BANGLADESH

TECHNOLOGY NEEDS ASSESSMENT AND TECHNOLOGY ACTION PLANS FOR CLIMATE CHANGE ADAPTATION

October 2012

Supported by:

UNEP

GLOBAL ENVIRONMENT FACILITY
INVESTING IN OUR PLANET

UNEP RISØ CENTRE
ENERGY, CLIMATE AND SUSTAINABLE DEVELOPMENT

AIT Asian Institute of Technology

DISCLAIMER

This document is an output of the Technology Needs Assessment project, funded by the Global Environment Facility (GEF) and implemented by the United Nations Environment Programme (UNEP) and the UNEP-RISO Centre (URC) in collaboration with the Regional Centre Asian Institute of Technology, Bangkok for the benefit of the participating countries. The present report is the output of a fully country-led process and the views and information contained herein is a product of the National TNA team, led by the Ministry of Environment and Forests (MoEF), Government of the People's Republic of Bangladesh.

FOREWORD

Climate change and its multi-dimensional impacts to the potential development sectors have become a reality for Bangladesh. Impacts of climate change are exacerbating many of the current problems the country faces and will relentlessly challenge country's ability to achieve continuous higher economic growth to eradicate poverty at an expected pace. In this context, Vision 2012 of the government of Bangladesh noted that climate change poses a serious threat to Bangladesh's goal to accelerate economic growth, substantially eradicate poverty and become a middle-income country by 2021. The Sixth Five-Year-Plan 2011-2015 (FYP 2011-2015) explicitly refers to climate change and the challenges it poses to Bangladesh's development. The Sixth FYP 2011-2015 recommends to tackle climate change vulnerability through programmes in agriculture, water, environment and disaster management. Environmental sustainability is one of the six core targets of the Sixth FYPs.

In addressing climate change, Bangladesh has prepared national policies and strategies to make its major development sector climate-resilient and also to mitigate green house gas mitigation from the potential sectors. Bangladesh was the first developing country to produce National Adaptation Programme of Action (NAPA) in 2005. The NAPA document further updated in 2009 and identified 45 adaptation measures with 18 immediate and medium-term adaptation measures. Building on lessons learnt from the NAPA Bangladesh prepared its own country-driven strategy 'Bangladesh Climate Change Strategy and Action Plan- BCCSAP' in 2009 through a participatory approach. BCCSAP identified a number of adaptation measures for short- and medium-term implementation to enhance adaptive capacity of vulnerable communities. In fact, the climate resilient development would require 'innovative adaptive measures' through introduction of new and appropriate technologies. Thus, in the country context, a technology needs assessment (TNA) is a pre-requisite task in implementing climate-resilient development planning.

I found the sectors and projects that have been prioritized in TNA Bangladesh adaptation report quite resemble to the sectors and projects emphasized in the BCCSAP. I strongly believe that the implementation of adaptation projects prioritized at the TNA Adaptation report will help the country in building resilience to the impacts of climate change.

I thank TNA National Team, my colleagues in the Ministry, experts of the relevant sectors for their invaluable contribution in the development of this report. I sincerely acknowledge the contribution of the project personnel and experts of UNEP, GEF, UNEP RISO Center and AIT for their all out effort in the implementation of TNA project and come-up with some specific and prioritized measures for climate change adaptation in Bangladesh.

Dr Hasan Mahmud, MP
Minister
Ministry of Environment and Forests
Government of the People's Republic of Bangladesh

PREFACE

There are two broad areas of policy action, globally as well as nationally, to face climate change. One of these is adaptation which relates to minimization of the adverse impacts of climate change and associated vulnerabilities at individual, household, community, local, sectoral, national, regional, and global levels through appropriate actions at those levels. The other is mitigation which calls for actions to lower and ultimately stop the emission of green house gases into the atmosphere.

Within this overall climate change context, adaptation measures involve the use of technology and its management (development, transfer, adaptation, adoption and diffusion) along with other related aspects such as financing. In the global context, technology development and transfer has increasingly gained a centre stage in the agenda of negotiations. Meanwhile in the country context, the technology needs assessment (TNA) becomes an important management tool in formulating development strategies at the national level for adaptation and climate-resilient development planning and program implementation.

