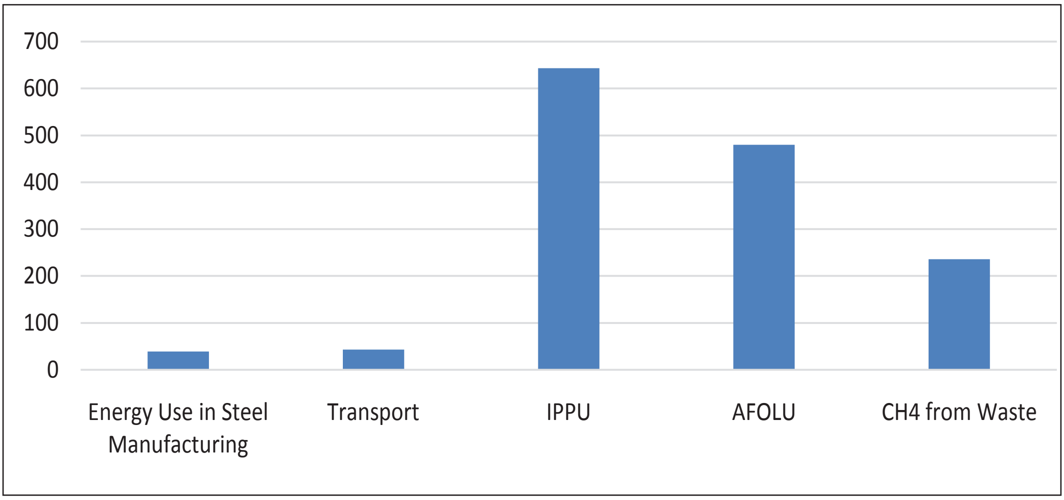

Figure 3. GHG Mitigation Potential

Present climate change and future projections

Bhutan lacks a series of long periods of temperature and rainfall data sets. The observed data have only been available since 1996, of which most are in the middle and southern parts of the country. As the data period is short, no accurate inferences could be made on the trend, both for rainfall and temperature. However, over recent years, extreme weather events have been observed to be more frequent and precipitation patterns have altered.

Future climate scenarios focused on two time slices: a short-term period (2021-2050) and a long-term period (2070-2099). The projection considers two socio-economic scenarios representing trends –Representative Concentration Pathways of high emission (RCP 8.5) and intermediate emission (RCP 4.5) of the IPCC fifth assessment report (2014).

The projection shows a stable increase in temperature across the country under both RCPs. The rise in temperature under RCP 4.5 is about 0.8°C– 2.8°C during 2021-2100 while projections under RCP 8.5 scenario show increases of about 0.8°C to more than 3.2°C towards the end of the century. There are indications of more significant warming during Spring and Winter seasons. The country would likely experience an increase in temperature with a more considerable increase projected in the high lands.

The mean annual rainfall over Bhutan is likely to increase in the future under both RCPs. Under the RCP 4.5 scenario, the yearly rainfall in Bhutan could increase by about 10% to 30%, with a 5% to 15% increase in summer rainfall/ monsoon. The projection also notes a likely increase of rainfall during the winter. However, rainfall levels in some parts of the northern and north-western parts of the country could even decrease.

Under the RCP 8.5 scenario, the mean annual rainfall indicates an increase of about 10-20% between 2021 and 2050. By the end of the century, the projected increase in rainfall levels across the country could be more than 30%. While the projections suggest increasing rainfall during the summer, the winter season is likely to receive a decrease in rainfall in some parts of the country, particularly in the north-western region of Bhutan.

Climate change impact, vulnerability, and adaptation assessment

Water resources

All river basins are projected to see the highest discharge in May, June and July (14 to 43%) for all the scenarios and time periods except for June in RCP 4.5 (2070 - 2100). Under the RCP 8.5 scenario, the monthly average flow shows an increase from January to November for both future time periods. However, December month flows are lesser in both scenarios. As evident from the results, the increases are concentrated more in the summer months when the flow is relatively high, while the decreases are more apparent in the winter months. Hence, in the future, dry periods are expected to get drier. In contrast, wet periods are expected to get wetter, making the overall system more vulnerable to the impacts of climate change.

The snow cover area for Bhutan estimated for the period 2002 to 2010 was 9030 km2, about 25.5% of the total land area (Gurung et al., 2011). The average snow cover area for winter was around 14,485 sq. km (37.7%), for spring 7,411 km2 (19.3%), for summer 4,326 km2 (11.2%), and for autumn 77,88 km2 (20.2%), mostly distributed in the elevation range 2,500–6,000 masl. The total snow cover area from 2002–2010 decreased by about –3.27 ± 1.28%. This decrease was at both annual and intra-annual scales at insignificant rates. The snow cover decline over the recent decade could result in a decrease in water resources availability in the long run.

To address increased disaster risks, limited access to water resources and seasonal water shortages, the following adaptation options have been proposed:

- Prepare an action plan based on a detailed multi-hazard zone mapping and set up relevant early warning systems and education.
- Develop Water Safety plans and implement proper water supply systems with an adequate design, and study ground water use and its risks and potentials across Bhutan.
- Examine the feasibility of storage reservoirs for seasonal storage, build multi-purpose storage reservoirs, and explore technologies for rainwater harvesting and efficient water usage and management.

Agriculture sector

The agriculture sector is vulnerable to change in monsoon season's timing (early/late) and the quantity of rainfall. About 61% of dry arable land is rain-fed as there are no adequate irrigation facilities.

Increases in temperature and irregular rainfall patterns have led to decreasing crop yield due to reduction in agricultural water availability and crop loss to extreme events like flash floods, windstorms, pest and disease outbreaks. Most villages across Bhutan are highly vulnerable to climate impacts and have low adaptive capacity. Factors contributing to the villages' low adaptive capacity are their limited resource base and precarious socio-economic status, including labour shortages; poor grid and road connectivity; unstable dryland agriculture; crop disease and low-yielding seeds; and, increased risk and exposure to drought, unseasonal precipitation, and wind events. The impact gets elevated due to the dependence of Bhutan's agriculture on largely rain-fed crops in the dry land.

The main constraints faced in the agriculture sector are climate change-induced water shortages, wildlife predation of crops, pests and diseases, poor mountainous shallow soils, further worsened by increasing soil loss through surface erosion and scarcity of farm labour. Adaptation priorities and options for agriculture are as follows:

- **Water Shortage:** Proper planning and implementation of irrigation projects considering climate change impacts, innovative storage, and pumping facilities;

strengthening database/inventory on water resources and capacity building.

- **Human-Wildlife Conflict:** Proper planning, capacity building, research and data inventory on animal migration and improved capacity in handling HWC.
- **Soil Erosion:** As most of small holders' farmlands occur on slopping lands, fertile topsoils are frequently lost to soil erosion. Sustainable Land Management (SLM) techniques and practices needs to be applied as adaptation measures.
- **Alternate Crop Production:** Conduct further research on the criteria for adopting new crops in Bhutan and identifying site-specific studies and options.
- **Marketing and Storage:** Improve post-harvest storage and preparation through initiatives like farmer schools where farmers with a good understanding of post-harvest technology and techniques could share their experiences.
- **Pests and Diseases**: Newer pests and diseases, along with their changing resilience, are huge risks to the agriculture and livestock sector. Develop and apply varieties of both crops and animals that are resilient to pests, diseases, and climate change. Exploring and continued dependence on native livestock breeds that have been able to cope with natural changes over the years instead of only depending on improved varieties is an alternative.
- **Extreme Climates:** Harsh unprecedented weather conditions, such as heat and cold waves, poses risks to both crops and livestock. Pasture development and providing proper shelters for animals in both hot and cold regions are also necessary to protect them from harsh climatic conditions.

Forests and biodiversity

Although Bhutan is endowed with rich biodiversity and mostly pristine forests, some of the threats to forest and biodiversity are forest fire, pest and diseases, loss of biodiversity, invasion of alien species, alteration in ecosystem composition as threats to biodiversity driven by climate change.

Based on the forest types classified in land use and land cover map of Bhutan, 2016, maximum entropy distribution modelling (Maxent) was used to assess the potential impact of climate change to forest types by the year 2050 and 2070 under RCP 4.5 and RCP 8.5 for broadleaf, mixed conifer, blue pine, fir, and chir pine.

Out of five forest types, Chir pine forest exhibited major potential gain in an area with a suitable climate under future climate change scenarios while remaining forest types are likely to experience a considerable decline. Several factors like anthropogenic land cover changes, dispersal limitation, pest and diseases, biotic interaction, migration, and disturbances such as forest fires are not included in the current model. Studies in central Himalaya indicated that gain in Chir pine forest would encroach and displace oak forest, which is an undesirable phenomenon. The gain in Chir pine forest area and their redistribution could contribute to water resource depletion. Further, gain in Chir pine forest will expose forests to increased incidences of fire damage and reduce floral diversity due to poor soil nutrients. Some of the adaptation options identified in forest and biodiversity sector are:

- ***Pest and diseases:*** Damages by pests and diseases will have the most immediate and possibly significant impact of climate change on the forest. This is because insects are ectothermic and change in temperature will directly influence their metabolic rate, consumption, development, survival, dispersal, and their destructive potential. Interaction between plant and insects are also dependent on the availability of water. Therefore, an in-depth understanding of the association between climate and forest pests and diseases. Their monitoring is important to enabling relevant authorities to expect, prepare and respond to change in pest behaviors, outbreak, and invasion.

- ***Forest fire***: Forest functions as an important carbon sink in the face of global climate change. However, an intense forest fire can potentially reverse this benefit by turning forest from sink to major source. The intensity, size and frequency of forest fires are expected to change as the temperature rise and precipitation pattern changes. Many aspects of post forest fire conditions will accelerate other natural environmental disturbances, resulting in modified vegetation patterns, land degradation, desertification, and hydrological cycle derangement.
- ***Invasion of alien species:*** As it is observed that both mean and annual temperature are increasing, exposure to high temperature for a very long time will affect forest flora and fauna inducing changes in forest biodiversity. Intrusion of agriculture farming into forests land is already occurring that will bring invasive weeds and alien species. This shift in mixtures of natural and domesticated plants and biodiversity would require a strong land use policy and measures to protect key biodiversity area.

Energy Sector

Bhutan's economy largely dependent on climate sensitive sectors like hydropower. The hydropower sector depends on the flow of the rivers, making it more susceptible to the impacts of climate change. The impacts of climate change on hydropower are demonstrated in the form of changes in flow, volume, inter-annual variability in the timing of flow. Heavy and erratic rainfalls during the monsoon, and drier periods in the winter, cause greater variance in total volumes between two consecutive years. Furthermore, it is expected that under a warmer and more variable climate, the onset of monsoons will be erratic, which will cause disruptions in natural cycles affecting hydropower generation. With the increase of frequency of heavy monsoon rains, flash floods and landslides are expected to occur, which may cause damage to infrastructure, power distribution, and eventually, the economy of the country.

The adaptation option includes diversification of energy sources and economic base, support promotion of renewable and energy-efficient technologies, and investments to harness hydropower energy. Storage of water during the lean season and explore the use of isolated valleys and alpine lakes for regulated storage. Watershed protection and check dams at strategic location will reduce the sedimentation and siltation of rivers and waterways. The operationalization of the Renewable Energy Development Fund (REDF) is also a measure that could be initiated sooner.

Human Health

Climate change affects social and environmental determinants of health – clean air, safe drinking water, food self-sufficiency and secure shelter. With climate change, Bhutan is expected to experience a wide range of health risks. Rising temperature, unpredictable weather patterns, unequal distribution, or water supply to the communities will influence the epidemiological pattern of many diseases, particularly vector-borne, airborne, and water-borne diseases. Diseases such as dengue and chikungunya have emerged over the last few years and indicate a growing trend. Emergency medical health requirements will also rise with climate-induced disasters such as GLOFs, floods and landslides.

The key adaptation options for the health sector to cope with the challenges and issues are emergency preparedness, enhancing monitoring and surveillance, strengthening capacity of health workers, deployment of health care facilities such as emergency and trauma centres and promotion of research needs.

Additionally, climate change also poses risks to other development sectors such as energy, manufacturing, and the service sector, including tourism and the hotel industry. Measures to adapt to such impacts should be developed to ensure that climate change does not nullify the gains of the past five decades of planned development.

Constraints and gaps, and related financial, technical and capacity needs

As a Least Developing Country with limited resources, technical, financial and human resources, constraints and gaps are a regular feature in both environmental governance and climate issues.

In GHG inventory, there are uncertainties associated with the emission estimates. These uncertainties are due to the degree of accuracy of the activity data and emission factors. The emission factors used in developing the inventory are IPCC default values except those used in the forestry sector. Currently, there is a complete absence of country-specific emission factors for the various emission-related activities.

Barriers such as financial resources, technology, research, development, and human capacity belong to high priority external barriers for all sectors. At the same time, insufficient legal environment, lack of coordination and integration, and absence of detailed research are in the category of high priority domestic barriers.

Bhutan's Country Work Program for Green Climate Fund has identified a total financing investment requirement of US$ 911.58 Million to adapt and mitigate climate change. These financial supports will need to be sourced in a phased manner considering the limited availability of climate finances as well as the implementing capacity of the agencies in the country. Additionally, assessment of biodiversity and climate change expenditure review report conducted under the Biodiversity Finance Investment projects expenditure requirement of Nu. 2,348 million in year 2021/22 for biodiversity and climate change under the business-as-usual scenario.

Other relevant information

In terms of integrating climate change into national policies and plans, the framework of mainstreaming Gender, Environment, Climate, Disaster Risk Reduction and Poverty Alleviation (GECDP) into local government plans were linked to the National Key Result Areas (NKRAs), Agency Key Result Areas (AKRAs) and Dzongkhag Key Result Areas (DKRAs). The framework thus developed was further fine-tuned for the formulation of the current 12th Five Year Plan (FYP), where central agencies have been given prime responsibilities in achieving the NKRAs. For instance, the National Environment Commission Secretariat works to accomplish the NKRA on Climate Action or Climate Resilient Development.

The National Center for Hydrology and Meteorology (NCHM), has been entrusted with the responsibilities of climate projections and other studies on cryosphere and weather.

Initiatives have been taken to include climate education at all levels of primary, secondary and tertiary education, and curriculum on environmental science has been developed and is taught in all the schools while curriculum on climate change is being developed to further improve on climate education.

New and additional sources of climate finance are needed to ensure Bhutan stays on the path of carbon neutrality through conscious low emission development pathways. The approval process for climate financing is cumbersome and often requires complex documentation that takes a long time to process. Therefore, it mandates the formulation and implementation of a national climate financing strategy by establishing a climate fund in partnership with local or multilateral banks.

NATIONAL CIRCUMSTANCES

1. NATIONAL CIRCUMSTANCES

1.1 *Profile of a country*

Bhutan is a small, landlocked country with an area of 38,394 Km^2 situated on the southern slope of the Eastern Himalayas, bordering China to the north and India to its south, east and west. The country is almost entirely mountainous. With altitudes ranging from about 100 meters in the foothills to over 7,500 meters in the north, the country's north-south border spans over 170 km while the east-west dimension measures around 300 km. The dominant topographic features consist of the high Himalayas in the north with snowcapped peaks and alpine pastures, north–south valleys and ranges forming watersheds, deep valleys created by fast-flowing rivers, rugged foothills, and alluvial plains with broad river valleys.

Owing to its fragile mountainous ecosystem, Bhutan is highly vulnerable impacts of climate change and extreme weather events. The situation is further worsened by country's low adaptative capacity, poor economic status constrained by limited financial, technical and human capacity. Additionally, the country's economy is still predominantly dependent on climate sensitive sectors like agriculture (more than 60% of rural population depend for livelihood) and hydropower. The mountainous landscape makes communication and transport very fragile and expensive.

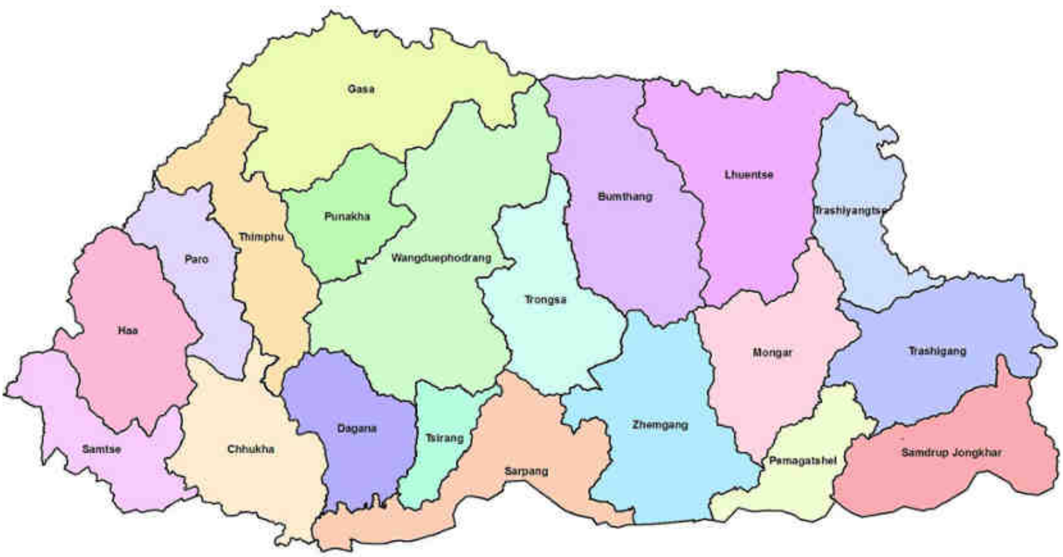

Figure 4: Administrative map of Bhutan

1.2 *Land area*

According to the land cover assessment, the land use is classified into the following classes. The *forests* cover (excluding shrubs) covers 70.77% of the total land area of which 45.94% is broadleaf forests, 13.53% is mixed conifer, 6.02% is Chir pine and 2.64% is Blue pine. The *Alpine Shrub* covers 3.39% of the land area, *shrubs* constitute 9.74%, *cultivated agriculture land* covers 2.75% and *meadows* 2.51%. The *snow cover* constitutes 5.35% and *rocky areas* is 4.15% while *water bodies, built-up areas, non-built-up areas, landslides* and *moraines* each constitutes less than 1%. (FRMD, 2017)

1.3 *Climate*

The climate of Bhutan is exceptionally diverse. Two main factors affect the variation in average temperature and precipitation: the vast differences in altitude in the country and the influence of the North Indian monsoons. Bhutan's location at the northern periphery of the tropical circulation is an important feature that determines the its climate. Bhutan has three distinctive climatic zones:

Subtropical: the southern belt with an altitude between 200 and 2000 meters, characterized by high humidity and heavy rainfall. The temperature ranges from 15^{0}C to 30^{0}C all year round.

Temperate: the central belt with an attitude ranging from about 2000 to 4000 meters, consisting of main river valleys, and characterized by cool winters and hot summers with moderate rainfall. The temperature ranges from 15^{0}C to 26^{0}C during monsoon season (June through September) and -4^{0}C to -15^{0}C during the winter season.

Alpine; the high region in the northern encompasses snowcapped peaks and alpine meadows above 4000 meters with cold winters and cool summers.

Bhutan receives about 70% of the precipitation during monsoons, while pre-monsoon rainfall accounts for 20%. The annual precipitation ranges widely in various parts of the country. The northern region gets about 40 mm of annual precipitation, mostly in the form of snow. The temperate central valley receives about 1,000 mm of rainfall, while the southern region gets about 1,500 mm of rainfall annually (NSB, 2018). The monsoons last from late June through late September.

Table 1 Land use and land cover class of Bhutan

Land use and land cover class	Area (ha)	Area (%)	Percent of forest area
Broadleaf forest	17,63,899	45.94	65
Conifer forest	9,53,262.2	24.83	35
Shrub	3,74,032.6	9.74	NA
snow and glacier	2,05,343.6	5.35	
Rocky outcrops	1,59,455.6	4.15	
Alpine Scrub	1,30,097.7	3.39	
Agriculture	1,05,682.4	2.75	
Meadows	96,273.61	2.51	
Waterbodies	25,175.78	0.66	
Moraines	14,393.94	0.37	
Built Up	7,457.03	0.19	
Landslides	3,730.22	0.10	
Non-built up	595.89	0.02	

Source: National Forest Inventory Report 2016, Volume I.

1.4 *Natural Resources*

1.4.1 Forest resources

Bhutan has a total of 70.77 % forest cover (2717161.64 ha) out of the total geographical area (3,839,400 ha) of the country (FRMD 2017). Broadleaved forests constitute around 65% of the forested area, while conifer forests make up about 35%. The forest cover of Bhutan marginally increased from 70.46%[1] in 2010 to 70.77% in 2016[2].

According to the National Forest Inventory, Bhutan's forests store 645 million tonnes of carbon in the form of biomass carbon and soil organic carbon (SOC). The biomass and soil organic carbon in forest land constitute about 457 million tonnes and 188 million tonnes of total carbon stock respectively (FRMD, 2020).

1.4.2 Protected Area Network

The protected area (PA) network of Bhutan consists of five National Parks, four Wildlife Sanctuaries, one Strict Nature Reserve, eight Biological Corridors (BC) and a Royal Botanical Park (RBP). The total PA, including BC and RBP, covers 51.44% of the country's area. The PA system in Bhutan is unique in terms of management from rest of the world. There are human settlements within the PAs that play an essential role in our conservation efforts, unlike in other parts of the world, where communities in the PAs get relocated (MoAF, 2019).

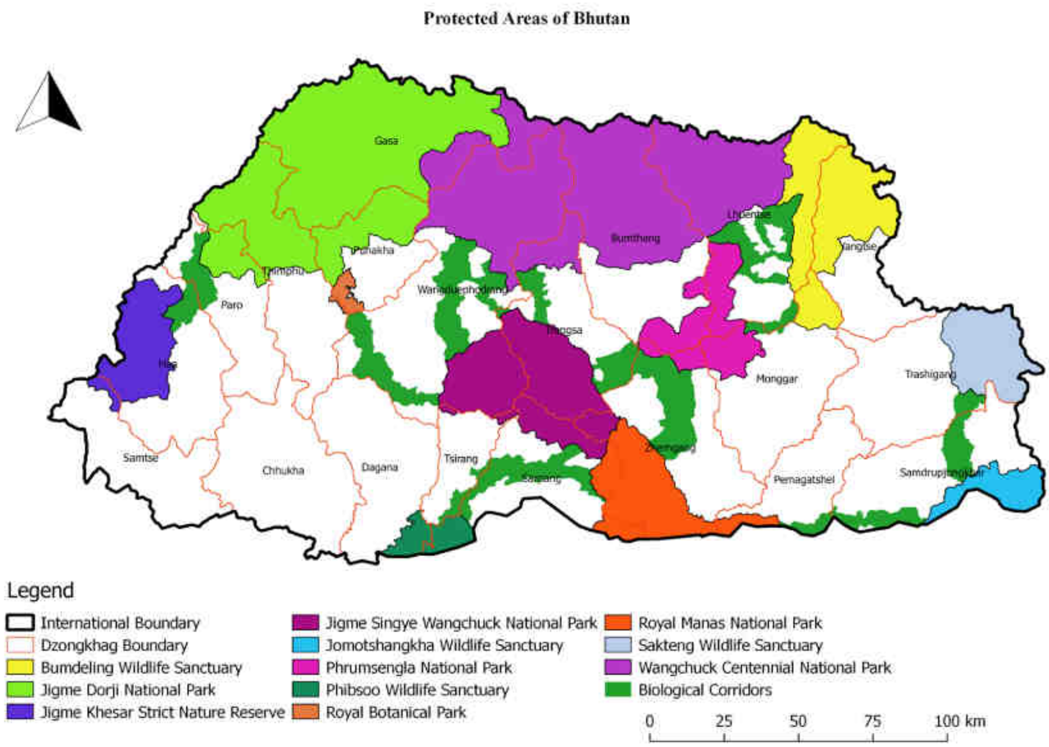

Figure 5 Network of Protected Areas of Bhutan

[1]*LCMP 2010*
[2]*Land Use and Land Cover of Bhutan 2016*

1.4.3 Biodiversity

Due to the high forest cover, pristine environment, strong conservation efforts and good network of Protected Areas, Bhutan has flourishing populations of some of the rarest flora and fauna on earth.

The 2017 Biodiversity Statistics of Bhutan records 11,248 species of all biodiversity groups found in Bhutan, namely 5,114 species under the Kingdom Animalia, 5,369 species under the Kingdom Plantae, 690 species of fungus, 55 species under the Kingdom Chromista, 18 species of Eubacteria, and two species of protozoa under the Kingdom Protista.

The country's biodiversity includes several plants and animal species listed as vulnerable, endangered, or critically endangered in the International Union for Conservation of Nature Red List of threatened species. The country is home to 15 vulnerable, 20 endangered and 13 critically endangered seed plants.

Bhutan hosts 13 vulnerable, 11 endangered and two critically endangered mammal species. Likewise, the country has 22 vulnerable, four endangered and four critically endangered bird species. There are also eight vulnerable and three endangered fish species, 11 vulnerable, five endangered and two critically endangered amphibians, and one vulnerable butterfly (MoAF, 2018).

1.4.4 Water resources

Most of the major rivers in Bhutan originate from glaciers and are fed by watersheds. The river system is generally distinguished by main rivers that flow from north to south, with tributaries flowing in an east-west direction. The main rivers are Amochhu, Wangchhu, Punatsangchhu and Manas. Two large rivers, Mangdechhu and Drangmechhu, converge into one river and make up the Manas just before crossing the Indian border. The Manas river covers about half the country.

Most of the river discharge results from rainfall, supplemented by an estimated 2-12% glacial melt and another 2% from snow melt. The combined outflow of the rivers is about 70,576 million m^3, or 2,238 m^3/s, which corresponds to a flow of 109,000 m^3 per capita per year, the highest in the region (NEC, 2016).

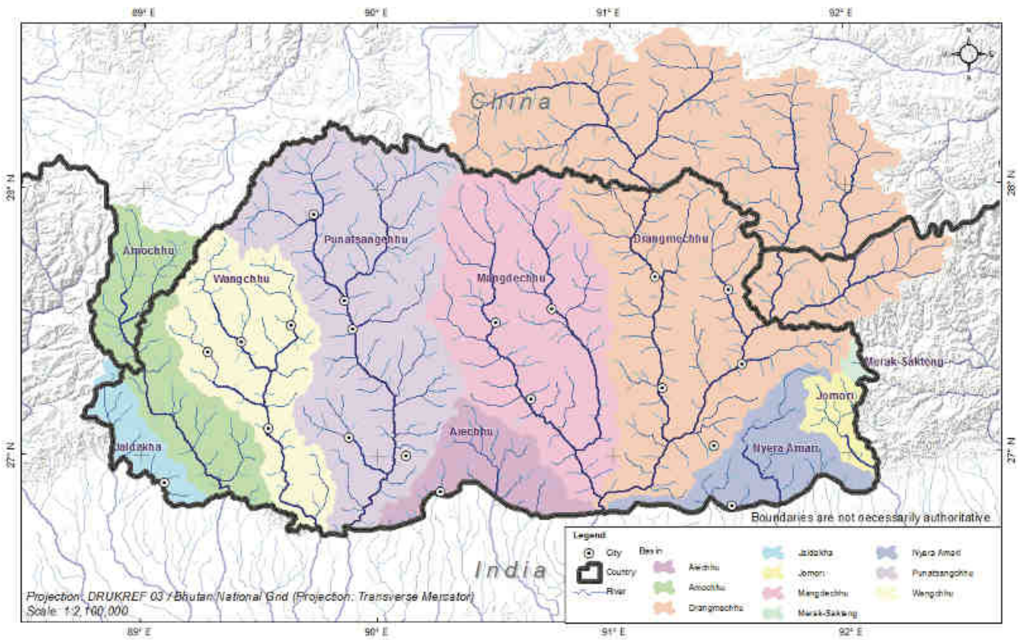

Figure 6 Hydrological basins of Bhutan

However, considering the rugged topography, climate variations and most settlement occurring on hill-tops and rivers flowing at the bottom of the valley, water scarcity and localized shortages are among the main concerns in the country (WMD, 2018). The impact of climate change on water availability is a concern for drinking water supply, agricultural production and hydropower generation.

The Watershed Management Division under the DoFPS will be conducting comprehensive national wetland inventory to establish national database system for the wetlands. The inventory of wetlands based on study conducted by UWICE and WWF Bhutan in 2010 is presented in the table below.

Table 2 Inventory based on study conducted by UWICER and WWF, 2010

Wetland type	Number	Total area m^2	Average area m^2	Largest area m^2	Smallest area m^2
Supra snow lake	110	52,327	475	4,759	36
Supraglacial lake	495	28,554,801	57,686	1,517,436	134
Glacial lake	637	23,230,604	36,468	878,311	115
Lake	1722	49,973,272	29,020	868,049	35
Marsh	63	497,334	7,894	63,811	126

1.5 *Population*

Bhutan is one of the least populated countries in Asia with a total population of 727,145 in 2017 and PGR of 1.3% per annum as per Housing and Population Census of Bhutan, 2017 (NSB, 2017). As a result of the gradual increase in the population size, the population density of Bhutan increased from 17 persons per km^2 in 2005 to 19 persons per km^2 in 2017. The distribution of the population over the land area is not uniform throughout the country. While the capital, Thimphu, has the highest population density at 67 persons per km^2 and Gasa Dzongkhag has the least population density of 1.3 persons per km^2.

Since the commencement of the planned socio-economic development in the 1960s, Bhutan has developed from a nascent health system to a closely-knit network of health facilities catering to its people's health needs. As of 2018, there are 211 Basic Health Units, 52 sub posts and 551 ORCs at the primary level, 26 hospitals at the secondary level and three referral hospitals at the tertiary level, spread across the country. Furthermore, the provision of TM services from 61 TM units and one national TM hospital has enhanced the health services delivery in the country. Health services are provided free of cost and is financed by the Royal Government (MoH, 2018).

The 2017 PHCB reported the literacy rate of 71.4% and the adult (aged 15 years and above) literacy rate of 66.6%. There is a marked difference in the literacy levels between the male and female populations with 78.1% of the male population literate as compared to 63.9% of the female population. Overall, the literacy rate is significantly higher in urban areas (84.1%) than in rural areas (63.6%).

Table 3:Population statistics of Bhutan

Population statistics				
	2000	**2005**	**2010**	**2017**
Total population	677,934	634,982	695,822	727,145
Male population	342,324	333,595	363,383	380, 453
Female population	335,610	301,387	332,439	346,692
Population density	14.6	16	18.1	19
Crude Birth Rate (per 1000)	34.1	20	-	15.5
Crude Death Rate (per 1000)	8.6	7	-	6.7
Natural rate of increase	2.5	1.3	-	0.9
Total Fertility Rate	4.7	2.6	-	1.7
Life Expectancy at Birth	-	66.25	-	70.2
Life Expectancy (Male)	-	65.65	-	71.7
Life Expectancy (Female)	-	66.85	-	68.8

Source: NSB 2006, 2010 & 2017. Note: Figures for 2000 are estimates from Health survey 2000. 2005 & 2017 figures are based on Population and Housing Census of Bhutan 2005 & 2017 and 2010 figures are projections.

1.6 *Socio-economy*

1.6.1 Macroeconomy

Bhutan's economy is primarily driven by three key sectors (hydropower, tourism and agriculture The country has a free trade connection with neighboring India and enjoys cordial relation with the region. Bhutan's main model of development is the concept of Gross National Happiness and the subsequent GNH index tool. Any form of development is deeply rooted into the realization that *Gross Happiness is more important than the Gross Domestic Product* which has descended from the fourth Monarch King Jigme Singye Wangchuck. The development philosophy envisions that any economic development should be holistic and emphasize on the happiness and over-all well-being of the people.

The GNH Commission has this crucial role in assessing plans, programs and projects through the lens of the GNH tool and ensure that there is a smooth inclusion of GNH at all levels of the government functioning. Bhutan is one of the world's smallest economies, with Gross Domestic Product (GDP) in 2017 recorded at NU 164.6 billion or approximately USD 2.4 billion. However, growth has been remarkable, with the economy growing at an average rate of seven percent over the past decade, mainly due to investments in the hydropower sector. GDP per capita increased from USD 2,464 in 2013 to USD 3,438 in 2017 (GNHC, 2019).

Bhutan was categorized as a LDC by the UNGA in 1971. However, over the decades, Bhutan has made remarkable socio-economic advancements, qualifying the country for graduation from this category for the first time at the 2015 triennial review of the list of LDCs (GNHC, 2019). Bhutan's economic freedom score is 62.9, making its economy the 74th freest in the 2019 index and ranked 16th among 43 countries in the Asia- Pacific region. Its overall rating is above the regional and world averages.

The public sector has long been the primary source of economic growth, but the government now recognized the significance of private-sector growth. Economic diversification is now a higher priority and Bhutan has made progress in modernizing its economic structure and reducing poverty.

1.7 *Agriculture*

The agriculture sector comprises of farming, livestock and forestry which continues to be a major player in the country's economy. With only 2.75% of the total land area used for agriculture (DoFPS, 2016), the sector accounted for 17.37% of GDP in 2017 (NSB, 2018) and employed about 60% of the total population in 2015 (RGoB, 2016).

With the majority of the population relying on agriculture, the sector is highly vulnerable to climate change. Also, characterized by remoteness and inaccessibility, marketing and large-scale commercialization are significant challenges for Bhutan. The farmers' main cash crops (rice, potatoes, chilies, apples, maize and oranges) are all highly sensitive to water and temperature variations (DoA, 2005).

1.8 *Energy*

Energy is the greatest opportunity for the country and the main driver of the economy. The availability of fast-flowing rivers and the abundance of sunshine, biomass, wind etc. offer tremendous opportunities for hydropower and renewable energy development, particularly in light of global climate change concerns. Bhutan has one of the largest repositories of hydropower in Asia with a theoretical potential of 30,000 MW. The total installed capacity as of 2018 is 1,606 MW (excluding embedded generations, solar and wind) (MoEA, 2018). The majority of the electricity is exported to

Table 4: Percentage contribution to GDP by services sectors of Bhutan (2018)

Years	2010	2011	2012	2013	2014	2015	2016	2017
1. Agriculture, Livestock & Forestry	16.80	16.33	15.96	16.10	16.69	16.71	16.61	17.37
2. Mining & Quarrying	2.23	2.29	2.01	2.65	2.81	3.39	4.33	4.22
3. Manufacturing	8.72	8.29	8.85	8.33	8.08	7.98	7.43	7.25
4. Electricity & Water Supply	17.61	14.02	12.62	14.45	14.08	14.33	13.35	13.22
5. Construction	14.22	16.38	18.13	16.92	15.88	15.63	16.28	15.87
6. Wholesale & Retail Trade	5.18	5.46	6.07	6.48	7.05	7.74	7.91	8.18
7. Hotels & Restaurants	0.84	1.12	1.33	1.54	1.70	1.88	1.92	2.11
8. Transport, Storage & Communication	9.58	10.04	9.50	9.31	9.58	9.00	8.82	9.06
9. Financing, Insurance, Real Estate & Business Services	7.65	8.25	7.61	7.65	7.53	7.38	7.30	7.09
10. Public Administration	7.61	7.63	6.95	6.63	6.73	7.48	7.52	7.07
11. Education & Health	5.17	5.18	4.59	4.32	4.06	3.76	3.54	3.24
12. Private Social & Recreational Services	0.41	0.40	0.40	0.41	0.39	0.38	0.36	0.40
13. Taxes Net of Subsidies	3.99	4.62	5.96	5.21	5.42	4.34	4.60	4.91
Overall GDP	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Source: NSB, 2018

India; however, during the lean season (winter months), power is imported from India.

Other sources of energy constitute coal, biomass, fossil fuels and other renewable energy sources. Biomass from the forest is still widely used for space heating and fodder cooking in rural areas.

1.9 *Transport*

Being landlocked and owing to rugged topography, road surface transport serves as the main lifeline in Bhutan. However, the sector is highly vulnerable to the impacts of climate change and extreme weather. Bhutan's transport network consists of road surface transport and air transport and minimal ropeways.

The national road network has expanded rapidly since the construction of the Phuentsholing - Thimphu Highway, the country's first road. As of 2017, there are over 18,181.3 km of motorable roads, including national highways, district roads, feeder roads, farm roads, urban roads, expressway, power tiller tracks, access roads and forest roads (NSB, 2018). As of June 2018, there were 96,307 registered vehicles in Bhutan and is increasing at an average of 9.2% annually (RSTA, 2018).

Druk Air, the national airline, has been in operation since April 1981, linking to neighboring countries. Tashi Air Pvt. Ltd is Bhutan's first Private Airline and introduced internal operations in 2011 and international operations in 2013 (NSB, 2018). They commenced domestic operations in 2011, connecting to all three domestic airports in Bhutan.

1.10 *Industries*

Most of the industrial establishments in Bhutan are found in the southern region of the country because of easy access to raw materials, labour, transport and market. However, this sector faces various limiting factors, such as low technological development and human skills.

The industrial sector has until recently played a relatively small role in the economy. Bhutan has deposits of several mineral resources, including limestone, coal, graphite, gypsum, slate and dolomite. Most mining activities are limited to relatively small operations, mainly involved in the mining of dolomite, gypsum, limestone, slate, coal, marbles, quartzite and talc.

The manufacturing industry is dominated by small and cottage industries as the country has good timber resources and favorable agricultural conditions. Wood-based industries comprise mainly of small sawmills, furniture making units, small traditional paper units, one particleboard factory, wood veneering, and resin and turpentine harvesting. Agro-based industries consist of fruit processing and alcoholic beverage production units. Other manufacturing units produce local handicrafts and textiles.

Table 5 Industrial establishments by type and size

Industrial establishment	2016	2017	2018
Total number of industries	**17,004**	**20,093**	**22,437**
Industries by size			
Large scale	423	485	494
Medium scale	1407	1576	1545
Small scale	3455	4029	4581
Cottage scale	11719	14003	15,817

Industries by type			
Production & Manufacturing	1,648	2,125	2,539
Contract	3,135	3,440	3,452
Services	12,221	14,528	16,446

Source: Department of Industry and Department of Cottage & Small Industry, MoEA, Thimphu.

1.11 *Tourism*

The tourism industry in Bhutan began in 1974, and it contributes more than 9% to GDP as the highest commercial source of convertible currency earnings. The revenue generated from the tourism sector has increased from over USD 2 million in the late 1980's to over USD 79.81 million in 2017 (NSB, 2018). Bhutan remains a favored destination throughout the global tourism industry because of the pristine state of the country's cultural and natural heritage and its reputation for conservation and under the developmental philosophy of Gross National Happiness.

Bhutan implements a "high value, low impact" tourism policy to curtail the impact of tourism on its culture and environment.

1.12 *Governance structure*

The government of Bhutan is a democratic constitutional monarchy with the executive power vested in the Cabinet (Lhengye Zhungtshog) headed by the Prime Minister (RGoB, 2008).

At the central level, the 10 different Ministry is headed by the Cabinet Ministers and at the local level, Bhutan is administratively divided into 20 *Dzongkhags* (districts), each governed by a district administrator or *Dzongda.* The Dzongkhags are sub-divided into small blocks or *geogs.* There are 205 *geogs* in the country, grouped under 47 constituencies.

The National Assembly (*Gyelyong Tshogdu*) has 47 members elected from 47 constituencies in the country who belong to one of the political parties, either ruling or opposition.

The National Council (*Gyelyong Tshogdey*) has 25 members, of which 20 members are directly elected by the people (one from each *Dzongkhag*), and the other five are nominated by His Majesty the King.

1.13 *Coordination Mechanism on Climate Change*

The institutional arrangements for climate change coordination in Bhutan have evolved over the years since the establishment of the NEC and Bhutan's signing of the Rio Conventions in 1992.

Bhutan ratified the United Nations Framework Convention on Climate Change (UNFCCC) on 15 August 1995, and the National Environment Commission Secretariat (NECS is the national focal point for all the multilateral environmental agreements.

The National Environment Protection Act 2007, Section 20, mandates the National Environment Commission (NEC) as an independent authority and the highest decision-making body on all matters relating to the environment and its management in the country. The Commission comprises of nine members with Prime Minister/ Minister of a relevant Ministry nominated by the Prime Minister as the Chairperson, highest ranking officials representing relevant ministries and representatives of civil society/ eminent persons as members.

The Commission is entrusted with the authority to take all such measures as it deems necessary or expedient for the purpose of protecting the environment and preventing, controlling and abating environmental harm or pollution.

The Commission is supported by the Secretariat and is responsible for implementing the policies, regulations and directives issued by the National Environment Commission, and for administering the provisions of the National Environment Protection Act, 2007.

The erstwhile Multi-Sectoral Climate Change Committee established in 2010 was revamped as Climate Change Coordination Committee (C4) through the Executive Order of the Prime Minister in October 2016, to serve as a forum to discuss and coordinate matters related to climate change in Bhutan and make recommendations for consideration by the Commission and ensure smooth implementation of climate change policies, projects and programs in the country.

The following provides an overview of the existing bodies and institutional arrangements dealing with climate change:

- The National Environment Commission, supported by the Secretariat, is the *National Focal Agency for UNFCCC*, with the Secretary, NECS serving as the *National Focal Point for UNFCCC*.

- The Commission has also served as the high-level *National Climate Change Committee* since 2000, when the Commission approved the "Initial National Communication from Bhutan" to UNFCCC. This function is also in line with mandates under NEPA 2007.

- The NECS is also the *Designated National Authority (DNA)* under the Clean Development Mechanism, Kyoto Protocol, to provide national endorsement for CDM projects. The DNA is supported by a National CDM Committee comprising members from the Department of Industries and Department of Hydropower and Power Systems, Ministry of Economic Affairs (MoEA); Department of Forest and Park Services, Ministry of Agriculture and Forest (MOAF); Ministry of Works and Human Settlement (MoWHS); Ministry of Finance; and NECS. The Secretary, NECS, chairs the CDM Committee.

- NECS is the National Designated Entity to the Climate Technology Center and Network (CTCN) of UNFCCC to disseminate relevant information and interact with CTCN about their technology needs.

- In 2009, the NEC approved the establishment of a Climate Change Unit at the Secretariat and later upgraded to a *Climate Change Division*. Currently, the Climate Change Division comprises of one Chief, six Officers and two Technicians.

- The erstwhile *Multisectoral Technical Committee on Climate Change (MSTCCC)* created by the NEC in 2010 serves as the technical level body for coordinating climate change activities. It was revamped to strengthen further the Committee's function as *Climate Change Coordination Committee* in October 2016. The Committee chaired by the Secretary NECS, with members from line agencies and CSOs reports to the NEC in their capacity as NCCC.

- The NECS function as the Co-National Focal Agency while the National Center for Hydrology and Meteorology function as *National Focal Agency* for the *Inter-Governmental Panel for Climate* Change (IPCC) as per the designation by Ministry of Foreign Affairs in September 2015.

- GNHC serves as the Designated Authority for the Adaptation Fund under the Kyoto Protocol.

- Bhutan Trust Fund for Environmental Conservation (BTEFC) is accredited as the National Implementing Entity for Adaptation Fund.

- GNHC is also the *National Operational Focal Point* and also serves as NDA for *Green Climate Fund.* The Ministry of Foreign Affairs is the *Political Focal Point* for the *Global Environment Facility (GEF)*. The GEF focal points are assisted by a *National GEF Steering Committee* comprising focal persons of the three Rio Conventions (biodiversity, climate change and desertification).

Bhutan has already made a global commitment to remain a carbon-neutral country for all times to come, which in itself is an explicit and more than its fair share responsibility. Nevertheless, Bhutan continues to effectively participate, engage and contribute towards the local, regional and global climate change programs.

Key coordination across the economic sectors to garner their support towards a low-carbon and resilient pathways are underway at various levels. Under this, formulation of key national documents like the enhanced Nationally Determined Contributions, National Adaptation Planning (NAP), Long-term Low Greenhouse Gas Development Strategies are already under process.

Nationally, the government in January 2020 has adopted the Climate Change Policy of the Kingdom of Bhutan is a highly cross-sectoral approach in combating the climate change.

In terms of regional network and cooperation governing environment and climate change, Bhutan is member to South Asia Association Regional Cooperation, regional cooperative mechanisms and land mark agreement like Male` Declaration established under the South Asian Cooperative Environment Program, Asia Pacific Adaptation Network and other initiatives in the regional information network facilitated by International Center for Integrated Mountain Development on sharing information on transboundary pollution resulting from atmospheric black carbon.

NATIONAL GREENHOUSE GAS INVENTORY, 2015

2. NATIONAL GREENHOUSE GAS INVENTORY, 2015

2.1 Introduction

This chapter describes Bhutan's Greenhouse Gas Inventory for 2015 from emission sources of energy, IPPU, AFLOU and waste and removals by sink. The inventory for the three main gases emitted, namely carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O), is estimated using the 2006 IPCC Guidelines. Carbon monoxide (CO) and nitrogen oxide (NOx) were calculated for forestry and other land use only. Due to changes in methodology and to ensure consistency in time series data, recalculation was conducted from 1994 for all sectors.

2.2 Methodology

All the methodologies and tools used for GHG inventory reporting followed the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006), Good Practice Guidance, and Uncertainty Management in National Greenhouse Gas Inventories (IPCC, 2000). The methodologies used was from Tier 1 using the default emission/removal factor except for forestry sector where some country specific carbon density data was used. The decision trees provided in the IPCC Guidelines guided the choice of methods for inventory.

Net emission has been presented in carbon dioxide equivalents (CO_2e) using the 100 - year global warming potentials (GWPs) from the 1995 IPCC Second Assessment Report (SAR).

In general, each method was applied based on the availability of data and analysis of key categories. The collection of data and information is still a challenge when compiling the GHG inventory for Bhutan. The data and information often come from national aggregated levels, but some are collected from point or direct sources. That makes the use of higher-tier methods difficult. However, higher tier and country-specific emission factors was applied in selected categories to estimate the emission and removals from forestry and other land use.