Bangladesh being one of the most vulnerable countries to the impacts of climate change is already striving to accelerate economic growth and substantially eradicate poverty by 2021 but avoiding the harsh environmental price many countries have paid in the pursuit of growth. In line with the fulfillment of country's sustainable development goal Bangladesh, with the assistance of UNEP, has undertaken the Technology Needs Assessment (TNA) project to identify the needs for new equipment, techniques, practical knowledge and skills, which are necessary to reduce the vulnerability of sectors and livelihoods to the adverse impacts of climate change.

Briefly, this project aims to produce Technology Needs Assessment (TNA) and Technology Action Plans (TAP) for climate change adaptation in Bangladesh which is urgent and focuses on immediate needs of the country. This report provides a list of prioritized sectors that are likely to be affected by the impacts of climate change and which require urgent and immediate adaptation actions.

The TNA process in Bangladesh has followed participatory analysis and consultation with the sector-specific experts and stakeholders. I thank all of my colleagues, experts and stakeholders who have been involved in TNA and contributed in this report.

Md. Shafiqur Rahman Patwari
Secretary
Ministry of Environment and Forests
Government of the People's Republic of Bangladesh

ACKNOWLEDGMENTS

Technology Needs Assessments Report, Part I is an outcome of efforts of a number of people, who shared their experiences and views on the impacts of climate change in important development sectors, discussed number of technological options for the adaptation of the vulnerable sectors, also discussed GHG mitigation potentials of country's energy and non-energy sectors.

Special acknowledgement is to due to the members of National TNA Team namely Dr Rezaul Karim, Environmentalist and Team Leader of National TNA Team, Dr M Asaduzzaman, Research Director, Bangladesh Institute of Development Studies, Dr Ainun Nishat, Vice Chancellor, BRAC University, Dr Ijaz Hussain, Professor, Bangladesh University of Engineering and Technology, Dr Zahirul Haque Khan and Engineer Tarek Bin Hossain of Institute of Water Modeling, Dr AKM Saiful Islam, Associate Professor, Bangladesh University of Engineering and Technology and Mr Md Shamsuddoha of Center for Participatory Research and Development (CPRD).

Acknowledgement is also due to experts and stakeholders of different government and non-government organizations who have participated in the national and local level consultations and provided substantive input throughout the TNA process.

Special thanks to Dr P Abdul Salam , Assistant Professor, Energy Field of Study, School of Environment, Resources and Development, Asian Institute of technology and Dr Mokbul Morshed Ahmed, Associate Professor, Regional and Rural Development Planning, School of Environment, Resources and Development, Asian Institute of Technology, Bangkok, Thailand and Mr Sudhir Sharma, Senior Climate Change Expert, UNEP RISO Centre for their comments, suggestions and technical inputs while implementing the TNA project in Bangladesh.

Sincere acknowledgement is due to the project personnel of UNEP, GEF, UNEP RISO Center and AIT for their technical support and constructive feedback in all aspects of TNA implementation.

Sincere acknowledgement is also due to Mr Meshba ul Alam, Former Secretary, Ministry of Environment and Forests, Mr Shafiqur Rahman Patwari, Secretary, Ministry of Environment and Forests and to Mr Aparup Chowdhury, Additional Secretary, Ministry of Environment and Forests for their guidance and encouragement in the implementation of TNA project in Bangladesh.

S M Munjurul Hannan Khan, PhD
Deputy Secretary
and
National Coordinator
Technology Needs Assessment (TNA)
Ministry of Environment and Forests
Government of the People's Republic of Bangladesh