Bhutan aspires to gradually improve its reporting by adopting higher tier methods as local capacity develops, and more disaggregated data becomes available. Bhutan's GHG inventory has been prepared using data from national statistics, surveys and activity data provided by different sectors.

2.3 Institutional arrangements for inventory preparation

The National Environment Commission Secretariat is mandated to coordinate and manage all climate change action and information, including the compilation and update of GHG inventories, which the Climate Change Division is tasked to carryout.

A National Thematic Working Group (NTWG) was formed through the TNC project to represent experts from different sectors covering the IPCC source and sink categories. The NTWG collected, analyzed, and managed the data and estimated the emissions and removals of GHGs.

Sectoral and Subcategory Leads were identified for the inventory preparation. Each Subcategory Lead coordinates, compiles, assesses, and computes the activity data for their respective sector and reports to the Sectoral Lead. The Sectoral Lead then validates that data and reports to the National Inventory Report (NIR) Coordinator that finally reports to the National Coordinator.

The institutional arrangement for national GHG inventory management is discussed in section 2.17.

2.4 Brief description of key categories

Key categories are defined as sources of emissions or removals that have a significant influence on the inventory, in terms of emission levels, the trend, or both. When summed together in descending order of magnitude, key categories add up to over 95% of total emissions (level assessment) or the inventory trend in absolute terms. The analysis of key categories was performed based on sectoral distribution and the Tier 1 approach for level estimates. The key categories from the analysis are presented below, while the results of the key category analysis for 2015 are provided in the annexure.

The analysis of key sources followed the 2006 IPCC Guidelines. IPCC Software Version 2.54 was used to populate the activity data and estimate the emissions. Two approaches can be used to determine the key categories: the level approach if only one year of data is available, and the trend approach if there are two comparable years.

The inventory provides emissions for more than one year; therefore, both the level and trend assessments for key category analysis were performed. For the trend assessment, the emission estimates for 2000 and 2015 were used. The most significant sources of GHG emissions in Bhutan are forest land remaining forest (CO_2), road transportation (CO_2), cement production (CO_2), ferroalloys production (CO_2), enteric fermentation (CH_4), manufacturing industries and construction- solid fuels (CO_2), wastewater treatment and discharge (CH4), direct N_2O emissions from managed soils, (N_2O). The 2015 inventory year's key categories for Bhutan are listed in tables 6 and 7 with their level and trend contributions.

Table 6 Level Assessment

IPCC Category code	IPCC Category	Greenhouse gas	2015 Ex,t (Gg CO2Eq)	|Ex,t|(Gg CO2Eq)	Lx,t	Cumulative Total of Column F
3.B.1.a	Forest land Remaining Forest land	CARBON DIOXIDE (CO_2)	-8181.187	8181.187	0.773	0.773
1.A.3.b	Road Transportation	CARBON DIOXIDE (CO_2)	416.778	416.778	0.039	0.812
2.A.1	Cement production	CARBON DIOXIDE (CO_2)	378.924	378.924	0.035	0.847
2.C.2	Ferroalloys Production	CARBON DIOXIDE (CO_2)	354.885	354.885	0.033	0.880
3.A.1	Enteric Fermentation	METHANE (CH_4)	348.490	348.490	0.033	0.913
1.A.2	Manufacturing Industries and Construction - Solid Fuels	CARBON DIOXIDE (CO_2)	236.815	236.815	0.022	0.935
4.D	Wastewater Treatment and Discharge	METHANE (CH_4)	106.204	106.204	0.010	0.945
3.C.4	Direct N2O Emissions from managed soils	NITROUS OXIDE (N_2O)	102.937	102.937	0.010	0.955

Table 7 Trend Assessment

IPCC Category code	IPCC Category	Green-house gas	2000 Year Estimate Ex0 (Gg CO2Eq)	2015 Year Estimate Ext (Gg CO2Eq)	Trend Assessment (Txt)	% Contribution to Trend	Cumulative Total of Column G
3.B.1.a	Forest land Remaining Forest land	CARBON DIOXIDE (CO_2)	-7001.571	-8181.187	0.128	0.413	0.413
2.C.2	Ferroalloys Production	CARBON DIOXIDE (CO_2)	45.455	354.885	0.037	0.120	0.533
1.A.3.b	Road Transportation	CARBON DIOXIDE (CO_2)	122.818	416.778	0.036	0.115	0.648
2.A.1	Cement production	CARBON DIOXIDE (CO_2)	153.140	378.924	0.028	0.089	0.738
1.A.2	Manufacturing Industries and Construction - Solid Fuels	CO_2	99.418	236.815	0.017	0.054	0.792
3.C.4	Direct N_2O Emissions from managed soils	NITROUS OXIDE (N_2O)	0.000	102.937	0.012	0.040	0.832
3.C.1	Emissions from biomass burning	METHANE (CH_4)	161.502	73.820	0.010	0.032	0.864
3.C.1	Emissions from biomass burning	NITROUS OXIDE (N_2O)	131.885	60.283	0.008	0.026	0.890
3.C.7	Rice cultivation	METHANE (CH_4)	0.000	52.987	0.006	0.021	0.910
4.D	Wastewater Treatment and Discharge	METHANE (CH_4)	60.222	106.204	0.006	0.018	0.929
3.B.5.b	Land Converted to Settlements	CARBON DIOXIDE (CO_2)	31.619	0.000	0.004	0.012	0.941
2.B.5	Carbide Production	CARBON DIOXIDE (CO_2)	21.612	50.629	0.004	0.011	0.952

2.5 Uncertainty Assessment

An uncertainty assessment is an essential element of the GHG emission inventory to prioritize efforts to improve future inventories' accuracy. In Bhutan, uncertainties are associated with data access/constraints, potential unsuitability of generic emission factors, and an incomplete understanding of emission processes.

Specialists participating in the development of the inventory evaluated the confidence in the results for each source/sink category relative to the uncertainty associated with data quality and emission factor suitability. Uncertainty and time series assessments were conducted using the Tier 1 methodology in accordance with the 2006 IPCC Guidelines and good practices, taking 2015 as the inventory year for the uncertainty level. Based on expert judgment, activity data collection uncertainty for almost all the sectors ranges between ± 3% and ±20%. The default emission factor's uncertainty values were taken to analysis the uncertainty for all sectors. The uncertainty analysis resulted in a total inventory uncertainty of 8.77% for 2015 and a trend uncertainty of 6.83% for 2000 and 2015.

Attention to two areas could help reduce uncertainty in Bhutan's GHG inventory. First, improving the accuracy of some emission factors to calculate emissions from various sources is vital. Most of the emission factors correspond to IPCC default factors. For example, the accuracy of current emission factors for enteric fermentation by animals at high altitude remains uncertain in the absence of local sampling and testing activities. Secondly, the availability of detailed activity data will support the refinement of inventory estimates. Although methodologies have been used to estimate emissions for some sources, problems arose in obtaining activity data at a level of detail in which aggregate emission factors can be applied. Addressing these areas through additional capacity strengthening and development of dedicated observation networks will enhance future emission inventories' quality and accuracy.

2.6 QA/QC for Data Collection and Compilation

The preparation of the National Inventory Report (NIR) to the TNC was based on a Quality Assurance / Quality Control (QA / QC) Plan. It started from the activity data collection to the estimation of emissions and removals and involved internal as well as external reviews. The implementation of this QA/ QC plan followed the TNC schedule, where the National Project Coordinator of the TNC Project took the primary responsibility of coordinating the activities.

The activity data collected based on questionnaires sent to the responsible agencies, including the private sector, were verified with available national statistics. All the activity data are archived and maintained with NECS in a dedicated server and the hard copy published by NECS. It plans to integrate the GHG inventory system to Environment Information Management System through the Biennial Update Report (BUR) project.

Validation workshops were held with the data suppliers to confirm that the data used for the NIR are valid. A National Technical Working Group (NTWG) was formed with members from the relevant IPCC sectors, including representatives from government agencies and industry associations. This group shouldered the main task of estimating the emissions and removals, supported by a national consultant.

During the compilation of the inventory, the NTWG, with the assistance of the PMU, ensures that the activity data and choice of emission factors are the best available based on national circumstances. The NTWG carries out the first layer of QA of the activity data and the emission factors and these are again run through a validation workshop as a second layer QC. The main objective at this stage is to proofread all GHG estimates, data, and methods used in the inventory, and ensure compliance with the IPCC Guidelines and the Good Practice Guidance.

The estimates were subject to multiple rounds of external validation workshops where the Technical Working Group presented the findings to a wider stakeholder group comprising government agencies, non-government organizations and the private sector.

QA/QC is a key tool for ensuring accuracy, transparency, consistency and completeness in the inventory. The QA/QC process in the compilation of the GHG inventory in Bhutan is depicted in figure 7:

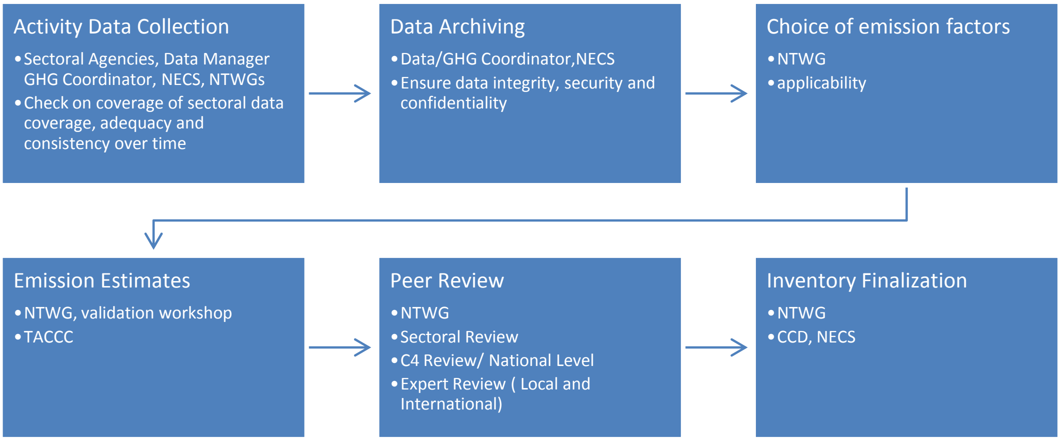

Figure 7 QA/ QC Flow chart

The output of this review is communicated to the sector experts for any corrections. Experts ensure that quality control protocols are followed rigorously and in compliance with the IPCC Guidelines and Good Practice Guidance at the working team level. Both national and international experts review the draft inventory and finalize after incorporating their feedback, recommendations and suggestions.

2.7 Completeness Assessment

The completeness assessment of the inventory within each source category was conducted following the IPCC Guidelines. The completeness assessment results are presented as notation keys as follows: - NA: Not Applicable, NO: Not Occurring, NE: Not Estimated and EE: Estimated Elsewhere.

Greenhouse gas source and sink categories	Net CO2 (Gg)	CH4 (Gg)	N2O (Gg)	CO Gg	NOx (Gg)	NMVOCs (Gg)	SOx (Gg)
Total National Emissions and Removals	**-6493.1424**	**30.493**	**0.623**	**80.0283**	**2.2438**	**0**	**0**
1 - Energy	*691.556*	*0.361*	*0.028*	*0*	*0*	*0*	*0*
1A - Fuel Combustion Activities	691.182	0.287	0.028	0	0	0	0
1A1 - Energy Industries	0.012	0.000	0.000	NE	NE	NE	NE
1A2 - Manufacturing Industries and Construction (ISIC)	241.624	0.027	0.004	NE	NE	NE	NE
1A3 - Transport	417.014	0.056	0.021	NE	NE	NE	NE
1A4 - Other Sectors	32.532	0.204	0.003	NE	NE	NE	NE
1A5 - Other	NA	NA	NA	NA	NA	NA	NA

1B - Fugitive Emissions from Fuels	0.3740	0.0742	0	0	0	0	0
1B1 - Solid Fuels	0.3740	0.0742	NE	NE	NE	NE	NE
1B2 - Oil and Natural Gas	NO	NO	NO	NO	NO	NO	NO
2 - Industrial Processes	*791.8342*	*0.2185*	*0*	*0*	*0*	*0*	*0*
2A - Mineral Products	378.9242	NE	NE	NE	NE	NE	NE
2B - Chemical Industry	50.6294	0.1301172	NE	NE	NE	NE	NE
2C - Metal Production	362.2806	0.0884	NA	NA	NA	NA	NA
2D - Other Production	NE	NE		NE	NE	NE	NE
2E - Production of Halocarbons and Sulphur Hexafluoride				NA	NA	NA	NA
2F - Consumption of Halocarbons and Sulphur Hexafluoride				NA	NA	NA	NA
2G - Other (please specify)	NA	NA	NA	NA	NA	NA	NA
3 - Solvent and Other Product Use	*0*	*0*	*0*	*0*	*0*	*0*	*0*
4 - Agriculture		*20.548*	*0.388*	*0*	*0*	*0*	*0*
4A - Enteric Fermentation		16.595		NE	NE	NE	NE
4B - Manure Management		1.430	0.0558	NE	NE	NE	NE
4C - Rice Cultivation		2.523		NE	NE	NE	NE
4D - Agricultural Soils			0.332	NE	NE	NE	NE
4E - Prescribed Burning of Savannas		NO	NO	NO	NO	NO	NO
4F - Field Burning of Agricultural Residues		NE	NE	NE	NE	NE	NE
4G - Other (please specify)				NE	NE	NE	NE
5 - Land-Use Change & Forestry	*-7976.532*	*3.515*	*0.195*	*80.028*	*2.244*	*0*	*0*

5A - Changes in Forest and Other Woody Biomass Stocks	-8181.1887			NA	NA	NA	NA
5B - Forest and Grassland Conversion	203.583	NA	NA	NA	NA	NA	NA
5C - Abandonment of Managed Lands	NA			NA	NA	NA	NA
5D - CO2 Emissions and Removals from Soil	1.073		NA	NA	NA	NA	NA
5E - Other (please specify)	0	3.515	0.194	80.028	2.244	NE	NE
6 - Waste	*0*	*5.849*	*0.012*	*0*	*0*	*0*	*0*
6A - Solid Waste Disposal on Land		0.792		NE	NE	NE	NE
6B - Wastewater Handling		5.057	0.012	NE	NE	NE	NE
6C - Waste Incineration	NE	NE	NE	NE	NE	NE	NE
6D - Other (please specify)	NE	NE	NE	NE	NE	NE	NE
7 - Other (please specify)	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Memo Items							
International Bunkers	8.243	6E-05	0.0002	0	0	0	0
1A3a1 - International Aviation	8.243	6E-05	0.0002	NE	NE	NE	NE
1A3d1 - International Marine (Bunkers)	NO	NO	NO	NO	NO	NO	NO
Multilateral operations	0	0	0				
CO2 emissions from biomass	EE						

2.8 National GHG Inventory

This section presents the trend in Bhutan's emission from sources and removals by sinks for the period 1994 to 2015.

2.9 Trends of GHG emissions from 1994 -2015

The trend analysis was carried out on the time series data of GHG emissions from the years 1994 - 2015. As seen in Table 8 & 9, Bhutan continues to sequester more carbon than it emits with net national emission of -5,572.50 Gg of CO_2e in 2015.

Total GHG emissions in 2015 was 3,814.098 Gg CO2e that includes 707.917 Gg CO_2e from energy, 796.423 Gg CO_2e from IPPU, -7203.346 from AFOLU (552.87 Gg CO_2e from agriculture and -7756.220 Gg CO_2e from Land Use, Land Use Change and Forestry) and 126.506 Gg CO_2e from waste.

The total sequestration of forest in 2015 is estimated at 9,386.597 Gg CO_2e. However, removals from non-forest lands are not estimated in the inventory due to lack of data.

The total carbon sink or sequestration by LULUCF in 2015 has increased from the previous estimate of 6,309.6[3] Gg CO_2e for the year 2000 reported in SNC. The gain in total carbon sink is attributed mainly to change in use of definition of managed forest[4], natural expansion and plantations. As a result of increase in forest area, the actual gain is estimated to be about 1,000 Gg CO_2e from 2000 to 2015[5].

Emissions of perfluorocarbons (FPCs), hydrofluorocarbons (HFCs) and sulfur hexafluoride (SF6) are not estimated in the inventory as product containing these gases are nor produced in the country.

Table 8 Bhutan's GHG emissions from sectors in 2015

GHG sources & sinks	GHG, Giga grams				
	CO_2	CH4	N2O	Nox	CO
Energy	691.556	0.361	0.028	0.000	0.000
IPPU	791.834	0.219	0.000	0.000	0.000
Agriculture	1.073	20.549	0.388	0.000	0.000
LULUCF	-7977.606	3.515	0.194	2.244	80.028
Waste	0.000	5.849	0.012	0.000	0.000
Total emission	-6493.142	30.493	0.623	2.244	80.028
CO_2e	-6493.142	640.36	193.00	-56.77	144.05
Net emission	***-5,572.50***				

Bhutan's GHG emission excluding removals by sink has been increasing and has almost doubled from 1994, in 2015 period. Table 8 shows trend in Bhutan's GHG emissions from sectors and removals by the sink.

Bhutan's net emission including removals by LULUCF has decreased by 23.11% compared from base year (1994) to inventory year of TNC (2015) and increased by 3.56% when compared from inventory year of SNC (2000) to that of the TNC.

[3]Based on recalculation conducted in the 3rd GHG inventory, the sink capacity for the year 2000 is 9,160.284 Gg CO_2e.
[4]In SNC, only forest managed under FMUs, CFs and 50% of forest under protected area was considered as managed forest. While in this inventory, entire forest of Bhutan is defined as managed forest.
[5]The actual gain is estimated as a product of actual increase in forest area and removal factor.

Table 9 Trend on GHG emissions and removals by sectors (1994 - 2015) in Gg CO2e.

	Energy	IPPU	Waste	Agriculture	LULUCF	Net emission
1994	93.600	166.931	55.780	600.838	-8165.342	-7248.194
1995	121.042	181.007	63.898	642.347	-6555.614	-5547.321
1996	131.533	166.513	60.347	618.403	-6774.879	-5798.083
1997	112.183	218.580	63.210	593.318	-6916.783	-5929.491
1998	124.840	197.451	66.099	642.889	-7668.839	-6637.560
1999	259.125	240.831	69.018	621.263	-6459.980	-5269.743
2000	259.125	220.446	67.937	575.307	-6503.821	-5381.006
2001	290.177	250.321	70.807	525.638	-7238.340	-6101.397
2002	303.139	261.398	73.719	525.051	-7856.821	-6693.514
2003	381.277	252.385	78.924	538.106	-8521.387	-7270.694
2004	411.432	242.070	79.164	542.214	-8721.302	-7446.422
2005	357.259	258.983	80.915	622.123	-8291.208	-6971.928
2006	332.830	293.282	69.192	600.204	-7430.718	-6135.210
2007	386.311	419.053	71.011	601.477	-4707.967	-3230.114
2008	368.122	465.964	72.887	600.643	-8070.574	-6562.958
2009	386.918	459.308	74.755	565.085	-8484.884	-6998.818
2010	468.633	497.134	87.752	570.007	-8078.898	-6455.372
2011	519.396	475.915	89.457	557.911	-7980.131	-6337.452
2012	588.626	482.842	113.764	542.285	-8011.378	-6283.860
2013	620.389	596.333	117.820	533.193	-7982.522	-6114.788
2014	689.202	660.419	122.062	549.933	-5615.964	-3594.348
2015	707.917	796.423	126.506	552.875	-7756.220	-5572.500

In terms of percentage contribution of emissions from the sectors in 2015, AFOLU (without removals) accounts for 57.242% followed by IPPU 20.881%, energy 18.561% and waste 3.317%. Emission in the AFOLU is largely contributed by forest disturbance in the form of CO_2 and non - CO_2.

Bhutan's national net emission has remained almost constant over the period, with inter-annual fluctuations at an aggregated level below 20%. This fluctuation is affected by emission and removals in forestry sector as shown in figure 8.

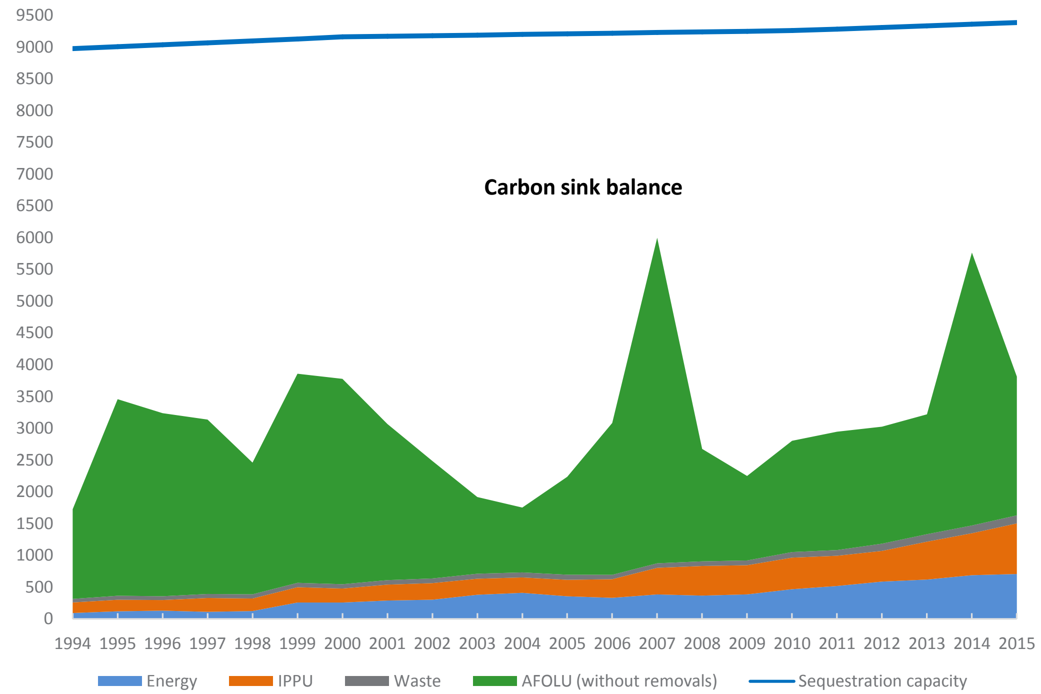

Figure 8 Trends of GHG emissions and carbon sink balance from 1994 to 2015 in Gg of CO2e.

2.10 Emission trends by gas

2.10.1 Carbon dioxide

While emissions and removals in absolute terms have seen slight inter-annual fluctuations due to forest emission (timber removal, firewood, disturbance), the emission of CO_2 in almost all the sectors has increased significantly as shown in Table 10 and Figure 9 below. The net emission in CO_2 compared from 1994 to 2015 has increased by 196.55% and 9.464% only when compared from 2000 – 2015 level.

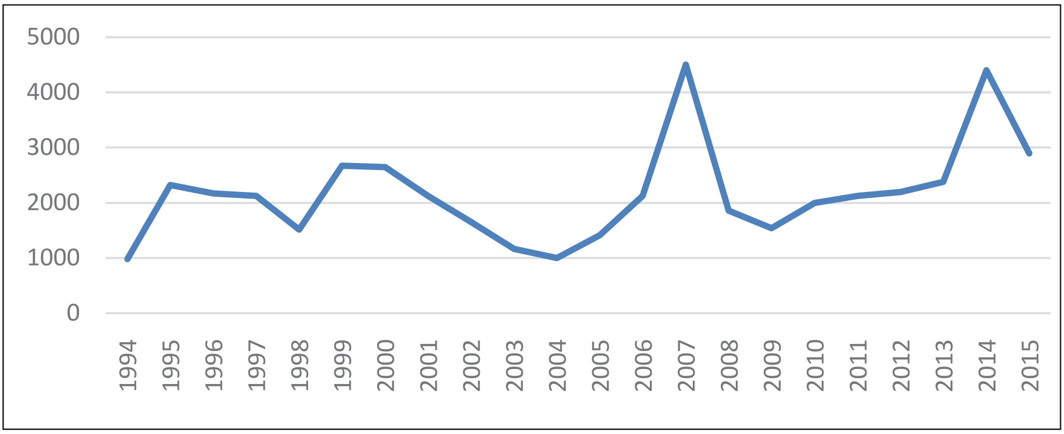

Figure 9 Trend in CO_2 emission from all sectors in Gg CO2e (1994 – 2015)

Carbon dioxide emission from LULUCF saw an increase of 93.010% when compared from 1994 – 2015 level and decrease of -35.132% comparing to 2000 – 2015 level. Emission in this sector is influenced by disturbances and wood removals occurring in the forest land.

Both energy and IPPU sector saw a significant increase in CO_2 emission and is driven by increase in energy use in transport sector and growth in metal and mineral industries.

Table 10 Percentage change in CO_2 emissions from Sectors

	Energy	IPPU	Agriculture	LULUCF	Net
1994 - 2015	763.9269	375.0309	221.0175	93.0301	196.155
2000 - 2015	176.6942	259.586	5.980901	-35.13293	9.464734

2.10.2 Methane

Table 11 shows percentage change in methane emission from various sectors. When comparing the CH_4 emission from 1994 to 2015 and 2000 to 2015, methane emission has been fluctuating except for IPPU and waste sectors that saw an increase. Although, IPPU saw very high increase in percentage change for both periods, in terms of absolute figure, the increase in CH_4 emission is quite negligible.

Methane emission in waste sector has more than doubled from 1994 – 2015 period and almost doubled comparing to 2000 – 2015 level. While on other hand, methane emission from Agriculture sector has been decreasing gradually.

Table 11 Percentage change in methane emission from Sectors (Gg CO_2e)

	Energy	IPPU	Agriculture	LULUCF	Waste	Net
1994 - 2015	-28.492	1813.353	-9.496	174.469	129.499	12.725
2000 - 2015	34.388	1822.815	-2.822	-54.291	88.317	-5.366

Methane emission from LULUCF is determined by occurrence of forest fire in the particular period as evident from spike in in 2007 and 2014 in figure 10. The increase in methane emission for those two years is attributed to high emission from biomass burning occurring in LULUCF.

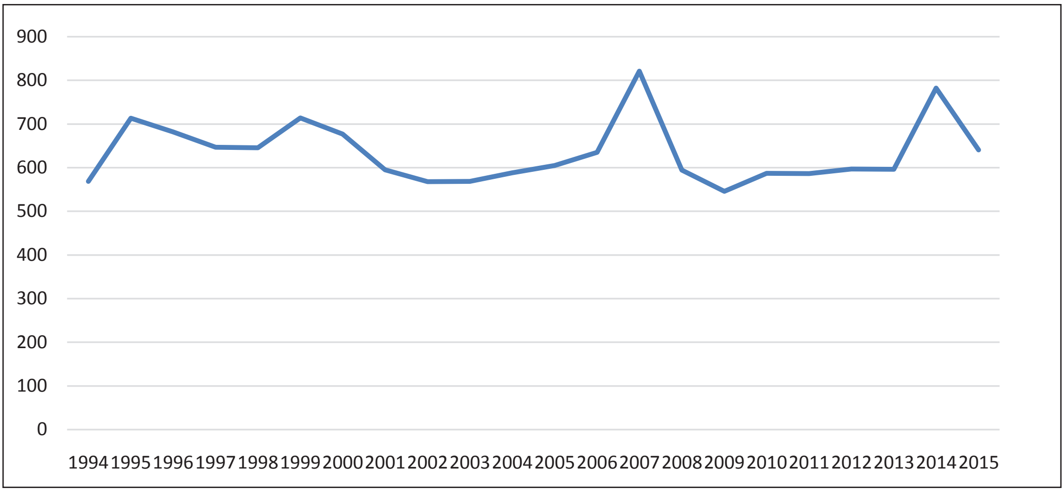

Figure 10 Trend in CH_4 emission from sectors in Gg CO2e (1994 – 2015)

2.10.3 Nitrous oxide

In general, the N_2O emission has remained more or less constant over time with slight fluctuation, as seen in figure 11. N_2O emissions is largely influenced by disturbance occurring in forest and other land use. Direct N_2O emissions from managed soils is the main source of emission.

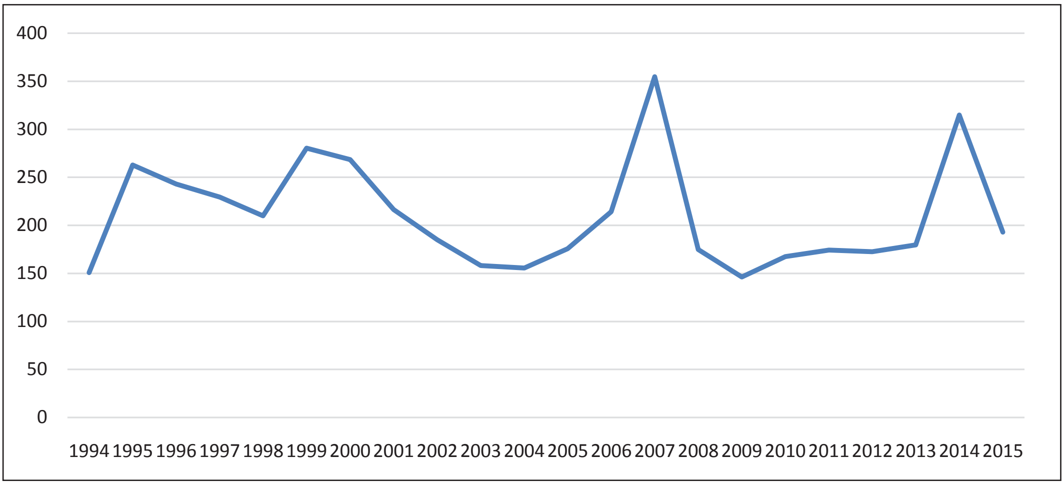

Figure 11. Trend in N_2O emission from all sectors (1994 – 2015)

2.10.4 Nitrogen oxides & Carbon monoxides

NOx and CO was only calculated from the LULUCF sector. Emission of these two gases is resulted from biomass burning and is directly proportionate to the total land area lost to forest fires in that particular period. The annual emission of these two gases has been fluctuating intermittently as shown in figures 12 and 13.

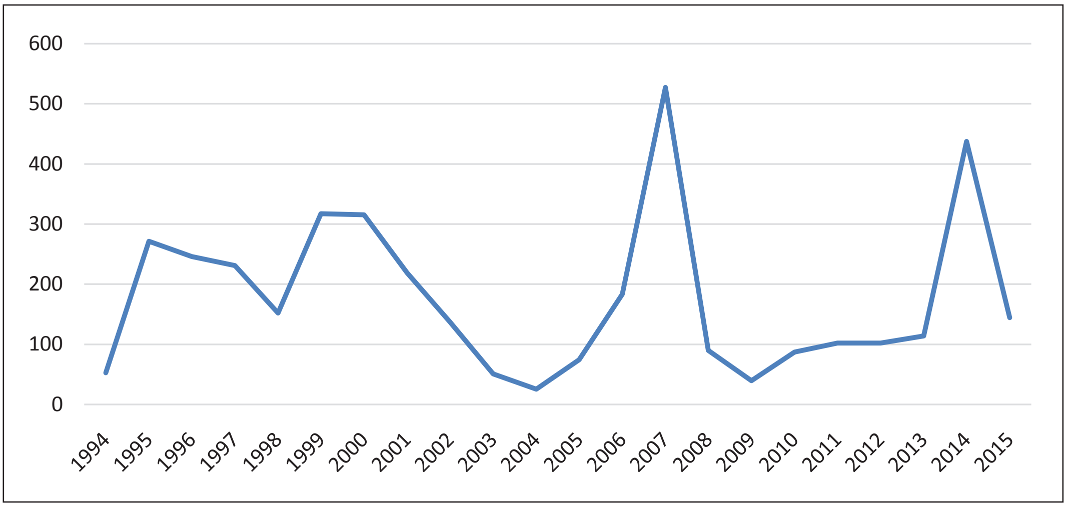

Figure 12 Trend in NOx emission from LULUCF (1994 – 2015)

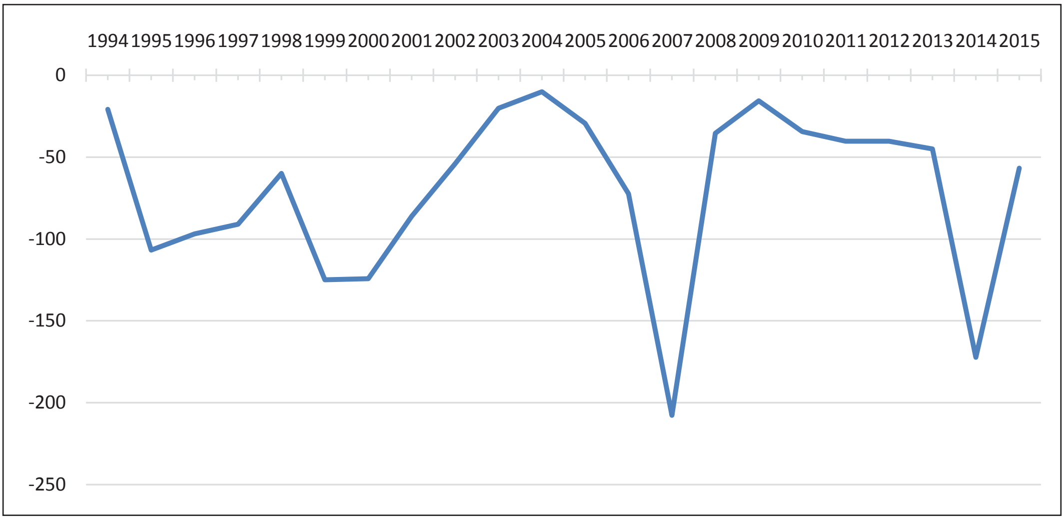

Figure 13 Trend in CO emission from LULUCF (1994 – 2015)

2.10.5 Sectoral Emissions

Bhutan's net GHG emission has been fluctuating annually and is influenced by emissions and removals in forestry sector. In terms of percentage change in Bhutan's GHG emissions from 1994 to 2015 and 2000 – 2015 level, all the sectors except Agriculture show an increase in emissions as presented in Table 12.

For the 1994 – 2015 period, energy sector witnessed the highest increase of emission of 656.33%, while Agriculture saw a decrease of 7.98%.

Although the sink capacity has increased over the period, the net national emission or carbon sink balance has decreased by 23.11% when compared from 1994 to 2015 and saw an increase of 3.559% in comparison from 2000 – 2015.

Table 12 Percentage change in emissions from Sectors

Year / Sector	Energy	IPPU	Agriculture	LULUCF	Waste	Net emission
1994 - 2015	656.325	377.097	-7.983	-5.010	126.795	-23.118
2000 - 2015	173.195	261.278	-3.899	19.256	86.210	3.559

2.11 Emission share by source category

As shown in Figure 14, the highest share of emissions in the national total in 2015 is from LULUCF (excluding removals), contributing 42.75%, followed by IPPU with 20.88%, energy with 18.56%, agriculture and waste accounting to 14.50% and 3.32% respectively. The share of emission from AFOLU (Agriculture and LULUCF without removals) represents 57.24% of national total in 2015.

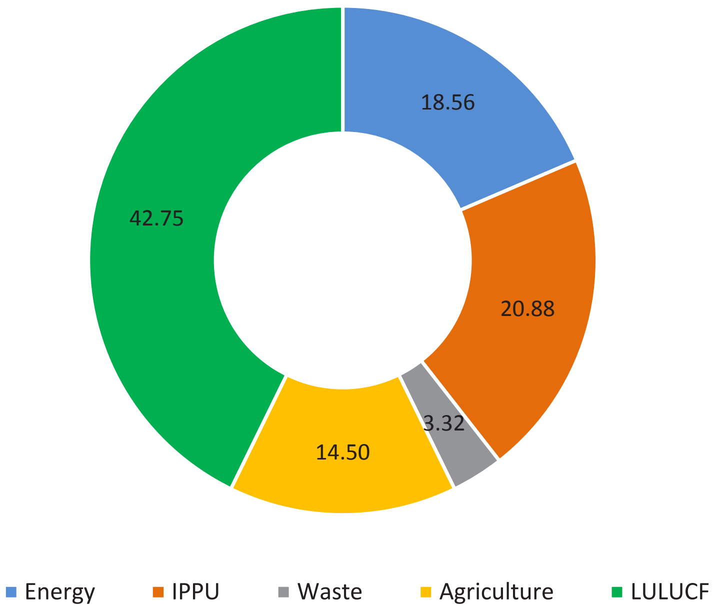

Figure 14: Percentage share of sectoral emissions to national total in 2015 (excluding removals from LULUCF).

2.12 Energy sector

2.12.1 An overview of the energy sector

In Bhutan, the primary sources of energy are biomass, hydropower, refined petroleum products, and solid fossil fuels (i.e., coal). There is no natural gas used in the country. All petroleum products are imported from India. Gasoline and diesel are used mainly for transport while kerosene and Liquefied Petroleum Gas (LPG) are used in the residential and commercial sectors. GHGs emitted from the energy sector are mainly CO_2, CH_4, and N_2O. CO is also emitted but to a lesser degree and is not reflected in this inventory.

2.12.2 GHG Emissions from the energy sector

In 2015, the energy sector's net emission was 707.91 Gg of CO_2e that contributed 18.56 % of the total national emissions, excluding the GHG removals by LULUCF. The transport category's energy emissions had the highest contribution to the sector with 60.01%, followed by manufacturing industries and construction 34.39%, other sectors 5.32%, solid fuels 0.27%, and energy industries (electricity generation) 0.002% only.

Table 13 GHG emissions from energy sector, 2015

Greenhouse Gas Source and Sink categories	CO2	CH_4		N_2O		Total
Unit	Gg CO_2e	Gg	Gg CO_2e	Gg	Gg CO_2e	Gg CO_2e
1 - Energy	**691.556**	**0.361**	**7.588**	**0.028**	**8.773**	**707.917**
1.A - Fuel Combustion Activities	***691.182***	***0.287***	***6.030***	***0.028***	***8.773***	***705.985***
1.A.1 - Energy Industries	0.012					0.012
1.A.2 - Manufacturing Industries and Construction	241.624	0.027	0.575	0.004	1.263	243.462
1.A.3 - Transport	417.014	0.056	1.173	0.021	6.642	424.829
1.A.4 - Other Sectors	32.532	0.204	4.282	0.003	0.869	37.683
1.A.5 - Non-Specified	0.000	0.000				
1.B - Fugitive emissions from fuels	***0.374***	***0.074***	***1.558***			***1.932***
1.B.1 - Solid Fuels	0.374	0.074	1.558			1.932

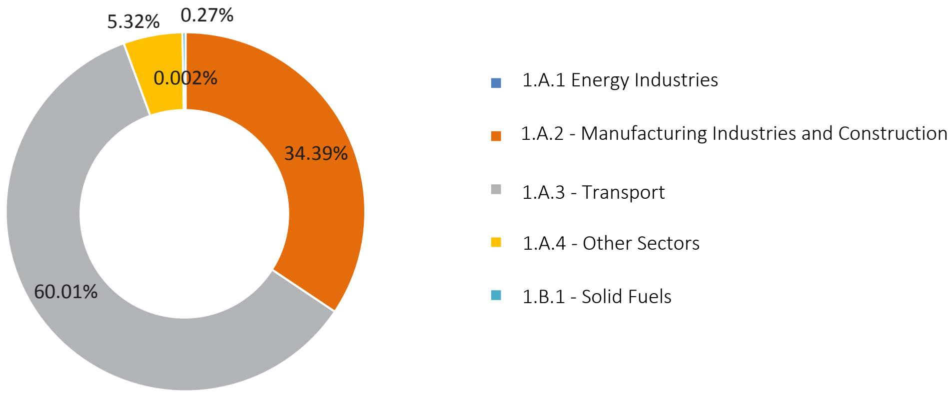

Figure 15 (a) Percentage share of emissions in Energy sector in 2015

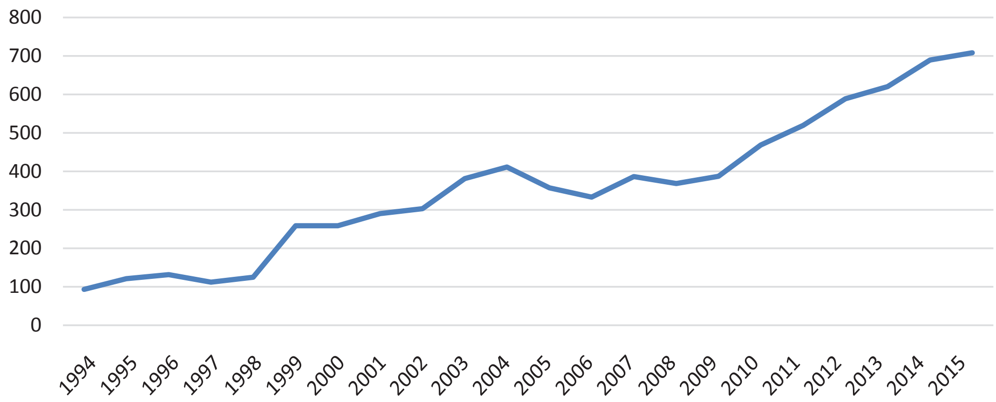

Figure 15 (b): trend in energy emissions (Gg CO_2e)

2.12.3 Fuel combustion activities

2.12.3.1 Comparison of the sectoral approach with the reference approach

The Reference Approach was used as a controlled energy consumption total for several sectoral energy sources while the sectoral approach calculated emissions following the 2006 IPCC Guidelines. The difference between reference to sectoral approach for sub-bituminous coal is 43.42%. This difference is resulting from unaccounted amount of solid fuels and the actual amount of consumption is reported only from cement productions.

There is a major difference in residual fuel oil arising due to lack of data or actual information on consumption by the sectors.

Table 14 Comparison between Reference and Sectoral Approach

	Reference Approach				Sectoral Approach		Difference	
Fuel	**Apparent Consumption (TJ)**	**Excluded Consumption (TJ)**	**Apparent Consumption (excluding nonenergy use and feedstocks) (TJ)**	**CO2 Emissions (Gg)**	**Energy Consumption (TJ)**	**CO2 Emissions (Gg)**	**Energy Consumption (%)**	**CO2 Emissions (%)**
Motor Gasoline	1156.3834		1,156.383	80.1374	1,156.383	80.1373	0.0000	0.0000
Jet Kerosene	3.2901	0.2352	0.0000	0.0000	3.2901	0.2352	0.0000	0.0000
Other Kerosene	165.6087	0.0000	165.6087	11.9017	165.6087	11.9073	0.0000	-0.0464
Gas/Diesel Oil	4571.2955	0.0000	4571.2955	338.5806	4592.3263	340.2914	-0.4580	-0.5027
Residual Fuel Oil	19.1147		19.1147	1.4788			100.0000	100.0000
Liquefied Petroleum Gases	345.4130	0.0000	345.4130	21.7840	345.4130	21.7956	0.0000	-0.0528
Lubricants	21.3696	0.0000	21.3696	1.5671	0.0000	0.0000	100.0000	100.0000
Sub-Bituminous Coal	3,535.581	0.0000	3,535.581	3,39.6515	2,464.254	236.8148	43.4747	43.4249

2.12.4 Energy industries [1A1]

Emissions from energy industries are minimal as the primary source of electricity in the country is run-of-the-river hydropower plants. The only distribution company in the Country, Bhutan Power Corporation, maintains diesel generators as back-up power that emitted 0.011 Gg CO_2 in 2015.

2.12.5 Manufacturing industries and construction [1A2]

The manufacturing industries in Bhutan meet a major portion of their energy requirement from the national electricity grid. The energy related emissions are from diesel consumption in boilers. In 2015, emissions from this category using default emission factor was 243.46 Gg CO_2e.

2.12.6 Transport [1A3]

Energy use in the transport sector relied partially on published sources and partly on calculations based on a control total for gasoline/diesel imports, namely the Bhutan Trade Statistics (1995-2016) and the Bhutan Energy Data Directory (2015). To avoid overestimation from double-counting fuels in the energy industries, manufacturing industries, and transport, the activity data used in transport excludes the fuel used for generators in the energy industries and boilers in the manufacturing industries.

Emissions from the Transport category in 2015 was from road and air transportation. A tier one methodology was adopted using fuel import data, and default IPCC emission factors resulting in emission of 424.82 Gg CO_2e.

Emission from the domestic aviation was 0.235 Gg of CO_2e only and this is attributable to limited domestic commercial flights in operation in three domestic airports. In addition, the fly time between these domestic airports is less than an hour's journey.

2.12.7 Other sectors [1A4]

Energy use in this subcategory includes the consumption of biomass and fossil fuels (LPG and kerosene) in the residential and commercial/ institutional sectors. Hydropower generated electricity provides for most of the energy needs. Electricity generated from hydropower meets most of the energy demand in Bhutan, and biomass is used as source of energy for cooking and space heating, especially in rural areas. In contrast, LPG is used mainly for cooking and kerosene for space heating in urban areas. The emission is estimated based on the Energy Directory 2005 ratio of fuel usage and results in an emission of 37.68 Gg of CO_2e in 2015.

2.12.8 Fugitive emissions from fuels [1B]

2.12.8.1 Solid fuels [1B1]

Bhutan has five surface coal mines, and production data from the mine is used with a default emission factor to estimate the emissions of 1.93 Gg of CO_2 in 2015.

2.12.9 Memo Items

2.12.9.1 International Bunkers

The activities occurring in this category are from the international flights operated by two airline companies. The emission from the International bunker is estimated to be 8.2434 Gg of CO_2e.

2.13 Industrial processes and other product use

2.13.1 An overview of the IPPU sector

In Bhutan, several important industrial processes account for the emissions of greenhouse gases. Major industries include those in the "mineral products" category (e.g., cement production), chemical products (calcium carbide) and metal industry (ferroalloys). Each of these categories is discussed in the sections below.

2.13.2 GHG emissions from the IPPU Sector

Industrial Processes and Product Use (IPPU) is the second-largest emitter of anthropogenic GHG emissions in Bhutan accounting for 796.423 Gg CO_2, or about 20.88% of total GHG emissions in 2015. The industrial sector's activity data was from surveys of individual industries, annual trade statistics and the national industrial license database.