ABBREVIATIONS AND ACRONYMS

AIT	Asian Institute of Technology
BADC	Bangladesh Agricultural Development Corporation
BCCSAP	Bangladesh Climate Change Strategy and Action Plan
BBS	Bangladesh Bureau of Statistics
BER	Bangladesh Economic Review
CCC	Climate Change Cell
CEGIS	Center for Environmental and Geographic Information Services
DDR	Disaster Risk Reduction
DFID	Department for International Development
EPA	Environmental Protection Agency
GDP	Gross Domestic Product
GEF	Global Environment Facility
GoB	Government of Bangladesh
HRD	Human Resource Development
IPCC	Intergovernmental Panel on Climate Change
LDC	Least developed country
MCDA	Multi Criteria Decision Analysis
MDGs	Millennium Development Goals
MoEF	Ministry of Environment and Forests
MSL	Mean Sea Level
NAMAs	Nationally appropriate mitigation actions
NAPA	National Adaptation Programme of Action
PIU	Project Implémentation Unit
PRDI	Participatory Research and Development Initiative
R&D	Research and Development
SFYP	Sixth Five Year Plan
SLR	Sea Level Rise
SST	Sea Surface Temperature
SSTA	Sea Surface Temperature Anomaly
TNA	Technology Needs Assessments
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
URC	UNEP RISO Centre
WB	World Bank

LIST OF FIGURES

LIST OF TABLES AND ANNEXES

Annex

TABLE OF CONTENTS

Part I

Technology Needs Assessments for Climate Change Adaptation in Bangladesh

Executive Summary

The First Part of the Technology Needs Assessments for Adaptation Report aims to identify and short-list prioritized sectors, sub-sectors that have maximum potential for adaptation benefits in the light of country's long-term development policies. This report also identified and prioritized sector-specific adaptation technologies that have synergies with the long-term country's development priorities i.e. making the country's prioritized sectors resilient to climate change vulnerabilities now and in the future.

This report has been prepared through a consultative process with the involvement of stakeholders from government and non-government organizations of the relevant sectors and sub-sectors prioritized for TNA. In the TNA consultation process, stakeholders from a wider sector and also from the grass-root level were involved to identify new knowledge, especially local knowledge, and insights on specific technology challenges and opportunities. Aside with stakeholder's consultation, a number of policy documents, for example country's Sixth Five-Year Development Plan (2011-2015) prepared in 2011 and Bangladesh Climate Change Strategy and Action Plan (BCCSAP) prepared in 2009, Second National Communication prepared in 2011 and Vision 2021 etc. have analyzed in identifying and prioritizing the sectors potential for mitigation benefits and adaptation necessities.

Thus, in view of country's efforts to undertake climate proofing activities, and to realise the targets set for vision 2021 and the Sixth Plan, the agriculture and water sector have been identified as a priority sectors where technological intervention through development and diffusion of climate smart technologies that will be required to make this sector resilient to the impacts of climate change.

In order to enable these sectors to adapt to the adverse effects of climate change, a number of measures have been identified by exploring how investments in technologies for adaptation would improve the situation beyond the baseline situation in the agriculture sub-sectors. Improvements have been expressed in terms of development priorities, adaptation benefits and other environmental impacts, as well as economic and social impacts.

The water sector technology includes;

- Rehabilitation of existing embankments/ dykes and dredging infrastructure development,
- Comprehensive disaster management incorporating early warning systems and involving community tidal system and infrastructures management,
- Monitoring of sea level rise, tidal fluctuation, salinity intrusion, sedimentation and coastal erosion,
- Tidal river management including computer simulation of tidal flow,
- Tidal barriers (Sluice gate),
- Urban Infrastructure development.

On the other hand, the agriculture sector technology includes

- Development of salinity-tolerant rice varieties,
- Development of drought-tolerant rice varieties,
- Development of short-maturing rice varieties,
- Establishment of climate-smart Technology Dissemination Center,

- Training on improved farming practices for crops, irrigation and water management, soil fertility management (conservation and restoration of soil quality) etc.
- Establishment of special agricultural R & D centre and
- Land-use planning

The criteria for prioritizing adaptation technologies have been established by exploring to what extent investments in technologies for adaptation would contribute to resilience-building in the context of the country's aspiration of achieving sustainable development goals. Thus, the criteria considered for technology prioritization are: development benefits, implementation potentials and contribution to climate change response goals.

Development benefits define climate change adaptation technologies, which offer the greatest value to the country in meeting its current national development priorities. Implementation potential defines scale of implementation and diffusion of the technology, which can be realistically achieved if key barriers are overcome. Contribution to climate change response goals defines technologies, which will make the biggest contributions to the country's efforts for facilitating adaptation to climate change, that will contribute to the country's effort to undertake and implement the climate-resilient development strategies and actions.