Mineral industry accounted for the largest share of emissions, with 47.58%, followed by the metal industry with 45.72%, and the chemical industry accounted for 6.70% only.

Table 15 GHG emissions from IPPU sector, 2015

Greenhouse Gas Source and Sink categories	CO2	CH_4		N_2O		Total
Unit	**Gg CO_2e**	**Gg**	**Gg CO_2e**	**Gg**	**Gg CO_2e**	**Gg CO_2e**
2 - Industrial Processes and Product Use	**791.834**	**0.219**	**4.589**			**796.423**
2.A - Mineral Industry	***378.924***					***378.924***
2.A.1 - Cement production	378.924					378.924
2.B - Chemical Industry	***50.629***	***0.130***	***2.732***			***53.362***
2.B.5 - Carbide Production	50.629	0.130	2.732			53.362
2.C - Metal Industry	***362.281***	***0.088***	***1.856***			***364.137***
2.C.1 - Iron and Steel Production	7.395					7.395
2.C.2 - Ferroalloys Production	354.885	0.088	1.856			356.741

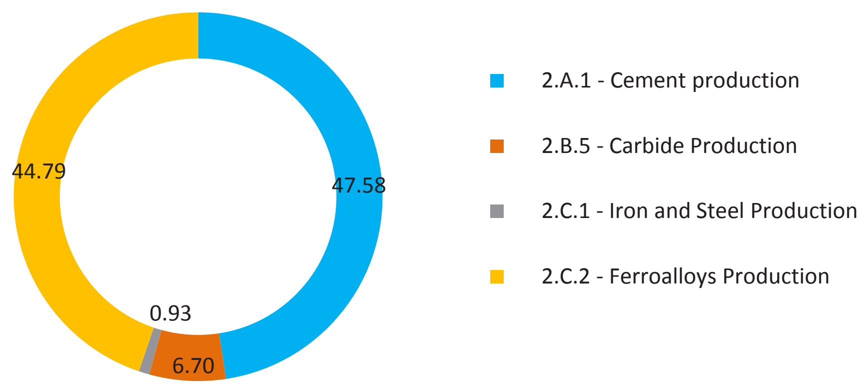

Figure 16 (a) Percentage share of emission from IPPU in 2015

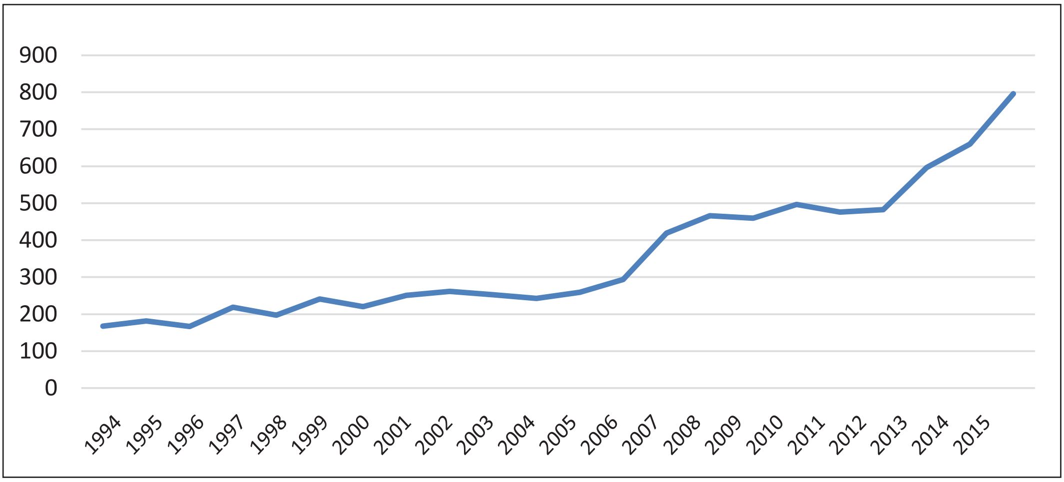

Figure 16 (b): trend in IPPU Sector emissions (Gg CO_2e)

2.13.3 Mineral industry [2A]

As of 2015, there were five cement plants in operation in the country. Carbon dioxide is produced during the production of clinker, an intermediate product used to make cement. A tier one methodology using plant specific activity data and default emission factors was used to estimate the emission of 378.92 Gg CO_2 in 2015.

2.13.4 Chemical industry [2B]

There is only one plant in this category. The activity data on the quantity of calcium carbide produced is used with default emission factors to estimate the emissions of 53.36 Gg CO_2 in 2015.

2.13.5 Metal industry [2C]

The production of ferro alloys was the only source of emission in this category. A single-tier methodology of using plant-specific activity data and the default emission factor was used to estimate the emissions of 364.14 Gg CO_2 in 2015.

2.14 Agriculture, forestry and other land use

2.14.1 Overview of the sector

The Agriculture, Forestry and Other Land Use sector when excluding removals is the highest contributor of Bhutan's total GHG emissions accounting to 57.24% translating to 2183.25 Gg of CO_2e in 2015. Agriculture sector emission for the period is 552.87 Gg of CO_2e translating to 14.49% of net emission while LULUCF (without considering removals) accounted to 42.74% of national emission with 1630.37 Gg CO_2e.

The estimation of GHG emissions and removals from the AFOLU Sector includes CO_2 emissions and removals resulting from Carbon stock changes in biomass, dead organic matter and mineral soils; CO_2 and non-CO_2 (NOx and CO) emissions from biomass burning; N_2O emissions from managed soils; CO_2 emission associated with urea application on managed soils; CH_4 emissions from rice cultivation; livestock (enteric fermentation and manure management); and N_2O emissions manure management systems.

2.14.2 Agriculture [3A]

Agriculture and livestock activities contributed 552.87 Gg CO_2e, corresponding to 14.49% of total national emissions in 2015.

The majority of the sector's emissions were from livestock that emitted 389.47 Gg of CO_2e, of which enteric fermentation accounted 348.90 Gg of CO_2e or about 63.03%. In comparison, manure management contributed only 40.98 Gg of CO_2e (7.41%), and similarly, rice cultivation emitted 52.98 Gg of CO_2e (9.58%).

N_2O emission from managed soils and manure management accounted for 18.62% and 1.15% respectively producing 102.93 Gg of CO_2e and 6.36 Gg of CO_2e.

The emission from urea application on land was only 1.07 Gg of CO_2, accounting for 0.19% in 2015.

Table 16 GHG emissions from Agriculture, 2015

Greenhouse Gas Source and Sink categories	CO_2	CH_4		N_2O		Total
Unit	Gg CO_2e	Gg	Gg CO_2e	Gg	Gg CO_2e	Gg CO_2e
3 - Agriculture	**1.073**	**20.549**	**431.525**	**0.388**	**120.276**	**552.875**
3.A - Livestock	*0.00*	*18.026*	*378.538*	*0.035*	*10.938*	*389.476*
3.A.1 - Enteric Fermentation		16.595	348.490			348.490
3.A.2 - Manure Management		1.431	30.047	0.035	10.938	40.986
3.C - Aggregate sources and non-CO2 emissions sources on land	*1.073*	*2.523*	*52.987*	*0.353*	*109.338*	*163.399*
3.C.3 - Urea application	1.073					1.073
3.C.4 - Direct N_2O Emissions from managed soils				0.332	102.937	102.937
3.C.5 - Indirect N_2O Emissions from managed soils				0.000	0.041	0.041
3.C.6 - Indirect N_2O Emissions from manure management				0.021	6.360	6.360
3.C.7 - Rice cultivations		2.523	52.987			52.987

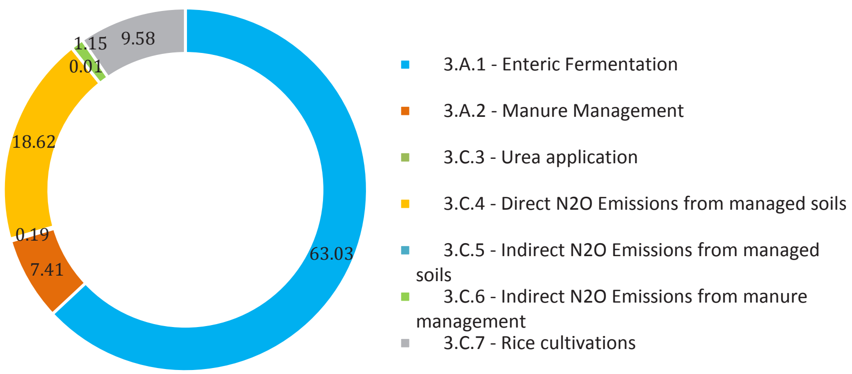

Figure 17 (a) Percentage share of emission in Agriculture sector in 2015 &

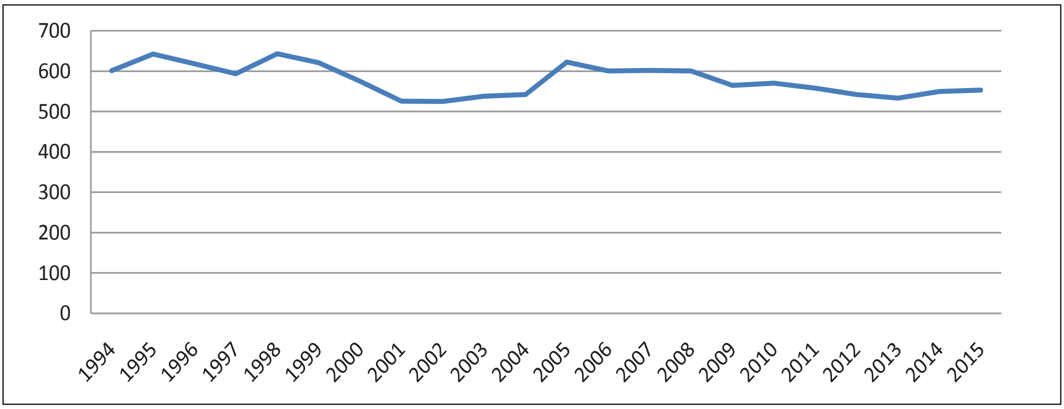

Figure 17 (b) trend in emissions from Agriculture sector (Gg CO_2e)

2.14.3 Land Use, Land Use Change and Forestry

This section provides an assessment of the greenhouse gas fluxes resulting from forestry and other land uses in Bhutan. 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 2006) recommends reporting fluxes according to changes within and conversions between all land-use types, including Forest Land, Cropland, Grassland, Wetlands, and Settlements (as well as Other Land). The greenhouse gas flux from Forest Land Remaining Forest Land is reported for all carbon stock in aboveground biomass, belowground biomass, deadwood, litter, and carbon stock changes from mineral and non-CO_2 emissions from forest fires.

The total emissions from LULUCF sector excluding removals in 2015 was 1630.37 Gg CO_2e representing 42.75% of net national emission. The total sequestration capacity of forest for the same period was -9,386.59 Gg CO_2e.

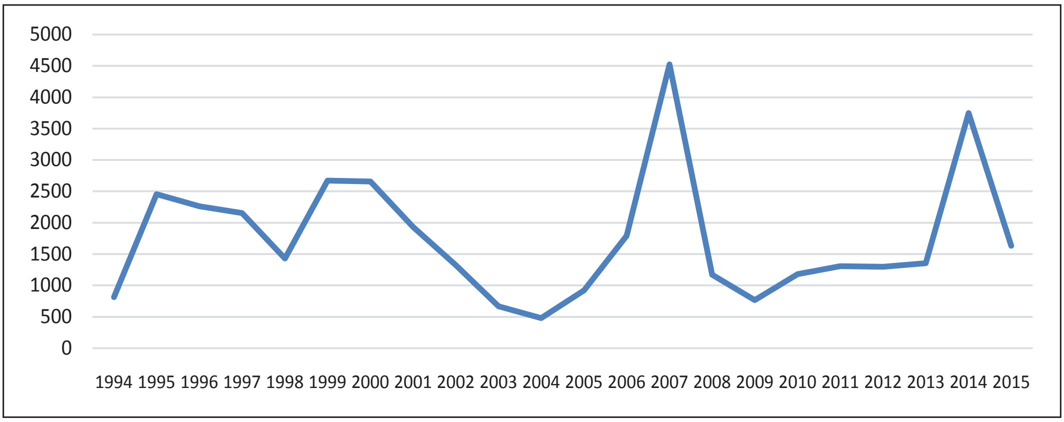

Figure 18 (a): Trend in emissions from LULUCF sector

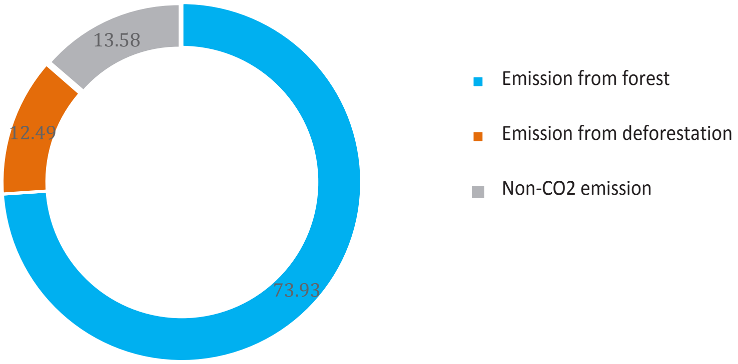

Figure 18 (b): percentage share of emission in LULUCF in 2015.

Emission from forestry (timber removal, firewood and disturbance) is the highest contributor to net national emission, contributing 42.75% or 1,630.37 Gg of CO_2e. As presented in Table 17, within LULUCF sector, emission from forest (wood removal, fuelwood and disturbance) accounts to 73.93% totaling to 1,205.40 Gg CO_2e; non-CO_2 emission from biomass burning in forest land represents 13.58% or 221.37 Gg CO_2e and emission from deforestation (conversion of forest land to cropland, grassland, settlements and other land) accounts to 12.49% or 203.58 Gg CO_2e in 2015.

Table 17 Trend in emissions from LULUCF sector in Gg of CO_2e

	Emission from forest	Emission from deforestation	Non-CO2 emission	Sequestration capacity	Net emissions
1994	627.779	102.154	80.66	-8975.935	-8165.342
1995	1931.343	103.191	416.511	-9006.66	-6555.615
1996	1780.6	104.232	337.673	-9037.384	-6814.879
1997	1691.369	105.274	354.684	-9068.109	-6916.782
1998	1090.157	106.319	233.518	-9098.834	-7668.84
1999	2074.967	107.367	487.245	-9129.559	-6459.98
2000	2063.703	108.416	484.343	-9160.284	-6503.822
2001	1486.726	109.468	335.69	-9170.225	-7238.341
2002	1002.19	110.301	210.855	-9180.166	-7856.82
2003	479.461	111.134	78.126	-9190.108	-8521.387
2004	327.743	111.967	39.037	-9200.049	-8721.302
2005	691.97	112.17	114.643	-9209.991	-8291.208
2006	1395.26	112.141	281.813	-9219.932	-7430.718
2007	3599.782	112.108	810.016	-9229.873	-4707.967
2008	919.012	112.074	138.155	-9239.815	-8070.574
2009	592.224	112.037	60.611	-9249.756	-8484.884
2010	851.691	195.053	134.055	-9259.697	-8078.898
2011	952.271	195.838	156.837	-9285.077	-7980.131
2012	945.528	196.621	156.931	-9310.457	-8011.377
2013	980.684	197.401	175.231	-9335.837	-7982.521
2014	2875.024	198.178	672.051	-9361.217	-5615.964
2015	1205.409	203.582	221.387	-9386.597	-7756.219

The country's sink has increased over the period and this is due to change in definition of managed forest and increase in forest area (natural expansion in forest area and forest plantation) from last inventory. However, total emission from LULUCF has been fluctuating and is determined by the level of changes in land uses or activities occurring in the forestry sector like disturbances, wood removal, biomass burning and conversion of forest land to non-forest land in that particular period.

The main data source used for the AFOLU sector is Land Use Land Cover Map of Bhutan 1990, 2000, 2010 (Gilani et al, 2014) and 2016 (FRMD, 2017); and National Forest Inventory (NFI). Data from the Land Use Land Cover studies were used to estimate the total areas of Forest Land, Crop Land, Grassland, Wetlands, Settlements and Other Land. The land area for intermittent years and years outside the study years were estimated using interpolation and extrapolation method.

NFI is used to estimate the growing stock, aboveground biomass, belowground biomass, dead organic matter, and soil organic carbon in mineral soils.

The statistics of forest burnt by wildfire, volume of round timber and fuelwood removed are obtained from published and unpublished reports maintained by the Department of Forest and Park Services. Land area accounting for the inventory has been done according to Approach 1 and Approach 2, as described in Chapter 3 of the IPCC 2006 Guidelines (IPCC 2006).

The forest is defined as all land area under vegetation cover with minimum of 10% canopy density, occupying minimum of 0.5 ha area and minimum tree height of 5 meters. Total forests area in 2015 is 27,09,835 ha. For the purpose of GHG inventory, entire forest is considered as managed forest on the premise that all forest of Bhutan experiences some form of human intervention through biomass collection, livestock grazing, harvesting of Non-Wood Forest Products, road construction, construction of transmission lines, as well as timber harvesting for house construction, flag poles for religious and cultural uses, and cremation. Therefore, whole forest of the Bhutan is classified as managed forest for this inventory.

2.15 Waste sector

GHG emissions from the waste sector was 126.50 Gg CO_2e in 2015 and represented 3.317 % of total national GHG emissions.

Sources for waste management data included survey findings, published literature and population statistics.

Emissions were estimated using a bulk waste approach with activity data of population/ GDP (tier 1).

Emissions from waste management were not quantified in Bhutan's first national communication due to the lack of reliable data.

Table 18 GHG emissions from waste sector, 2017

Greenhouse Gas Source and Sink categories	CO_2	CH_4		N_2O		Total
Unit	Gg CO2eq	Gg	Gg CO2eq	Gg	Gg CO2eq	Gg CO2eq
4-Waste		5.849	122.839	0.012	3.667	126.506
4.A - Solid Waste Disposal	*0*	*0.792*	*16.635*	*0.000*	*0.000*	*16.635*
4.D - Wastewater Treatment and Discharge	*0*	*5.057*	*106.204*	*0.012*	*3.667*	*109.872*

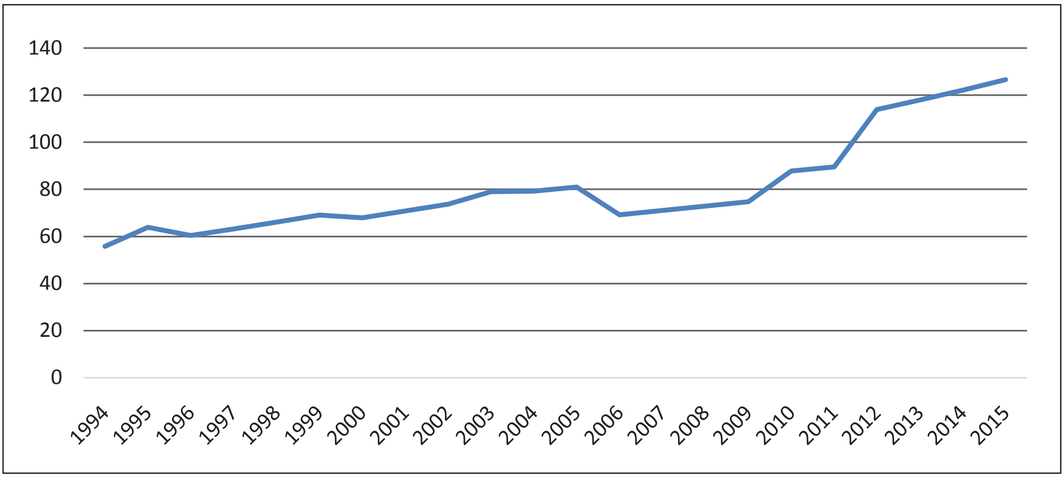

Figure 19: Emission from waste sector (Gg CO2e)

Emission from waste sector has increased by 126.79% compared from 1994 – 2015 period and saw an increase of 86.21% for 2000 – 2015. The increase in emission is attributed to increased waste generation, rapid urbanization, growing affluence and population increase.

There are two main sources of GHG emissions within Bhutan's waste sector. Wastewater treatment and discharge accounted for 86.85% of total waste-related GHG emissions, while 13.14% constitute emissions from solid waste disposal.

The inventory includes only ten urban areas (i.e. Thimphu, Phuentsholing, Samtse, Paro, Gelephu, Damphu, Samdrup Jongkhar, Bumthang, Trashigang and Monggar). The remaining population emitted meager amounts of methane due to waste disposal sites, mostly shallow and open dump yards.

Emission from domestic wastewater handling was estimated using a tier 1 approach for the two major urban areas, i.e., the capital city Thimphu and Phuentsholing.

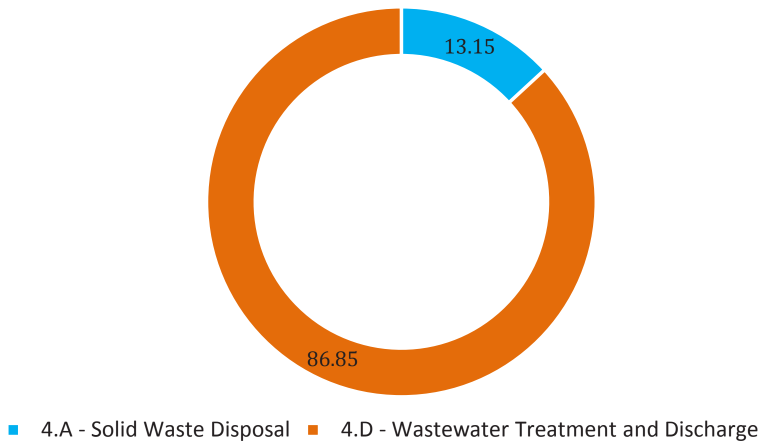

Figure 20 Emissions from waste sector, 2015

2.16 Improvements Made and Improvement Plans of GHG Inventory

2.16.1 Improvements since SNC

Since the submission of the SNC, the following improvements have been made in the national GHG inventory system:

- The improved institutional arrangement with the sectoral agencies resulted in more detailed discussions and better emission estimates.
- The detailed study of the forest GHG emissions and removals through the National Forest Inventory project has led to a higher tier estimate of GHG removals in the sink category.
- The GHG estimation method was shifted from the Revised 1996 IPCC Guidelines to the 2006 IPCC Guidelines.

2.16.2 Improvement Plans

There are constraints on the availability of resources, both financial and human and the limited technical knowledge on GHG inventory systems in the country that are subject to the availability of resources. Therefore, the main focus of improvement will be on national systems and improved data accuracy, particularly institutional arrangements and developing country-specific data.

2.17 Institutional Arrangements

The experiences from the INC, SNC and the TNC show a gap in the institutional arrangements and coordination of activities for collecting activity data and preparation emission/removal estimates. The NTWG is formed each time before the commencement of National Communication works. Members of this body nominated by the respective agencies are mostly new with limited experience and no institutional memory from the last exercise. To ensure continuity of shared experiences and sustainability of the compilation experience, NECS will institutionalize an NTWG on climate change and expand its membership to academic institutions, independent experts, NGOs/CSOs, and the agencies representing the IPCC sectors. Besides assisting in the National Communication process, this body will also serve as a technical body providing technical advice.

As industries provide the basic activity data for the GHG inventory, data sharing protocol and confidential pact will be signed between Industries and NECS for periodic submission of activity data by industries as agreed during the consultative meeting with the industries. The capacity of industries to build a sustainable GHG inventory system will be addressed through the CBIT financing window.

Under the CBIT, key areas of action are: (i) to develop Energy Directory Data, (ii) build capacity on GHG Inventory (iii) set up a robust MRV system, (iv) conduct assessment to improve reporting from livestock sectors, and (v) develop country specific emission factors for appropriate sectors.

The National Statistics Bureau (NSB) is the clearinghouse of statistical data in Bhutan. The NSB publications sourced the background and some activity data for the current exercise of GHG Inventory compilation. While data are sourced from the sectoral agencies, there is no formal linkage between the NSB and the sectoral agencies and that there is often limited QA/QC on the data submitted to the NSB. The NECS will institutionalize regular data collection, analysis and publication and improve QA/QC systems through capacity building of both NSB officials and focal points of sectoral agencies. An online data submission and mining system will also be developed, particularly for the compilation of the GHG inventory. The data collection system used currently is inadequate, particularly when it comes to data accuracy and consistency. This issue will be improved with regular data collection from the sectoral agencies through climate reporting obligations built into the current compliance reporting regime. At the NECS, a national GHG database will be established with an automatic data archiving system.

Bhutan lacks capacity and experience in inventory compilation, and this was found to be a critical constraint in all the processes related to the National Communications. While the IPCC GHG Inventory Software is user friendly, it is more important to understand the processes involved in the estimation of GHG emissions and removals. To address this lack of experience and capacity, NECS will build the government and private sector capacity in inventory processes, in partnership with external institutions and agencies.

In the INC, SNC and the TNC, Bhutan has relied on IPCC default conversion factors, emission factors, and default uncertainty figures in the estimation of GHG emissions and removals. Bhutan has also generally used Tier 1 methodologies due to the lack of accurate and reliable country-specific information. While this is accepted in the IPCC Guidelines, to improve accuracy and comparability, it is essential to develop country-specific emission factors and uncertainty data, and use higher tier approaches in the next inventory period. Of particular importance are the following: developing CS emission factors for enteric fermentation; updating Land Use/Land Cover maps on an annual basis; developing CS soil carbon estimates based on soil types, climatic zones, etc.; building on experiences from Forest and Non-forest soil C content; etc.

MITIGATION ASSESSMENT

3. MITIGATION ASSESSMENT

3.1 Introduction

During the 15th Session of Conference of Parties (COP15) of the United Nations Framework Convention on Climate Change (UNFCCC) in Copenhagen, the Royal Government of Bhutan committed to remaining carbon neutral, ensuring that the country's greenhouse gas (GHG) emissions will remain less than the sequestration capacity of its forests for all times (NEC, 2012). Therefore, the policy objective of mitigation assessment is carbon neutrality for the duration of the evaluation (2010-2040). Bhutan's carbon sink, estimated at 6,309.6 Gg CO_2e (NEC, 2012), will be surpassed in the BAU Scenario in the 2035-2040 period, putting the country's Carbon Neutral status at risk.

Therefore, the challenge facing Bhutan is to achieve the right balance between economic development and carbon neutrality while increasing the degree of economic self-sufficiency. Most importantly, the country must decouple economic growth from GHG emissions, which will be possible through investments in climate-friendly technology, raising public awareness, international financing, and capacity building.

Three scenarios of GHG trends are described and analyzed based on the gross domestic product (GDP) growth under Business as Usual (BAU), High Economic Growth (HEG), Low Economic Growth (LEG) using a Computable General Equilibrium Model of the Bhutanese economy (National Environment Commission, 2018). The mitigation options of sectors with the highest emission trends are selected for the mitigation assessment and mitigation options, along with marginal abatement costs, which are worked out with potential financing options.

3.2 Existing policies and measures

A summary of the relevant policies and legislation on climate change mitigation in Bhutan is provided in the following paragraphs:

3.2.1 The Constitution of the Kingdom of Bhutan (2008)

The Constitution of Bhutan entrust every citizen to contribute to the protection of the natural environment, conservation of the rich biodiversity of Bhutan, and prevention of all forms of ecological degradation including noise, visual and physical pollution. It accords the rights over mineral resources, rivers, lakes and forests to the state to be regulated by law. It requires the state to preserve, protect and promote the country's cultural heritage, including monuments, places and objects.

The state is assigned to ensure a safe and healthy environment , always maintaining a minimum of sixty percent of Bhutan 's total land under forest cover . It must secure ecologically balanced sustainable development and sovereign rights of the state over its biological resources , including legislation to ensure sustainable use of natural resources and intergenerational equity . By the constitution , the Parliament can, by law, declare any part of the country to be a National Park , Wildlife Reserve , Nature Reserve, Protected Forest, Biosphere Reserve, Critical Watershed , and such other categories meriting protection.

3.2.2 The National Environment Protection Act (NEPA 2007)

NEPA 2007 is the umbrella legislation on environment conservation and protection and outlines principles and a legal framework that has implications for all spheres of development in Bhutan. It requires that a person taking natural resources or deriving economic benefits from the environment should ensure sustainable use and management of the resources and ecosystems. It also paves the way for specific legislations such as the Water Act, The Waste Prevention and Management Act, and possibly, specific legislation on climate change.

3.2.3 Environment Assessment Act 2000 and its Regulations

The Environmental Assessment Act 2000 establishes procedures for assessing potential effects on the environment from strategic plan, policies, programs, and projects; and for the determination of policies and measures to reduce potential adverse effects and to promote environmental benefits. The Act makes Environmental Clearance (EC) from Competent Authority a pre-requisite for a project, and EC sets out environmental terms for the project. The Act also requires the RGoB to ensure that environmental concerns are fully taken into account when formulating, renewing, modifying and implementing any policy, plan, or program as per regulation that may be adopted within EAA provisions. The Act outlines general procedures for environmental assessment including assessment steps, requirements for EC issuance, consultation; information disclosure; functions and powers of the agencies charged with implementing EAA; monitoring and control of offenses and penalties; and appeals and dispute resolution procedures under EAA. Regulations and guidelines supporting the EA Act include the Regulation for the Environmental Clearance of Projects, Regulation on Strategic Environmental Assessment, Application for Environmental Clearance Guidelines, and Environmental Codes of Practices.

3.2.4 Forest and Nature Conservation Act of Bhutan (1995)

This Act ensures the protection and sustainable utilization of flora, fauna, and other natural resources of Bhutan to benefit present and future generations incorporating the concepts of sustainable development. The Department of Forests and Parks Services is entrusted with the responsibility for sustainably managing, protecting, producing, and regulating all-natural resources within Government Reserved Forests Land and outside. Wild animals and plants listed in Schedule I are declared as totally protected. The Forest and Nature Conservation Rules of Bhutan 2017 has been formulated to support the implementation of this Act.

3.2.5 The Water Act of Bhutan (2011)

The Act determines priorities for water allocation for drinking, agriculture, energy, industrial use, tourism, recreation, and other uses. It requires the location of water to be based on the principle that water is a resource owned by the State and that every citizen has an equal right to these resources. The Act stipulates that the use of water by any person should not result in denial of water to any individual or community, including downstream and upstream needs or discharge of any effluent directly or indirectly to any water resource unless the discharge complies with the Effluent Discharge Standard. This Act is relevant in enabling safeguard measures in water use for the project activities and the management of drinking and irrigation water within communities that are part of the project areas.

3.2.6 Waste Prevention and Management Act (2009)

This legislation incorporates the Precautionary Principle and the Polluters Pay Principle. Under section 8, the Act stipulates that every person shall take all precautionary measures in maintaining a clean and healthy environment. Further, in section 10, the Act prescribes that a person polluting the environment or causing ecological harm shall be responsible for the costs of avoidance, contamination, abatement, medical compensation, mitigation, remediation and restoration in the application of the Polluter Pays Principle. The lead implementing agencies and collaborating agencies are responsible for implementing the Act.

3.2.7 Nationally Determined Contribution (NDC) to Paris Agreement, 2015

Bhutan submitted its first Nationally Determined Contribution in September 2015, which looks at mitigating GHG emission through several sectoral interventions as outlined below (NEC, 2015):

i. Sustainable forest management and

conservation of biodiversity to ensure sustained environmental services through:

- Sustainable management of forest management units (FMUs), protected areas, community forests, forest areas outside FMUs, and private forests
- Enhancing forest information and monitoring infrastructure through national forest inventories and carbon stock assessments
- Forest fire management and rehabilitation of degraded and barren forest lands

ii. Promotion of low carbon transport system by:

- Improving mass transit and demand-side management of personal modes of transport by
- Exploring alternative modes of transportation to road transport such as rail, water, and gravity ropeways.
- Improving efficiency in freight transport
- Promoting non-motorized transport and non-fossil fuel-powered transport such as electric and fuel cell vehicles
- Improving efficiency and emissions from existing vehicles through standards and capacity building
- Promoting the use of appropriate intelligent transport systems

iii. Minimize GHG emission through the application of zero waste concept and sustainable waste management practices:

- Enhancement of the three R principles including the conversion of waste to resources
- Improving the current system and infrastructure for waste management

iv. Promote a green and self-reliant economy towards carbon-neutral and sustainable development through:

- Improvement of manufacturing processes in existing industries through investments and adoption of cleaner technology, energy efficiency and environmental management
- Enhance and strengthen the environmental compliance monitoring system
- Promote investment in new industries at higher levels in the value chain and green industries and services.
- Promote industrial estate development and management in line with efficient, clean and green industry development objectives

v. Promote clean, renewable energy generation:

- Pursue sustainable and clean hydropower development with support from CDM or other climate market mechanisms to reduce emissions within Bhutan and the region by exporting surplus electricity

vi. Promote climate-smart livestock farming practices to contribute towards poverty alleviation and self-sufficiency through:

- Organic livestock farming and eco-friendly farm designs
- Improvement of livestock breeds, including conservation of native gene pool/diversity
- Expansion of biogas production with stall feeding
- Agro-forestry or agro-silvopastoral systems for fodder production

vii. Promote climate-smart agriculture to contribute towards achieving food and nutrition security through:

- Organic farming and conservation agriculture
- Development and promotion of sustainable agricultural practices
- Integration of sustainable soil and land management technologies and approaches

viii. Energy demand-side management by promoting energy efficiency in appliances, buildings and industrial processes and technologies.

ix. Integration of low emission strategies in urban and rural settlements through green buildings, sustainable construction methods and climate-smart cities.

3.2.8 National strategy and action plan for low carbon development, 2012

The National Strategy and Action Plan for Low Carbon Development was prepared to enable Bhutan to fulfill its commitment of remaining carbon neutral. In other words, it will help in ensuring that national emissions of greenhouse gasses (GHG) remain less than the national sequestration capacity. The strategy comprises of various scenarios analyzing development paths from 2005 till 2040. As a supplement to the scenarios, the action plan presents several short- and medium-term interventions to achieve sustainable economic development through green growth.

3.2.9 Economic Development Policy 2016

The economic development policy (EDP), which has a total of 252 policy provisions, provides the overall enabling environment to continue creating a transparent and conducive environment for business and investment in the Bhutanese economy**.** The Economic Development Policy sets the agenda and the general direction for the development of sectors with the highest potential. This Policy departs from the usual sector/agency-based approach. It is a document prepared in consultation with a wide range of stakeholders from private to government. Its success depends on an integrated and wholesome involvement of all the stakeholders. A clear, stable and transparent policy framework is necessary to accelerate economic growth. The document also includes a comprehensive set of incentive packages to boost growth. However, the EDP remains silent on climate change mitigation and adaptation and presumes that climate considerations are included in pollution control measures.

3.2.10 Bhutan Sustainable Hydropower Policy 2008

The policy's key objectives are to mobilize funds and attract investments for accelerated hydropower development, enhance the revenue contribution to the Royal Government, contribute towards development of clean energy to mitigate problems related to global warming and climate change. According to section 1 of Bhutan Sustainable Hydropower Development Policy 2008, there is great potential for increased electricity export and, consequently, substantial revenues. Huge energy demand in the region offers a big opportunity for Bhutan to develop its rich hydropower resources for the export market and mitigate climate change in the importing countries.

3.2.11 National Transport Policy (2006)

The National Transport Policy of Bhutan covers policy objectives and a framework for institutional arrangements. It also introduces financing mechanisms and a framework for monitoring and evaluating the outcomes of this policy. As a result, it addresses many of the existing policy gaps for Bhutan's transport sector. In particular, it provides the rationale and guiding principles for sub-sector policies. For example, it describes the existing landscape for important transport sub-sectors (roads and road transport; urban transport; civil aviation; regional connectivity) and details policy objectives. It also provides policy statements as benchmarks for meeting the objectives.

3.2.12 Transport 2040: Integrated Strategic Vision

The overall transport vision is to provide the entire population with a safe, reliable, affordable, convenient, cost effective, and environment-friendly transport system. The vision supports strategies for socio-economic development, which includes the goals of accessibility to activities and supplies needed by people and enterprises, efficient use of economic resources, environmental sustainability, and transport safety, especially on roads. It contains nine transport strategies where the first eight strategies cover the main transport sectors, in terms of physical infrastructure, services, and regulation. The final strategy concerns the coordination and management of the overall transport sector. Transport Vision 2040 and the set of supporting transport strategies constitute an integrated approach to the three modes of transport: road transport, urban transportation, and civil aviation.

3.3 Methodology

3.3.1 Scenario development

The BAU Scenario of both GDP and GHG emission is taken from the Draft CGE Model on the economic analysis of carbon neutrality developed by the National Environment Commission. The Model has two BAU scenarios of High Growth (GDP growth rate of 8%) and Low Growth (GDP growth rate of 4.2%). Against this GDP Growth, emissions are projected from 2014 to 2050.

3.3.2 Business As Usual (BAU)

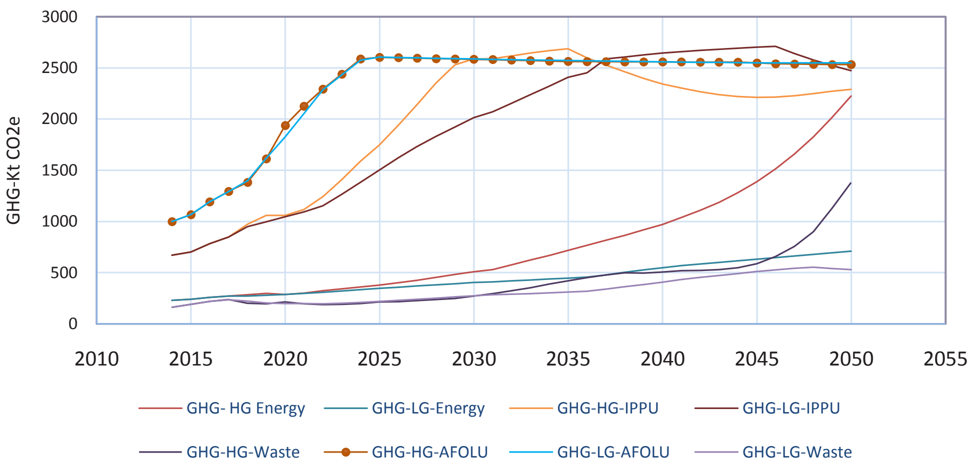

Figure 21 GHG profile following IPCC 2006

In the High Growth Scenario (HG), the emission of GHGs reaches the capacity of the sink (6.4 million tonnes CO_2e) in 2041 and increases to 8.431 million tonnes CO_2e by the year 2050. In the Low Growth Scenario (LG), the emission peaks to the sink capacity (6.4 million tonnes CO_2e) between 2044 and 2046 and decreases to 6.258 million tonnes CO_2e by 2050. These predictions are significant because Bhutan has committed to remain carbon neutral for all times to come (Royal Government of Bhutan, 2009), and carbon neutrality is at risk in both the scenarios. The major contributions in the GHG emissions are from Energy (Transport, Industry and Air Transport), IPPU (heavy industries) and Waste sectors, as shown in figure 21.

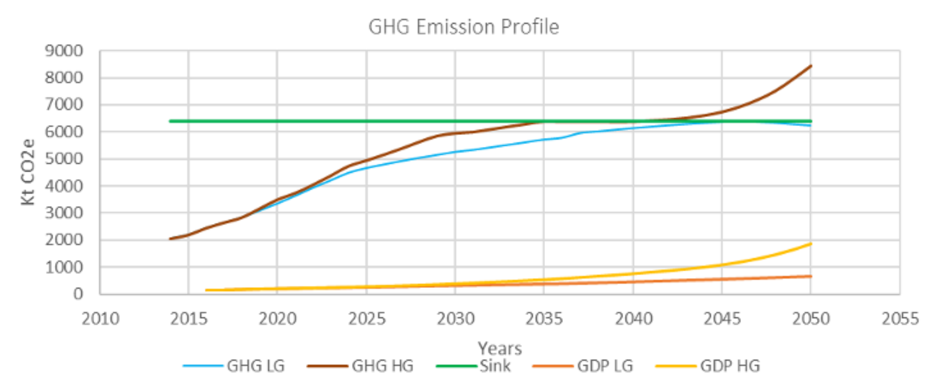

Figure 22 GHG profile

The mitigation options formulated with the policy goal of Bhutan remaining carbon neutral for all times are chosen from a range of activities identified in the Low Emission Development Strategies and from the sectoral plans and Low Carbon Development Strategy (National Environment Commission, 2012). The emissions are projected using different mitigation actions and GHG mitigation potentials calculated.

3.4 Energy

3.4.1 Sector description

Due to rapid economic growth over the last few decades, GHG emissions in the energy sector increased significantly from 93.60 Gg CO_2e in 1994 to 259.125 Gg CO_2e in 2000 and 707.917 Gg CO_2e in 2015. This substantial increase was mainly due to increasing energy emissions from transportation and industries. Emissions from the residential sector increased marginally as compared to the transport and manufacturing sub-sectors. The emissions in the energy sector are from energy sources imported from India and other countries.

3.4.2 BAU scenario

The energy sector emissions in the BAU Scenario are directly linked to the growth of GDP. In the period up to 2018, the emissions from the construction sector increase and then decrease till 2040 owing to the expectation that many hydropower and other mega infrastructure projects will be taken up and completed by 2020 (low growth scenario). The ongoing mega hydropower projects would be completing their civil works, and as a result, the emissions drop in the latter half of 2018. However, the emissions from land transport (road transportation) take over as the major source of emission in the energy sector from 2018 onwards. There is a consistent increase in the trend of this emission. As the economy develops, the share of other service sectors increases but does not overtake the emissions from road transportation. In the high growth scenario, the emissions from construction and road transportation continuously increase while the contribution of the other sub-sectors' contribution increases marginally.

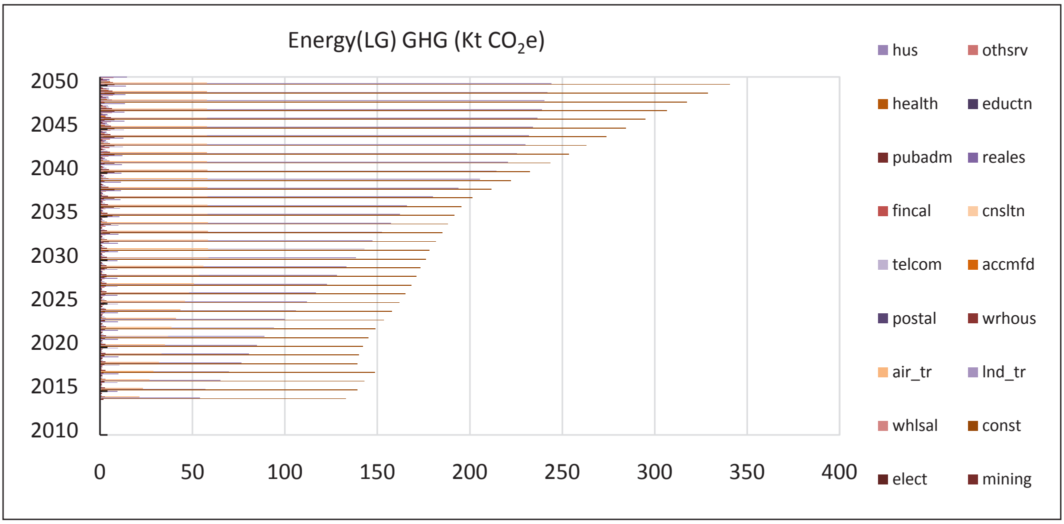

Figure 23 Energy Sub-categories

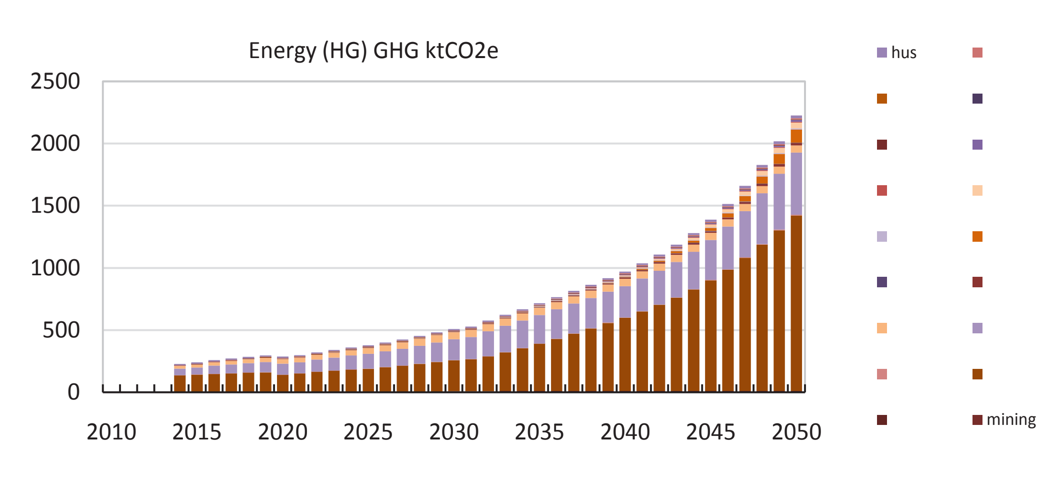

Figure 24 Energy Emissions-High Growth

3.4.3 Mitigation options

The mitigation options identified in the energy sector include energy efficiency (electricity), energy efficiency (fuels/ fossil-based), fuel switching (from fossils to biomass or waste), promotion and improvement in mass transit system (buses and trams) and promotion of electric and hybrid vehicles. The improvement in energy efficiency (electricity) is based on the premise that any electricity saved in Bhutan gets exported to India, where it will displace fossil-based electricity contributing to overall global emission reductions.

The energy efficiency (electricity) measures are identified in the Energy Efficiency Roadmap 2030 (Department of Renewable Energy, 2016). If the identified measures are implemented, energy savings of 410 GWh are estimated annually using the Indian Grid Emission Factor (S. Bhawan, 2014). The GHG mitigated works out to 402 kt CO_2e per annum. Similarly, for energy use in the manufacturing sector, fuel switching in the cement industry and food and agro-industries lead to relatively lower significant mitigation benefits (National Environment Commission, 2017).

Name of Mitigation Action: Improving Energy Efficiency in the Iron and Steel Industry
Scope of Mitigation Action: Iron and Steel Industries
Mitigation Potential: Maximum of 39.6 kt CO_2e / annum

Based on data provided by Bhutan Rolling Mills Ltd., an emission reduction potential of approximately 18 kt CO_2e per year from furnace oil savings could be achieved by direct hot charging implemented in the production facility. Here the hot billet is directly charged to the rolling mill without going through the reheating furnace. With the recent approval of a second steel industry promoted by the Druk Holding and Investment as an FDI project, the mitigation potential is expected to increase by 120% calculated based on the production capacity of the plants. It is estimated at 39.6 kt CO_2e/ annum.

Name of Mitigation Action: LEDS Transport
Scope of Mitigation Action: Introduction of plug-in electric and hybrid vehicles and mass transit system
Mitigation Potential: Maximum of 43 kt CO_2e / annum

The number of vehicles in the country has been increasing rapidly from 13,584 vehicles in 1997 to 75,190 in 2015 and 110,367 in 2020 with a corresponding increase in the volume of fuels imported from India. The primary fuels used in the transport sector are diesel and motor gasoline. The mitigation assessment carried out in the draft LEDS (Transport) covered strategies on mass transit, alternative transport, hybrid and electric vehicles and improved efficiency vehicles. While estimating mitigation potential in the transport sector poses inherent challenges due to lack of research on response to specific policy measures, the LEDS (Transport) estimates total accumulated emission reductions using high and low uptake of electric and hybrid vehicles. The assessment resulted in an accumulated mitigation of 416.897 kt CO_2e and 17.276 kt CO_2e by 2027 in low uptake scenario.

3.5 Industrial Processes and Product Use

3.5.1 Sector description

Bhutan has emerged from a subsistence agriculture economy in the second half of the 20th century, and large-scale industrial development started only in the 2000s. The manufacturing sector accounted for 8% of the GDP in 2015 (NSB 2016). There are a small number of energy-intensive heavy industries producing ferroalloy, carbide, cement and steel, located along the southern border. These industries, developed since low-cost electricity from hydropower became available, mainly serve the export market. Food processing, handicrafts, wood and paper processing is dominated by small companies, located mainly in the densely populated valleys. The manufacturing sector faces critical challenges in assuring public health and environment protection, as witnessed by local community complaints about high pollution levels in the Pasakha industrial estate, where most heavy industry is located (BBS 2015). Official emissions measurements corroborate this (see below).

In terms of greenhouse gas (GHG) emissions, the industrial sector has the highest emission growth of all economic sectors. Between 2000 and 2015, the industrial GHG emissions increased by 261.28%, from 220.446 to 796.423 Gg of CO_2e, mainly due to the expansion of ferrosilicon production. The commissioning of the additional three industrial parks at Jigmeling (Sarpang), Motanga (Samdrupjonkhar), Bongdeyma (Mongar) and Dhamdhum (Samtse) by 2018 (Kezang Deki, 2018) is expected to increase both energy and industrial process-related emissions by as many as two folds from the current levels.

3.5.2 BAU scenario

The emissions from the basic metal sub-sector increase to more than 1.6 million tonnes CO_2e towards 2030 in the high growth scenario and 2035 in the low growth scenario. Meanwhile, emissions from the mineral processing sub-sector increase to more than 800 kt CO_2e in 2030 and stabilize till 2050. Emissions from the other sectors increase gradually till 2030, and then sharply after that due to the shift in economic activities from manufacturing to a more knowledge-based service sector.

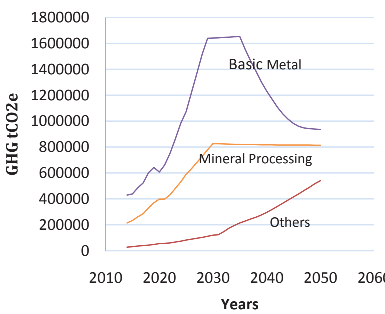

Figure 25 IPPU High Growth

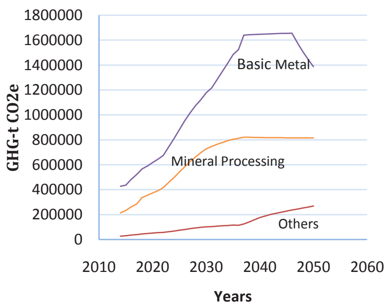

Figure 26 IPPU Low Growth

3.5.3 Mitigation options

Mitigation actions to reduce GHG emissions from industrial production include substituting fossil-based to biomass-based raw materials, changing products (blending in cement), and improving efficiency and productivity through cleaner production techniques (NEC, 2017). These mitigation actions have a global climate benefit and provide real, local benefits at a national level on human health, agriculture and well-being through the reduction of local and regional air pollution. They are thus in line with the indicators underpinning GNH. The mitigation actions are also expected to enhance the efficiency and competitiveness of the manufacturing sector. The mitigation actions in the IPPU sector are described below (National Environment Commission, 2017). The following chart shows the mitigation potential of various mitigation options:

Name of Mitigation Action: Replacement of fossil-based reductant by biomass-based materials.
Scope of Mitigation Action: Mineral Processing and metal industries utilizing coal and coke as reductants.
Mitigation Potential: Maximum of 235 kt CO_2e / annum

Replacement of reductant from fossil origin by charcoal has a huge mitigation potential as long as the charcoal is produced in a sustainable method. Currently, charcoal is imported from North East and South India in the absence of the domestic charcoal industry. While emissions from charcoal production and transportation are thus not accounted for under the GHG inventory of Bhutan, these emissions could be (partially) avoided by domestic charcoal production. Under the strict legislation related to the conservation of forests in Bhutan, domestic charcoal production would face strong limitations. However, Feuerbacher et al. (2016) estimate that domestic charcoal production has the potential to offset up to 61% of Bhutan's charcoal import by an increase in utilized forest area, which is under sustainable forest management practices from 5% to 15% of total forest area. The domestic charcoal production could also be utilized to increase the share of charcoal among the mix of reductant used and thus replace the reductant of fossil origin. The total emission reduction potential assuming current production estimates and based on 100% charcoal use, is 235 kt CO_2e per year.

Name of Mitigation Action: Waste Heat Recovery and electricity generation.
Scope of Mitigation Action: Mineral Processing and metal industries generating waste heat
Mitigation Potential: Maximum of 170 kt CO_2e / annum

Electricity generation from waste heat recovered from ferroalloy and carbide production has been analysed by TERI (2016). The study also reviewed the potential to use recovered waste heat internally for drying raw material and reductant. The energy-saving potential has been determined to be higher for the power generation option. Accordingly, the power generation option parameters have been applied for the determination of the mitigation potential. Assuming existing production of waste heat, electricity generation would reach 175 GWh per year, resulting in annual emission reductions of 170 kt CO_2e based on the Indian grid emission factor.

In the period 2014 to 2016, approximately 780 kt clinker and 920 kt cement have been produced per year in Bhutan. Roughly 10% of the cement production consists of Ordinary Portland Cement (OPC), 70% of Portland Pozzolana Cement (PPC), and 20% of Portland Slag Cement (PSC). The collected company data it has been estimated that the clinker content in PPC is around 75% and in PSC, around 70%. For OPC, a clinker share of 97.5% has been assumed.

Name of Mitigation Action: Cement Blending.
Scope of Mitigation Action: Cement Industry
Mitigation Potential: Maximum of 50 kt CO_2e / annum

Clinker is partially replaced by alternative materials such as slag or fly ash. Each ton of clinker produced from 2013 to 2016 resulted in GHG emissions of 0.946 t CO_2e due to fuel combustion and process emissions (i.e., calcination process). Assuming the Indian grid emission factor, GHG emissions of 0.17 t CO_2e /t clinker would be added as a result of electricity consumption reaching an emission intensity of 1.116 t CO_2e /t clinker. Blending could be applied either by switching from OPC to blended cement types or increasing the share of blending material in PPC and PSC. Assuming 5% of the average yearly clinker production could be replaced by blending, an emission reduction potential of 50 kt CO_2e per year would be possible. It should be noted that net emission reductions can only be achieved if less clinker is produced than the assumed baseline situation. On the other side, blending can also help to prevent the need for further production capacity increase.

Name of Mitigation Action: Refuse Derived Fuel.
Scope of Mitigation Action: Cement
Mitigation Potential: Maximum of 170 kt CO_2e / annum

Replacement of coal by refuse-derived fuels (**Measure B3**) has several emission effects. Waste is a composition of various fractions such as food, garden, wood, paper, plastic and other fractions. Some of these fractions have a high heating value. RDF production ideally utilizes those fractions in the waste that cannot be recycled and have high heating value. Especially a certain share of wood, paper and plastic would be suitable as an alternative fuel in cement kilns. These fractions are partially biomass and partially of fossil origin (e.g., plastics). A higher share of biomass in RDF would lower the resulting GHG emission factor accordingly. In addition, biomass fractions dumped in landfills will generate methane and constitute a significant GHG emission source. Given the various aspects of emission sources affected under this measure, the overall emission reduction to be achieved is difficult to predict and would require a more detailed analysis of the waste sector of Bhutan. Under this report, a minimum emission reduction of 1 tCO2e/t RDF used is assumed. As a result, assuming an overall 2% coal /coke replacement by RDF, emission reductions of 5.3 kt CO_2e per year can be achieved.

Name of Mitigation Action: Switching Diesel Boilers to Electric Boilers
Scope of Mitigation Action: Agro and Forest based units with boiler
Mitigation Potential: Maximum of 18 kt CO_2e / annum

The existing small and medium agro-industries in Bhutan use fossil fuel and wood-based boilers. Switching fossil fuel to electric boilers using zero-carbon electricity and promoting heat exchange systems with other industries will lead to reduced GHG emissions and associated environmental and economic costs. Compared to processing abroad and importing, mitigation will be achieved by the use of zero-carbon electricity and the reduction of transportation and lead to mitigation of 18 kt CO_2e / annum.

3.6 Agriculture Forestry and Other Land Use

3.6.1 Sector description

Although the AFOLU share of GDP decreased to just below 17% in 2008, majority of the rural population is still dependent on agriculture for their sustenance. Therefore, emissions from this sector are survival emissions for Bhutan.

The main emissions in this sector are from Forest (removal of round wood, timber, firewood and disturbances) and other land use (conversion of forest land to non-forest land) and biomass burning. The level of activities occurring within the sector in a particular period influences the emissions in this sector. For instance, emission from the forest increased by 100.47% compared between 1994 and 2015 and decreased by 43.78% between 2000 and 2015. The trend is quite similar to non-CO_2 emissions from biomass burning, which increased and decreased by 174.46% and 54.29% in between 1994 and 2015, and 2000 and 2015, respectively. However, emissions from the conversion of forest land to non-forest land have been increasing and saw a rise of 117.02% between 1994 and 2015, and 103.10% between 2000 and 2015.

Share of GHG emissions from Agriculture decreased gradually and saw a decrease of 7.98% between 1994 and 2015, and 3.90% between 2000 and 2015.

Carbon emissions from agricultural activity stem from livestock rearing and management, crop production, and energy consumption for tools and machinery. The non-energy related emissions within agriculture are significant, primarily due to CH_4 emissions from enteric fermentation and manure management.

In this sector, emissions from the forest sub-sector are negligible, while the emissions from the BAU Scenario for the Agriculture and Livestock sub-sectors are significant. The livestock-related emissions show a sharp increasing trend until 2024 and stabilize at 1.6 million tonnes CO_2e till 2050 in both the HG and LG scenarios. Similarly, the agriculture-related emissions show a sharp increasing trend till 2022 and then stabilizes at less than 1.0 million tonnes CO_2e till 2050.

3.6.2 BAU scenario

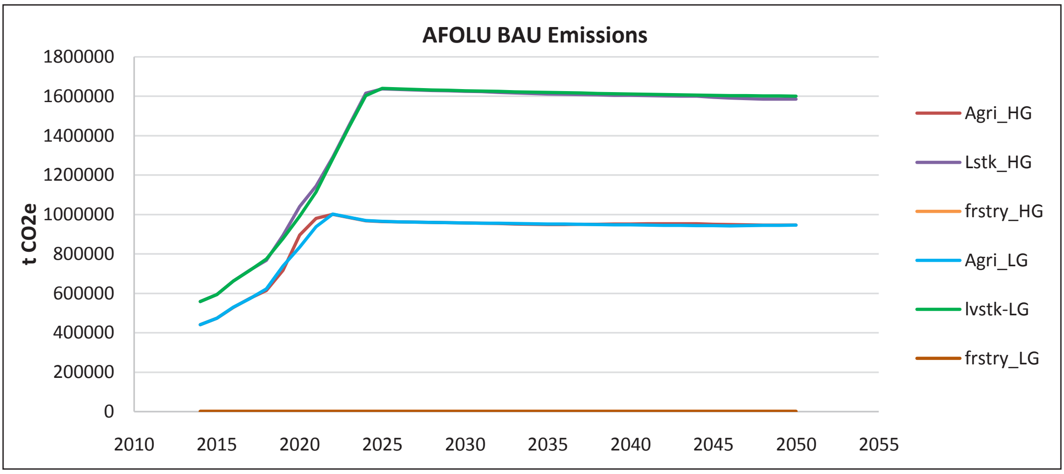

Figure 27 AFOLU BAU emissions

3.6.3 Mitigation options

While emission share in the national greenhouse gas inventory by the Agriculture sector is substantial, the mitigation actions do not substantially reduce GHG emissions. Instead, more focus and attention need to be spent on country-specific emission estimation methodologies to reflect the sector's estimates correctly. Mitigation options in the Agriculture sector consist of organic farming, reducing the use of synthetic nitrogen containing fertilizers, and crop selection. It also includes improving productivity in the livestock sector through improved grazing and a variety of high yield animals and improved manure management by promoting biogas generation from animal manure. Expert judgements of the sectoral experts point to a mitigation potential of 30% per annum equivalent to 480 kt CO_2e per annum.

3.7 *Waste*

3.7.1 Sector description

GHG emissions from the Waste sector have increased by 126.79% and 86.21% in 2015 compared to the 1994 and 2000 levels. The total GHG emissions from Waste sector in 1994, 2000 and 2015 were 55.789, 67.937 and 126.506 Gg of CO2e in national GHG inventory. It is assumed that an increase in waste is directly proportional to the population growth (i.e. 1.9% per year until 2020). According to IEMMP 2010 (Department of Renewable Energy, 2010), Thimphu and Phuentsholing generated 37 and 25 tonnes of solid waste per day, respectively, and the national waste generation figure was 81,119 tonnes/year in 2005.

3.7.2 BAU scenario

The CGE model shows emission from the waste sector gradually increasing from under 200 Kt CO_2e in 2015 to about 500 Kt CO_2e in 2045 for both the low and high growth scenarios. However, from 2045, in the high growth scenario, emission takes a sharp increasing trend to about 1300 Kt CO_2e in 2050 while in the low growth scenario, the emission stabilizes at around 500 Kt CO_2e by 2050.

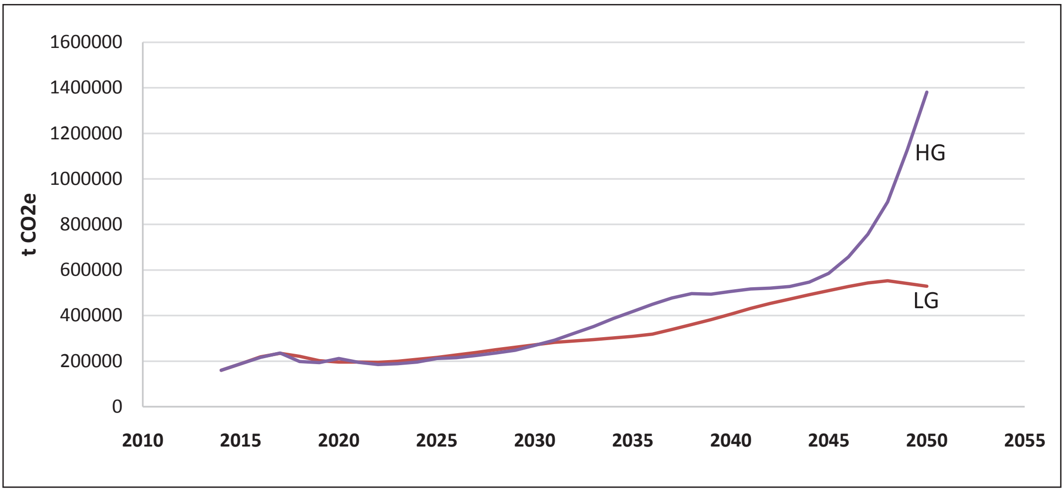

Figure 28 GHG emissions from Waste sector

3.7.3 Mitigation options

Mitigation options in the waste sector include the practice of 3 Rs through segregation of waste at source, combined composting and biogas generation, and improved collection and transport systems. Using the results from (National Environment Commission, 2018), and as shown in Figure 29 below, the mitigation of CH_4 from the waste sector can be achieved by either composting or biogas production or an integrated system where biogas generated from the compost pile is used for heating and cooking. Such a system will yield up to 236 kt CO_2e per annum of mitigation potential.

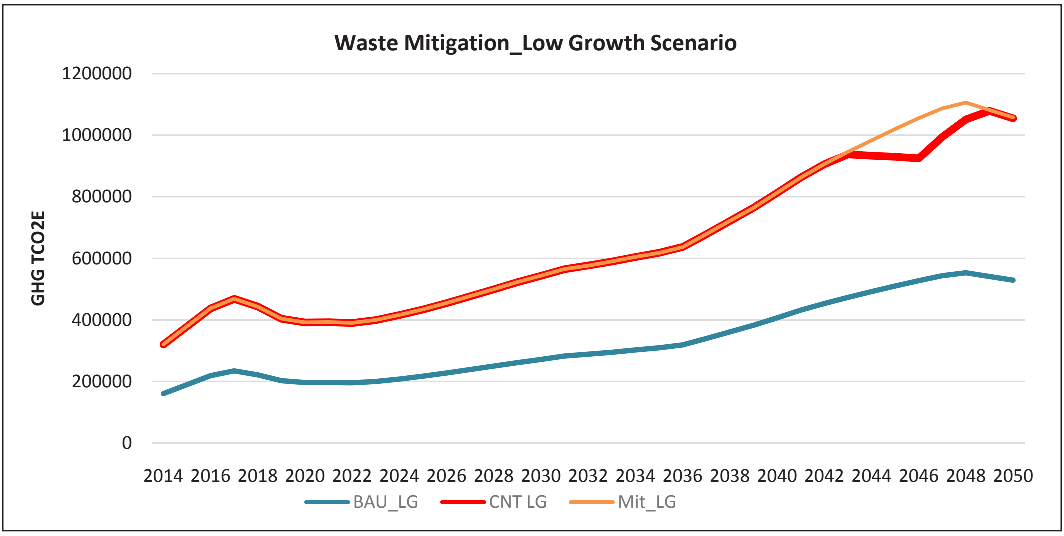

Figure 29 Waste mitigation

3.8 Total Mitigation Potentials

The total mitigation potential from the various options identified is 1441 kt CO_2e per annum and implementing at least half of them would ensure that Bhutan remains carbon-neutral till 2050.

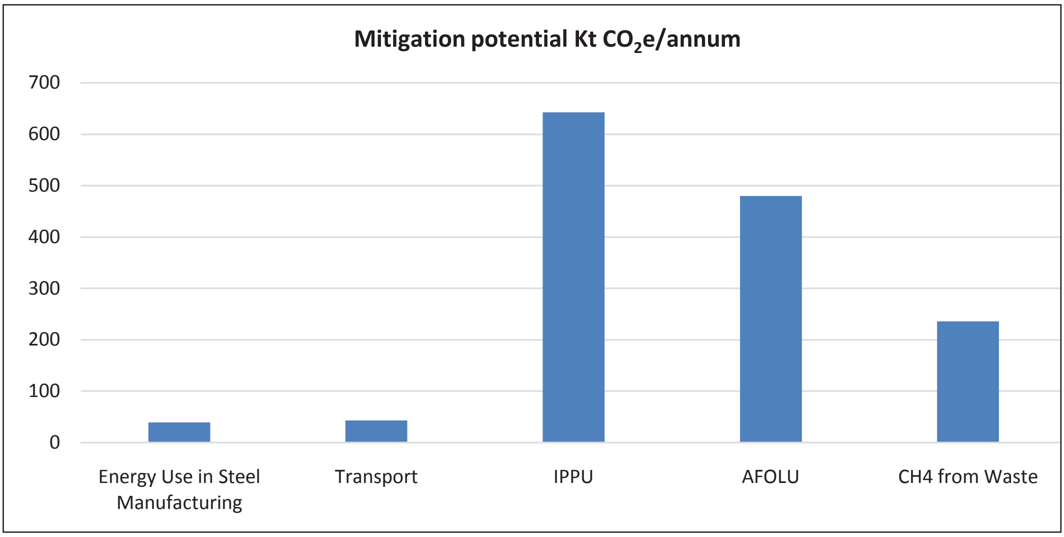

Figure 30. Mitigation options and potentials

VULNERABILITY AND ADAPTATION ASSESSMENT

4. VULNERABILITY AND ADAPTATION ASSESSMENT

4.1 Introduction

Climate change is expected to affect various sectors at different levels across the world. Changing climate and variability brings new types of vulnerabilities and risks to communities affected by poverty, lack of livelihood options, and means for survival. The level of vulnerability of each sector will vary across different regions depending on their geography, socio-economic conditions, and climate change impact. The impacts differ among the poor and marginalized women, men and children.

Vulnerability is evaluated based on assessing climate change impacts and adaptive capacity to the process of change. These assessments may be qualitative or quantitative, ranging from straightforward indicator-based approaches to sophisticated models. A recent assessment of the Hindu Kush Himalaya (HKH) region (Wester et al., 2019) indicates a substantial overlap between the determinants of vulnerability and poverty in the HKH region. The vulnerability comes from many factors, including remoteness, poor accessibility, and dependence on natural resources.

Climate change will impact Bhutan's overall development and economy since its major economic sectors (agriculture, hydropower, and forestry) are climate sensitive. The country's National Adaptation Programme of Action (NAPA) has identified key climate change vulnerable sectors as forest and biodiversity, agriculture, natural disasters, water, energy, and human health. Bhutan's Second National Communication to the UNFCCC, 2011, elaborates on the climate change impacts and vulnerabilities of these sectors and the adaptation priorities. The TNC will further prioritize human health, water resources, sustainable agriculture, forest & biodiversity, and energy as part of the V&A assessment.

Within the scope of the present work, extensive consultations with relevant stakeholders and the National Technical Working Group (NTWG) were carried out to assess each sector's current risks and vulnerabilities. The NTWG and key stakeholders agreed on the sectoral assessment and models for impact assessment during the consultations.

The Chapter consists of sections on climate baseline and projections for Bhutan based on CMIP 5 (Climate Model Inter-comparison Project – General Circulation Models) GCMs for 2030-2050 and 2070-2099, the impact of climate change on Agriculture, Forestry, Water Resources and Glaciers, Health, Energy, Disaster, Urban planning and infrastructure development. Issues of disaster and gender have been included as a section. Even though it was considered to have section on gender to be cross-cutting, the lack of sex-disaggregated was a limitation. The analysis of vulnerability is followed by possible adaptation options for the respective sectors.

4.2 Climate baseline information and scenario

The information contained in this section is largely extracted from reports and analysis, including climate projections from the National Center for Hydrology and Meteorology (NCHM) publication ''Analysis of Historical Climate and Climate Projection for Bhutan" 2019. The NCHM clusters the seasons for different months, as shown in the table below (Table 19):

Table 19 Months, abbreviation and seasons

Months	Abbreviation	Corresponding season
December, January, February	DJF	Winter
March, April, May	MAM	Spring
June, July, August, September	JJAS	Summer
October, November	ON	Autumn

Bhutan lacks extensive and long-term historical temperature and rainfall data sets. The observed climate data are available only from 1996. For the analysis, climate data from 15 reliable manual meteorological stations data were used, of which all are located in the middle and southern parts of the country and none from the northern high-altitude zones. As the data period is short, no concrete inference could be made on the trend, both for rainfall and temperature.

Expansion of coverage for data collection under the external support projects has been taken up in recent years. Automatic Weather Stations and river gauging stations have been established to collect hourly observations in some parts of the country (NCHM 2017). The effort needs to be sustained further so that data quality improves over time.

For climate modelling, NCHM used temperature and rainfall data from the Climatic Research Unit (CRU), University of East Anglia, the United Kingdom as a proxy for tracing historical climate change in Bhutan. The CRU data was validated against the available observed data from the 15 climate stations of the available period. This is the best alternative in case of a lack of historically observed data.

The country's climate projections have been assessed for two future periods: a short-term period (2021-2050) and a long-term period (2070-2099). The projection considers two socio-economic scenario representing trends – Representative Concentration Pathways (RCP) of high emission (RCP 8.5) and intermediate emission (RCP 4.5) of the IPCC fifth assessment report (2014). There is no projection for a medium-term period (2051-2069), which needs to be considered in future assessment.

4.2.1 Mean Annual and Seasonal Air Temperature Trend (1976 – 2005)

An analysis of trends in climate parameters using CRU data for the country from 1976 to 2005 showed an increasing trend in temperature. The mean annual temperature has increased by 0.8 degrees Celsius (NCHM, 2019). Similarly, seasonal temperature has increased as well, with the highest increase during the winter season by 1.3 degrees, as presented in Table 20:

Table 20 Changes in mean temperature

(Source: NCHM, 2019)

CRU	Change in mean temperature (°C)
DJF	1.3
MAM	0.6
JJAS	0.8
ON	0.7
Mean	0.8

Figure 31 shows the variation of annual and seasonal temperatures over the years. The spring and summer season are warmer than the rest of the seasons, and the northern regions are relatively cooler than the rest of the regions.

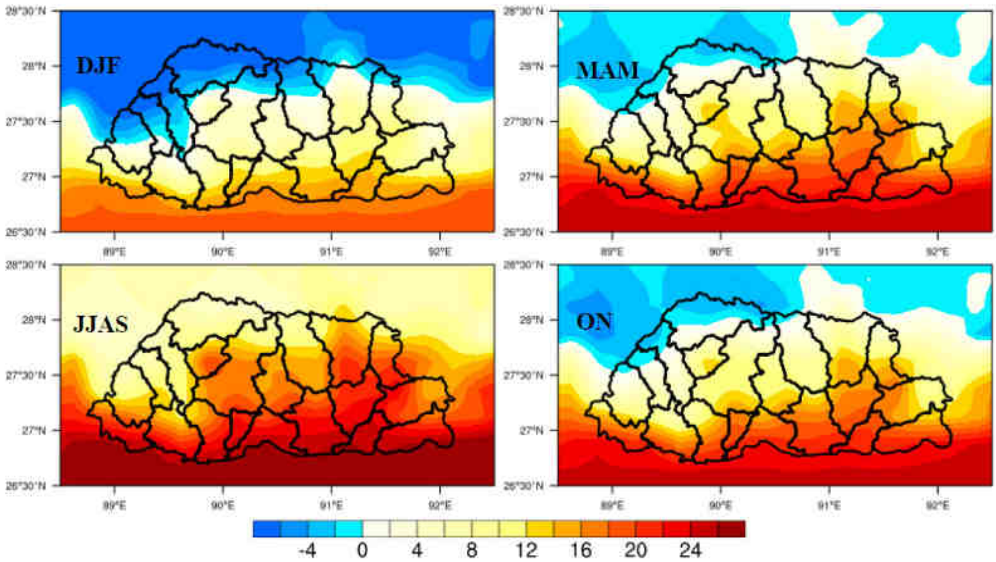

Figure 31 Spatial distribution of seasonal mean temperature (°C) over Bhutan for the period 1976-2005 (Source: NCHM, 2019)

4.2.2 Mean Annual and Seasonal Rainfall Trend (1976-2005)

The analysis of historical data revealed a decreasing trend in rainfall at mean annual scales with high variability. Seasonal rainfall trends reveal a wet summer monsoon (JJAS) and dry winter season (DJF). Figure 32 shows the spatial variation of mean annual and seasonal rainfall across Bhutan. It can be observed from Figure 32 that the rainfall amounts are highest for the summer season (JJAS) while the other seasons are relatively dry. The spatial variation between the regions can also be observed with much higher rainfall in the country's southern belt.

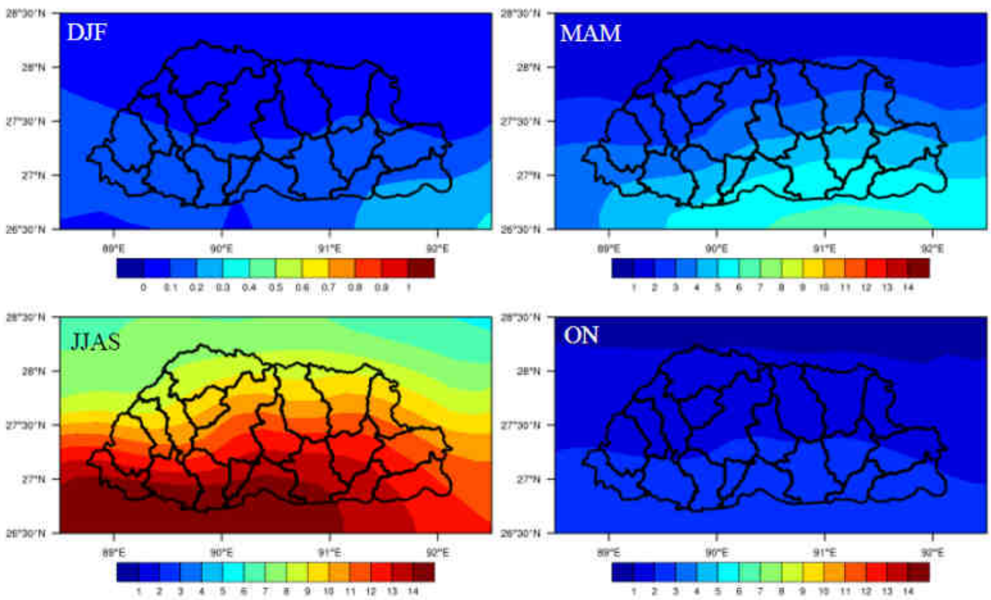

Figure 32 Spatial distribution of seasonal mean rainfall, DJF (Winter), MAM (Spring), JJAS (summer) and ON (Autumn) (Source: NCHM, 2019)

4.2.3 Climate Scenarios: Annual and Seasonal Temperature (2021-2100)

NCHM used an ensemble of five model data from NASA Earth Exchange Global Daily Downscaled Projections (NASA GEX-GDDP) for the projection of temperature and rainfall parameters. Projection for temperature and rainfall is done for two socio-economic scenarios of RCP 4.5 and RCP 8.5.

The projection shows a consistent increase in temperature over the country under both RCPs. The increase in temperature under RCP 4.5 is about 0.8°C– 2.8°C during 2021-2100 while projections under RCP 8.5 scenario show increases of about 0.8°C to more than 3.2°C towards the end of the century. Greater warming is indicated during MAM and DJF seasons. The country is expected to experience an increase in temperature with a larger increase projected in higher altitudes. The figures below (Figure 33 to Figure 39) shows the projected temperature increases.

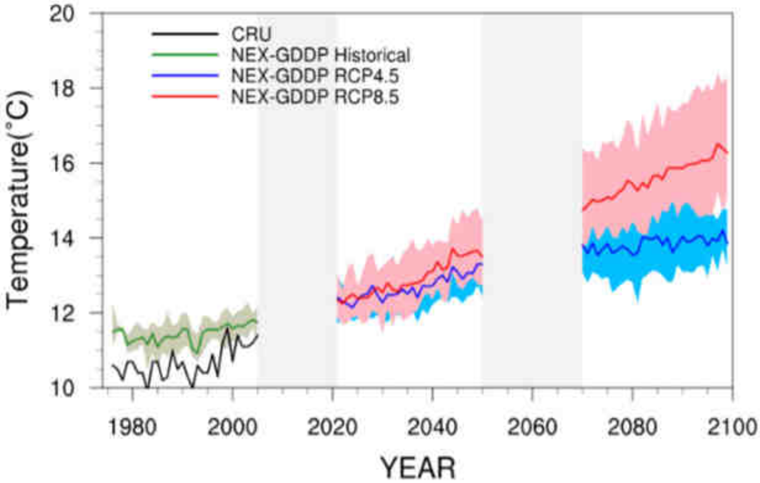

Figure 33Historical climate and climate projections for temperature (Source: NCHM, 2019)

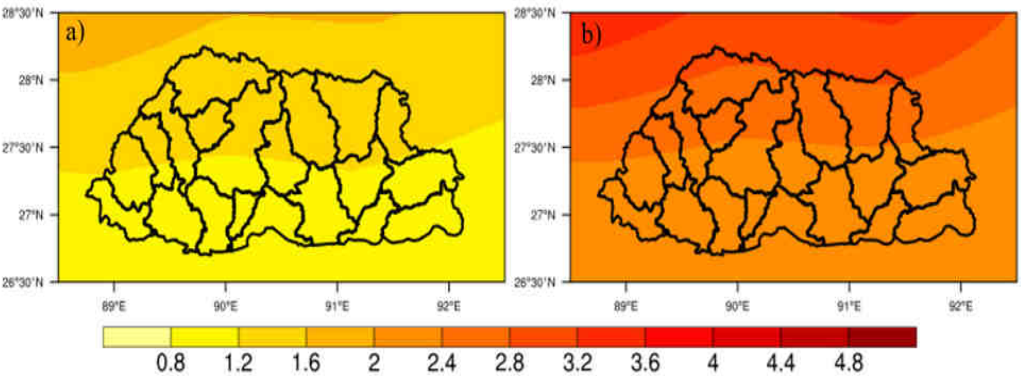

Figure 34 RCP 4.5 Difference in annual mean temperature (°C) between future and present-day climate (a) 2021-2050 (b) 2070-2099 (Source: NCHM, 2019)

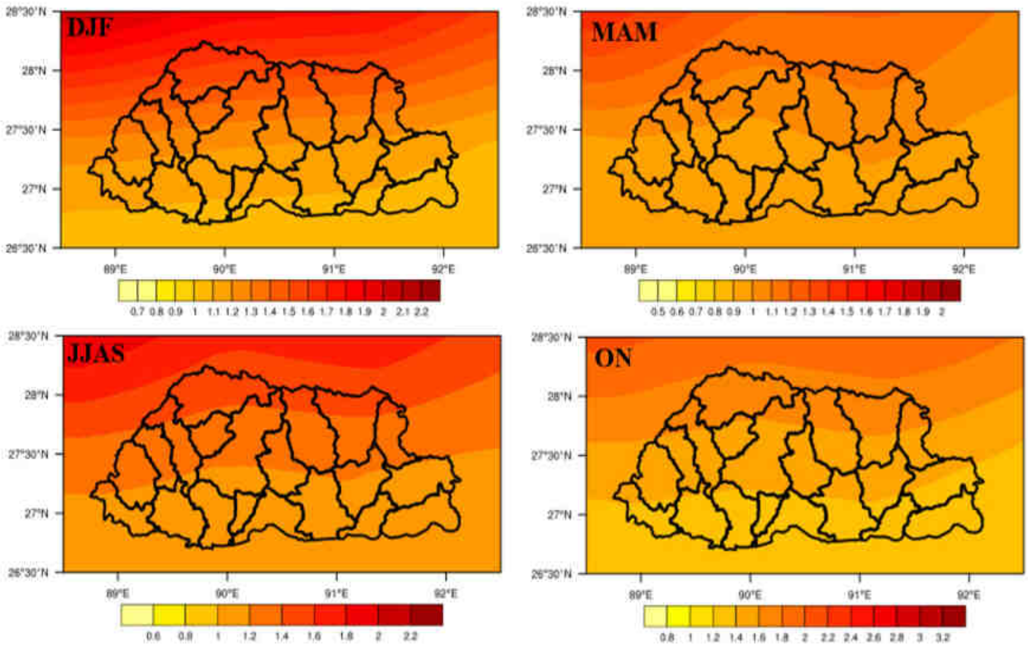

Figure 35 RCP 4.5: Difference in seasonal mean temperature (°C) between future and present-day climate: 2021-2050 (this map should be for seasonal variation for short term period under RCP 4.5 and not for present and future comparison)

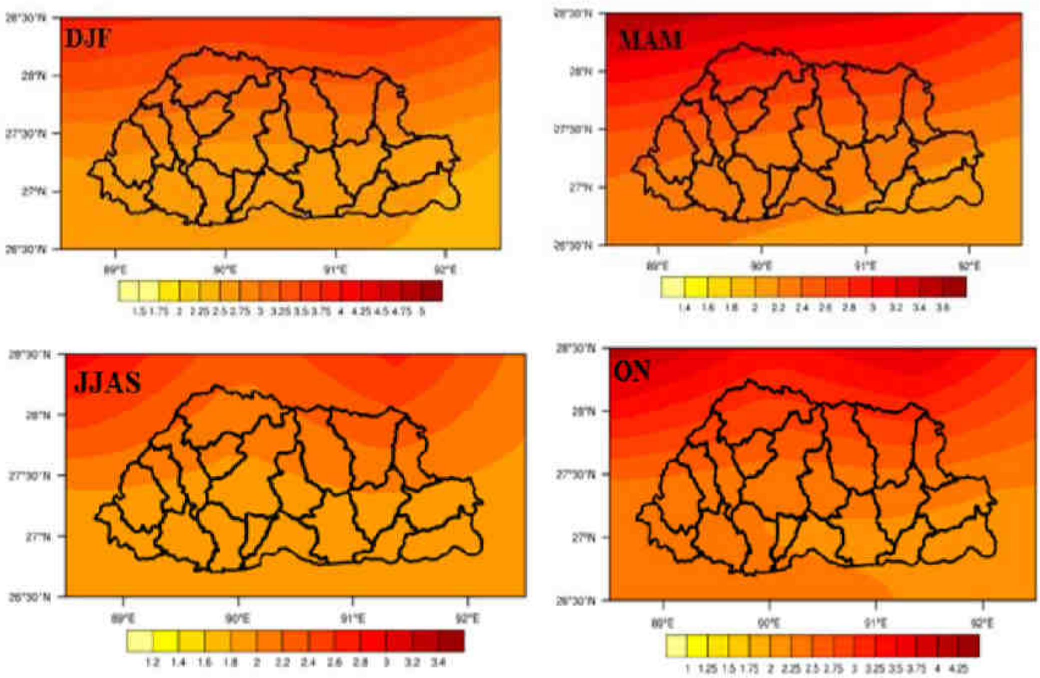

Figure 36 RCP 4.5: Difference in seasonal temperature (°C) between future and present-day climates: 2070-2099 (Source: NCHM, 2019)

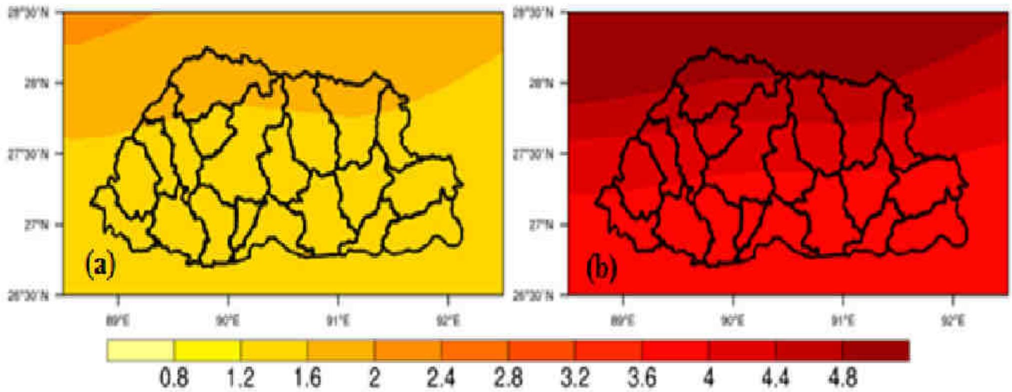

Figure 37 RCP 8.5: Difference in annual mean temperature (°C) between future and present-day climates (a) 2021-2050 (b) 2070-2099 (Source: NCHM, 2019)

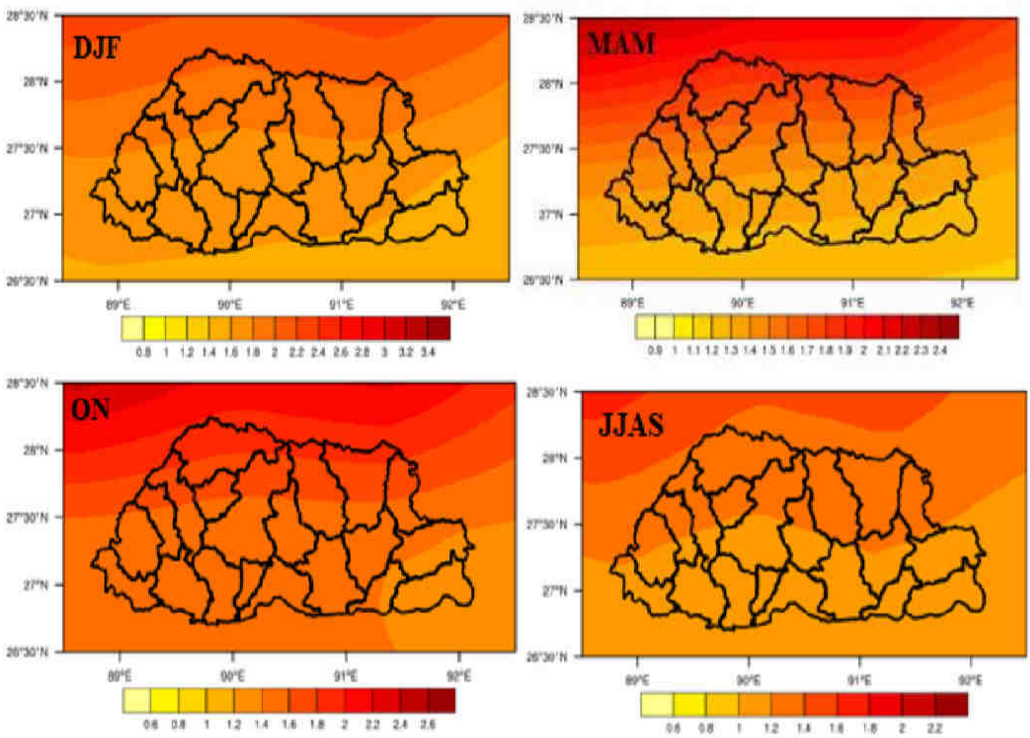

Figure 38 RCP 8.5: Difference in seasonal mean temperature (°C) between future and present-day climates: 2021-2050 (Source: NCHM, 2019)

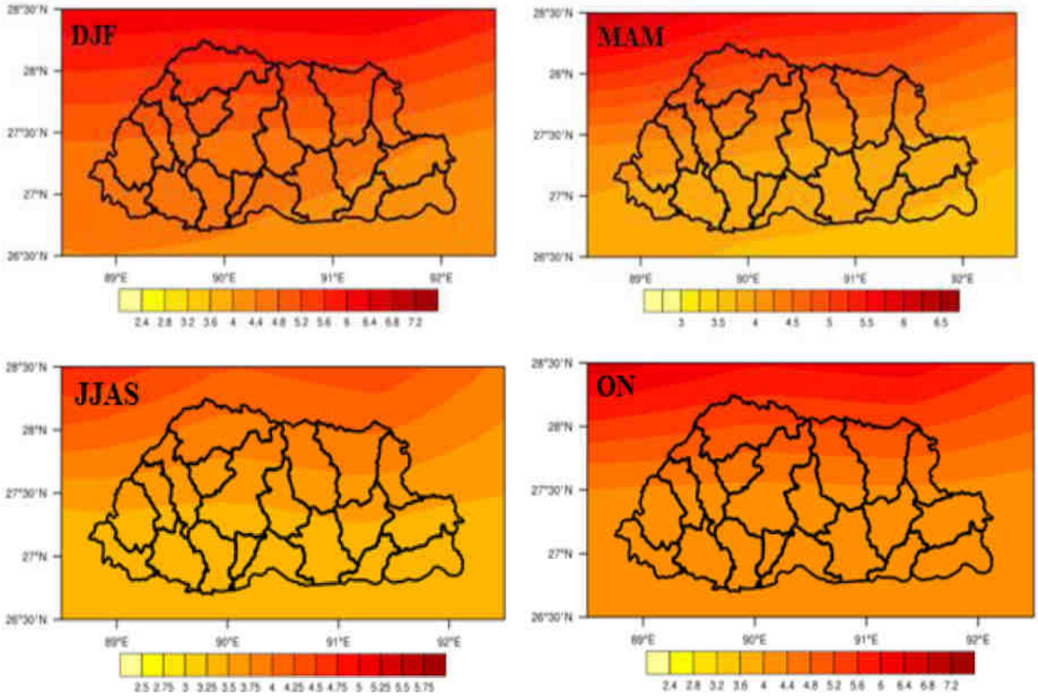

Figure 39 RCP8.5: Difference in seasonal mean temperature (°C) between future and present-day climates: 2070-2099

4.2.4 Climate Scenarios: Annual and Seasonal Rainfall (2021-2100)

The mean annual rainfall over Bhutan is likely to increase in the future under both the RCPs. Under the RCP 4.5 scenario, the yearly rainfall in Bhutan could increase by about 10% to 30%, with a 5% to 15% increase in summer rainfall (JJAS). The projection also notes a likely increase of rainfall during the winter (DJF) with some parts in the north and northwest likely to experience a decrease in rainfall. The projections for rainfall under different scenarios are shown in Figure 40.