CHAPTER 1: Introduction

1.1 Background of Technology Needs Assessment report

Bangladesh is widely recognized to be one of the most vulnerable countries in the world to the impacts of climate change. The country is already experiencing the adverse impacts- hotter summers, irregular monsoon, untimely rainfall, heavy rainfall over short period causing water logging and landslides, little rainfall in the dry season, increased river flow and inundation during monsoon, coastal erosion and river bank erosion. Aside with the changes in weather pattern Bangladesh is facing with increased frequency, intensity and recurrence of floods, crop damage due to flash floods and monsoon rain, crop failure due to drought etc. Salinity intrusion along the coast leading to scarcity of potable water and redundancy of prevailing crop practices (CCC, 2008).

The Government of Bangladesh not only recognizes the vulnerability of the country, its people and overall development, to the adverse effects of global warming and climate change but also included the issue in the country's overall development and policy planning. The GoB has prepared the Vision 2021, which is based on the principle of sustainable development.

Besides, Vision 2021 and the Sixth Five-Year Development Plan of the Government of Bangladesh are based on the principle of sustainable development i.e. management of climate change for uninterrupted and sustainable development. Very briefly, it is to eradicate poverty, increase employment opportunity, ensure food security, provide access to energy and power, and achieve economic and social well-being of all citizen of the country. Bangladesh will achieve this goal through a strategy of pro-poor, climate resilient and low carbon development, based on the four buildings blocks of the Bali Action Plan- adaptation to climate change, mitigation, technology transfer and adequate and timely flow of funds for investments within an inviolate framework of food, energy, water, livelihoods and health security.

The Government of Bangladesh also has undertaken a more comprehensive planning process, with its own financial and intellectual resources and prepared Bangladesh Climate Change Strategy and Action Plan (BCCSAP) in 2009. The Climate Change Strategy and Action Plan (BCCSAP) of Bangladesh is a part of the overall development strategy of the country (MoEF, 2009). The BCCSAP outlines the core policy, strategy, and action thrusts as a mechanism to respond to and address the risks related to climate change. The climate change constraints and opportunities are being integrated into the overall plan and programmes involving all sectors and processes of economic and social development. The BCCSAP outlines 44 programme under six thematic areas, one of which is mitigation and undertaking low carbon development path. Though adaptation and undertaking climate resilient development activities is the major policy and programme thrust but the Government of Bangladesh is committed to following a low carbon path, given adequate financial and technological resources are provided by the international community for both adaptation and mitigation, without compromising the need for accelerated economic growth and poverty reduction.

Within this overall climate change context, both the adaptation and mitigation involve the use of technology and its management (development, transfer, adaptation, adoption and diffusion) along with other related aspects such as financing.

To identify, evaluate (feasibility of) and prioritize technological means for required adaptation actions, Ministry of Environment and Forests (MoEF) of the Government of Bangladesh, with the assistance from UNEP, has been implementing Technology Needs Assessment project, starting January 2011.

It is important that the eventual technology choices are clearly in line with the long-term development priorities of the country and are intended to make country's prioritized sectors resilient to climate change vulnerabilities now and in the future. In this context, the TNA team, following a consultative process, has identified the country's development priorities based on national development strategies, such as five-year National Plans, Poverty Reduction Strategies, Bangladesh Climate Change Strategy and Action Plan, Sector Policies, and National Communications.

Mitigating the impact of climate change is considered as a cornerstone for sustainable development in the perspective plan. Other priorities for achieving sustainable development are outlined as: ensuring effective governance, promoting innovative people for a digital Bangladesh, creating a caring society, addressing globalization and regional cooperation challenges, ensuring broad-based growth and food security, providing energy security for development and welfare and building a sound infrastructure.

Based on these official publications, the TNA National Team generated a list of development priorities which they considered most applicable to the country's sustainable development, with a view to both the short and longer term, for the purpose of guiding technology needs assessment.

1.2 Objectives of TNA report

The key objective is finalizing a short-list of prioritized (sub) sectors in the light of country's long-term development policies and according to the maximum potential for adaptation benefits of the prioritized sectors.

The specific objectives are:

i) Identify country's development priorities through reviewing of long-term development policies and respective strategies

ii) Identify possible implications of climate change on the country's development priorities

iii) A short-list of sectors according to their development benefits and whether sectors have a balanced sustainable development contribution and deliver the maximum level of economical, environmental and social benefits.

CHAPTER 2: Institutional arrangement for the TNA and the stakeholders' involvement

2.1 Process followed in TNA

Though this section is not needed here, but it is helpful. So it is better to place this section as section 2.1 followed by the "Institutional structure for implementation of TNA".

Technology needs assessment is aimed at prioritizing technologies for adaptation actions in the light of countries' development objectives and to explore how this could be fed into strategic development plans at the country level. TNAs are likely to form a key element and information on how technologies may contribute to long-term development goals, their costs, and appropriateness for reduction of GHG emission and/or making the country climate resilient.

In this context, it is important to identify country's development priorities which could be used as criteria for selecting strategic sectors for adaptation. The National Team for coordinating technology needs assessments undertook the following activities in four states to identify sectors/ sub-sectors for technology needs assessment for climate change adaptation actions.

STAGE I: Knowing country's development priorities through a broader reflection on national economy and long-term development policies

STAGE II: Implications of Climate Change on Country's Development Priorities

STAGE III: Clustering Development Priorities

STAGE IV: Initial Identification of Priority Sectors

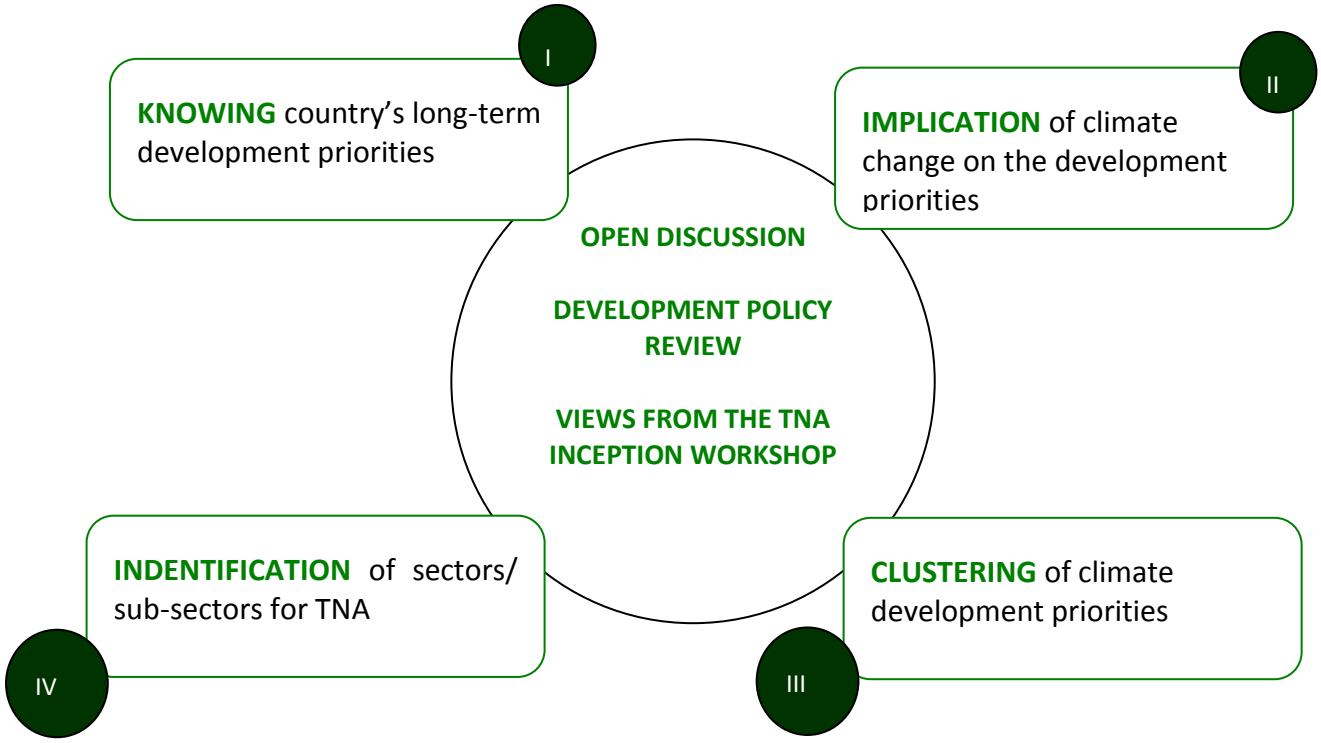

Figure 1: Stages of TNA Sector Prioritization

2.2 Institutional structure for implementation of TNA

With the overall policy guidance of the National Project Coordinator and the National Steering Committee for TNA, PRDI, a research-based development organization, has been leading implementation of the TNA through facilitating a coordinated effort of several renowned climate experts in the country, who have substantial experiences in the climate change mitigation and adaptation actions and have sector-specific specialization in country's sustainable development planning. The expert team comprises of 5 members who are familiar with national development objectives and sector policies, overall insights in climate change science, and potential climate change impacts for the country, and adaptation needs. Aside with the five-member expert team, there is also flexibility to accommodate additional experts, whenever needed. *Details of National TNA Team provided in Annex 2.*

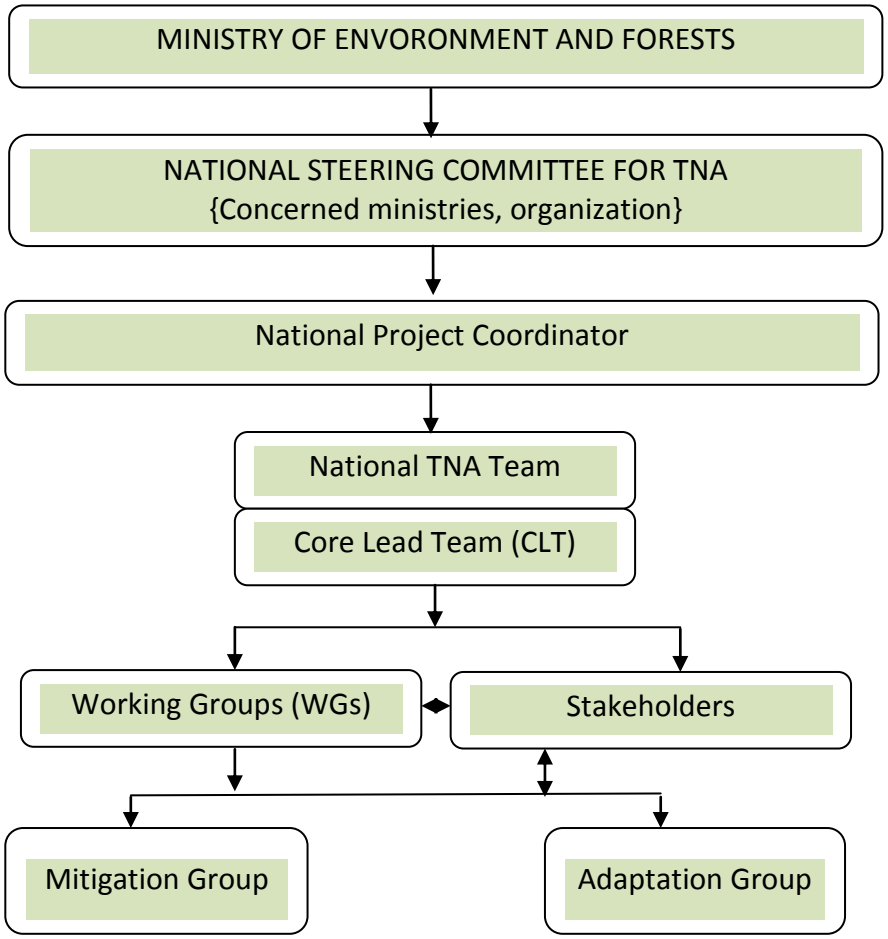

Figure 2: The institutional structure for TNA

The TNA team includes a Team Leader who for many years has been participating in the negotiation on technology transfer of the UNFCCC and also contributing to country's policy process on technology innovation and transfer for change mitigation and adaptation

actions. The Team Leader provides vision and leadership for the overall effort, facilitating communication with the National TNA Team members.