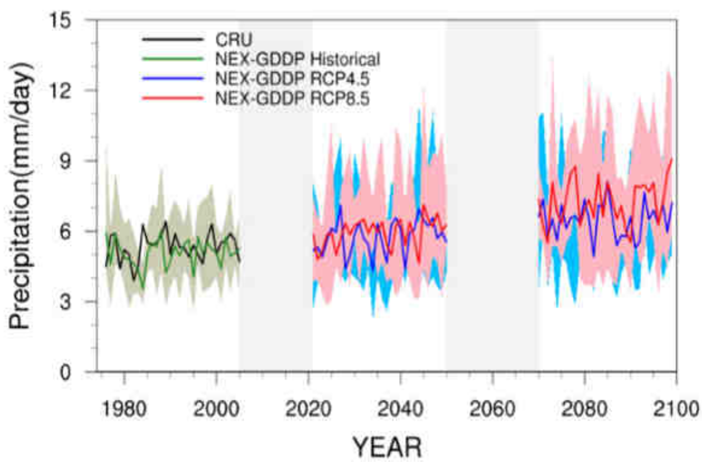

Figure 40 Historical climate and climate projection for Rainfall (Source: NCHM, 2019)

Under the RCP 8.5 scenario, the mean annual rainfall indicates an increase of about 10-20% in the short term period and more than 30% increase all over Bhutan towards the end of the century. While the projections suggest increasing rainfall during the summer season (JJAS), the north-western region of the country is expected to experience a decrease in rainfall in winter (DJF). The annual and seasonal precipitation changes under different scenarios are shown in the following figures (Figure 41 to Figure 45).

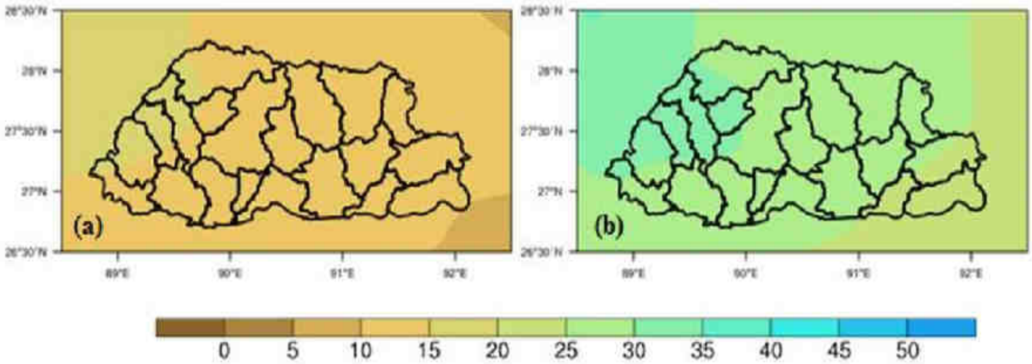

Figure 41 RCP4.5 Change (%) in annual mean precipitation between future and present-day climates: (a) 2021-2050 (b) 2070-2099 (Source: NCHM, 2019)

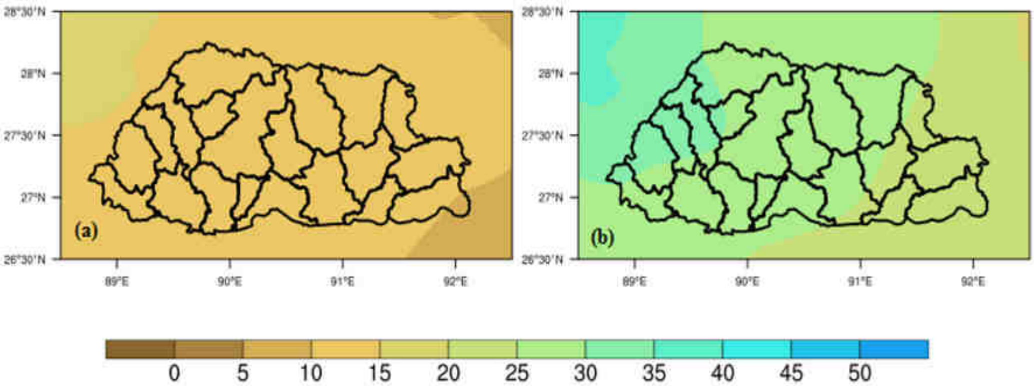

Figure 42 Change (%) in JJAS precipitation between future and present-day climates: (a) 2021-2050 (b) 2070-2099. (Source: NCHM, 2019)

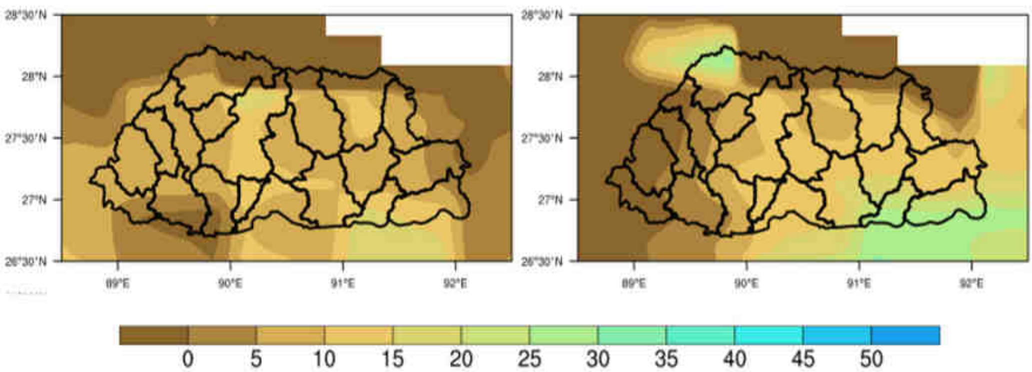

Figure 43 RCP 4.5 Change (%) in DJF precipitation between future and present-day climates: (a) 2021-2050 (b) 2070-2099 (Source: NCHM, 2019)

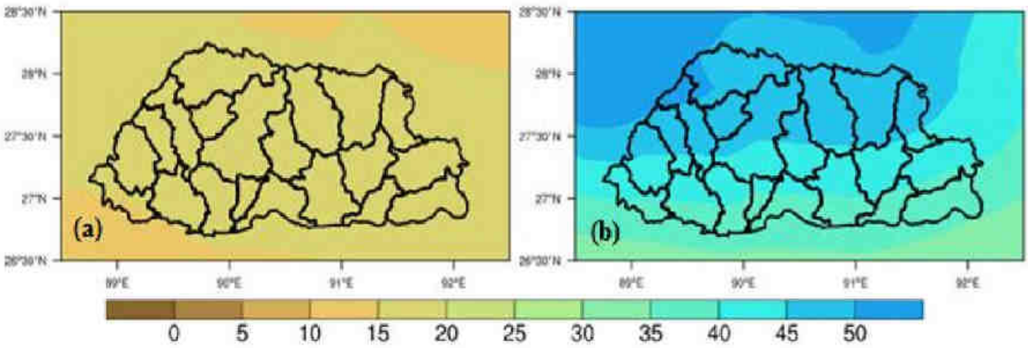

Figure 44 RCP 8.5 Change (%) in annual mean precipitation between future and present-day climates: (a) 2021-2050 (b) 2070-2099 (Source: NCHM, 2019)

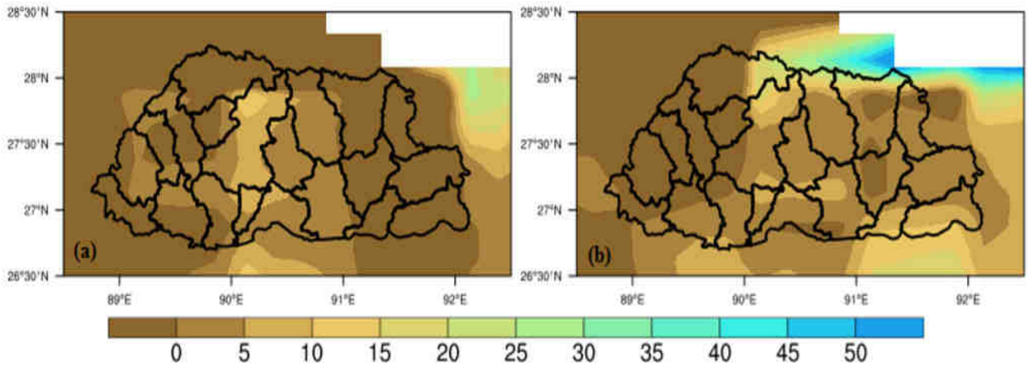

Figure 45 RCP 8.5 Change (%) in DJF seasonal mean precipitation between future and present-day climates: (a) 2021-2050 (b) 2070-2099 (Source: NCHM, 2019)

4.2.5 Climate Scenarios: Temperature and Rainfall change by elevation (2021-2100)

An Asian Development Bank supported study for NEC in 2016 developed climate projection by elevation, considering the effect of the country's diverse topography. This study broadly divides the country into three climatic zones along the north-south direction, based on the elevation presented in the table below (Table 21) (NEC, 2016):

Table 21 Climatic Regions of Bhutan

Region	Climate	Elevation (m)
Southern foothills	Subtropical, high humidity, heavy rainfall	100 -1,500
Inner Himalayas	Cool winters, hot summers, moderate rainfall	1,500 - 3,000
Higher Himalayas	Alpine, cool summers, cold winters	3,000 - 7,550

Source: Adapted from NEC, 2016 a

4.2.6 Temperature and Rainfall change for higher Himalayas (2021-2100)

For the higher Himalayas, increase in temperature is projected to be more than 3 degrees under RCP 8.5, while temperature for RCP 4.5 is projected to increase by 2 degrees. The warming is projected to be higher during the winter months. Following figures, Figure 46 to Figure 48 shows projections of mean annual and monthly temperature change over higher Himalayas for two RCPs during mid to the end of the century.

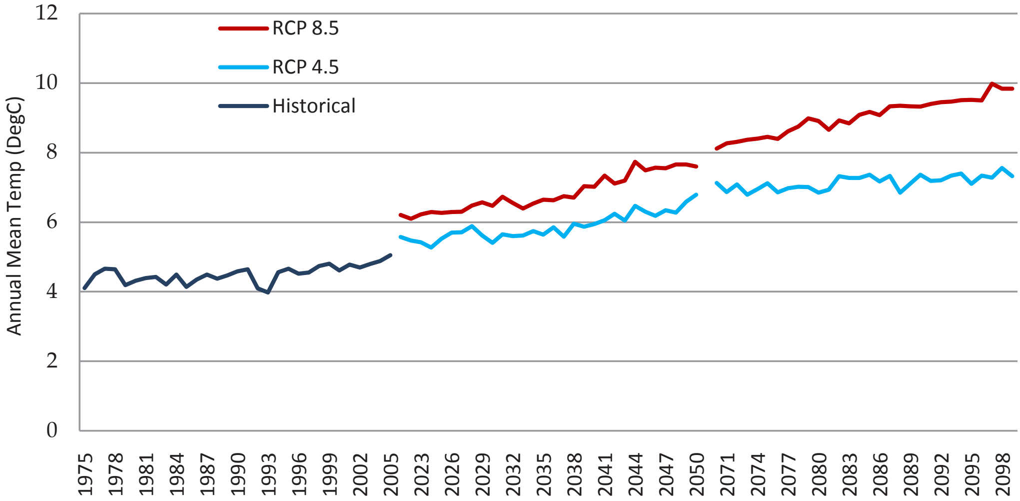

Figure 46 Changes in mean annual temperature under RCP 4.5 and RCP 8.5 (Higher Himalayas)

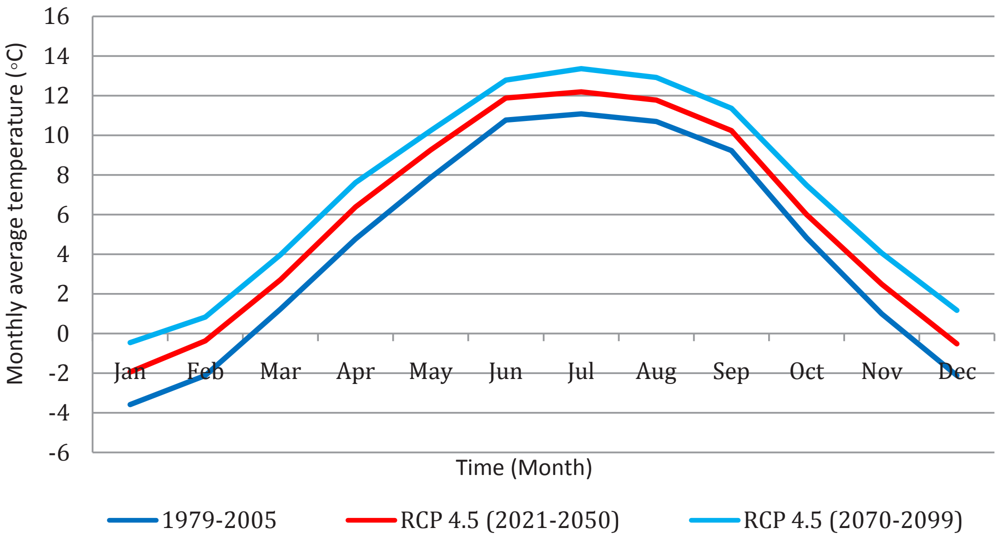

Figure 47 Monthly average temperature changes under RCP 4.5 (Higher Himalayas)

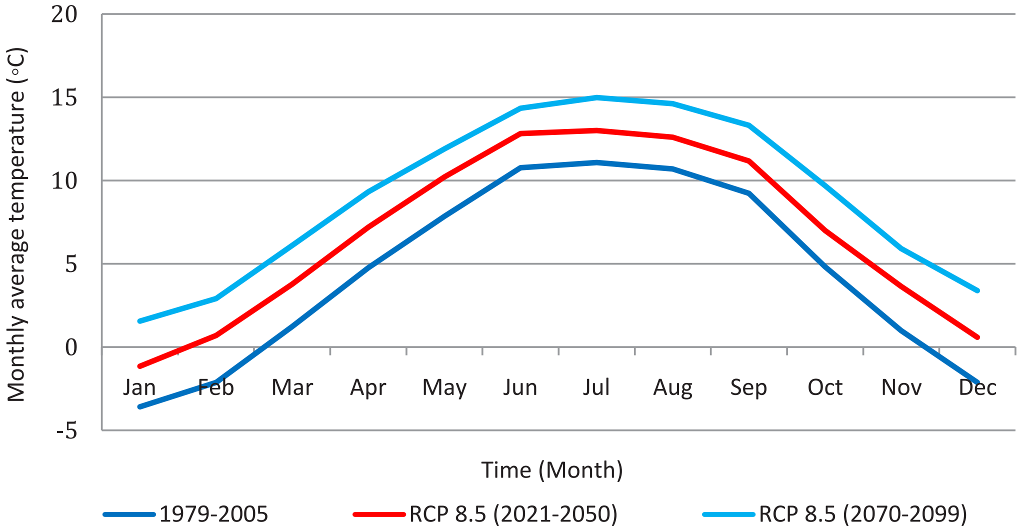

Figure 48 Monthly average temperature changes under RCP 8.5 (Higher Himalayas)

While there is a marginal increase in rainfall under both RCPs for this zone, the model also projects a decrease in rainfall in certain regions. In terms of the monthly average rainfall, this zone is expected to receive higher rainfall during the summer and have a drier winter. The rainfall projections for the Higher Himalayas are shown in Figure 49 to Figure 51.

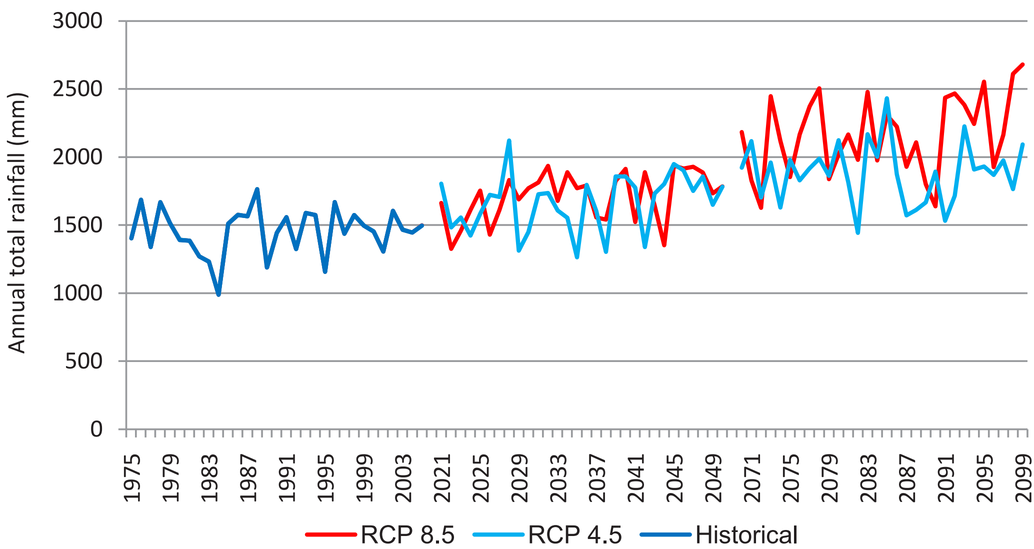

Figure 49 Changes in mean annual rainfall under RCP 4.5 and RCP 8.5 (Higher Himalayas)

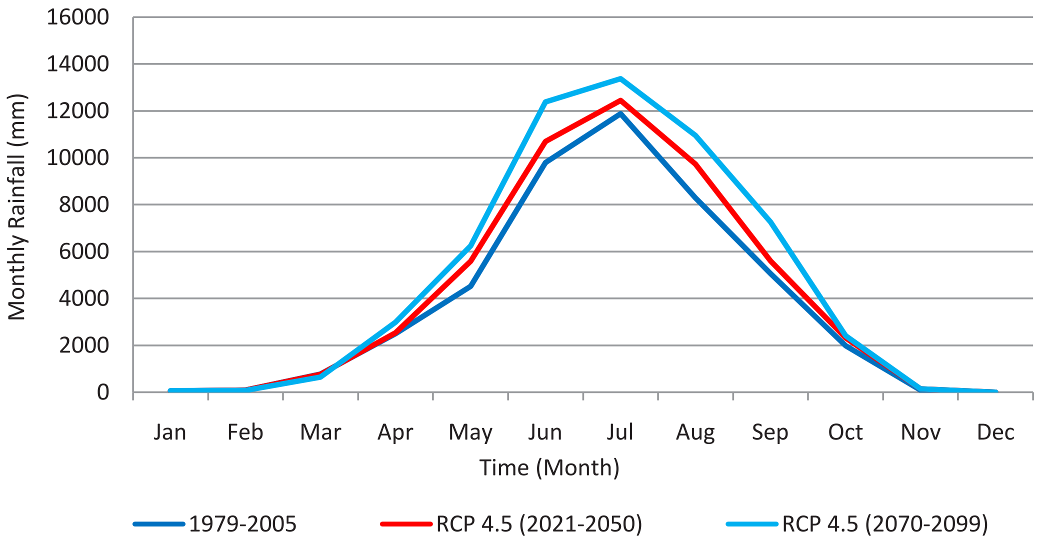

Figure 50 Changes in monthly average rainfall under RCP 4.5 (Higher Himalayas)

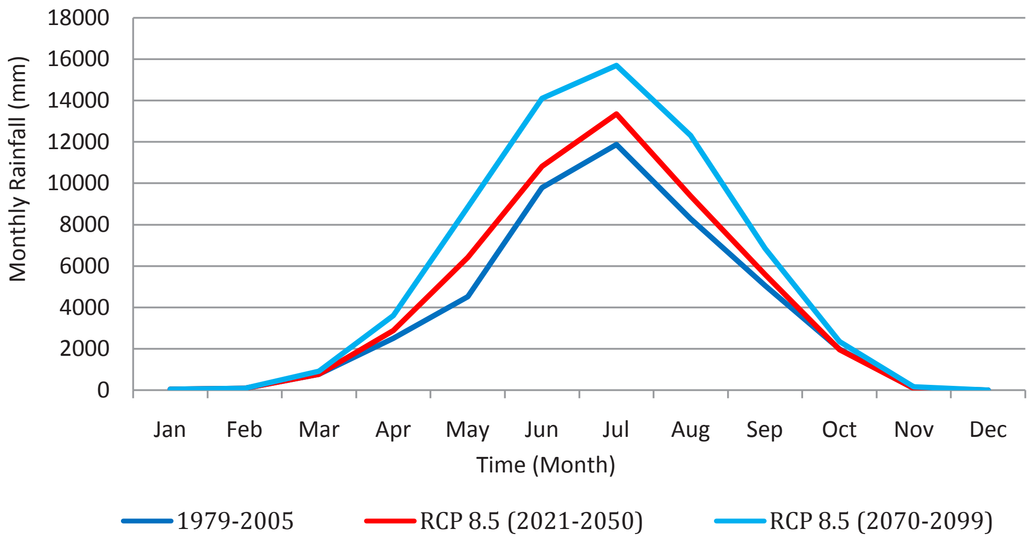

Figure 51 Changes in monthly average rainfall under RCP 8.5 (Higher Himalayas)

4.2.7 Temperature and Rainfall change for Inner Himalayas (2021-2100)

For the Inner Himalayas, there is consistent warming under both the RCPs. However, warming is projected to be higher during the winter months. Figure 52 to Figure 54 shows projections of mean annual and monthly temperature change over the inner Himalayan zone for two RCPs during the mid and the end of the century.

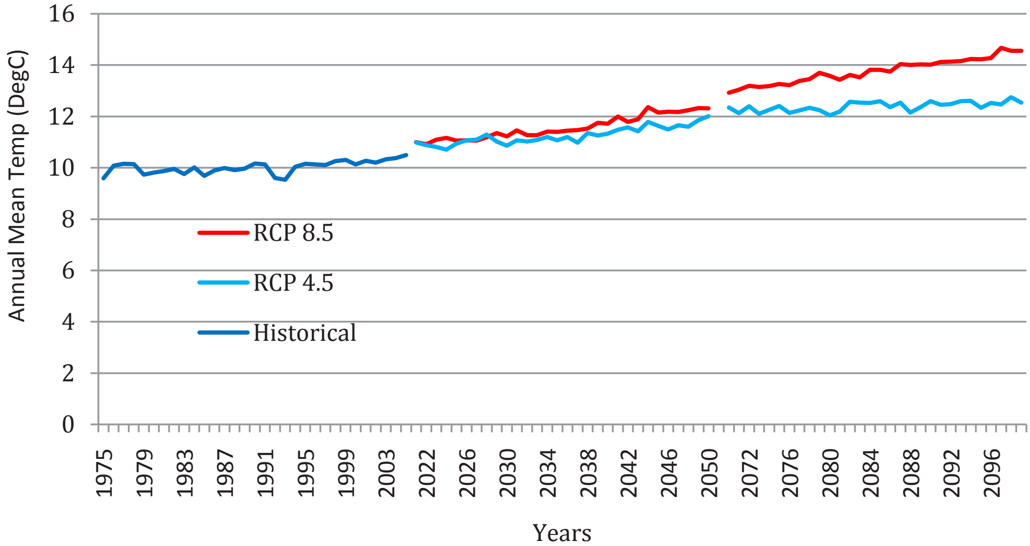

Figure 52 Changes in mean annual temperature under RCP 4.5 and RCP 8.5 (Inner Himalayas)

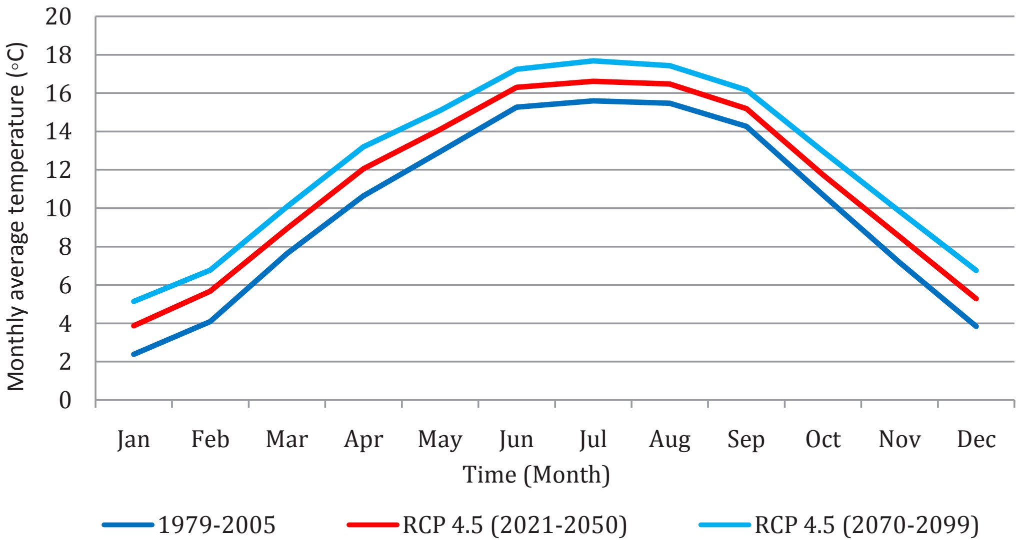

Figure 53 Monthly average temperature changes under RCP 4.5 (Inner Himalayas)

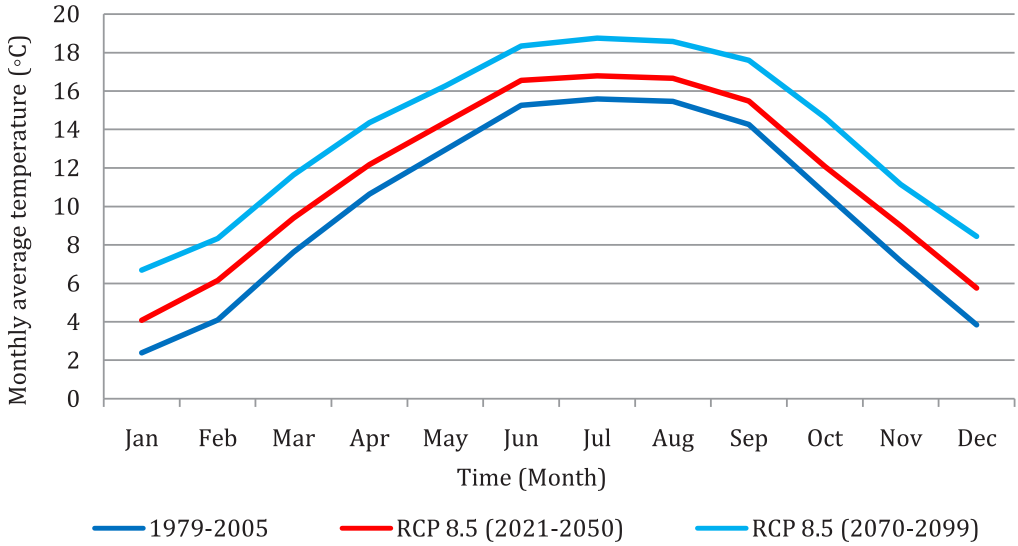

Figure 54 Monthly average temperature changes under RCP 8.5 (Inner Himalayas)

For this elevation zone, the rainfall projection shows an increasing trend under both the RCPs. The seasonal and monthly projection shows a drier winter and wetter summer under both the RCPs. However, it is projected that rainfall will increase during winter season under RCP 4.5 in the long term. Figure 55 to Figure 57 shows the rainfall projections for the Inner Himalayas.

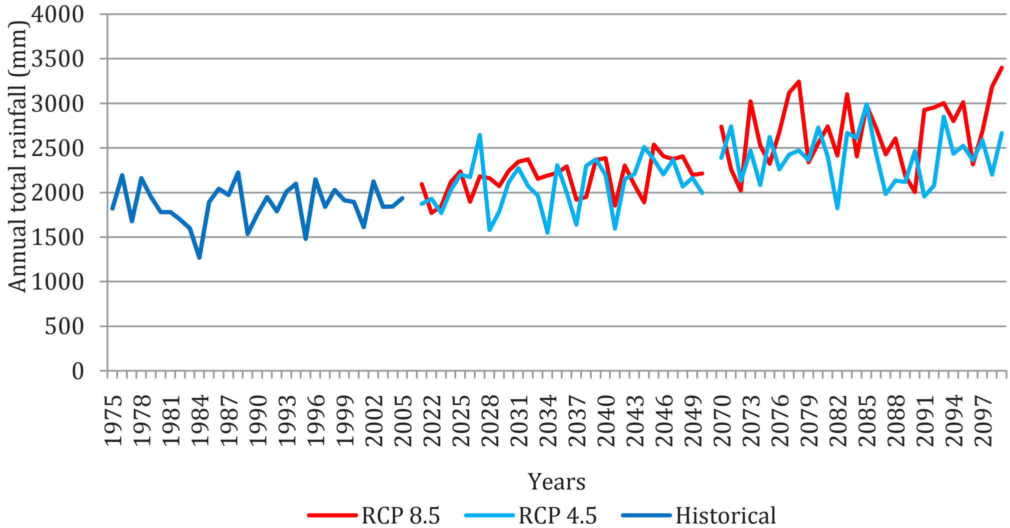

Figure 55 Changes in mean annual rainfall under RCP 4.5 and RCP 8.5 (Inner Himalayas)

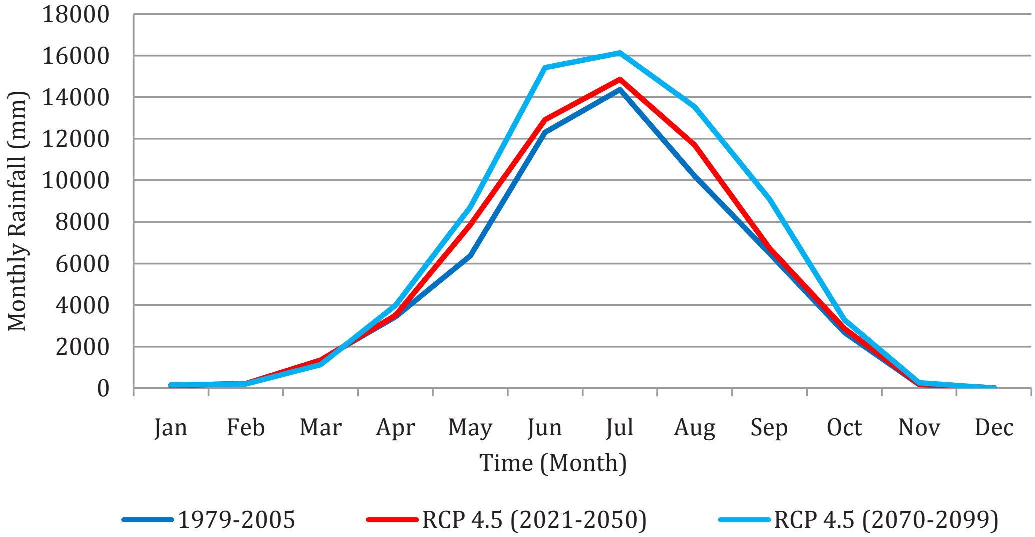

Figure 56 Changes in monthly average rainfall under RCP 4.5 (Inner Himalayas)

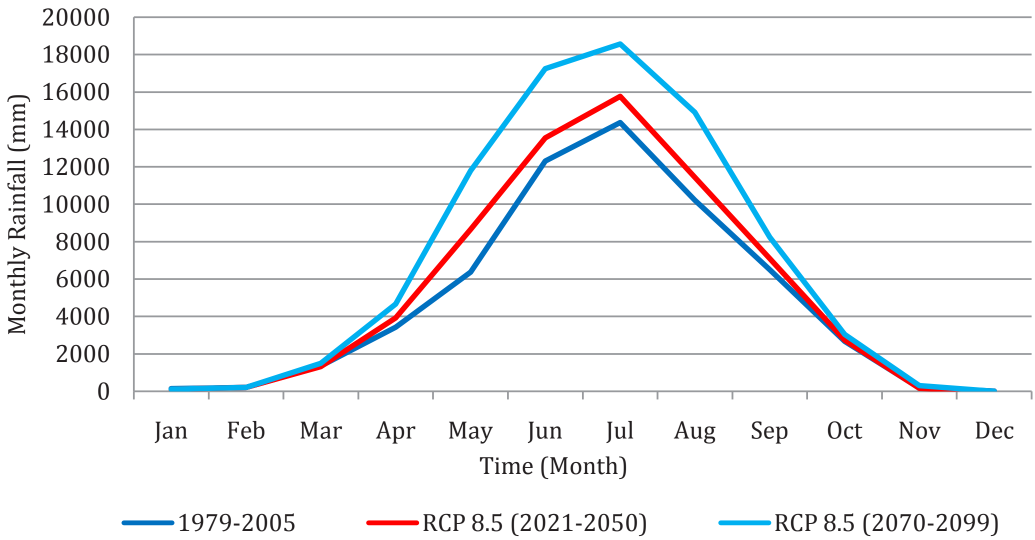

Figure 57 Changes in monthly average rainfall under RCP 8.5 (Inner Himalayas)

4.2.8 Temperature and Rainfall change for Southern Foothills (2021-2100)

In the southern foothills, increase in temperature is consistent with the elevation zones in both the RCPs with a higher warming projected for the winter months. Figure 58 to Figure 60 shows projections of mean annual and monthly temperature change over southern foothills for two RCPs by the end of the century.

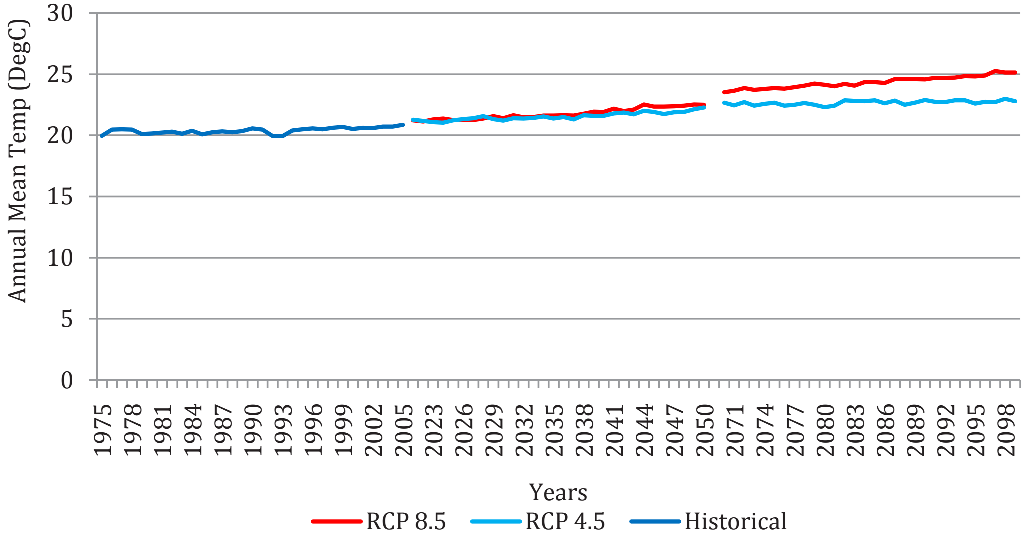

Figure 58 Changes in mean annual temperature under RCP 4.5 and RCP 8.5 (Southern Foothills)

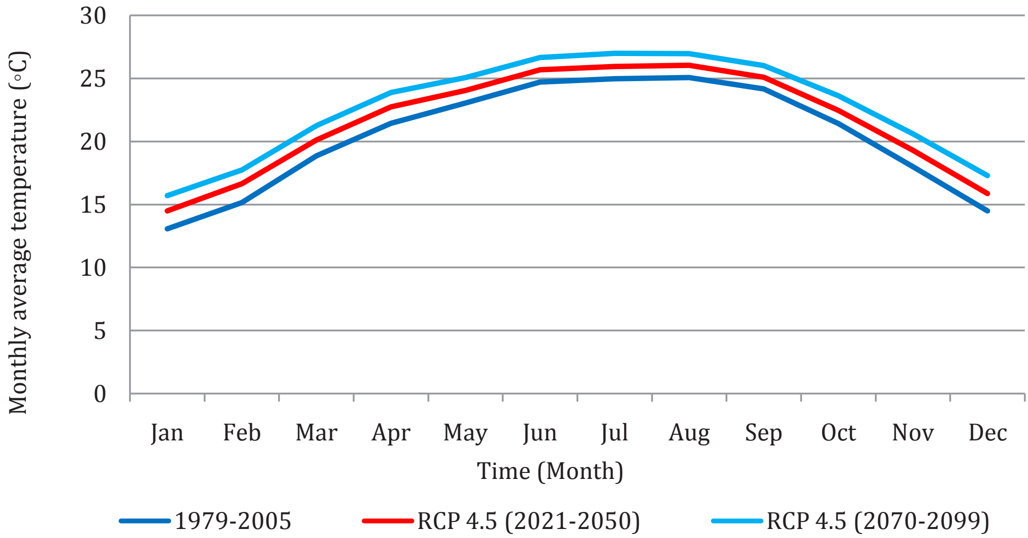

Figure 59 Monthly average temperature changes under RCP 4.5 (Southern Foothills)

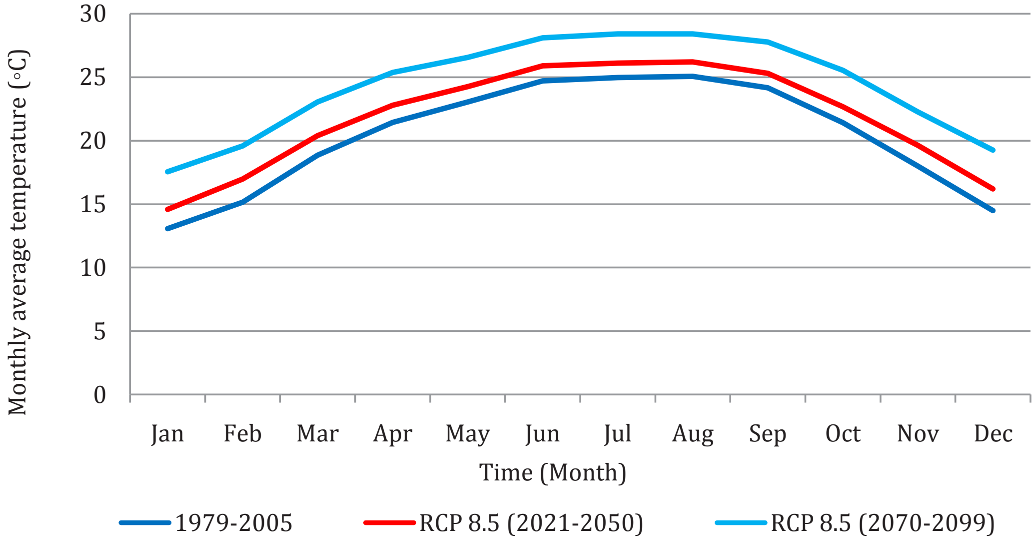

Figure 60 Monthly average temperature changes under RCP 8.5 (Southern Foothills)

The rainfall projection for this elevation zone shows an increasing trend of rainfall under both the RCPs. The winter season is projected to get drier and wet summer under both the RCPs. However, just as in the Inner Himalayan zone, the rainfall is projected to increase even during winter months under RCP4.5 for 2070-2099 periods. Nonetheless, it is not as clearly visible as the increase in summer precipitation in the graph. The rainfall projections for the southern foothills are shown in the Figure 61 to Figure 63.

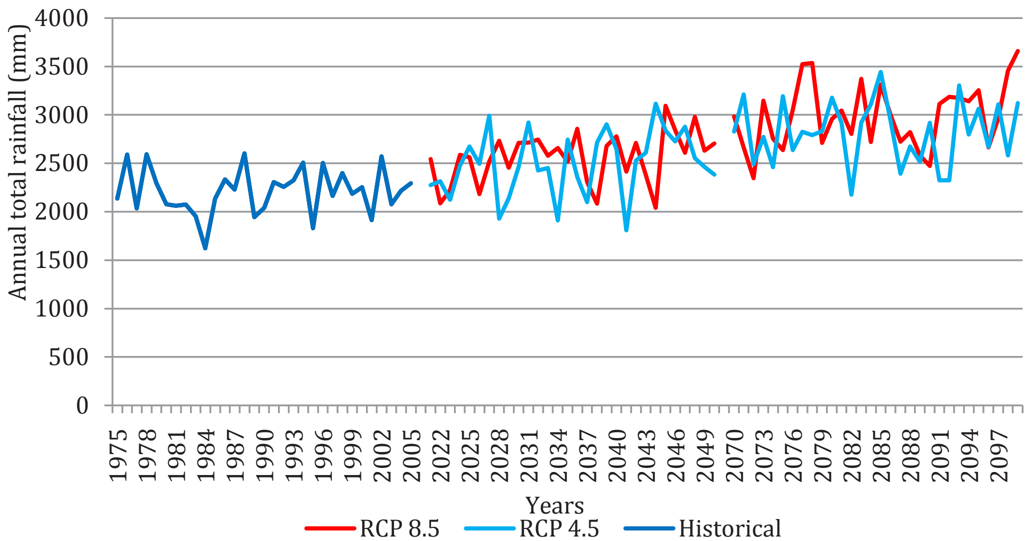

Figure 61 Changes in mean annual rainfall under RCP 4.5 and RCP 8.5 (Southern foothills)

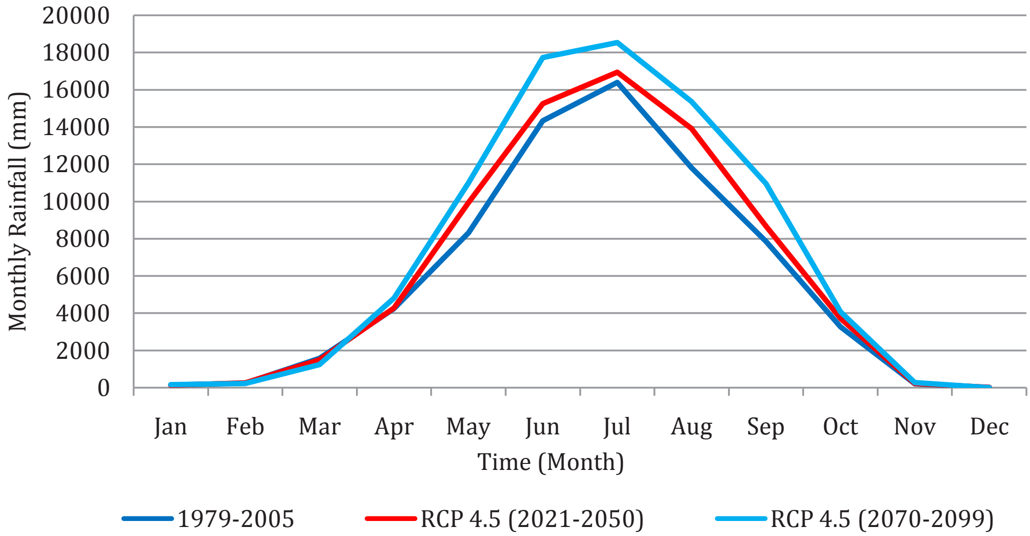

Figure 62 Monthly average rainfall changes under RCP 4.5 (Southern Foothills)

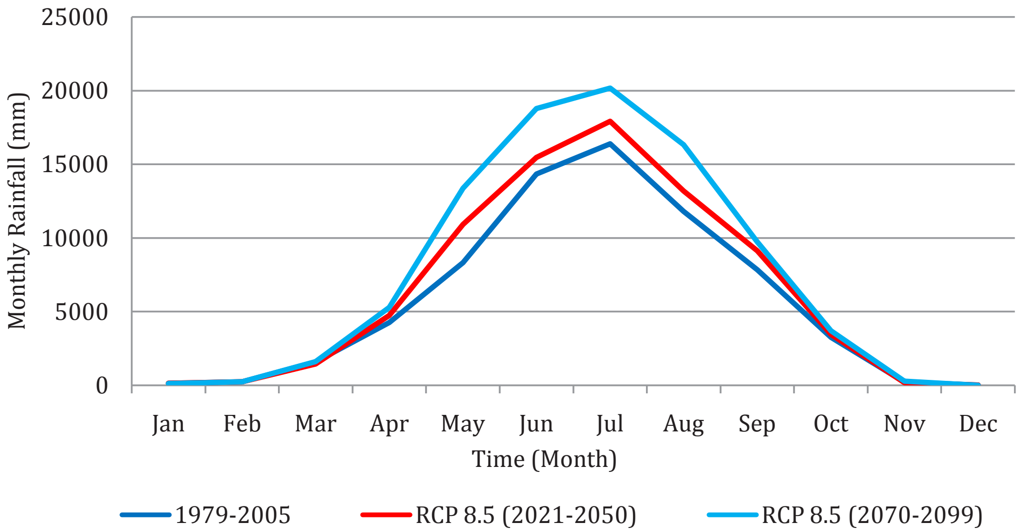

Figure 63 Monthly average rainfall changes under RCP 8.5 (Southern Foothills)

4.3 Water Resources

Bhutan has one of the highest per capita availability of water in the world with the total annual flow estimated to be around 70,576 MCM i.e., 94,500 m³/person per year, the highest in the region (ADB & NEC, 2016). Major water sources for Bhutan include lakes, wetlands, marshes, springs, streams, and rivers. High-altitude wetlands and glacial also contribute to the water sources. Bhutan has five main river basins namely Amochhu, Wangchhu, Punatsangchhu, Mangdechhu and Drangmechhu and about 3,182 rivers and rivulets (Figure 64).

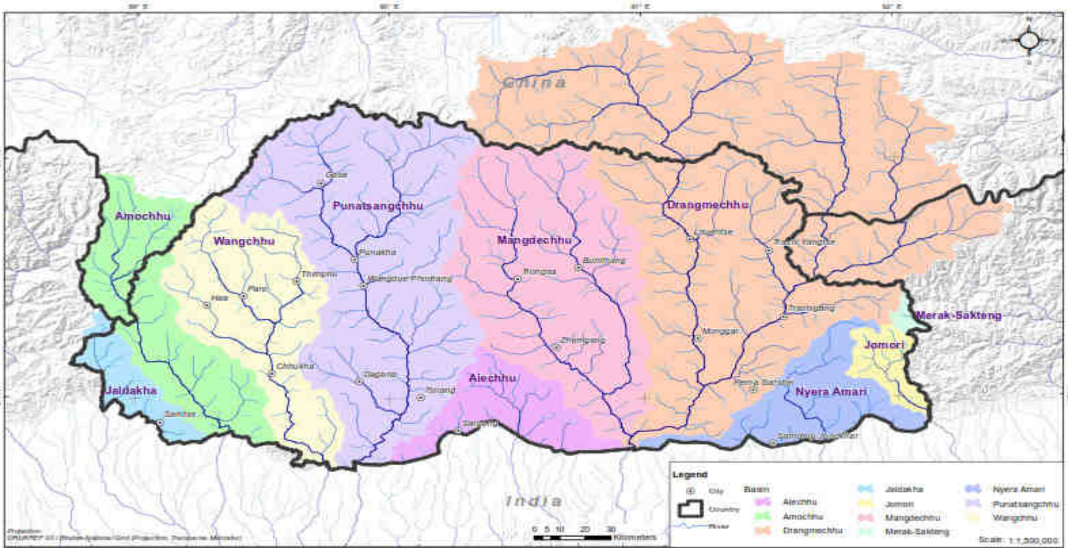

Figure 64 River Basins of Bhutan (NECS, 2016)

Despite having one of the highest per capita water availabilities, the general population faces difficulties in accessing water due to location of human settlements and farmlands occupying the upper slopes and hilltops.

4.3.1 Assessment of Water Resources Vulnerability

Hydrological models using HEC GeoHMS in Arc-GIS environment and HEC-HMS software were developed for the country's major river basins to project flow variability and changes under projected change in temperature and precipitation for future periods.

Generally, the model output indicates that average total annual flow in all the major river basins is projected to increase in both the future periods and scenarios.

Table 22 Percentage increase in Annual Flows

Basin	% Change in Annual Flows			
	RCP 4.5		RCP 8.5	
	2021-2050	2070-2100	2021-2050	2070-2100
Wangchhu Basin	8%	6%	9%	14%
Punatsangchhu Basin	5%	7%	12%	13%
Manas Basin	6%	8%	10%	15%

All river basins are projected to see the highest discharge in May, June and July (14 to 43%) for all the scenarios and time periods except for June in RCP 4.5 (2070 - 2100). Under the RCP 8.5 scenario, the monthly average flow shows an increase from January to November for both future time periods. However, December month flows are lesser in both scenarios. As evident from the results, the increases are concentrated more in the summer months, when the flow is relatively high, while the decreases are more apparent in the winter months. Hence, in the future, dry periods are expected to get drier. In contrast, wet periods are expected to get wetter, making the overall system more vulnerable to the impacts of climate change.

4.3.2 Vulnerability Assessment of Cryosphere

Glaciers in Bhutan generally occur from an elevation of 4075 meters, exhibiting a size distribution of low-altitude regions. According to the Bhutan Glacier Inventory 2018, Bhutan has 700 glaciers covering 629.55 Km^2 (NCHM, 2019). Among the basins, Wang Chhu Basin has the least number of glaciers (47 glaciers). In comparison, Punatsang Chhu has the highest number of glaciers (341 glaciers), which makes up approximately 48.71% of Bhutan's total glaciers (NCHM, 2019). Glacier change is a key indicator of climate change, and according to Ageta and Iwata (1999), glaciers in Bhutan like the Tarina Glacier retreated around 0.7 km (30 – 35 m) from 1967 to 1998. Raphstrang Glacier retreated about 0.5 km (35 m) during the 14-year interval while Luggye glacier retreated at a rate of 16 m from 1988 to 1993 (NCHM, 2019).

According to Reassessment of Potentially Dangerous Glacial Lakes (PDGL) in Bhutan, the study updated the PDGLs from 25 previously recorded to 17 as eight were deemed safe based on lake morphology, its surrounding features, bathymetry condition and associated feeding glacier (NCHM, 2019).

An assessment by ICIMOD, 2019 concluded that glaciers in the region are thinning and retreating, as observed over most regions since the 1970s. These trends are projected to persist in the future with larger increases in timing and magnitude of glacier melt runoff and glacier lake expansion. The study concludes that HKH region will lose one-third of the ice cover by the end of the century, even if the average global temperature is maintained below 1.5 degree Celsius.

The snow cover area for Bhutan estimated for the period 2002 to 2010 was 9,030 km^2, about 25.5% of the total land area (Gurung et al., 2011). The average snow cover area for winter was found to be around 14,485 sq. km (37.7%), for spring 7,411 km^2 (19.3%), for summer 4326 km^2 (11.2%), and for autumn 7,788 km^2 (20.2%), mostly distributed in the elevation range 2500–6000 masl. The total Snow Cover Area from 2002–2010 decreased by about –3.27 ± 1.28%. This decrease was seen at both annual and intra-annual scales at insignificant rates. The snow cover decline over the recent decade could result in a decline in a water resources availability in the long run.

4.3.3 Adaptation Options for Water Sector

As per projections, the overall volume of freshwater is expected to increase by mid-century and end of century. Given that, the main report summarizes a list of adaptation actions that could be carried out to protect water resources. The adaptation measures for the water sector should address the following issues:

- ***Drying water sources and spring decline:*** A large population depends on spring water for drinking and irrigation purposes. Thus, water availability is under threat with declining spring water. Comprehensive mapping of springs with geo-tagging and monitoring plan leading to watershed management planning, Community involvement in spring-shed management and protection, Capacity building of relevant departments and community leaders for spring monitoring and restoration, and development of manuals and guidelines on sustainable use of springs streams effectively are required to be developed.

- ***Water induced disasters:*** There is a likely increase in water-induced disasters as landslides, floods, GLOFs and flash floods affect lives, livelihoods, and infrastructure. Mapping of multi-hazard for Bhutan to prepare an action plan based on detailed multi-hazard zone mapping and relevant early warning systems and education are essential to be set up.
- ***Limited access to water resources:*** Limited water across Bhutan impacts lives, livelihood, health, and sanitation. The recommended measures to tackle this issue are developing Water Safety Plans and implementing proper water supply systems with adequate design. It should also be complemented with studying ground water use and its risks and potentials across Bhutan.
- ***Seasonal Water shortage:*** Seasonal water shortage for drinking, irrigation and hydropower generation is expected under a climate change scenario. The options to resolve the issues are to study the feasibility of storage reservoirs for seasonal storage, build multi-purpose storage reservoirs, and explore technologies for rainwater harvesting and efficient water usage and management.

4.4 Agriculture

Bhutan is predominantly an agricultural country, with majority of the population in rural areas depending on this sector (PHCB 2017). Currently, agriculture is practiced on 2.75% of the country's existing cultivated land (MoAF, 2017). As a mountainous country, most of the land is on steep slopes, prone to landslides and other erosions. The small agricultural landholding is further exposed to the vagaries of changing climate and its consequences.

Paddy and maize are the staple cultivated crops while other crops such as wheat, barley, millet, buckwheat, mustard and different types of vegetables are grown on a smaller scale. The main cash crops are potato, citrus, apple and cardamom. In addition to growing different crops, the farmers also rear livestock such as cattle for dairy, poultry mainly for eggs, horses and mules for transport. Few communities in the alpine zones depend solely on the rearing of Yaks.

4.4.1 Current Vulnerabilities of Agriculture Sector

The agriculture sector is vulnerable to change monsoon timing (onset/departure) and the quantity of rainfall. About 61% of dry arable land is rain-fed as there are no adequate irrigation facilities (LCMP, 2010; SYB, 2018).

According to the Ministry of Agriculture and Forests (MoAF,2016), an increase in temperature and irregular rainfall patterns has led to decreasing crop yield due to reduced agricultural water availability and crop loss to extreme events like flash floods, windstorms, pests and diseases outbreaks. Most villages across Bhutan are highly vulnerable to climate impacts and have low adaptive capacity. The factors contributing to the low adaptive capacity are their limited resource base and precarious socio-economic status, including labour shortages; poor grid and road connectivity; unstable dryland agriculture; crop disease and low-yielding seeds; and, increased risk and exposure to drought, unseasonal precipitation, and wind events (GNHC 2017). The impact gets elevated due to the dependence of Bhutan's agriculture on largely rain-fed crops in the dry land that mostly occur on steep slopes (MoAF, 2016).

4.4.2 Vulnerability Assessment: Crop suitability change under climate change scenarios

This assessment looked at how the crop suitability for Potato, Rice and Maize, in terms of the area available, will change under the projected climate change. The assessment uses the Eco-Crop model, developed by the International Center for Tropical Agriculture, in collaboration with the Biodiversity International and the International Potato Center. The model provides impacts of climate on the spatial extent of areas classified as climatically suitable for crops, between the "historical baseline" period (i.e., the present) and the future date (2050 and 2070) under two different RCPs (RCP 4.5 and RCP 8.5). However, this model is purely based on the temperature and precipitation and does not consider other factors such as elevation, slope, solar radiation and soil aspect. Such factors have not been included in this assessment due to the lack of reliable data on biophysical parameters. These are the main limitation of the assessment.

Agro-climatically, Bhutan is divided into six zones (Table 23). In the alpine zone and cool temperate zones, the farming system is dominated by yaks, cattle, sheep and horses, dairy products, barley, wheat and potatoes on dry land, buckwheat and mustard under shifting cultivation; and cultivation of temperate fruits and vegetables. Crop production, such as rice and maize, are concentrated from warm temperate to wet sub-tropical zones.

Table 23 Agro-ecological zones of Bhutan, Source: MOAF, 2018.

Agro-ecological zone	Altitude (m)	Temperature ^{o}C			Rainfall (mm)
		Max	Min	Mean	
Alpine	>3500	12	-1	5.5	<650
Cool temperate	2500 – 3500	22	1	10	650 – 850
Warm temperate	1800- 2500	26	1	13	650 – 850
Dry sub-tropical	1200 – 1800	29	3	17	850 – 1200
Humid sub-tropical	600 – 1200	33	5	20	1200 – 1500
Wet sub-tropical	150 – 600	35	12	24	2500 - 5500

4.4.3 Potato Suitability

Under the future scenario of RCP 8.5 for 2050, areas that have currently suitable conditions become "no longer suitable" using the threshold of 50%, as shown in (Figure 65 – 68). It reveals that lower altitude areas in the south (<1,000 m) become unsuitable, driven by increasing temperatures, while the mid-latitude areas (1,000–3,000 m) experience expansion in suitable areas. This is notable in both RCP 8.5 and, to a lesser extent, in RCP 4.5. The high-elevation areas (>3,000 m) remain largely climatically unsuitable for potato.

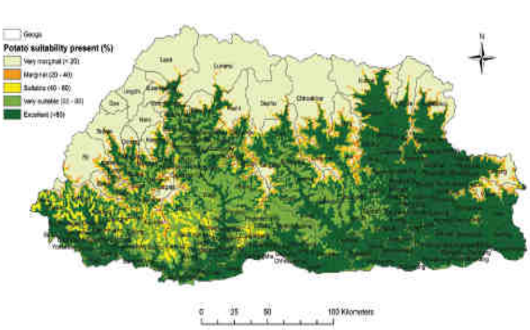

Figure 65 Potato suitability area under present condition

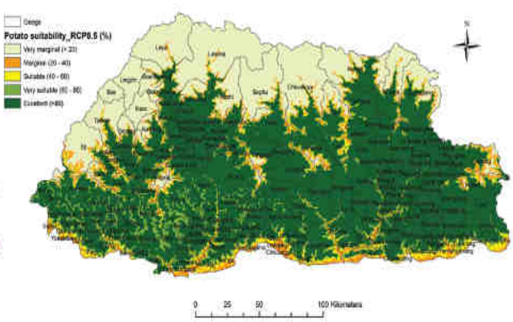

Figure 66 Potato suitability area under future condition RCP 8.5 ensemble

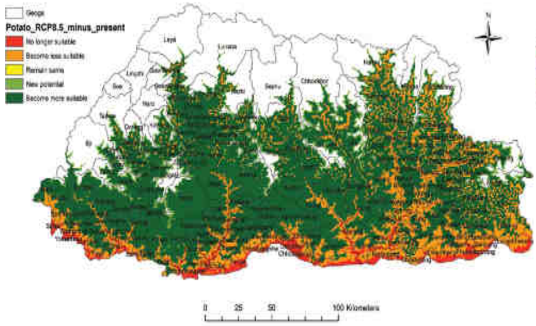

Figure 67 Change in potato suitability area under RCP 8.5 ensemble compared to present condition using threshold of 50%

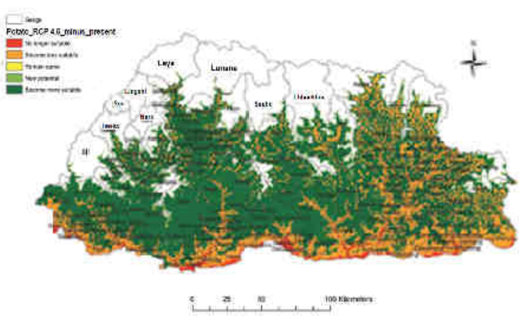

Figure 68 Change in Potato suitability area under RCP 4.5 ensemble compared to present condition using threshold of 50%

4.4.4 Rice suitability

Rice suitability under present and future scenarios were developed using the Eco-Crop model. The Eco-Crop model assesses the suitability of the crop based on the crop's precipitation and temperature requirements. The Eco-Crop model was first run for current conditions and then for future conditions (2050 and 2070), using the mean of the GCMs calculated for RCP 4.5 and RCP 8.5. The output from Eco-Crop was then imported to ArcGiS for further analysis. The same methodology was used for maize.

Table 24 parameters used for the rice crop modelling in EcoCrop

Crop	Growing season min	Growing season max	Temp killing	Temp min	Temp min optimum	Temp max optimum	Temp max	Rainfall min	Rainfall min optimum	Rainfall max optimum	Rainfall max
Rice	120	240	0	100	200	300	400	300	800	1200	1800

Bhutan will gain suitable rice production areas under both RCP 4.5 and RCP 8.5 for 2050 and under and will lose areas in 2070 under both RCPs (Table 24), which is about 48 km^2 (3%). The highest gain in suitable areas for rice production will be under RCP 8.5 2050, which is about 222 km^2 (14%).

Table 25 Predicted changes in rice suitability area (km^2) under different climate scenarios

Suitability class	Current suitability (km^2)	Future suitability (km^2)			
		RC4.5 2050	RCP8.5 2050	RCP4.5 2070	RCP8.5 2070
Excellent	44.9352	225.8467	252.1755	227.0494	0.0000
Very suitable	175.5201	224.5217	247.6689	225.3310	16.0867
Suitable	240.6473	361.9595	426.7748	361.6478	205.1861
Marginal	438.8198	602.5661	590.2910	602.8261	712.5624
Very marginal	698.1266	326.1460	303.2684	324.4936	615.7845
Total	**1598.0490**	**1741.0400**	**1820.1787**	**1741.3479**	**1549.6198**
	Loss/Gain (km2)	-142.9910	-222.1296	-143.2988	48.4293
	Loss/Gain (%)	-8.95	-13.90	-8.97	3.03
	Remarks	Gain	Gain	Gain	Loss

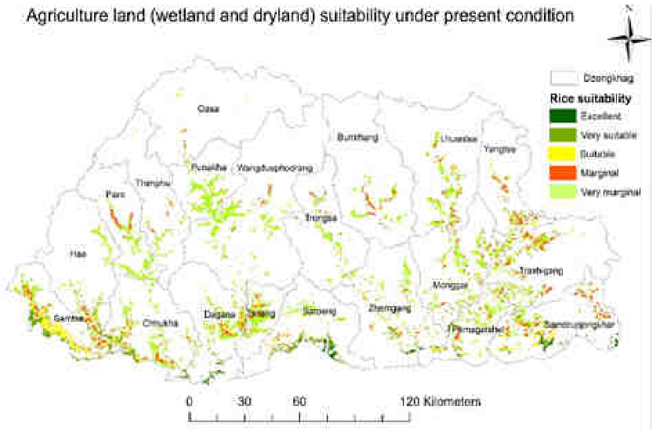

Figure 69 Rice suitability under present conditions

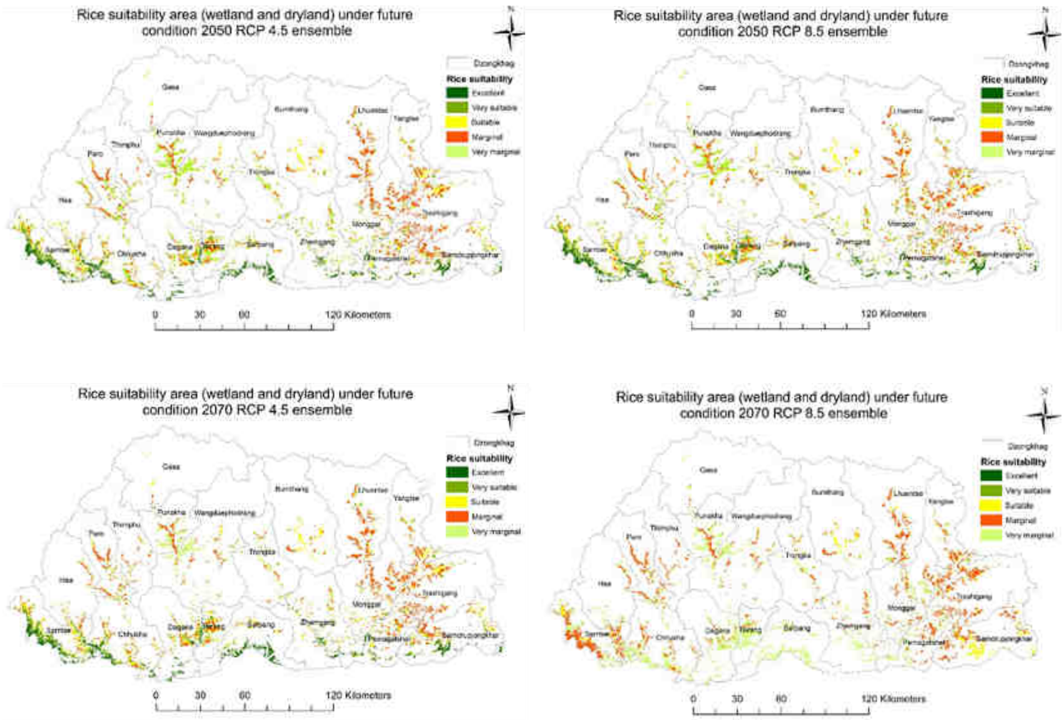

Figure 70 Rice suitability under RCP4.5 2050, RCP 8.5 2050, RCP 4.5 2070 and RCP 8.5 2070.

4.4.5 Maize suitability

Bhutan will lose maize suitability areas under all the scenarios. However, the loss is not significant, ranging only from 0.04 - 3.43%. The highest area loss is about 53.35 km^2 (3.43%) under RCP 4.5, 2070 (Table 26).

Table 26 parameters used in modelling in EcoCrop

Gmin	Gmax	Tkmp	Tmin	Topmin	Topmax	Tmax	Rmin	Ropmin	Ropmax	Rmax
100	200	0	100	200	300	320	300	800	1200	1800

Table 27 Predicted changes in rice suitability area (km2) under different climate scenarios

Suitability class		Current suitability (km^2)	Future suitability (km^2)		
		RCP 4.5 2050	RCP 8.5 2050	RCP 4.5 2070	RCP 8.5 2070
Excellent	20.1273	87.1498	97.7240	21.1294	87.0778
Very suitable	159.4098	340.9589	360.6920	113.1919	340.4237
Suitable	384.6909	688.7019	692.2178	501.4860	689.7685
Marginal	667.6407	394.2012	366.2368	702.0739	393.9592
Very marginal	321.7690	34.0022	36.2174	162.4111	34.3872
Total	**1553.6377**	**1545.0140**	**1553.0880**	**1500.2924**	**1545.6164**
	Loss/Gain (km2)	8.6237	0.5497	53.3453	8.0213
	Loss/Gain (%)	0.56	0.04	3.43	0.52
	Remarks	Loss	Loss	Loss	Loss

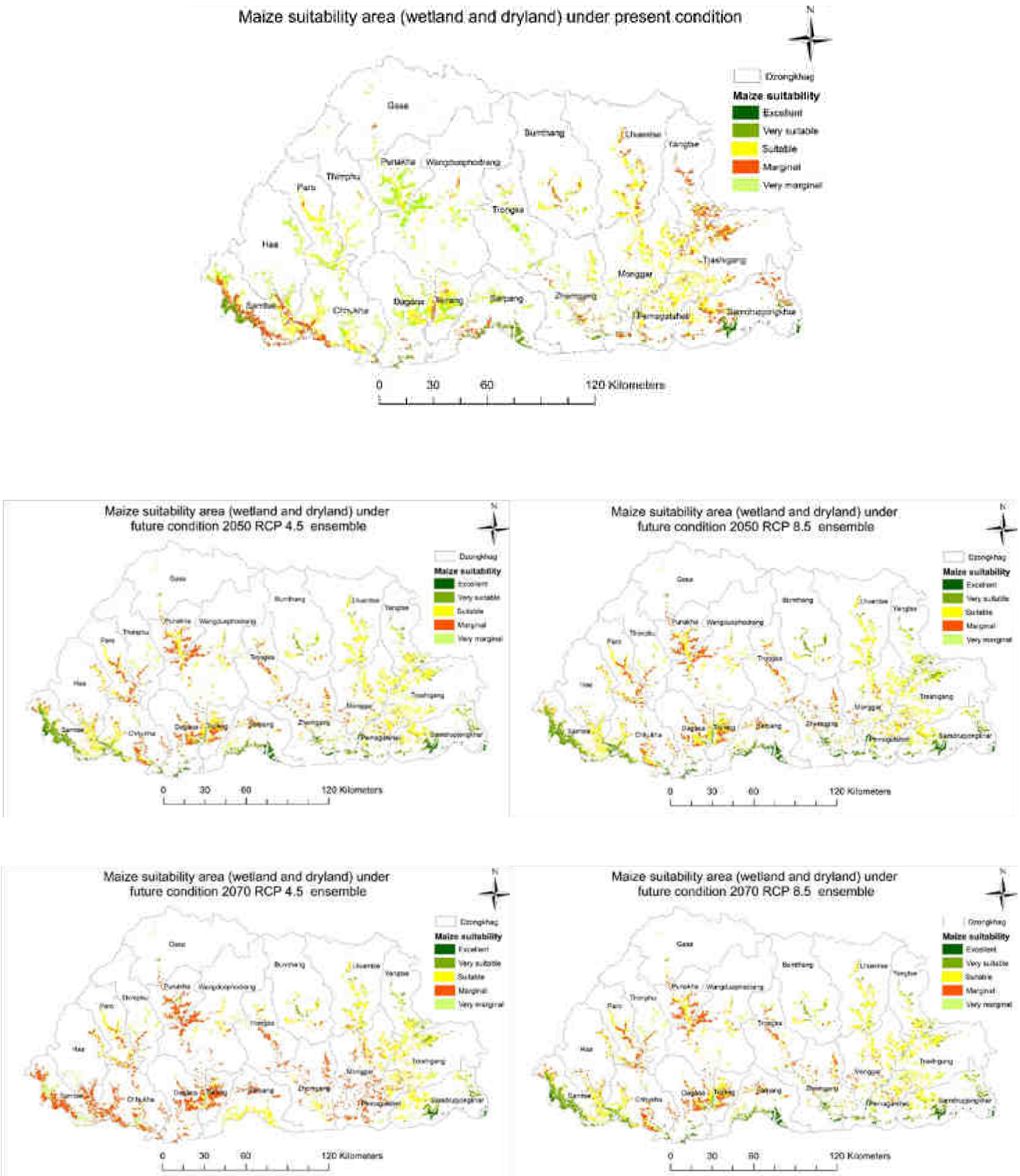

Figure 72 Maize suitability under RCP4.5 2050, RCP8.5 2050, RCP 4.5 2070 and RCP 8.5 2070.

4.4.6 Adaptation Options for Agriculture Sector

The main constraints faced in the agriculture sector are localized water scarcity and drying of water sources, wildlife predation of crops, outbreak of pests and diseases, poor mountainous shallow soils that is further worsened by increasing soil loss through surface erosion and scarcity of farm labour. Adaptation options is listed under Annexure. The summary of adaptation options for the agriculture sector are:

- **Water Shortage:** It is projected that climate change shall render dry areas more dry and wet areas wetter. Many field crops and crop areas in river-dependent irrigated areas will reduce significantly in dry season. Only 18% of arable wetland land, mostly for rice cultivation, are irrigated, while 61% of dryland remain without irrigation facilities. A majority of the 1307 existing irrigation schemes are open canal gravity fed systems. Such open systems have a conveyance efficiency of only about 30 – 40% and remain prone to significant water loss through seepage and evaporation. Programs on water harvesting, efficient conveyance system, water storage structures, use of groundwater, and modern irrigation technologies (drip, sprinkler) are infantile. Therefore, there is a need to conduct detail assessment including proper planning and implementation of irrigation system taking into consideration impacts of climate change; innovative storage and pumping facilities; strengthening data base/inventory on water resources and building capacity.
- **Human Wildlife Conflict:** Decreased crop and livestock depredation by wild animals is a challenge in rural communities across the country. While this is not a direct climate change issue, it is closely linked with impacts of climate change, such as animal and plant migration, yield change/ decrease, etc. Proper planning, capacity building, research and data inventory on animal migration and improved capacity in handling HWC are necessary to handle the situation.
- **Soil Erosion:** As most of smallholder farmlands occur on slopping lands, fertile top soils are frequently lost to soil erosion. Sustainable Land Management (SLM) techniques and practices needs to be applied as adaptation measures.
- **Alternate Crop Production:** Further research on the criteria for adoption of new crops in Bhutan is required. Crops such as quinoa showed suitability under current climatic and biophysical conditions, but farmers do not grow them. This might be due to cultural preferences in diets, lack of awareness, lack of technical skills and knowledge on cultivation, access to markets, or seed challenges which need to be further investigated before investment. Site-specific studies and options need to be identified as well.
- **Marketing and Storage:** Currently, agricultural products do not fetch good prices and lack efficient storage techniques and technologies. Thus, it is necessary to improve post-harvest storage and preparation. This could be undertaken through farmer schools, where farmers with a good understanding of post-harvest technology and techniques could share their experiences. Inculcating the concepts in School Agriculture Program is also an option.
- **Pests and Diseases**: Newer pests and diseases, along with their changing resilience, are huge risks to the agriculture and livestock sector. Developing and applying varieties of both crops and animals that are resilient to climate change, including pests and diseases, are necessary. Exploring and continued dependence on native livestock breeds

that have been able to cope with natural changes over the years instead of only depending on improved varieties is an alternative.

- **Extreme events:** Harsh unprecedented weather conditions, such as heat and cold waves, poses risks to both crops and livestock. Pasture development and providing proper shelters for animals in both hot and cold regions are also necessary to protect them from harsh climatic conditions.
- **Livestock Risks:** There is no study conducted on risk of livestock to varying climate conditions so far and needs to be considered.

4.5 Forest and Biodiversity

The Constitution of the Kingdom of Bhutan mandates a minimum of 60% of its total land area under forest cover in perpetuity. Currently, (51.4%) of the total land area is under protected areas, parks and biological corridors. The total forest cover of Bhutan is 71%, with 11 forest types ranging from 200 meters to 4,600 meters and diversity, which includes more than 5,600 species of plants, nearly 700 species of birds, and about 200 species of mammals (NBC, 2014). Climate change affects the forest and biodiversity of the country, causing more droughts and forest fires, loss of plants and animal species, and changes in the state of some ecosystems.

4.5.1 Threat to forest and biodiversity resources

Although Bhutan is endowed with rich biodiversity and mostly pristine forests, there are environmental issues that require timely interventions. The State of Environment Report (NECS 2016) and other publications have identified forest fire, pest and diseases, loss of biodiversity, invasion of alien species, alteration in ecosystem composition as threats to biodiversity driven by climate change.

4.5.2 Current vulnerabilities of forest and biodiversity sector

Maximum entropy distribution modelling (Maxent) was used to assess the potential impact of climate change to forest types by the year 2050 and 2070 under RCP 4.5 and RCP 8.5. This model is applied to broadleaf, mixed conifer, blue pine, fir, and chir pine. The forest types are classified based on the Land Use and Land Cover (LULC) map of Bhutan 2016.

Out of five forest types used in this study, Chir pine forest exhibited major potential gain in an area with a suitable climate under future climate change scenarios while remaining forest types are likely to experience a considerable decline. Several factors like anthropogenic land cover changes, dispersal limitation, pest and diseases, biotic interaction, migration, and disturbances such as forest fires are not included in the current model. Studies in central Himalaya indicated that gain in Chir pine forest would encroach and displace oak forest, which is an undesirable phenomenon. The gain in Chir pine forest area and their redistribution could contribute to water resource depletion. Further, gain in Chir pine forest will expose forests to increased incidences of fire damage and reduce floral diversity due to poor soil nutrients.

Despite the scope and limitations discussed in the preceding section, findings can contribute towards providing some useful information on the potential impacts of future climate change on forest types of Bhutan.

4.5.3 Blue pine forest

Currently, Blue pines are generally found at an elevation between 1500 m and 3200 masl. The majority of the Blue pine forest is in Bumthang, Paro, Thimphu and Haa dzongkhags.

The model projects that blue pine forest is likely to reduce under both projected climate scenarios for the year 2050 and 2070 (mean AUC = 0.946). Maximum and minimum loss of suitable climate area for Blue pine is predicted for the year 2070 under RCP 4.5 and RCP 8.5, respectively (Table 28). With RCP 4.5, the south-western region is predicted to gain a suitable climate for the growth of the blue pine forest. However, in the case of RCP 8.5, the eastern region is predicted to have a more favorable climate for Blue pine. Additionally, Blue pine forest is likely to experience a range shift toward a relatively higher elevation except for RCP 8.5 (2050). Further, the south-western part of the country is predicted to gain a suitable climate for the growth of Blue pine forest under RCP 4.5 for the years 2050 and 2070, while with RCP 8.5, it is likely to shift towards eastern region. See the table and maps below.

Table 28 Predicted changes that Blue pine forest is likely to experience under different climate scenarios.

Period	Climate Scenarios	Change in forest cover (%)	Avg. elevation (m)	Shift in elevation [predicted avg. elevation - current elevation] (m)
Current	Current	0.00	2895.53	0.00
2050	RCP4.5	-79.94	2515.57	-379.96
	RCP8.5	-66.24	2407.50	-488.03
2070	RCP4.5	-85.34	2520.84	-374.69
	RCP8.5	-50.82	2577.87	-317.66

Note: In terms of suitable area () denotes gain and (-) denotes loss in comparison to area under current climate scenario. In terms of range shift (-) denotes shift towards higher elevation and (+) denotes shift towards lower elevation in comparison to current average elevation

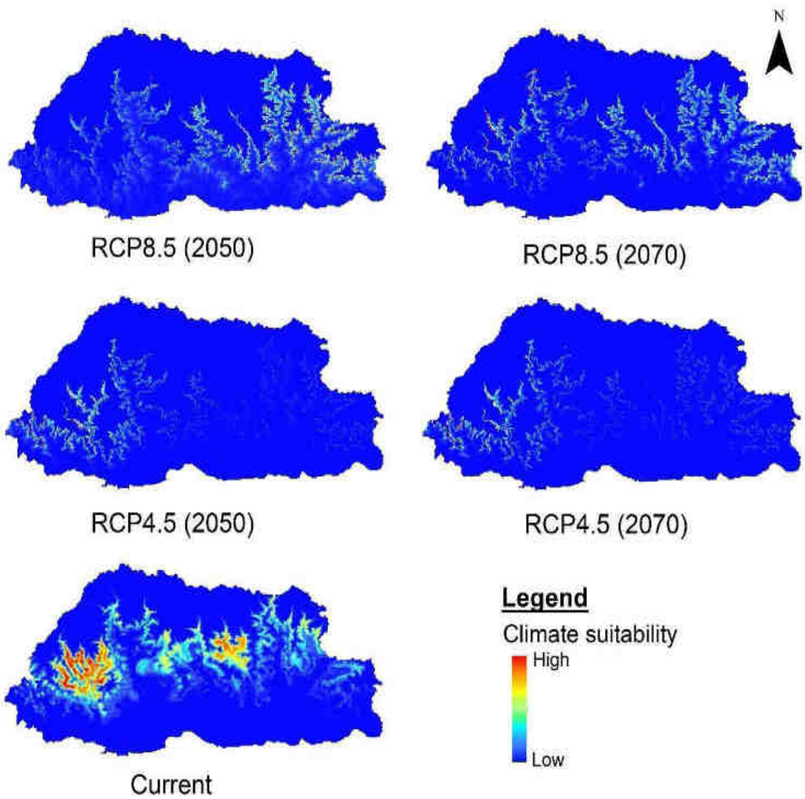

Figure 73 Model Predicting the Potential Impacts of climate change to Blue Pine Forest

4.5.4 Chir pine forest

In Bhutan, Chir pine forest is dominant in Wangdue Phodrang, Mongar, Tashigang, Punakha and Lhuentse Dzongkhags. It occurs at an elevation between 700m to 2000 masl at relatively dry areas. The model predicts that Bhutan is likely to gain a suitable climate area for Chir pine forest with both the climate scenarios for the year 2050 and 2070 (mean AUC =0.951). A shift in the range of Chir pine forest to relative higher elevation is predicted with RCP 8.5 (2070). Meanwhile, a downward shift is predicted for the rest of the other climate scenarios (Table 29). With climate change, suitable climate for Chir pine is predicted to occur in the central parts (central belt across east to west) of Bhutan.

Table 29 Predicted changes that Chir pine forest is likely to experience under different climate scenarios.

Period	Climate Scenarios	Change in forest cover (%)	Avg. elevation(m)	Shift in elevation [predicted avg. elevation - current elevation] (m)
Current	Current	0.00	1438.75	0.00
2050	RCP4.5	214.38	2365.70	926.95
	RCP8.5	325.71	2611.74	1172.99
2070	RCP4.5	343.92	2609.46	1170.71
	RCP8.5	330.77	2791.87	1353.12

Note: In terms of suitable area (+) denotes gain and (-) denotes loss in comparison to area under current climate scenario. In terms of range shift (+) denotes shift towards higher elevation and (-) denotes shift towards lower elevation in comparison to current average elevation

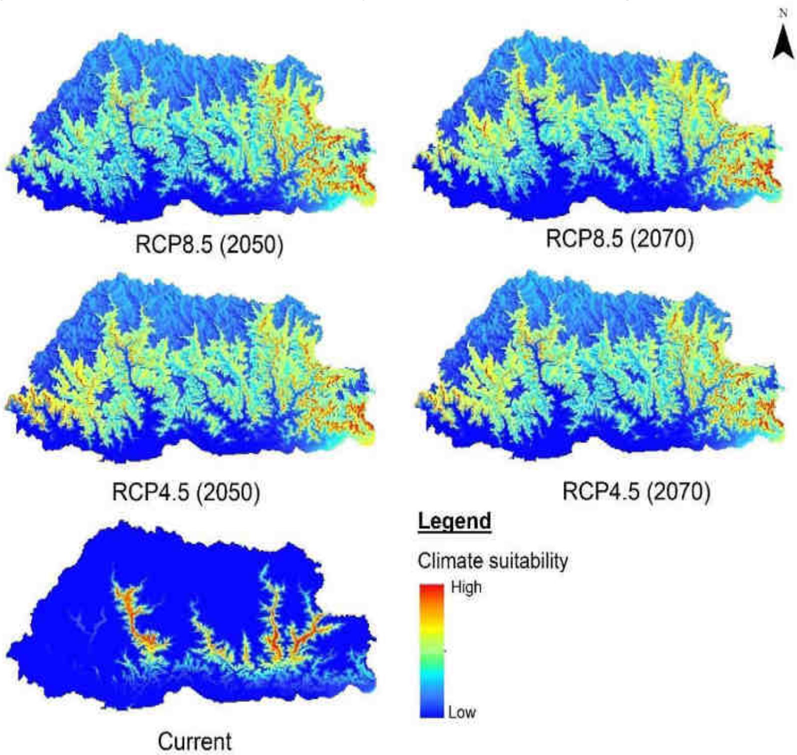

Figure 74 Model Predicting the Potential Impacts of Climate Change on Chir Pine Forests.

Gain in Chir pine is observed in most of the areas but more pronounced in central regions like Bumthang, Trongsa and Zhemgang.

4.5.5 Broadleaf forest

The Broadleaf is the most dominant forest type in Bhutan. It occurs throughout the southern belt to inner parts of central Bhutan up to an elevation of 3000 m.

With climate change it is also predicted that the broadleaf forest is likely to migrate (range shift) toward relatively higher elevation with all the climate scenarios. The maximum shift in elevation is predicted under RCP 8.5 for 2050 and 2070 (Table 30). Climate from central towards eastern Bhutan is predicted to become suitable for the growth of broadleaf forests with future climate change. However, the Model's performance was comparatively weak (mean AUC = 0.728) for the Broadleaf forest.

Table 30 Predicted changes that broadleaf forest is likely to experience under different climate scenarios.

Period	Climate Scenarios	Change in forest (%)	Avg. elevation (m)
Current	Current	0.00	1947.57
2050	RCP4.5	-30.35	2310.00
	RCP8.5	-29.04	2347.89
2070	RCP4.5	-29.63	2180.14
	RCP8.5	-25.91	2426.88

Note: In terms of suitable area (+) denotes gain and (-) denotes loss in comparison to area under current climate scenario. In terms of range shift (+) denotes shift towards higher elevation and (-) denotes shift towards lower elevation in comparison to current average elevation

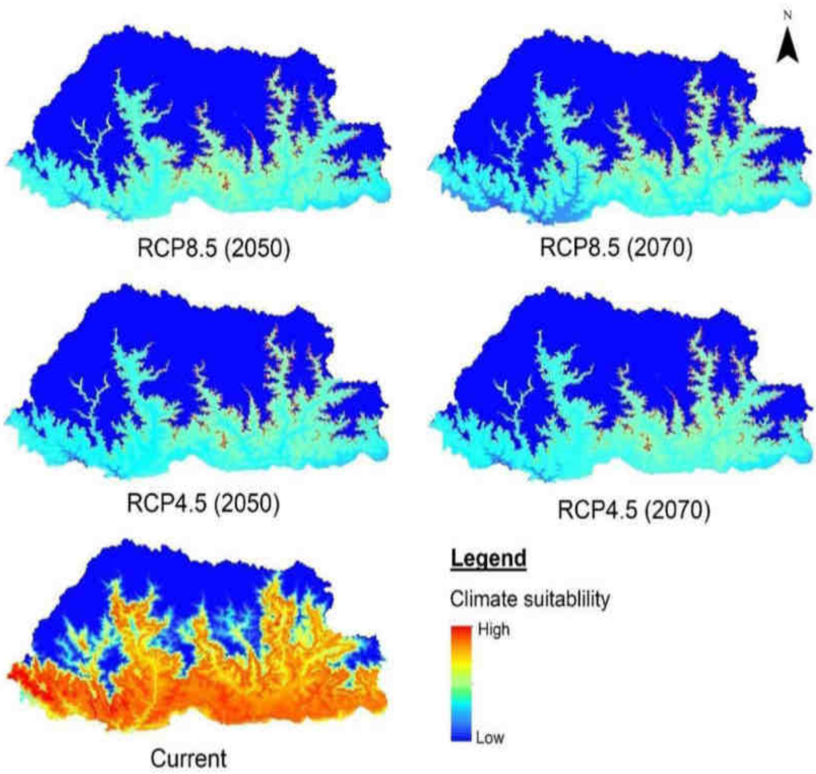

Figure 75 Model Predicting the Potential Impacts of Climate Change on Broad-leaf Forests

4.5.6 Mixed conifer forest

Mixed conifer forest is the second dominant forest type found in Bhutan next to Broadleaf. Generally, it occurs within the elevation range of 2500 m to 3500 masl, spread across the central belt of the country right from Trashigang in the east to Haa in the west. It is widely observed in the regions of Wangdue Phodrang, Bumthang, Trongsa and Lhuentse.

The model prediction suggests that area with suitable climate for Mixed conifer forest is likely to reduce by approximately 87% and 86% under RCP 4.5 and RCP 8.5 respectively for both the year 2050 and 2070 (mean AUC = 0.873). Under RCP 4.5 (2050) and RCP 8.5 (2070), it is predicted that Mixed conifer will likely experience a range shift towards a relatively higher elevation and vice versa with RCP 8.5 (2050) and RCP 4.5 (2070) (Table 31). With future climate change, the country's northern belt is predicted to have suitable climate for the growth of mixed conifer forest.

Table 31 Predicted changes that mixed conifer forest is likely to experience under different climate scenarios.

Period	Climate Scenarios	Change in forest cover(%)	Avg. elevation(m)
Current	Current	0.00	3321.06
2050	RCP4.5	-86.80	3738.87
	RCP8.5	-85.97	3841.68
2070	RCP4.5	-85.99	3956.63
	RCP8.5	-86.86	3811.73

Note: In terms of suitable area (+) denotes gain and (-) denotes loss in comparison to area under current climate scenario. In terms of range shift (+) denotes shift towards higher elevation and (-) denotes shift towards lower elevation in comparison to current average elevation.

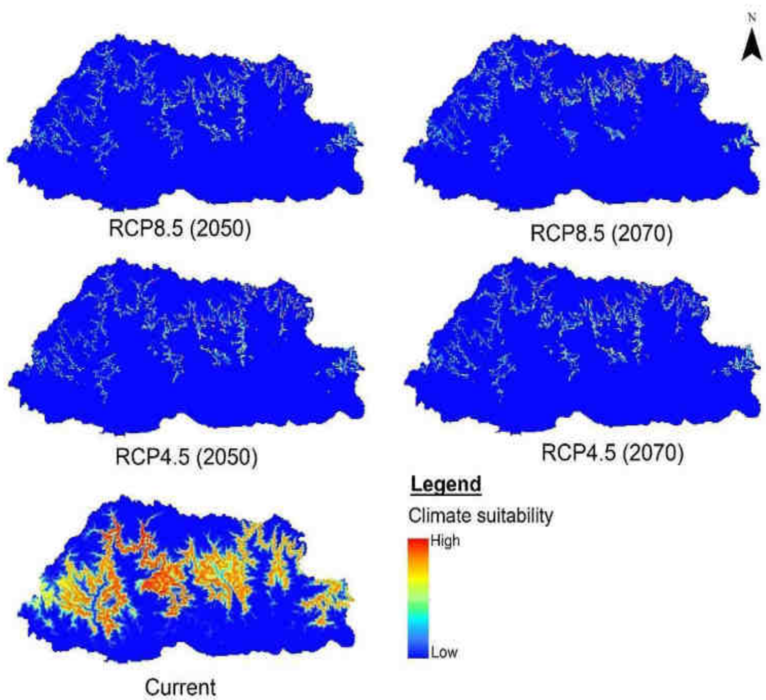

Figure 76 Model predicting the potential impact of climate change to Mixed conifer forest with different climate scenarios

4.5.7 Fir forest

In Bhutan, this type of forest occurs above 3000 masl and is dominant in the region of Bumthang, Wangdue Phodrang, Gasa, Trashigang, Lhuentse and Haa. The Model predicted loss in area with suitable climate for Fir up to 38% and 48% by the year 2050 and 2070, respectively (mean AUC=0.905). With RCP 8.5 (2070), Fir forest is predicted to migrate (range shift) towards relatively higher elevation while migration towards lower elevation is predicted in all the climate scenarios (Table 32). The climate in the north-western region of the country is predicted to be suitable for the growth of Fir forest under future climate change scenarios.

Table 32 Predicted changes that Fir forest is likely to experience under different climate scenarios.

Period	Climate Scenarios	Change in forest cover (%)	Avg. elevation(m)
Current	Current	0.00	3823.83
2050	RCP4.5	-31.33	4402.76
	RCP8.5	-38.79	4328.24
2070	RCP4.5	-33.88	4380.34
	RCP8.5	-47.42	4599.43

Note: In terms of suitable area (+) denotes gain and (-) denotes loss in comparison to area under current climate scenario. In terms of range shift (+) denotes shift towards higher elevation and (-) denotes shift towards lower elevation in comparison to current average elevation

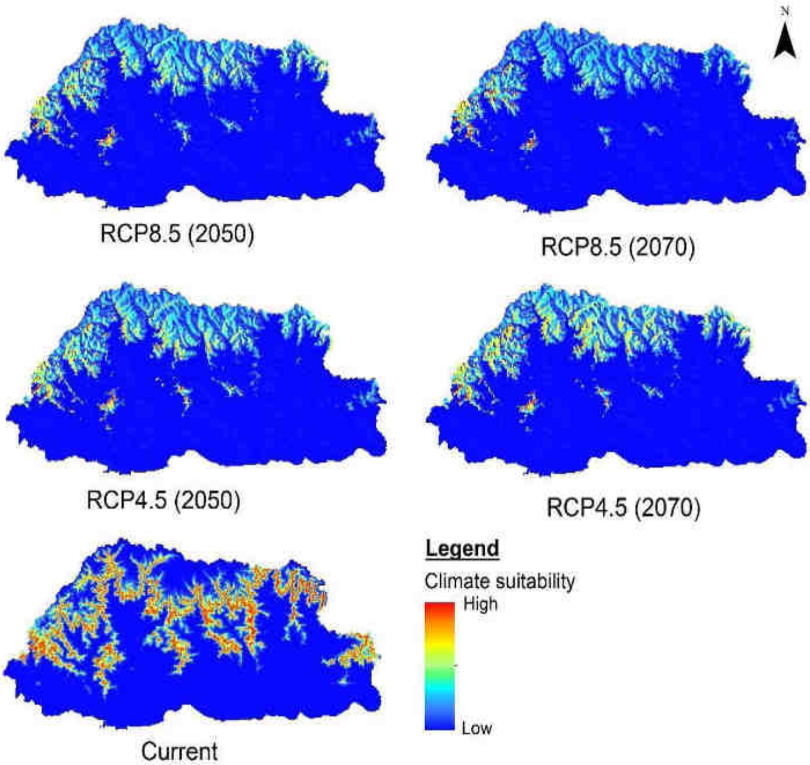

Figure 77 Model predicting the potential impact of climate change to Fir forest with different climate scenarios

4.5.8 Adaptation options for forests and biodiversity

The adaptation options for forest and biodiversity should address the following issues:

- ***Pest and diseases:*** Damages by pests and diseases will have the most immediate and possibly significant impact of climate change on the forest. This is because insects are ectothermic and change in temperature will directly influence their metabolic rate, consumption, development, survival, dispersal, and their destructive potential. Interaction between plant and insects are also dependent on the availability of water. Therefore, an in-depth understanding of the association between climate and forest pests and diseases. Their monitoring is important to enabling relevant authorities to expect, prepare and respond to change in pest behaviors, outbreak, and invasion.
- ***Data gaps and monitoring stations***: Due to the lack of high resolution spatial and insufficient monitoring stations limits temporal data. Therefore, the establishment of sufficient permanent monitoring plots in different forest types across the country is recommended.
- ***Forest fire***: Forest functions as an important carbon sink in the face of global climate change. However, an intense forest fire can potentially reverse this benefit by turning forest from sink to major source. The intensity, size and frequency of forest fires are expected to change as the temperature rise and precipitation pattern changes. Many aspects of post forest fire conditions will accelerate other natural environmental disturbances, resulting in modified vegetation patterns, land degradation, desertification, and hydrological cycle derangement.
- ***Invasion of alien species:*** As it is observed that both mean and annual temperature are increasing, exposure to high temperature for a very long time will affect forest flora and fauna inducing changes in forest biodiversity. Intrusion of agriculture farming into forests land is already occurring that will bring invasive weeds and alien species. This shift in mixtures of natural and domesticated plants and biodiversity would require a strong land use policy and measures to protect key biodiversity area.
- ***Deforestation:*** The detailed adaptation strategies for the Forest and Biodiversity sector are in Annexure.