A Project Implementation Unit (PIU) has been established at PRDI to provide support as needed for project execution, especially in organizing workshops, focus group organization, and discussion moderation. The PIU ensures implementation of stakeholder consultations both in national and local level, coordinates tasks among the TNA Team members and also ensures required logistics to the TNA Team members.

The PIU hired required professionals (e.g. Task Coordinator, Technology Assistants and requited other staff) to assist the TNA National team, in undertaking all activities to realize the project objectives, that includes collection, analyses, and synthesis of all available data and information in support of the TNA exercise.

2.3 Stakeholder engagement process followed in TNA – overall assessment

Stakeholder consultations are the main feature of TNA (Figure 3). Consultation in various forms, layer and scale took place at various steps. Stakeholders ranged from sectoral experts and professionals from different educational and research institutions government ministries, department and agencies, and NGOs.

Stakeholders from relevant sectors are identified and grouped into a core group and sub-groups to deal with specific issues in depth, with links to the core group. These groups represent a network of organizations/institutions/individuals working in the field of technology development and transfer in the country. It has been ensured that stakeholders from a wider sector and also from the grass-root level are engaged in TNA process to contribute to the transfer of new knowledge, especially local knowledge, and insights on specific technology challenges and opportunities.

From a practical point of view, since a large number of people are legitimately classified as stakeholders in some of these categories, only representative members (core team) are involved in the assessment process. They are - Core Lead Team (CLT) and the Working Groups (WGs). The CLT was responsible for overall supervision and guidance, comprised of reputed experts. This team was basically a multi-sectoral expert team. Sectoral experts again led respective sectoral/thematic teams (or WGs) responsible for TNA for particular sector. The CLT of stakeholders comprises of 10-15 people from each identified sector potential for climate change adaptation and mitigation measures. The CLT then formed working groups by inviting key personnel/ experts from the relevant sector.

The CLT deals with the most substantive issues of the TNA process such as; management, resource assessment, technology costing and preparation of reports and other materials while the working group participates in consultation and engagement activities, such as workshops, and stakeholders' consultation. Outputs from the CLT consultations are communicated to all stakeholders through workshops and brief meetings. In all aspects, the National TNA Team has facilitated the active participation of all relevant stakeholders in the prioritization of technologies.