4.6 Energy Sector

At present, the primary sources of energy are hydropower, refined petroleum products, solid fossil fuels (i.e., coal), and biomass. All petroleum products (kerosene, diesel, petrol and liquefied propane gas, aviation turbine fuel) are imported for lighting, transportation, cooking and heating purposes (Uddin, Taplin, & Yu, 2007). Currently, hydropower is the main resource for electricity generation in Bhutan and biomass caters to most of the residential energy demands, such as cooking and space heating, in the form of fuelwood, especially in the rural areas (Ministry of Economic Affairs, 2015).

In the last decade, Bhutan witnessed a major shift from dependency on biomass (mainly fuelwood) to electricity due to a significant increase in electrification. This trend of increased dependence on electricity in the future is expected to rise. The heavy reliance on energy for social and economic development with the main source from natural resources, mainly water, rivers and forest cover are a major issue with the challenges brought about by climate change. Bhutan is fortunate to have abundant water in terms of per-capita availability, which is positive in terms of the reliance on the energy source. However, hydropower is highly sensitive to climate change.

As energy security is closely associated with the basic needs and key economic sector, it has become a priority to plan energy sources as adaptation initiatives. The main measures are to use other renewable energy sources for diverse energy, which may have positive strategic consequences on security of energy supply; lean flow energy generation through storage systems; and storage of water in isolated valleys and high-altitude lakes. Different types of energy sources used in Bhutan are identified with risks and various adaptation options.

The Energy sector is one of the highest contributing sectors to the country's GDP. Bhutan is rich in natural resources from which energy can be harnessed. Fast-flowing rivers, thick forest cover, high solar radiation and wind systems are some of the natural resources that could be used as potential sources of energy. Mineral resources like coal are used in some industries for production purposes as Bhutan has small deposits in the South-East part of the country.

4.6.1 Vulnerability assessment for Energy sector

As Bhutan is highly dependent on hydropower, the assessment for vulnerability is carried out for hydropower by providing information on the flow of some of the major river basins and potential impacts of future climate change on their flow.

Bhutan has a high potential of generating electricity, which is as much as 30,000 Megawatts of hydropower potential. However, the current total installed electricity-generating capacity in Bhutan as of 2019 is approximately 2,335 MW, with few major projects under construction.

The hydropower sector depends on the flow of the rivers, making it more susceptible to the impacts of climate change. The impacts of climate change on hydropower are demonstrated in the form of changes in flow, volume, inter-annual variability in the timing of flow. Heavy and erratic rainfalls during the monsoon, and drier periods in the winter, cause greater variance in total volumes between two consecutive years. Furthermore, it is expected that under a warmer and more variable climate, the onset of monsoons will be erratic, which will cause disruptions in natural cycles affecting hydropower generation. With the increase of frequency of heavy monsoon rains, flash floods and landslides are expected to occur, which may cause damage to infrastructure, power distribution, and eventually, the economy of the country.

For future projection, three major river basins were assessed using HEC HMS hydrological model under RCP 4.5 and RCP 8.5. The result suggests that overall, the flow is going to increase across all assessed basins, as shown in Figure 78.

However, the increase in flow would be during the monsoon, and either a slight increase or decrease would be during the dry months. This is going to have an adverse impact as the higher flow in the monsoon would only spillover, and the lean season flow generation would not be positive or even become worse. The details of the average change in flow for the three river basins are shown in Table 33.

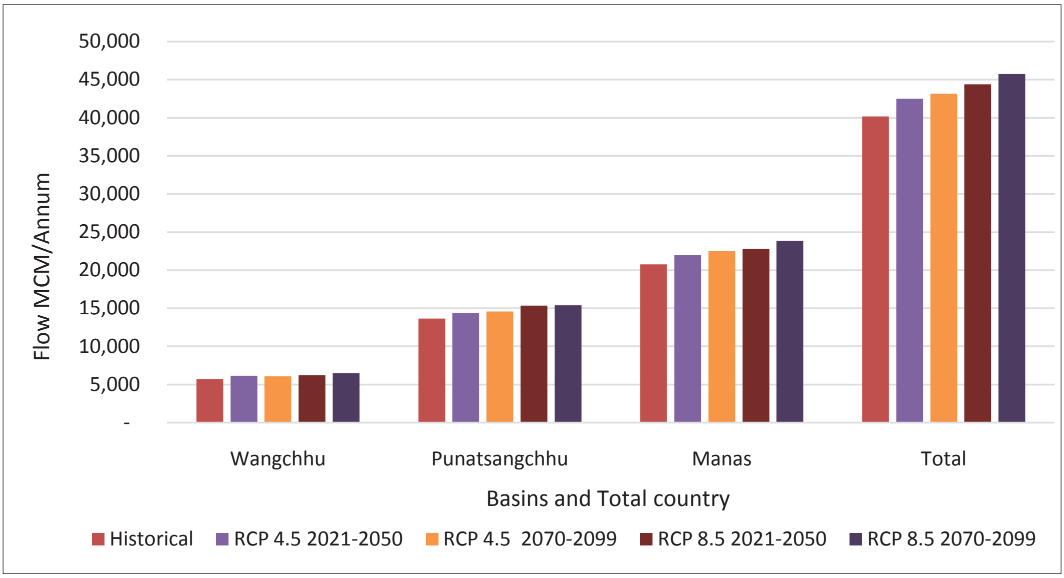

Figure 78 Total annual flows in the basins of Bhutan under different climate scenarios

Table 33 Change of monthly average flows

Month	Change in Wangchhu (%)	Change in Punatsangchhu (%)	Change in Manas chhu (%)
January	0.8%	0.9%	0.9%
February	4.4%	3.3%	4.7%
March	2.2%	1.4%	5.2%
April	4.5%	2.5%	6.6%
May	29.2%	27.0%	19.2%
June	11.4%	18.0%	6.8%
July	27.2%	20.1%	18.2%
August	11.0%	9.3%	24.9%
September	9.5%	13.2%	10.2%
October	3.3%	4.4%	3.7%
November	-1.2%	1.3%	1.3%
December	-2.2%	-1.3%	-1.7%

Table 34 Wangchu River Basin

Months	Percentage change per month			
	RCP 4.5		RCP 8.5	
	2021-2050	2070-2100	2021-2050	2070-2100
January	3.2%	-2.6%	1.8%	1.0%
February	5.5%	5.2%	4.5%	2.3%
March	3.7%	-1.2%	4.5%	1.7%
April	10.0%	-2.8%	3.9%	6.8%
May	33.1%	31.2%	28.1%	24.3%
June	35.5%	-5.9%	5.0%	10.8%
July	19.0%	35.4%	31.7%	22.7%
August	5.0%	20.5%	7.2%	11.3%
September	-10.7%	24.2%	8.6%	15.9%
October	3.5%	-3.0%	8.1%	4.4%
November	-4.1%	1.4%	-1.1%	-1.1%
December	-3.6%	-2.6%	-2.3%	-0.2%

For the Wangchu basin, under RCP 4.5, the flow is highest in May, June and July in the year 2021-2050, which is the monsoon season, while it is lowest in November and December during the lean season. This will adversely impact hydropower as the higher flow in the monsoon would only spillover and the lean season flow would negatively affect the electricity generation. Under the same RCP 4.5, in 2070-2100, there is a huge variation in flow throughout the year with a decline in March, April, October and December and an increase in flow percentage in November.

Under RCP 8.5 for both periods, there is a high variation in flow during monsoon and a decrease during the lean season (November and December).

Table 35 Result for Punatsangchhu

Months	Percentage change per month			
	RCP 4.5		RCP 8.5	
	2021-2050	2070-2100	2021-2050	2070-2100
January	2.6%	-0.9%	1.6%	0.3%
February	4.4%	3.8%	3.1%	1.8%
March	-0.7%	2.4%	2.7%	1.3%
April	5.0%	-2.0%	3.7%	3.4%
May	36.8%	24.9%	21.9%	24.3%
June	42.8%	-3.8%	15.2%	17.6%
July	14.2%	30.0%	18.2%	18.0%
August	0.5%	9.5%	11.5%	15.8%
September	-4.0%	32.8%	11.5%	12.5%
October	1.8%	1.0%	8.7%	5.9%
November	-1.4%	3.5%	2.1%	0.9%
December	-2.2%	-1.1%	-0.1%	-1.7%

For Punatsangchhu basin, under RCP 4.5, the flow is highest in May, June and July in the year 2021-2050, which is the monsoon season, and a sharp drop in flow percentage can be seen from August. The flow is lowest in November and December during the lean season in the same projected year. This would negatively affect the electricity generation, as mentioned in the earlier section. Under the same RCP 4.5, in 2070-2100, there is a huge variation in flow percentage from May to June until September with a decrease of flow in June. There is also an increase in the flow percentage in November.

However, under RCP 8.5, the flow percentage during monsoon is somewhat in the same range, for a longer period from May until September for 2021-2050 as well as 2070-2100 and also decrease of flow percentage in the lean season (December).

Table 36 Result for Manas (Mangdechhu and Drangmechhu)

Months	Percentage change per month			
	RCP 4.5		RCP 8.5	
	2021-2050	2070-2100	2021-2050	2070-2100
January	2.7%	-0.7%	0.9%	0.6%
February	8.6%	4.1%	3.9%	2.4%
March	5.1%	5.0%	6.9%	3.6%
April	8.9%	1.7%	8.4%	7.5%
May	25.5%	15.5%	21.3%	14.7%
June	28.1%	-21.0%	10.1%	10.1%
July	4.2%	36.2%	12.1%	20.3%
August	23.0%	30.5%	16.5%	29.5%
September	-5.2%	22.8%	15.2%	8.0%
October	2.9%	1.4%	6.3%	4.0%
November	-0.7%	5.8%	-0.6%	0.7%
December	-3.1%	-1.2%	-1.1%	-1.3%

For the Manas basin, the flow trend is similar to that of the Punatsangchhu basin.

There is flow percentage variability, which in some cases is very high, leading to disruption of hydropower generation. High variability in the because climate change makes the country highly vulnerable to climate change, depending only on one source of energy, hydropower. Therefore, for adaptation measures, Bhutan has to source out alternative sources of energy. The alternate sources of energy such as solar, wind, and geothermal, could be explored as an option for diversification of energy sources.

4.6.2 Adaptation options for energy sector

The adaptation option includes diversification of energy sources and economic base, support promotion of renewable and energy-efficient technologies, and investments to harness hydropower energy. Storage of water during the lean season and explore the use of isolated valleys and alpine lakes for regulated storage. The operationalization of the Renewable Energy Development Fund (REDF) is also a measure that could be initiated sooner. The adaptation measures for the energy sector should address the following issues:

- ***Diversification of energy sources:*** High reliance on hydropower energy, which increases the economic vulnerability and energy security can be reduced by diversification of energy sources such as solar, wind and geothermal, demand-side management through the promotion of enhanced energy-efficiency and conservation measures effectiveness.

- ***Seasonal water shortage for Hydropower:*** The hydropower sector is determined by water availability and flow that is highly dependent on precipitation and lean season flows. The suggestions to cope with these challenges are to explore possibilities of small-scale storage schemes for seasonal variations and fluctuations and study the possibility of high-altitude lakes and isolated valleys to be used as storage sites. Modelling, forecasting and planning for better hydropower production are also possible, which would reduce risks.
- ***GLOF and Flood risk to Hydropower:*** Threats to hydropower systems and plants due to natural disasters such as floods, flash floods and GLOFs are imminent. The risk can be minimized by mapping, planning, preparing contingency plans and setting up EWS with real-time monitoring. It could also be enhanced with high-tech flood forecasting in advance.
- ***Sedimentation and Siltation:*** Increased sedimentation and siltation of rivers and waterways affecting the reservoir are possible due to increased monsoon runoff and erratic and intensive rainfalls. Watershed protection and check dams at strategic locations will help reduce the problem of sedimentation and siltation.

4.7 Health Sector

The health care system in Bhutan is mandated to provide free access to basic public health to all. As of 2017, life expectancy at birth for Bhutan's female population is 71.7 years and the male population is 68.8 years; the average is 70.2 years (PHCB 2017). While significant improvements in the health care systems and indicators have been made over the years, success thus far could be challenged by emergent of climate sensitive diseases, and climate induced disasters compromising the free health care for all.

4.7.1 Vulnerability Assessment of Human Health

Climate change affects social and environmental determinants of health – clean air, safe drinking water, food self-sufficiency and secure shelter (WHO). With climate change, Bhutan is expected to experience a wide range of health risks. Rising temperature, unpredictable weather patterns, unequal distribution, or water supply to the communities will influence the epidemiological pattern of many diseases, particularly vector-borne, airborne, and waterborne diseases. Diseases such as dengue and chikungunya have emerged over the last few years and indicate a growing trend. Emergency medical health requirements will also rise with climate-induced disasters such as GLOFs, floods and landslides.

In 2019, Bhutan witnessed a dengue outbreak in two places. The usual dengue outbreaks with more than 3,000 cases are shown in following table.

Dengue Cases in Phuentsholing

April	May	June	July	August	September	October	Nov	TOTAL
1	6	12	627	1268	1042	189	21	**3166**

(Source VDCP case investigation report)

In addition to Phuentsholing, a small town called Duksum under Trashi Yangtsi district also had an outbreak with more than 112 cases. There were six deaths attributed to dengue in 2019.

The health and climate change study used is a Poisson Regression relationship between Temperature and Malaria and Dengue. It is also projected that future risk and incidences of these Vector-Borne Diseases (VBDs), will increase both for 2050 and 2070-2099.

4.7.2 Projections of Malaria and Dengue

The long-term projection of Dengue and Malaria was carried out using the projected data on temperature and total monthly rainfall (NCHM, 2019). The increase in annual mean temperature from 2005 till 2050 under RCP 4.5 is by 1.1%. The prevalence of Dengue will increase from the existing 16.3% probability of occurrence in 2019 to 25.3% in 2050 and 26.7% in 2070-2099 with a change in temperature. Similarly, the Malarial incidence will reach 23.9% in 2050 and 25.1 % in 2070-2099 from the existing 10.4% probability of occurrence in 2019 under the RCP 4.5 scenario with temperature change. However, the Malarial incidence rate will decline by a 1% point upon an increase of relative humidity by 0.99 times.
Similarly, the malarial incidence is expected to increase by 3.2 percentage points, as depicted in Table 36. Like the 2021-2050 case, the malarial rate will decline by 1 percentage points between 2070 and 2099 with increased humidity. No conclusive findings between humidity and Dengue were found based on the data available.

Table 37 Long-term forecasting of Dengue and Malarial incidence in southern foothills in relation with temperature and humidity (RCP 4.5)

Month	Monthly Mean t (1979 – 2005)	Monthly Mean t (2021 – 2050)	Monthly Mean t (2070 – 2099)	Rate of dengue incidence with change in t (2021 – 2050)	Rate of dengue incidence with change in t (2070 – 2099)	Rate of malaria with change in t (2021 – 2050)	Rate of malaria with change in t (2070 – 2099)	Rate of malaria incidence when humidity increases (2021 – 2050)	Rate of malaria incidence when humidity increases (2070 – 2099)
Jan	13.1	14.5	15.7	17	18.5	16.1	17.4	15.1	16.4
Feb	15.2	16.7	17.74	19.6	20.9	18.5	19.7	17.5	18.7
Mar	18.9	20.1	21.24	23.6	25	22.3	23.6	21.3	22.6
Apr	21.4	22.7	23.89	26.8	28.1	25.2	26.5	24.3	25.5
May	23	24	25.07	28.3	29.5	26.7	27.8	25.7	26.8
June	24.7	25.7	26.65	30.2	31.4	28.5	29.6	27.5	28.6
July	25	25.9	26.99	30.5	31.8	28.8	30	27.8	29
Aug	25.1	26	26.95	30.6	31.7	28.9	29.9	27.9	28.9
Sept	24.1	25.1	26.03	29.5	30.6	27.8	28.9	26.9	27.9
Oct	21.4	22.5	23.63	26.4	27.8	24.9	26.2	27.8	28.9
Nov	18	19.3	20.6	22.7	24.2	21.4	22.9	20.4	21.9
Dec	14.5	15.8	17.28	18.7	20.3	17.6	19.2	16.6	18.2
A. Avg	20.4	21.5	22.65	25.3	26.7	23.9	25.1	22.9	24.1

Similarly, under the RCP 8.5 scenario, the Malarial incidence will reach 24.1% in 2050 and 27.0 % in 2070-2099 from the existing 10.4% in 2019. Dengue prevalence will also increase from existing 16.3% in 2019 to 25.6% in 2050 and 28.6 % in 2070-2099.

Month	1979 – 2005	RCP 8.5 (2021 – 2050)	RCP 8.5 (2070 – 2099)	Rate of dengue incidence with change in t (2021 – 2050)	Rate of dengue incidence with change in t (2070 – 2099)	Rate of malaria with change in t (2021 – 2050)	Rate of malaria with change in t (2070 – 2099)	Rate of malaria incidence when humidity increases (2021 – 2050)	Rate of malaria incidence when humidity increases (2070 – 2099)
Jan	13.1	14.6	17.5	17.2	20.6	16.2	19.5	13.6	19.5
Feb	15.2	17.0	19.6	20.0	23.0	18.8	21.7	16.0	18.6
Mar	18.9	20.4	23.0	24	27.1	22.7	25.6	19.4	22.1
Apr	21.4	22.8	25.4	26.8	29.9	25.3	28.2	21.8	24.4
May	23.0	24.3	26.6	28.6	31.3	26.9	29.5	23.3	25.6
June	24.7	25.9	28.1	30.5	33.1	28.7	31.2	24.9	27.1
July	25	26.1	28.4	30.7	33.4	29	31.5	25.1	27.4
Aug	25.1	26.2	28.4	30.8	33.4	29.1	31.5	25.2	27.4
Sept	24.1	25.3	27.8	29.8	32.7	28.1	30.8	24.3	26.8
Oct	21.4	22.7	25.5	26.7	30.1	25.2	28.4	21.7	24.6
Nov	18	19.6	22.3	23.1	26.2	21.8	24.7	18.7	21.3
Dec	14.5	16.2	19.2	19.1	22.7	18	21.4	15.2	18.3
A. Avg	20.4	21.8	24.3	25.6	28.6	24.1	27	20.8	23.3

4.7.3 Adaptation Options

The key adaptation options for the health sector to cope with the challenges and issues are emergency preparedness, enhancing monitoring and surveillance, risk monitoring and early warning systems, training, awareness, better information management and sharing, deployment of health care facilities such as emergency and trauma centres and promotion of R&D. Details of the health adaptation plans are attached as Annexure 5, while a list is below.

- ***Enhancing monitoring and surveillance:*** Due to erratic seasonal changes, rainfall and unpredicted weather conditions, vector-borne and water-borne diseases are further expected to increase. Proper monitoring of diseases, implementation of safety plans, awareness and capacity building are required to reduce risks.
- ***Strengthening public health system:*** Although there are adequate health facilities and capacity for regular operations, infrastructure and human skills are questionable in a disaster and climate change context. Therefore, improvement in the capacity to handle climate-sensitive diseases and their early signs and construction of climate-resilient health infrastructures, laboratories and equipment are necessary.
- ***Promoting research needs:*** there is limited or no dedicated climate change research conducted on human health and more so on scientific literature on the population burden of disease attributable to current or future climate change. It is important to improve understanding of the process of adaptation. This includes gaining better knowledge of the processes of adaptation decision-making; roles and responsibilities in adaptation of individuals, communities, nations, institutions and the private sector; conditions that stimulate or act as a barrier to adaptation; and what level of certainty is needed for public health decision-makers to act.

4.8 Urban Planning and Infrastructure Development

Bhutan has been rapidly undergoing urbanization in recent decades. As per the report of PHCB 2017, 37.8 % of the total population lives in urban areas compared to 30% in 2015 (National Statistical Bureau, 2018). While urbanization has brought immense opportunities in economic development, access to health services employment opportunities, education, and other public services, it has also led to many issues and challenges.

Infrastructure and services include urban buildings and spaces, energy, transportation, water, wastewater and drainage, communication, healthcare, and industries. These infrastructures that have been designed and built in the past cannot cope with the extremes of climate and weather events such as floods, flash floods, windstorms and cyclones, posing a greater risk to infrastructure and services. For instance, the storm water drainage built in the past cannot cope with the change in rainfall patterns and its intensity, causing clogging and flooding in the urban centres. Thus, there is a need for the proper design of climate-resilient infrastructures.

At present, most of the country's urban areas are exposed to risks to hazards with developmental activities carried out in hazard/red-zone areas such as Wangdue Phodrang, Punakha, Thimphu and Phuentsholing. Additionally, most settlements in the country occur along the river valley. There is a lack of adequate infrastructures such as drainage systems and improper urban planning with a lack of enforcement of building by-laws and codes, and inadequate settlement planning policy, and hazard zonation mapping.

4.8.1 Current Vulnerabilities of Urban development sector

In recent years, high-intensity rainfall has caused frequent flooding in urban areas resulting in unsanitary situations, imposing a threat to human health. Some of the potential impacts of climate change and its vulnerability on infrastructure are roads, bridges and transportation damaged by higher temperatures, severe storms and flooding, and higher storm surges, affecting the reliability and capacity of transportation systems.

In urban towns, clogged drains and storm water drains have caused frequent flooding during high-intensity rainfalls, resulting in unsanitary situations that affect people's health. Thimphu has also witnessed frequent leakage or overflow of sewerage tanks, which flood roads and footpaths in the main city areas.

4.8.2 Adaptations options for infrastructure development

The impacts of climate change are being observed in urban areas through urban flooding, disruption of transportation, etc. Some of the adaptation options are:

- ***Ecosystem based conservation***: The impacts of climate change could manifest in the form of inadequate water supply, air pollution, disruption of ecological systems, and eventually, the food supply chain. Therefore, the protection of ecosystems and buffers by identifying and protecting significant wetlands (natural water ecosystems such as marshes, ponds, lakes, streams), open green space from being converted to other land uses in and around the urban settlement is important.
- ***Strengthening infrastructure sector***: Flooding is one of the common problems faced by all urban areas in Bhutan. Waste management is also becoming an issue, further aggravating climate change through the emission of greenhouse gas, especially from landfills. Therefore, there is a need for investment in critical infrastructures to reduce disaster risks like Flood Management and Early Warning Systems in urban areas. There is a need for a comprehensive waste

management plan, storm water master plan, water management plan for every Dzongkhag and Thromde, which should be implemented accordingly.

- ***Climate change integration*: the current policy and institutional mechanisms for urban planning and development in place are quite weak and inadequate. Thus, most of the urban infrastructures are not climate resilient, such as land use and buildings, storm water drains, water distribution (supply and network), telecommunications (wireline, wireless, internet), transportation and public health. Therefore, there is a need to integrate climate change concerns in plans, policies and programs and prepare land use plans and development that are responsive to climate resilience by integrating Climate SMART Planning principles.

4.9 Cross cutting issues

The main cross-cutting issues in terms of climate vulnerability and adaptation are Disasters and Gender. The following sections present the issue of disasters and gender.

4.10 Disasters

Bhutan is prone and vulnerable to a range of natural disasters. Climate-induced disasters such as GLOF, windstorms and other hazards such as landslides, flash floods and forest fires cause significant loss and damages to lives, properties and public infrastructures. With climate change, the occurrence and intensity of such disasters are increasing, as shown in Table 38. It is clear from the table that the numbers and incidences of disasters are increasing yearly, with 2017 having the highest number of disasters.

Bhutan is highly vulnerable to disasters, mainly induced by climate change. It is because of its location and mountainous terrains, as mentioned in the previous section. However, many such disasters have occurred in the country. Some of them have been identified based on the increasing trend of climate change-induced disasters. These identified disasters are as follows:

a) Floods and Flash floods
b) GLOFs
c) Drought
d) Landslides
e) Windstorm/Cyclones
f) Heat waves and cold waves

With climate change, the occurrence and intensity of such disasters are increasing, as shown in the table 38. Detailed events of hydrometeorological disaster in Bhutan is available in publication by NCHM on Compendium of Climate and Hydrological Extremes in Bhutan since 1968. :

Table 38 The list of disasters since 2009 until 2017

Year	Disasters	Area affected	Damages and loss
2009	Flash floods, landslides, triggered by Cyclone Aila	17 Dzongkhags	damages losses of Nu.719 million
2009	Earthquake (6.1 Richter scale)	Mongar	12 lives lost, damaged 4950 households, 45 BHUs, 117 schools, over 800 cultural heritage buildings; 29 RNR offices and 26 Gup's office Total estimated loss of Nu. 2501.00 million (US$ 42.00million)
2011	Earthquake (6.9 Richter scale)	4 Dzongkhags	Loss of one life due to landslides and 14 injuries. 6977 rural home damaged, 36 schools, 22 hospitals, 286 heritage sites, monasteries, 27 RNR centers.
2011	Windstorm	17 Dzongkhags	2424 rural homes roof damaged, 77 lhakhangs, 4 chortens, 57 schools/NFE centres, 21 BHU/ORC, 6 RNR offices, 4 Gups office and 3 RBP buildings
2012	Windstorm	4 Dzongkhags	221 rural homes roof damaged, 10 lhakhangs and 4 schools, 1 RNR office
2013	Flash floods caused by Jichurong-chhu due to heavy rainfall	5 villages in Kabisa gewog, Punakha	Over 14 acres of agricultural land filled with debris
2013	Windstorm	Sarpang, Zhemgang	26 homes roofs blown away, both in rural and urban areas, 12 schools affected, 58 cultural heritage sites, 3 local government offices and 8 BHUs
2014	Windstorm	6 Dzongkhags	102 rural homes roof damaged, 2 schools and 4 lhakhangs affected, 106 homes, 20 government structures are affected
2016	Landslides	19 Dzongkhags	Properties damages such as houses, cultural monuments, water supply tanks, irrigation channels, farm road, roadblocks
2016	Heavy rainfall and flood	13 Dzongkhags	Damaged river protection walls and washed away riverbanks, washed away bridges and roads, damaged agricultural lands, water supply plants and irrigation channels.
2017	Heavy rain and river swelling	4 Dzongkhags	River protection wall damage
2017	Hailstone	3 Dzongkhags	Crop damages
2017	Landslides	6 Dzongkhags	Properties, roadblocks, irrigation channels
2017	Insect infestation	1 Dzongkhag	Crop damages
2017	Windstorm	2 Dzongkhags	Agricultural crops, roofs
2017	Drought	1 Dzongkhag	Agricultural crops

4.10.1 Vulnerability

The cascading effects of climate change due to rising temperatures cause loss of ice and snow in the region, affecting water availability in terms of quality and variation in different seasons. Most of Bhutan's rivers and streams are glacial melts with high flows in summer months that would affect the hydropower.

Ongoing climate change over succeeding decades will likely have additional negative impacts across the country, including significant cascading effects on river flows, groundwater recharge, natural hazards, and biodiversity; ecosystem composition, structure, and function; and human livelihoods (Xu et al., 2009).

An example of a recent case of a heat wave in Bhutan has resulted in the glacial melt causing in swelling of lake and breaching of moraine dams. This has resulted in swelling of the river (Pho chhu), posing a threat to the communities downstream (thethirdpole.net, 2019). According to the report, an increase in temperature combined with delayed monsoon has caused the melting of huge volumes of ice and snow at Thorthormi Tsho (lake), causing the water level to rise by almost two meters. Satellite images showed much of the melting on Thorthormi took place between June 6 and 15 of 2019 as temperatures increased. While there are uncertainties associated with these damages and disasters, some extreme events are projected to increase in frequency and severity.

4.10.2 Adaptation options

Adaptation to disasters requires both hard infrastructures as well as soft measures to build resilience to disaster. Climate change adaptation (CCA) strategy in Bhutan focuses on disaster risk reduction (DRR) and the threat of glacial lake outburst floods. The hard infrastructures are early warning systems, technical assessments, mapping and physical infrastructures such as walls, embankments, better buildings for vulnerable areas. Soft programs are training and awareness, building codes, policies, monitoring and evaluation, etc.

Disasters occur in all sectors and are thus cross cutting issues. Thus, for each type of disaster, adaptation measures are discussed as follows:

- ***Monitoring floods and flash floods*:** Floods and flash flood damage agricultural fields and crops, affecting livelihoods of smallholder farmers, different infrastructures both in rural and urban areas such as buildings, roads, communications systems, irrigation channels, roads, houses including lives and properties, and also involves environment and ecosystem degradation. Most of the adaptation measures are already being carried out, such as mapping targeted areas with specific, action-oriented communication before, during and after the flood events such as places in Punakha and Wangdue Phodrang. Some of the adaptation options that could be further enhanced, are:
    - Forecasting of floods from modelling and the number of incidences in the past and installing more early warning systems.
    - Strict rules and regulations against construction in vulnerable/flood-prone areas and guide resilient floodplain designs.
    - Advocate, train and prepare the communities about floods and flash floods.
    - Inform communities about the evacuation centres if any.
- ***Monitoring and mapping prolonged dry periods*:** Climate change affects the agricultural production due to prolonged dry spells leading to loss of crops affecting the farmers and the farming system. Dry spells could also lead to loss of plants and animal species and changes in the state of some ecosystems. Therefore, dry spells not only affect agriculture but

also forest and biodiversity environment are detrimental to animal health. It also increases the risk of forest fires for which the adaptation measures are discussed under the forestry and biodiversity section.

- For agricultural production, it is important to introduce drought and stress-resilient crops for which research and development need to be enhanced. There is a need to establish sufficient monitoring plots across the country and map drought-prone areas both in agriculture and forestry sectors to enable long-term monitoring of agricultural as well as ecological parameters. This would improve the data for future research and help identify areas and provide precautionary measures such as forest fire. Therefore, overall, there is a need to improve institutional capacity for drought and climate resilience.
- ***Landslides***: In the rugged mountain environment of Bhutan, landslides form an ever-present natural hazard and are very common. According to reports by DDM in 2015 and 2016, landslides in Bhutan are triggered mainly by heavy rainfall and earthquakes. To date, the number of landslide occurrences are mainly associated with intense and heavy rainfall in combination with steep geographical terrain. Some of the current vulnerabilities in this sector area are lives and properties, national highway, biodiversity and infrastructures like roads and channels. In 2018, the Department of Geology and Mines under the Ministry of Economic Affairs has identified landslide incidents in the major areas. They have formulated different adaptation and mitigation measures for each identified area. However, some of the major adaptation measures are construction of physical defenses (e.g., walls, piles, drainages, retaining basins). They are designed considering the type and size (magnitude) of the expected landslides, recording historical data for future references and monitoring data, and considering modelling tools. It is also recommended to introduce and enhance bioengineering with suitable species of trees/plants and grasses. This should be done before the onset of monsoon and to prohibit cutting down of trees/plants and overgrazing.
- ***Windstorm***: Windstorm disasters have affected mostly the rural homes in Bhutan and thus have affected the livelihoods of the people. The record shows that Bhutan is experiencing more frequent and widespread windstorm occurrences. Information on past windstorm damages shows that the roofs of traditional Bhutanese houses are particularly vulnerable to windstorms due to the construction practices of traditional Bhutanese buildings. Some of the adaptation measures for windstorm are similar to that of floods and flash flood: monitoring and forecasting of windstorms; installation of an early warning system, especially for the farmers with proper communication; preparedness and awareness of the communities; and to have a policy to ensure wind resilient construction in rural and urban areas.

4.11 Earthquakes

Bhutan has been affected several times by past earthquakes like the 1897 earthquake measuring M8.7 with the epicenter located in Shillong Plateau, India, which affected many Dzongs in Bhutan. Another earthquake event was in 2009 followed by 2011. Although there were minor reports on earthquakes in 2017 and 2018, it is important to note that Bhutan's location in a high-risk seismic zone increases the exposure of people and all other elements at risk to earthquakes as well as natural hazards related to climate change.

Due to limited studies in this area, the direct relation between earthquakes and climate change is unsure. However, with the Glacial

Lake Outburst Floods in 2015, which was associated with an earthquake, it is important to have the hazard or seismic zonation map. This will help in identifying the areas of seismic activities in Bhutan and also plan-post disaster recovery. Some of the adaptation options are: continuously monitoring earthquakes, enhance understanding of seismic activity and provide critical long-term information for strengthening seismic building codes and planning for the worst possible scenarios and making proper disaster management plans. Some of these measures, such as monitoring, and disaster management plans, are already being carried out.

4.12 Heat waves and cold waves

The impacts of heat and cold waves on health of human and environment in Bhutan is not studied and sectors such as health, agriculture and energy (hydropower) are most vulnerable to it. In light of the climate change, both heat and cold waves are likely to intensify. Therefore, it is crucial to assess and study the impacts of risks from heat and cold waves.

4.13 Gender and social differentiation in Bhutan

Gender relations in Bhutan have traditionally been based on equality and reciprocity. Bhutan has always maintained a gender-neutral position in the formulation and implementation of its plans, policies and programs. Therefore, Bhutanese society do not discriminate or differentiate between male and female and respects equality in almost all spheres of life. Amongst South Asian countries, Bhutan is regarded as having a high level of gender equality. "Laws in Bhutan treat women and men equally, and women's rights and interests are safeguarded by the provisions of different legal acts, including the Constitution of the Kingdom of Bhutan". Bhutan's Inheritance Act of 1980, for example, guarantees equal inheritance rights to men and women. Traditional inheritance practices – which in Bhutan favour daughters – are even more progressive than modern law. As a result, about 60 percent of rural women hold land registration titles, which is higher than anywhere else in South Asia. However, there are several areas in which they are at a disadvantage compared to men. Such areas are politics and decision-making, tertiary education and economy, with rural women being more vulnerable. The literacy rate for women, which stands at 63.9 percent, is lower than that for men, which is 78.1 percent in urban areas (PHCB 2017). This translates into lower levels of female participation in formal employment and high public office.

Gender mainstreaming in national plans in Bhutan was initiated with the 10th FYP. It started with the adaptation of guidelines to mainstream gender into all planning aspects to elevation as one of the 16 National Key Result Areas for the 11th Five-year Plan. In the ongoing 12 FYP, gender is recognized as a cross-cutting theme strongly advocates all ministries, agencies and concerned sectors to address gender gaps by integrating into their plans and programs based on gender analysis. This Plan also has "Gender Equality and Women and Girls Empowered" as a National Key Result Area with key performance indicators and targets that will measure women's representation in Parliament.

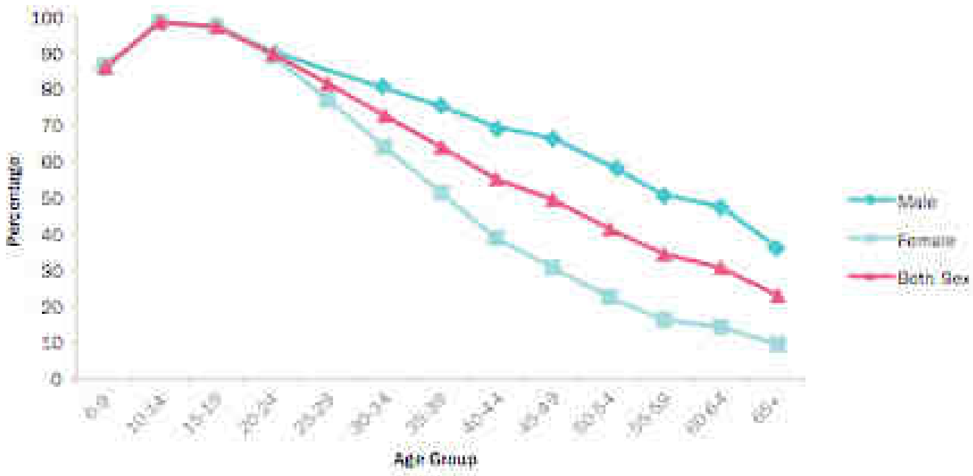

Figure 79 Literacy Rate by Age Groups and Sex, Bhutan 2017 (Source: PHCB 2017)

4.13.1 Vulnerability and adaptation options in gender

As majority of the population are still directly dependent on agriculture, it is mostly women that is required to work in the field to support the children and elderly that are left back home. These group of people are the ones most vulnerable to the impacts of climate change and have limited capacity and resources to adapt as male migrate out seeking employment and work for wages.

Many settlements in the country still faces acute shortages of water for drinking and irrigation and the problem will be further exacerbated by changing monsoon patterns and decreasing snow cover. Such phenomenon will have additional bearing on the women.

Any proposed plans, programs and projects should try to integrate gender concern and consider incorporating gender friendly technology and application to be implemented as an adaption options where possible.

CONSTRAINTS, GAPS AND RELATED FINANCIAL, TECHNICAL AND CAPACITY NEEDS

5. CONSTRAINTS, GAPS AND RELATED FINANCIAL, TECHNICAL AND CAPACITY NEEDS

5.1 Introduction

Bhutan has always taken a leadership role among the comity of nations on environmental conservation and climate change action.

At the COP15 in Copenhagen, Bhutan declared its intention to be carbon neutral for all times to come. The National Adaptation Programme of Actions have been implemented with resounding successes and has currently entered into Phase III.

And Bhutan continues to take an active role in the negotiation of the Paris Agreement and its subsequent articles, primarily through the LDC Group whose chairmanship is currently held by Bhutan. Several projects on climate change mitigation and adaptation have been carried out, and the completed projects are now sustained through the national resources.

5.2 Information on Constraints, Gaps and Related Financial, Technical and Capacity Building Needs.

The TNC preparation process faced several challenges, the most significant of which is the unavailability of reliable and consistent data. To overcome such shortcomings, sampling of activity data sources was carried out and cross checked with the reports compiled by the NECS. Although data quality was given high priority, there is still the possibility of data inconsistency and inaccuracy due to the lack of human and financial resources both with the data sources and the compilation team. Efforts were made to come up with realistic assumptions through discussion with and among the GHG Task Force representatives of activity data sources and a thorough review of relevant literature and best international practices.

As an LDC with limited resources, technical, financial and human resources, constraints and gaps are a regular feature of environmental governance and climate issues. The following paragraphs summarize the constraints and gaps in Bhutan, particularly related to the Third National Communication.

5.3 Data Quality and Uncertainty in GHG Inventory

The Good Practice Guidance and Uncertainty Management in the National Greenhouse Gas Inventories (IPCC 2000) guide improved GHG estimation methods. The IPCC inventory methods for each gas-activity pair are stratified into tiers by the intensity of data requirements and model complexity. In GHG inventory, there are uncertainties associated with the emission estimates. These uncertainties are due to the degree of accuracy of the activity data and emission factors. The emission factors used in developing the inventory are IPCC default values except those used in the forestry sector. Currently, Bhutan lacks country-specific emission factors for all most all the sectors for the various emission-related activities except in forestry sector. Therefore, emission factors relevant to Bhutan will need to be developed.

5.4 Legal, Institutional, Financial, Technical and Capacity Constraints and Gaps

Assessments were conducted to identify key constraints and gaps in the implementation of climate change activities and ways to improve the continuous and timely preparation of the national communications to UNFCCC. The results show that financial resources, technology, research, development and human capacity belong to high priority external barriers for all sectors. At the same time, insufficient legal environment, lack of coordination and integration, and absence of detailed research are in the category of high priority domestic barriers.

These constraints and barriers are mainly related to:

- o Legal and policy enforcement and planning of climate change actions
- o Uncertainties related to research on climate change projections, its potential impacts, and consequences of the implementation of climate change response actions
- o Availability of financial resources for addressing climate change challenges
- o Adequacy of technical and technological support and knowledge
- o Capacity-building support and availability for climate change action
- o Mainstreaming and integration of climate change issues into national, subnational, and sectoral development programmes and plans
- o Coordination among the government ministries and agencies, as well as among the international financing and project implementing entities

5.5 Information on support received for preparation of the TNC.

The Royal Government of Bhutan received financial assistance of US$. 500,000 from the Global Environment Facility through UNEP to prepare the TNC. The project started in March 2016 and ends in March 2020 with the main activities of the project being:

- Supporting the collection of activity data and carrying out adequate QA/ QC procedures to improve the data's accuracy and consistency.
- Developing institutional capacity for future national communication.
- Developing the capacity of individuals involved in the TNC process.
- Promoting awareness of climate change issues.

Apart from the financial assistance, the country also received capacity support to participate in international and regional climate change capacity building program organized by multilateral, regional and bilateral programs.

5.6 Financial, technical and capacity needs

The Royal Government of Bhutan in the draft Country Work Program (CWP) for GCF Financing presented priority climate actions based on existing policies, strategies and plans such as the 12th FYP, Bhutan's Nationally Determined Contribution (NDC) and other documents related to climate change actions in Bhutan (GNHC, 2019).

The draft CWP is a product of a broad public discourse, direct stakeholder inputs, and analysis of existing policies related to climate change in the country. A series of consultations at national and regional levels, including local government leaders, were conducted; the private sector was engaged from the beginning of the process, and their priorities reflected in the CWP.

The CWP identifies the Royal Government of Bhutan's priorities in three strategic areas ecosystem and agriculture, sustainable infrastructure and resilient communities as reproduced below (GNHC, 2019):

Table 39 investment priorities identified in CWP

Strategic Theme 1: Ecosystem and Agriculture	
Investment Priorities	**Action Areas**
1. Climate resilient Agriculture and livestock development and management	• Organic farming and conservation agriculture. • Development and promotion of sustainable agricultural practices. • Integration of sustainable soil and land management technologies and approaches. • Organic livestock farming and eco-friendly farm designs. • Improvement of livestock breeds. • Conservation of native gene pool/diversity. • Promote biogas production with stall-feeding. • Promote breed intensification and improve pasture development. • Promote manure composting/bio-fertilizer inputs for organic farming. (Bullet 1 in agriculture supplements this) • Agro-forestry or agro-silvo pastoral system for fodder production (falls under eco-friendly farm designs). • Enhance early warning and surveillance system for monitoring the climate induced pest and diseases. • Promote integrated pest and disease management. • Promote climate resilient crop varieties. • Climate proofing of agriculture and livestock infrastructures. • Promote climate smart and micro-efficient irrigation system and water management. • Establish cold storage facilities at sub-national regions. • Initiate crop and livestock insurance programs against climate induced extremes. • Climate resilient farm designs and practices. • Promote R&D and capacity development
2. Sustainable forest management and conservation of biodiversity	• Enhance forest information system and monitoring infrastructure through national forest inventories and carbon stock assessments. • Habitat management, improvement and enrichment (Management of degraded wildlife habitats (saltlicks, waterholes/wetlands, grassland) both inside and outside the protected areas. • Promote wood technology through infrastructure and capacity development. • Upscale use of innovative technologies that would minimize the use of fuel wood for heating and cooking directly contributing to addressing one of the drivers of deforestation and forest degradation. • Forest fire management and rehabilitation of degraded and barren forestlands. • Sustainable management of forest and conservation of biodiversity including management of forest management units (FMUs), heritage forests, community forest, local forest management plans, and private forests. • Research on trans-boundary wildlife and invasion of alien flora and fauna. • Promote R&D & capacity development

Strategic Theme 2: Sustainable Infrastructure	
Investment Priorities	**Action Areas**
3. Energy Security	• Pursue sustainable and clean hydropower development • Pursue other renewable energy sources such as solar, wind and biogas • Encourage use of energy efficient appliances and technologies. • Encourage partnership and private investment to promote EE in public lighting, buildings and industries. • Energy storage. • Ensure energy security during the lean dry seasons through water storage and reservoir. • Protect catchment areas for hydropower. • Promote R&D and capacity development
4. Low Emission Transport Modes	• Improve mass transit and develop financial products for promotion of private investment through concessions and Public Private Partnerships. • Explore other modes of transport such as rail, electric and gravity ropeways. • Expand use of more efficient and effective modes of cargo movement. • Promote electric vehicle. • Improve efficiency and emission from existing vehicles through standards and capacity building. • Promote use of appropriate intelligent transport systems. • Promote R&D and capacity development
Strategic Theme 3: Resilient Communities	
Investment Priorities	**Action Areas**
5. Climate resilient and Low emission Human Settlement (Rural and urban)	• Promote climate smart cities and villages. • Improve storm water management and sewer system. • Promote green and climate resilient infrastructures • Environmental management and safeguards for development activities, • Consider climate resilient housing solutions for low-income people. • Enhance application of three R principles including composting, effluent treatment, sewerage treatment and conversion of waste to resources. • Strengthen integrated risk monitoring and early warning systems and response for climate sensitive diseases. • Promote climate resilient household water supply and sanitation. • Geological, geo-tectonics, and geological hazards mapping and risk assessment. • Assess and manage forest fire and seismic risk. • Continue assessment of glaciers, glacial lakes and potentially dangerous glacial lakes and improvement of early warning system for GLOFs. • Assess and manage risk and damage from windstorms on agricultural crops and human settlements. • Enhance emergency medical services and public health management to respond to climate change induced disasters. • Enhance preparedness and response to climate change induced disasters at the national and local levels. • Enhance geological knowledge for all land use planning since developments are mostly based on earth systems. • Promote R&D and capacity development.

6. Climate smart water management and Climate resilient technology	• Conduct water resources assessment and mapping. • Implement spring shed management interventions. • Ground water assessment. • Promote efficient water use and harvesting technologies. • Wetland inventory. • Integrated watershed and wetland management. • Improve skills and develop capacity for water management and maintenance of water infrastructure. • Climate proofing water distribution system. • Adopt cultural and traditional practice of sanctifying water sources. • Improve hydro-meteorological observation methods and network coverage. • Improve monitoring and detection of hydro-meteorological extremes using remote sensing and satellite-based technologies and approaches. • Enhance weather and flood forecasting services. • Develop a monitoring, assessment and warning systems for flash flood and geological hazards. • Enhance coordinated approach on climate data collection and providing advisory services. • Develop climate change scenarios for Bhutan with appropriate resolution for mountainous situation. • Strengthen climate information system, agro-met station and services. • Improve forecasting and aviation meteorological services. • Enhance capacity for air and water quality monitoring and forecasting services. • Promote R&D and capacity development
7. Green and Sustainable Economy	• Invest in cleaner technology, energy efficiency and environmental management. • Reclamation/restoration of mine areas and strengthen environmental compliance monitoring system. • Invest in new industries that are at higher levels in the value chain, and green industries and services. • Promote eco-tourism. • Pursue holistic industrial estate development and management in line with efficient, clean, climate resilient and green industry development objectives. • Enhance new skills and knowledge in the technical educational institution to promote green and climate resilient economy. • Promote R&D and capacity development of climate change, adaptation, vulnerability and risk assessment and other areas, including development and use of state-of-art technologies for building climate resilience and pursuing low carbon developmental pathways.

The CWP also gives an update of the projects approved or in the pipeline as reproduced below in Table 40 and Table 41:

Table 40 Summary of GCF readiness and other projects/approved

Summary of approved projects/program				
Proposal	**Accredited Entity**	**Implementing Agency**	**Status**	**Amount (in USD)**
Bhutan for Life	WWF	Ministry of Agriculture and Forestry	Approved	26.6M
Supporting Climate Resilience and Transformational Change in the Agriculture Sector in Bhutan	UNDP	GNHC	Approved	25.34M
Project Preparation Facility (PPF) for Bhutan Green Transport Program (BRT)	World Bank	Ministry of Information and Communication/ Thimphu Thromde	Approved	0.526M
Strategic framework to strengthen the Capacity of NDA to access resources from the Green Climate Fund and support for direct access accreditation process		Gross National Happiness Commission	Approved	0.400M
Preparation of the National Adaptation Plan (NAP) for Bhutan with a focus on implementation of comprehensive risk management in the water sector	UNDP	National Environment Commission	Approved	2.99M
Strengthening NDA and related institutions, including financial institutions, in Bhutan for effective engagement with GCF		Gross National Happiness Commission	Approved	0.400M
Strengthening REDD+ and watershed management in Bhutan		MoAF	Approved	0.595M

In addition to the above projects, the CWP identifies potential projects which need support, both financial and technical as summarized below:

Table 41 Pipeline projects

Project title	Estimated cost (USD) in Million
Enhancing Climate Resilience of Water Sources in Bhutan	19
Bhutan Green Transport program	49.8
Identification, distribution and strengthening the inventory of current weeds and invasive alien species database in agricultural/pastoral land, human settlements, degraded areas and transportation routes	5
Increasing resilience to flash flood in Gelephu	20
Building Resilience to High Impact Hydro-meteorological Events through the Strengthening of Multi-Hazard Early Warning System (MHEWS) in Bhutan	10
Climate smart livestock production for reduced GHG emission and increased resilience to climate change	40.93
Increasing resilience of Human settlements, infrastructures and build environment in Bhutan and pursuing low carbon and energy efficient pathways	270
Scaling up Sustainable Land Management (SLM) and conservation and promotion of sustainable use of traditional crop varieties for Food Security, enhancing rural livelihoods and Climate Change Mitigation and Adaptation	19.42
Enhancing Climate Resiliency of Road Network and its Assets	270
National REDD+ Strategy and Action Plan Implementation Project	49.13
Assessment on National Water Resource including ground water and associated Hydrological Hazards	22
Climate resilient and green industrial development	55
Development of Solar and Wind power plants in Bumthang and Wangduphodrang Districts; Promotion and dissemination of Energy Efficient Electrical Appliances	61.30
Enhancing climate information services through expansion of hydro-meteorological network and building robust data management and early warning systems.	20

While the financing requirement for the above projects work out to US$. 911.58 Million, support will need to be sourced in a phased manner considering the limited availability of climate finances.

Additionally, biodiversity and climate change expenditure review undertaken through the biodiversity finance initiative (BIOFIN), 2018 projects expenditure requirement of Nu. 2,348 million in year 2021/22 for biodiversity and climate change under the business-as-usual scenario.

OTHER RELEVANT INFORMATION FOR THE ACHIEVEMENT OF THE OBJECTIVES OF THE UNFCCC

6. OTHER RELEVANT INFORMATION FOR THE ACHIEVEMENT OF THE OBJECTIVES OF THE UNFCCC

6.1 Introduction

To assess the relevant information in achieving the objectives of the UNFCCC, a desktop review of the following documents was carried out:

i. User Manual for the guidelines on National Communications for Non- Annex I countries;

ii. Other Relevant Information Section of Stocktaking Report for the preparation of Bhutan's Third National Communication;

iii. Other Relevant Information Report from Bhutan's Second National Communication;

iv. National Circumstances Report for Bhutan's Third National Communication and national socio-economic and environmental publications and reports including the national statistics from the Bhutan Statistics Bureau, 10th and 11th Five Year Plan Documents, Bhutan Human Development Report and annual publications on the State of the Environment.

Relevant agencies, both Public and Private, as well as national experts, including the Gross National Happiness Commission, Ministry of Agriculture and Forest, Ministry of Economic Affairs, Ministry of Works and Human Settlement, Ministry of Information and Communications, National Center for Hydrology and Metrology, Association of Bhutanese Industries and NGOs such as Tarayana Foundation and Royal Society for Protection of Nature, were consulted.

The chapter elements are drafted based on the outcomes of the desktop literature and the consultations with the agencies listed above.

6.2 Steps taken to integrate climate change considerations into national development policy formulation

Climate Change is an emerging environmental issue and did not get as much attention as poverty alleviation until the Tenth Five Year Plan. During the period 2001 – 2008 (9th Five Year Plan), climate change is covered under the general environmental management, and integration of climate change into the national development policy was not apparent. For instance, the areas of focus in the 9th Five Year Plan was stated to be key cross-sectoral issues that are essential to the successful integration of environmental concerns with economic planning, including

(i) the need for baseline information on key environmental indicators;

(ii) the need for environmental legislation based on environmental quality standards; and

(iii) the need for effective monitoring mechanisms and effective enforcement procedures (Planning Commission, 2003). Environment and Gender mainstreaming in the Five-Year Plans into the development planning process began in the 9th Five Year Plan.

The 11th FYP was developed as a Green plan and aimed to prioritize environmental management and reduce GHG and pollution. The plan was geared towards pursuing development based on pro-poor, low carbon, eco-friendly, energy and cost-efficient modalities and strategies. A framework to mainstream environment, climate change and poverty (ECP) were developed to facilitate the sectors in the formulation of ECP integrated 11th FYP programme in pursuing a carbon-neutral and climate-resilient development as one of the national key result areas.

Bhutan's environmental regulatory framework is underpinned by the National Environment Strategy (1998). It consists of several Policies and Acts, including the National Environment Protection Act of Bhutan 2007 and the Environmental Assessment Act 2000 and its associated regulations, sectoral guidelines, codes of best practice, and environmental standards. The environmental regulatory framework is sound and has been institutionalized within Government agencies with roles and responsibilities mapped between the National Environment Commission and the line ministries and agencies.

The Royal Government of Bhutan also initiated the formulation of the National Adaptation Programmes of Action (NAPA), prioritizing actions based on a grassroots consultative formulation process. Many of the activities in the Bhutan NAPA have already been implemented, including the artificial lowering of Thorthormi glacial lake, sustainable land management, climate resilient agricultural development, etc., through two rounds of NAPA implementation and ongoing implementation of the third round of NAPA.

6.3 Activities related to transfer of environmentally sustainable technologies

Bhutan has undertaken Technology Needs Assessment (TNA) to identify, assess and prioritize environmentally sound technologies that will, within national development objectives, reduce the impact of climate change and its vulnerabilities (National Environment Commission, 2013). The TNA resulted in the formulation of a Technology Action Plan (TAP) to implement the prioritized technologies within the overall framework of sustainable development in the country. The final prioritized sectors for the preparation of TAP were water resources (efficient irrigation), agriculture (drought and pest-resilient crops) and infrastructure (climate-resilient roads).

With financial support from the Government of Denmark through the Environment Sector Programme Support, the erstwhile Ministry of Trade and Industry implemented a project component on Cleaner Technology and Environment Management in the industries and mines. The project led to the demonstration of improved housekeeping and waste minimization, tapping fume collection system in ferroalloy industries, and replacing explosives with mechanical breakers in gypsum mines.

6.4 Information on climate change research and systematic observation

Bhutan's immediate challenge on climate change systematic observation is the general lack of environmental data and monitoring services. Research on climate change mitigation and adaptation are at their infancy and carried out by academic institutions such as the Ugyen Wangchuck Institute for Conservation and Environmental Research (UWICER) and College of Natural Resources.

Weather and climate data were collected through the Agromet Division in the Department of Agriculture and the Hydromet Division in the Department of Energy. These two agencies were combined to form the Department of Hydromet Services under the Ministry of Economic Affairs, which was upgraded to the National Center for Hydrology and Meteorology (NHCM) in 2016. The NHCM is an autonomous scientific and technical organization of the Royal Government of Bhutan responsible for understanding the behaviors of atmosphere, its interaction with cryosphere and water bodies, the weather and climate and distribution of country's water resources. It is the nodal agency responsible for the generation of information and delivery of products and services on weather, climate, cryosphere and water resources in Bhutan.

As a Least Developing Country, Bhutan does not have the human, technical, or financial resources to improve climate observation and data archiving systems. However, with the national resources and assistance from the development partners, Bhutan has been focusing primarily on data needs for adaptation, including near accurate weather forecasting and dissemination.

Unlike in past, Bhutan does not have to rely on external fly-in expertise to conduct the long-term climate projection and real time weather forecasting. Climate projection and modelling used in the report was done using the in-house capacity of NCHM. The TNC project also supported NCHM in building the capacity of the NCHM officials in climate projection and modelling.

The NEC in collaboration with the National Institute for Environmental Studies and Institute for Global Environmental Strategies also developed socio-economic modelling using the computed general equilibrium model to assess Bhutan's carbon neutrality.

6.5 Information on climate change education, training, and public awareness

Climate Change features in the Environmental Studies syllabus of the students starting from primary education to higher secondary education. Some schools in the country have also engaged students in developing science projects on climate change. The Royal Society for the Protection of Nature and the Royal Education Council initiated a three-year project on "Introducing Environmental Science in Formal Education system in Bhutan," with support from Bhutan Trust Fund for Environmental Conservation and NECS. Through this project, the curriculum for middle secondary schools in environmental education was developed and handed over to the Ministry of Education for implementation.

Tertiary education institutes under the Royal University of Bhutan, like Royal Thimphu College, Sherubste College, College of Natural Resources, offer full-time courses on climate change for undergraduate studies.

6.6 Public awareness campaigns on environment management and climate change

A report commissioned by the NEC for the Joint Support Program on Capacity Development for Mainstreaming Environment, Climate Change and Poverty Concerns in Policies, Plans and Programs (JSP, 2011) assessed the existing capacity situation and various proposed capacity development actions for strengthening capacity for in-country training in the area of Environment Climate and Poverty (ECP) mainstreaming. The assessment covered eleven institutes, namely the College of Natural Resources, College of Science and Technology, Gaeddu College of Business Studies, Institute for Management studies, Paro College of Education, Royal Institute of Management, Royal Thimphu College, Sherubtse College, Ugyen Wangchuck Institute of Conservation and Environmental Research (UWICER), Jigme Namgyal Polytechnic and Samtse College of Education. The assessment found that institutional capacities exist in the form of favorable programmatic structures of the environmental institutes to infuse ECP mainstreaming training, good institutional partnerships with international institutes, the existence of courses and modules that offer substantial scope to embed ECP, mainstreaming: elements, excellent training infrastructure and facilities, and good location of the institutes concerning their training/ educational programs (NEC, 2011).

6.7 Measures to promote information exchange and networking

6.7.1 Activities to promote information sharing

The limited information that Bhutan has on climate change, particularly weather data from a few stations in the country are available from the National Center for Hydrology and Meteorology (NHCM).

Real-time weather data from all the stations across the country are linked to the NHCM. During extreme weather events or when water levels exceed pre-determined trigger levels, the Early Warning Systems are activated. These early warning systems are currently active in the Punatsangchhu, Mangdechhu and Chamkharchhu Basins.

Bhutan is also member to regional cooperative mechanisms and land mark agreement like Male Declaration established under the South Asian Cooperative Environment Program and other initiatives s in the regional information network facilitated by ICIMOD on sharing information on transboundary pollution resulting from atmospheric black carbon.

The Himalayan Environmental Rhythms Observation and Evaluation System (HEROES) project, implemented by the UWICER in partnerships with schools and nature clubs across Bhutan, employs a combination of weather data collection (through a network of weather stations) and citizen science to help understand climate change. The high-tech weather stations provide an uninterrupted flow of weather and climatic data (temperature, humidity, and wind speed) across Bhutan's varied ecological and elevation gradient. In the meantime, the citizen science component of the project encourages hundreds of students to actively observe their immediate environment to detect changes in how plants and wildlife respond to climate change.

As part of the World Health Organization (WHO) and UNDP, global project on public health adaptation to climate change, the "Piloting Climate Change Adaptation to Protect Human Health in Bhutan" is working to strengthen national capacity to identify and prevent adverse climate change-related health outcomes.

This pilot project will provide better information and surveillance of climate change-related health risks in Bhutan. Improved data collection will allow the country to monitor and receive early warnings and thus the opportunity to prepare and respond to potential health risks. The project will also provide training and development tools for health providers to understand the influence of climate change and variability on the transmission of vector-borne diseases, extreme weather events, and other health issues.

Bhutan is one of seven countries taking part in this Global Pilot. The seven countries, Barbados, Bhutan, China, Fiji, Jordan, Kenya and Uzbekistan, represent four distinct environments (Highlands, Small Islands, Arid Countries and Urban environments) and their related health risks.

6.8 Part C: Information following the UNFCCC required topics;

Based on the discussions in the preceding sections, the Issues, Challenges, Opportunities and recommendations are summarized in the following table:

Sl. No	Issue	Challenge	Opportunity	Recommendation
1	Mainstreaming Climate Change	Climate Change outside of the development spectrum	Incorporate climate risks into the development planning framework	A clear directives on the need to mainstream climate in the planning process. Development of coordination mechanism to foster inter-institutional collaboration and synergy for training. Advocacy of ECP mainstreaming in the context of the policy for GNH-infused learning;
2	Technology Transfer	Lack of access to climate smart technology	Approach regional and global technology centers	Establish a National Technology Excellence Center and develop networks with regional and global technology centers.
3	Climate research	Lack of resources and skills	Build local capacity to undertake climate research	Access potential donors to build local capacity to carry out climate research, both for mitigation and adaptation.
4.	Systematic Observation	Limited number of stations and historical data	Expansion of stations and use of modelling tools	Build capacity of NHCM to carry out climate modelling and allocate additional resources to expand stations.
5	Information exchange, networking and climate education	Limited due to resources and access	Join regional networks and improved access	Develop national climate information network and link with international organizations. Encourage participation of local experts and academics in international meetings and workshops. Review and enhance existing curricula/ modules to build in or enhance climate mainstreaming elements Development of teaching aids/ materials and knowledge for climate mainstreaming training depending upon the design of revised/ newly developed curricula.
6	Financial Resources and Capacity Building	Limited financial resources and capacity to achieve the objectives of the UNFCCC	Holistic capacity development and climate change programming	Develop a masterplan for climate change mitigation and adaptation including resource requirement and capacity building.

ANNEXURES

ANNEXURES

Adaptation Options

Table A 1 Water, Glaciers and GLOFs Adaptation Options

Sl. No.	Strategic Objective	Strategic Outcome	Strategic Action	Short Term (0-5 yrs)	Medium term 5 – 15 years
1.	Strengthening data inventory and Capacity for handling climate change related disasters	Improved data network & Capacity in handling climate change related disasters/risks	Development of hydro-meteorological stations and capacity building	Evaluation & assessment of hydro-meteorological stations Expansion of hydrological and meteorological stations across the country	Expansion of hydrological and meteorological stations across the country
				Capacity building of stakeholders and community members	Capacity building of stakeholders and community members
2.	Reducing catastrophic impacts of GLOFs	Proper Response System for GLOFs set up	Comprehensive DM & CP plans Monitoring of PDGL, glaciers, snow.	Assess effectiveness of DM & CP plans and ensure responsive DM & CP	Strengthen assessment studies to monitor snow and glaciers
				Detailed mapping of GLOF risk zones	
				More and comprehensive EWS especially in Kurichhu basin	
				Improve/ensure timely snow and glaciers monitoring including PDGLs with field assessments.	Glaciers and snow (Hydrological modelling) and forecasting
3.	Combat water shortages and drying up of water springs under Climate Change	Reduced incidences of springs drying up and water shortages	Evaluation and reassessment of policies and plans on water and water management	Strong measures and policies for rainwater harvesting/water storage, water supply networks and water source protection	Explore use of rainwater harvesting in larger scale and implement pilot projects.

				Comprehensive mapping of springs with geotagging and monitoring plan leading to spring-shed management planning	Study feasibility of storage reservoirs for seasonal storage in high altitudes/ lakes/ dries lakes and isolated valleys. Conduct socio-economic analysis, design and planning.
				Strengthen community water user association and Spring shed management	Build reservoirs in high altitudes lakes and small isolated valleys
				Assessment of water supply network and their resilience to climate change.	Hydrological Modelling and ground water modelling
					Development of manuals and guidelines on sustainable use of springs/ small rivers effectively
		Ground water tapped as an alternative source	Groundwater properly assessment monitored and used for water supply where feasible	Systematic study of Ground water availability, use, its risks and potential across Bhutan	Initiate use of groundwater or discontinue based on findings from the study
4.	Ensuring safe drinking water under climate change	Improved access to Safe drinking water	Ensuring proper monitoring, planning and supply of water and information system on water quality	Assessing existing water treatment facilities and water supply network systems	Formal action and implementation of grey water management Improvement of water treatment and network systems with proper management mechanisms.
					Proper Water treatment infrastructure as per requirements
				Ensure timely monitoring of water quality across the country	Development of Water Safety Plans and implementing proper water supply systems with adequate design.

Table A 2 Agriculture Sector Adaptation Options

Sl. No.	Strategic Objective	Strategic Outcome	Strategic Action	Short Term (0-5 yrs)	Medium term 5 – 15 years
1	Ensuring adequate water for irrigation	Climate proof irrigation infrastructures in place, ensuring adequate irrigation water and improved capacity in handling climate related disasters	Proper planning and implementation of irrigation projects taking into consideration climate change impacts Strengthen data base/ inventory on water resources Capacity building	Improve existing irrigation infrastructures promoting use of Water-efficient technology, including pump systems	Bring academic institution on board to conduct research and studies on varying issues.
				Lake rehabilitation / water storage	Promote Research and Development practices
				Water harvesting technology (rainwater and spring water)	
				Capacity need assessment and building capacity	
				Develop Resource mobilization plan	
				Review and strengthen Water User Association	
				Improve collaboration and cooperation with relevant institutions	
				Linking Source protection to water utilization (overall water management – source to tail beneficiary)	

				Promotion of local and traditional/indigenous knowledge and technology	Promote Research and Development practices
2	Ensuring adequate crop yield and production	Increased yield and improved use of climate-resilient crops and crop diversification	Using climate resilient crops and crop diversification and promote research	Develop Resource mobilization plan	
				Water harvesting technology (rainwater and spring water) (1 vote)	
				Use of bio-pesticides and bio-fertilizers	
				Promote and adopt climate smart/resilient crop (traditional crops)	
				Capacity building	
				Use of bio-pesticides and bio-fertilizers	
3	Avert land degradation and flood impacts on crops	Reduced incidences of land degradation and crop loss	Proper planning, training of stakeholders, hazard mapping and capacity building	Promote SLM	Promote Research and Development practices
				Proper Mapping of degraded areas, flood prone and landslide areas	
				Capacity building of staffs and community members.	
				Strengthen database for weather and climate	
				Promotion of local and traditional/indigenous knowledge and technology	

4	Reduce pests and diseases	Reduced incidences of Pests & diseases in crops and livestock and improved capacity	Proper monitoring of Pest and diseases (crops and livestock, plants)	Strengthen Surveillance and monitoring of Pest and diseases (crops and livestock, plants)	Climate projections and modeling impacts to livestock due to CC
				Capacity building	
				Resource mobilization	
				Research	
				Integrated Pest Management	
5	Reduce Human Wildlife Conflict	Decreased crop and livestock depredation by wild animals and improved capacity in handling HWC	Proper planning, capacity building, research and data inventory on animal migration	Promote research on mitigating HWC	Capacity building.
				Develop strategy on managing HWC	Crop/livestock insurance scheme
				Review conservation strategies and policies	Habitat enrichment plantation.
				Capacity building of stakeholders	
				Crop and livestock depredation by wild animals	
				Collect data on animal migration/ herding practices (inventory)	
				Resource mobilization	
6	Reduce vulnerability of farming communities to climate change	Improved adaptability of farming communities to CC	Proper planning, research and promote good farming practices	Promote SLM	Formulate gender sensitive, nature-based solutions and EbA actions.
				Landscape/watershed based/ spring shed approach	Crop/livestock insurance scheme.
				SLM (agro-forestry)	Strengthen Micro-credit Facilities for farmers
				Promote PES	Promote integrated nutrient management

				Improve soil carbon sequestration	Monitoring of invasive weeds
				Replicate Organic flagship program	
				Strengthening market mechanisms for sale of local products of both agriculture and livestock	Create new wetland from feasible dry land and forest area
7	Move towards achieving food security/sufficiency	Increase in food production and crop diversification	Identifying new wetlands to increase food production, promote crop diversification and awareness	Reclaim fallow wetland of 27,362 ac	
				Promote diversification of crops like wheat, barley, buckwheat, millet, sorghum	
				Capacity building/Create awareness on food preparation especially from flours of different cereals	
8	Reduce problems of farm labor shortage	Reduced Farm-labor shortage problems	Providing subsidies and incentives for farming community	Government to provide subsidy, loan, space and incentives to reduce rural-urban migration	Assessment, study & formation of private company/cooperative to recruit, train and employ youth to work on farm across Bhutan.

Table A 3. Forest and Biodiversity Sector Adaptation Options

Sl. No	Strategic Objective	Strategic Intervention	Strategic Action	Short Term (0-5)	Medium Term (5-15)
1	Strengthen forest fire management in Bhutan through participatory and consultative approach	Minimized risk of forest fire	Develop fire management Strategies and plans	Develop fire management plans and strategy Upscale Dzongkhag level fire management interventions Implementation of the plan	Evaluation and assessment of the plans and strategies. Formulate gender sensitive, nature-based solutions and EbA actions- Community Forest, PES and NWFP approach.
			Sensitization and awareness on forest fire.	Develop materials for sensitization and awareness. Conduct awareness during fire seasons	Integrate fire ecology into RUB curriculum. Integrate basic fire related studies in general education system.
			Capacity building to manage and fight forest fire	Conduct Capacity Need Assessment Capacity building to manage and fight forest fire	Formulate HR plan and implement capacity building
			Applied research on forest fire	Conduct research and study on fire ecology under different ecosystems and tree species that are fast growing and more resistant to fire damages	Long term research on the impacts of forest fire
			Resource mobilization	Develop project and program-based resource mobilization plan	Develop project and program-based resource mobilization plan

2	Consistently monitor and maintain inventories of biodiversity	Conduct research and document changes in distribution of flora and fauna	Conduct assessment of spatial distribution of CC vulnerable flora and fauna	Long term research on the forest and biodiversity composition. (Develop database of the assessment and monitor the change	Develop long-term forest and biodiversity monitoring system. Develop database of the assessment and monitor the change and decision making
3	Reforest important habitats and wildlife corridors	Carry out plantation in collaboration with Social Forest and Extension Division (SFED)	Based on the deforested area identified by SFED, carry out plantation in line with the plantation guideline/framework.	Identify plantation sites and carry out plantation	Carry out maintenance of the plantation sites.
4	Prevent and control the increasing incidences of pest and diseases	Minimize the incidences of pests and diseases	Strengthen Surveillance and monitoring of Pest and diseases Mapping of pests and diseases prone areas. Promote Capacity building and Research.	Strengthen Surveillance and monitoring of Pest and diseases. Identify areas that are prone to pest and diseases. Catalogue the types of pest and diseases according to the site	Strengthen Sustainable Forest Management Promote Capacity building and Research. Develop a Pest and diseases management plan. Develop Pest and Diseases Strategy Plan
		Control and manage the establishment of invasive species (2 votes)	Identification of new IAS (both local and foreign). Reduce the impacts on biological system (prevent introduction and establishment of IAS and remove existing IAS). Resource mobilization. Strengthen Surveillance and monitoring of IAS	Engage communities in the management of IAS Promote Capacity building and Research.	Reduce the impacts on biological system (prevent introduction and establishment of IAS and remove existing IAS). Resource mobilization. Strengthen Surveillance and monitoring of IAS

5	Control and prevent degradation of forest cover and biodiversity through scientific management and community engagement	Prevent and control degradation of Forest Cover/ Biodiversity/ Protected Area, Biological Corridors, FMU, Community Forest.	Reduce all forms of illegal Poaching Reduce unsustainable harvesting of NWFPs and poor management of natural resources. Prevent and reduce displacement of biodiversity and wildlife (contributing to HWC). Poor developmental plans contributing to ecosystem/forest destruction.	Enhance SMART patrolling programs Promote alternative livelihood sources and ecosystem based, nature-based adaptation Sustain fundamental ecological functions (Reduce impacts on soil, maintain hydrology, riparian area, improve Promote Community Based Natural Resource Management (CF, NWFP, Plantations) and improve governance. Capacity building of CFMG and NWFP groups Strengthen Sustainable Forest Management Promote Landscape approach to development and ensure connectivity (reduce landscape fragmentation, improve BC habitat, enrichment plantation)	Promote Community Based Natural Resource Management (CF, NWFP, Plantations) and improve governance. Promote alternative livelihood sources and ecosystem based, nature-based adaptation Sustain fundamental ecological functions (Reduce impacts on soil, maintain hydrology, riparian area, improve Promote Community Based Natural Resource Management (CF, NWFP, Plantations) and improve governance. Capacity building of CFMG and NWFP groups Strengthen Sustainable Forest Management Capacity building of CFMG and NWFP groups

6	Recommend formulation of policies, legislations, rules and regulations (PLRS) for climate change adaptation and biodiversity conservation	PLRs needs to be strengthened to support and guide implementation of Climate Change related interventions	Finalization and endorsement of the draft Climate Change policy	Formulation of National Adaptation Plan to support resource mobilization and capacity building.	Formulation of National Adaptation Plan to support resource mobilization and capacity building.
7	Improve collaboration among institutions for effective implementation of the adaptation strategies and promote institutional development amongst these institutions.	Improve and strengthen implementation of adaptation strategies.	Identification of gaps and challenges related to implementation of adaptation strategies. Formulate an implementation plan in consultation with all the relevant stakeholders.	Identification of gaps and challenges related to implementation of adaptation strategies. Formulate an implementation plan in consultation with all the relevant stakeholders.	Identification of gaps and challenges related to implementation of adaptation strategies. Formulate an implementation plan in consultation with all the relevant stakeholders.

Table A 4 Energy Sector Adaptation Options

Sl. No.	Strategic Objective	Strategic Outcome	Strategic Action	Short Term (0-5 yrs)	Medium term 5 – 15 years
1	Diversification of energy use and improve energy saving’	Increase in alternative energy sources (biomass, wind, solar) other than hydropower and improved energy saving	Explore alternate energy sources, energy saving technologies and improve capacity of stakeholders	Research on/ Explore other major sources/places for energy tapping.	Use of energy efficient technologies in urban areas
				Immediate implementation of use of biomass, biogas, solar energy (pilot projects and implementation) - Adopt biogas as cooking fuel in rural houses	Promote Research and Development practices
				Promote Research on energy efficient technologies and use More research and subsidy for solar PV, Solar heating systems and wind projects	Policy on the use of alternative energy to be implemented
				Capacity building of stakeholders	
				Explore possibilities of small-scale storage schemes for seasonal variations and fluctuations in hydropower.	
				Harnessing of wind energy as an alternative energy.	
2	Improve sustainability of hydropower projects	Increased Resilience hydropower infrastructures to climate change	Review design of existing hydropower plants to improve resilience and watershed management plans	Review design and increase capacity/ strength of hydropower dams in the context of climate change.	Pump storage mechanisms for existing hydropower plants.

				Mapping, planning, Contingency plans and Early Warning Systems with real time monitoring. Flood forecasting in advance.	Modelling, forecasting and planning for better hydropower production
				Watershed protection and check dams at convenient locations.	Improve Research and development studies on hydropower plants.
				Implementation of watershed management plans.	
3	Decrease dependence on fossil fuels especially in the transport sector	Increased use of energy efficient public transport and electric vehicles	Improve existing public transport system and review existing tariffs and tax system	Improve access/purchase of electric vehicles by reviewing tax systems on electric/hybrid cars.	Efficient infrastructure development for transportation
				Research and capacity building for the implementation of energy efficient public transport system.	Subsidy or tax exemption on energy efficient goods and services policy
				Promotion of electric mobility	
				Promotion of biofuel by blending fossil fuel	

Table A 5 Health Sector Adaptation Options

Sl. No.	Strategic Objective	Strategic Outcome	Strategic Action	Short Term (0-5 yrs)	Medium term 5 – 15 years
1	Proper monitoring of Water and vector borne diseases and safety plans	Improved capacity in handling water and vector borne diseases	Proper monitoring of diseases, implementation of safety plans, awareness and facilities in place	Create Awareness on VBDs and WBDs	Research and monitoring on VBDs and WBDs and its risk due to Climate Change.
				Monitoring of vector borne disease	Early Warning System for Disease Surveillance and warning (Cross cutting.)
				Implementation of Water safety plans.	Review and proper design of Water supply infrastructure.
2	Increase institutional capacity	Improved capacity in handling climate sensitive diseases and their early signs	Capacity building and awareness	Capacity building of health workers, awareness.	Long Term Trainings and Research to aid in forecasting diseases and early treatment/ containment.
3	Improve health Infrastructure, equipment to handle climate sensitive diseases	Proper heath infrastructure, equipment, labs in place	Construction of climate resilient health infrastructures, labs and equipment, capacity building,	Research on impact of climate change on animal health.	Continuous capacity development and awareness.
				Institutional strengthening. Labs and equipment to deal with climate sensitive diseases.	
4	Promote One health approach.	Improved emergency health preparation	CP for emergency healthcare and improve understanding/research on animal health care/ diseases	Emergency health preparation with Contingency plans.	Tertiary health care system and promote traditional health care.
				Research on impact of climate change on animal health-zoonotic diseases.	

Table A 6 Disaster- Adaptation Options

Sl. No.	Strategic Objective	Strategic Outcome	Strategic Action	Short Term (0-5 yrs)	Medium term 5 – 15 years
1	Increase capacity in handling cascading risks and coping capacity	Improved capacity in terms of preparedness in handling cascading disasters	Strengthen CP and DP (responsive CP & DP plans), Capacity building and awareness, and increase coordination, Infrastructure resilience to CC, proper evacuation/ management plans and facilities in place	Vigorous awareness/ mock drills,	Plan and design proper structural measures to prevent disasters
				Evacuation areas in different vulnerable Dzongkhags	Improve Emergency communication facilities
				Enhance disaster preparedness	Rehabilitation or recovery centers
				Strengthen disaster management and contingency plans	Risk maps for various hazards.
				Implementation of disaster management and contingency plans.	Enforcing of building by-laws and codes
				Infrastructure and capacity building for Emergency preparedness	Proper layout and installation of Multi -hazard EWS
				Installation of Flood EWS in vulnerable areas	Preparation of Multi-hazard atlas.
				Capacity building for communication, volunteers and institution.	
				Enhance multi-sectoral collaboration	
				Upgrade Food and other reserves	

2	Reduce windstorm impacts on human settlements and crops	Improved capacity in handling windstorm disasters	Strengthen windstorm management plans, Capacity building and awareness, and increase coordination, and infrastructure resilience to CC, proper evacuation/ management plans and facilities in place	Enhance/improve disaster preparedness through infrastructure capacity building, awareness and trainings.	Agriculture input support, crop insurance.
				Strengthen and implement disaster management and contingency plans	
				Documentation of indigenous knowledge and practices	
3	Increase resilience to prolonged dry periods	Improved capacity in handling climate change induced dry periods	Proper watershed management plans and implementation, capacity building and water storage facilities in place	Rainwater harvesting and recharge	Agriculture input support, Insurance for crops
				Building water reservoirs/storages after proper design and layout plans	Research on use of drought resilient crops
				Documentation of indigenous knowledge and practice	Mapping drought prone areas and forest fire prone areas
				Implementation of proper watershed management plans	
				Capacity building of stakeholders and awareness	

4	Increase capacity in handling flood disasters	Improved flood forecasting, preparedness and response system	Improve Flood forecasting, mapping of vulnerable areas, advocacy, capacity and infrastructure for handling flood disasters	Forecasting of floods from modelling as well as from number of incidences in the past and installation of early warning systems as needed	Introduction and implementation of flood resilient housing construction.
				Map and target all areas with specific, action-oriented communication before, during and after the flood events.	Review design of Flood management protective structures like dams, drainage systems, and barriers in flood prone areas
				Coordinate and mainstream weather forecasting with agricultural sectors.	
				Strong rules and regulations against construction in vulnerable/ flood prone areas and provide guidance for resilient floodplain designs.	
				Promote and maintain volunteerism and community initiatives facilitating response, evacuation, recovery and support for residents affected by floods such as Dessup and others.	
				Advocate, train and prepare the communities about the floods and flash floods.	

5	Reduce landslide risks and improve preparedness	Increased capacity in handling landslide related disasters	Landslide mapping, bioengineering, capacity building and proper infrastructures in place	Landslide risk mapping for the country	Highway tunnelling
				Bioengineering with suitable species of trees/plants and grasses in vulnerable areas	
				Construction of check dams and gabion retaining structures	
				Review designs of drainage systems and retaining walls along landslide prone areas	
6	Increase capacity in handling earthquake disasters and earthquake triggered disasters	Earthquake disaster management plans and DM plans for earthquake triggered disasters developed	Proper monitoring, design and management plans	Continuously monitoring earthquakes.	Research and development
				Enhance understanding of seismic activity and provide critical long-term information for strengthening seismic building codes.	
				Proper disaster management plans for cascading disasters.	
				Research and investigation on heat waves and cold waves	Resilient building codes and design
7	Improve understanding and preparedness in handling heat wave and cold wave	Increased capacity in handling heat waves and cold waves associated disaster	Proper monitoring, design and management plans	Inclusion of heat and cold waves as potential risks	Planning for proper shelters and supports for emergencies.
				Awareness to the communities and the government.	

Table A 7 Urban Infrastructure and Development- Adaptation Options

Sl. No.	Strategic Objective	Strategic Outcome	Strategic Action	Short Term (0-5 yrs)	Medium term 5 – 15 years
1	Combat risk of Urban heat island	Climate proof infrastructures in place, climate sensitive policies, green building designs enforced, and green spaces concepts adopted	Ensure green building designs and green spaces concept under planning, climate sensitive policies and capacity building	Ensure/Green space; micro parks in urban/town areas.	Climate resilient infrastructure development in urban areas,
				Proper enforcement of green building design	Climate sensitive policies and institutional capacity building
				Research/promote traditional practices (construction materials) (energy saving)	Research and development
				Ensure multi-stakeholder coordination	
				Developing skills and incentives for skilled workers (Construction sector)	
				Ensure roadside plantation	
2	Controlling air pollution	Reduced risk of air pollution and air quality monitored	Increase/improve number of air quality monitoring stations, waste management and reduce vehicular pollution	Installation of air quality monitoring stations across the country	Proper quality control and assurance based on climate change
				Proper waste management system in place for all (Solid, liquid and gas)	
				Identification of no car zone - cycle lanes in place and efficient public transport	
				Solar energy subsidies and electric vehicle subsidies	

3	Storm water properly managed	Storm water management systems in place	Design and construction of proper storm water drains, capacity building and awareness raising	Development of code/ guideline/ design criteria for storm water drains in Bhutan	Study on precipitation for localized flooding for design purpose
				Proper wastewater management plan/system in urban areas	Research and development
				Ensure multi-stakeholder coordination and capacity building.	
5	Proper climate resilient planning and infrastructure development	Climate resilient development ensured	Policy for climate resilient infrastructures and capacity building	Development of climate resilient infrastructure policy and institutional capacity	Research and development
				Capacity building	
				Enforcement of green building design	

CLIMATE CHANGE COMMITTEES, NATIONAL THEMATIC WORKING GROUP MEMBERS AND TNC PROJECT MANAGEMENT UNIT AND REVIEWERS

National climate change committee (NCCC)

i. Dr. Tandi Dorji, Chair, Minister, Ministry of Foreign Affairs
ii. Dasho Paljor J. Dorji, Deputy Minister, Special Advisor to NEC
iii. Dasho Rinzin Dorji, Secretary, Ministry of Agriculture and Forests
iv. Dasho Karma Tshering, Secretary Ministry of Economic Affairs
v. Dasho Chencho Dorji, Secretary, Ministry of Works and Human Settlement
vi. Dasho Pema Tshewang, Secretary, National Land Commission
vii. Dr. Lam Dorji, Private Sector Representative
viii. Dr. Kinley Tenzin, Executive Secretary, Royal Society for Protection of Nature
ix. Aum Phub Zam, President, Bhutan Chamber of Commerce and Industries
x. Dasho Sonam P. Wangdi, Member Secretary, National Environment Commission Secretariat

Climate Change Coordination Committee (C4)

i. Secretary, NECS, Chair
ii. Director General, RSTA, MoIC
iii. Director General, Research and External Relations, RUB
iv. Director, DDM, MoHCA
v. Director, GNHC
vi. Director, DLG, MoHCA
vii. Director, NCHM
viii. Director, DoPH, MoH
ix. Secretary General, Tarayana Foundation
x. Chief, PPD, MoAF
xi. Chief, DMEA, MoF
xii. Chief, PPD, MoWHS
xiii. Chief, PPD, MoEA
xiv. Head, Private Sector HRCDD, BCCI
xv. Chief, CCD, NECS, Member Secretary

National Thematic Working Group on GHG Inventory and Mitigation

i. Mr. Jigme Wangdi, Specialist, Department of Livestock, MoAF
ii. Mr. Suraj Chhetri, Principle Soil Fertility and Plant Nutrition Officer, National Soil Service Centre, DoA, MoAF
iii. Mr. Dawa Chogyel, Environment Analyst, Environment Unit, Department of Trade, MoEA
iv. Ms. Dawa Chhoedron, Chief, Department of Hydropower and Power Systems
v. Mr. Tshewang Dorji, Dy. Chief Environment Officer, Climate Change Division, NEC
vi. Ms. Dechen Pema Yangki, Executive Engineer, Department of Renewable Energy, MoEA
vii. Mr. Jamyang Dukjey, Architect, Department of Engineering Services, MoWHS
viii. Mr. Tobden, Dy. Chief Statistical Officer, National Statistical Bureau
ix. Mr. Dorji Wangdi, Dy. Chief Forestry Officer, Forest Resource Management Division, DoFPS, MoAF
x. Mr. Thinley Dorji, Deputy Chief Statistical Officer, Ministry of Information and Communication
xi. Dr. Jigme Tenzin, Sr. Forestry Officer, Watershed Management Division
xii. Mr. Sonam Dorji, Senior Research Officer, Bhutan Chamber for Commerce and Industries
xiii. Ms. Deki Gyamtsho, Deputy Collector of Customs, Department of Revenue and Customs, MoF

xiv. Mr. Sangay Chedar, Program Officer, Gross National Happiness Commission
xv. Ms. Chhimi Dema, Program Officer, Gross National Happiness Commission
xvi. Mr. Leki Choda, Program Officer, Road Safety and Transport Authority
xvii. Ms. Jigme Choki, Environment Officer, Environment Unit, DoT, MoEA
xviii. Mr. Rinchen Penjor, Environment Officer, Waste Management Division, NEC
xix. Ms. Tshering Yangzom, Environment Officer, Thimphu City Corporation
xx. Mr. Sonam Dagay, Environment Officer, Climate Change Division, NEC
xxi. Mr. Drodhel Zangpo, Environment Officer, Environment Assessment and Compliance Division, NEC
xxii. Mr. Pema N Ghalley, Program Officer, Association of Bhutanese Industries
xxiii. Mr. Rinzin Namgay, IT Officer, NEC
xxiv. Mr. Wangdi Phuntsho, Environment Officer, EACD, NEC
xxv. Mr. Tashi Dendup, Environment Officer, CCD, NEC
xxvi. Mr. Lobzang Tempa, Environment Officer, CCD, NEC
xxvii. Mr. Tshering Tashi, National Coordinator, TNC Project, CCD, NEC

National Thematic Working Group on Vulnerability and Adaptation Assessment

i. Dr. Karma Tenzin, Assistant Professor, Khesar Gyalpo University of Medical Science of Bhutan
ii. Ms. Sonam Lhaden Khandu, Chief Environment Officer, Biodiversity and Land Use Division, National Environment Commission Secretariat
iii. Mr. Tayba Buddha Tamang, Chief, National Center for Hydrology and Meteorology
iv. Mr. Norbu Wangdi, Chief, FRMD
v. Dr. Phurba, Lecturer, Khesar Gyalpo University of Medical Science of Bhutan
vi. Mr. Tshering Tashi, TNC Project Coordinator, CCD, NECS
vii. Ms. Monika Thapa, Lecturer, College of Science and Technology
viii. Mr. Jigme Tenzin, Dy. Chief Horticulture Officer, Agriculture Production Division, DoA, MoAF
ix. Mr. Tsencho Dorji, Dy. Executive Engineer, Weather and Climate Service Division, NCHM
x. Mr. Jamyang Dukjey, Architect, Department of Engineering Services, MoWHS
xi. Ms. Rinchen Yangzom, Dy. Chief Biodiversity Officer, National Biodiversity Center, MoAF
xii. Ms. Sonam Choden, Senior Forest Officer, WMD/MoAF
xiii. Ms. Sonam Deki, Senior Program Officer, Department of Disaster Management
xiv. Mr. Sonam Dagay, Environment Officer, NECS
xv. Mr. Netra Binod Sharma, Project Support Officer, NAPA II Project
xvi. Mr. Sangay Dorji, Program Officer, Department of Local Governance
xvii. Mr. Chador Wangdi, Sr. Program Officer, Ministry of Health
xviii. Ms. Sonam Choden, Environment Officer, Samdrup Jongkhar Thromde
xix. Mr. Sangay Chedar, Planning Officer, GNHCS
xx. Ms. Tashi Choden, Planning and Coordination Division, DHPS
xxi. Mr. Phuntsho Wangdi, Environment Officer, Water Resource Coordination Division, NEC
xxii. Mr. Tsheten Dorji, Project Officer, WASH, RSPN
xxiii. Ms. Sonam Yangzom, Engineer, Department of Roads, MoWHS
xxiv. Mr. Jamyang Phuntsho, Program Officer, Tarayana Foundation, Thimphu
xxv. Ms. Chhimi Dema, Planning Officer, Gross National Happiness Commission
xxvi. Mr. Rinzin Namgay, ICT Officer, NECS
xxvii. Ms. Tshering Yangzom, Environment Officer, CCD, NEC

Third National Communication Project Management Unit

i. Dasho Sonam P. Wangdi, Secretary, Chair
ii. Ms. Tenzin Wangmo, Chief, CCD, Project Director
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FRMD, DoFPS, MoAF, Thimphu, Bhutan
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Dy. Chief Forestry Officer
FRM, DoFPS, MoAF, Thimphu, Bhutan
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Principle Agriculture Officer
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Environment Officer, Climate Change Division, NECS, Bhutan
xiii. Mr. Rinzin Namgay
IT Officer, NECS, Bhutan
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Environment Officer, Climate Change Division, NECS, Bhutan
xv. Ms. Lily Yangchen
Hamilton College, USA, Intern with CCD, NECS
xvi. Ms. Kinley Zam
Project Support Officer, Gender NDC Project, NEC, Thimphu
xvii. Mr. Tshering Tashi
Offtg. Chief, Climate Change Division, NECS, Bhutan
xviii. Ms. Tenzin Wangmo, Policy Anaylyst
Climate Analytics
LDC Office, Bhutan

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%20 1980%20(English).pdf
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National Environment Commission
Royal Government of Bhutan
P.O. Box 466, Thimphu, Bhutan
www.nec.gvo.bt