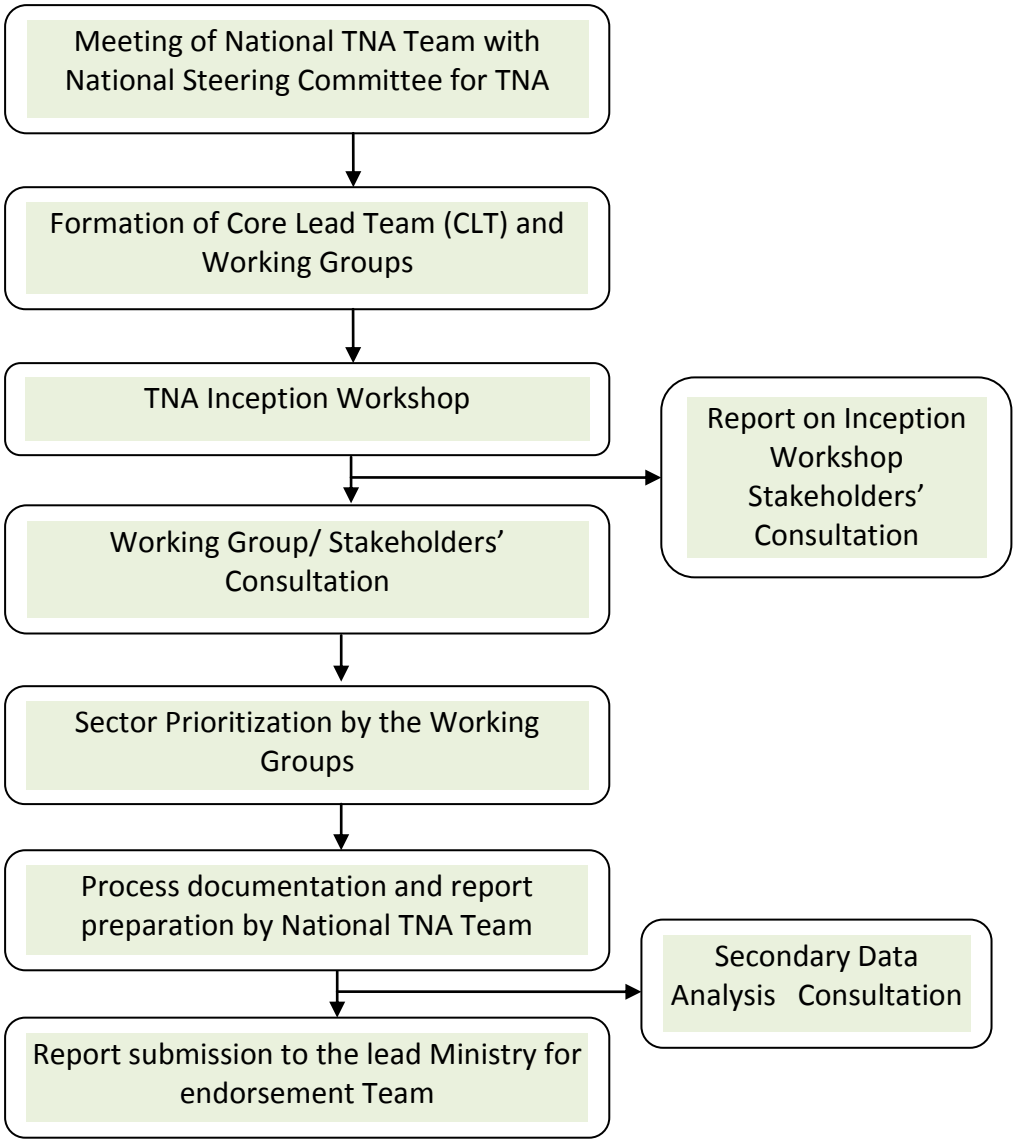

Figure 3: Main feature and snapshot of the whole process followed in TNA

The each working group has reviewed literature, consulted among and beyond and presented preliminary findings to a wider audience during the national consultation workshops held in 24th July 2010.

A list of stakeholders participated in different workshops and meetings are provided in Annex 3.

CHAPTER 3: Climate Change: Adaptation Challenge

3.1 Climate change impacts and adaptation challenge

Bangladesh ranks low on just about all measures of economic development. The low level of development, weak institutions, poor service delivery and in absence of appropriate policy strategy combined with other factors such as its geography and climate, makes the country more vulnerable to the existing as well as to the future disasters to be multiplied due to climate change.

The geo-physical location and geo-morphological conditions of Bangladesh have made the country one of the most vulnerable ones to natural disasters. Bangladesh is situated at the interface of two different environments, with the Bay of Bengal to the south and the Himalayas to the north. This peculiar geography of Bangladesh causes not only life-giving monsoons but also catastrophic ravages of natural disasters, to which now are added climate change and Sea Level Rise (SLR). The country has a very low and flat topography, except the northeast and southeast regions. About 10% of the country is hardly 1 meter above the mean sea level (MSL), and one-third is under tidal excursions. Offshore islands, in particular, are exposed to climate change impacts. Over 3 million people into 72 islands are not protected against storm surge or tidal waves. In the severe climate change scenario, sea-level rise poses an existential threat that would inundate 18 percent of Bangladesh's total land, directly impacting 11 percent of the country's population. Salt water intrusion from sea-level rise in low-lying agricultural plains, along with other hazards, could lead to 40 percent decrease in food grain production and would cause displacement of 30 percent people from their habitat.

Many of the anticipated adverse affects of climate change, such as sea-level rise, intensity, will aggravate the existing stresses that already impede development of Bangladesh, particularly by reducing water and food security and damaging essential infrastructure. Table 1, adapted from National Adaptation Programme of Action (NAPA 2005), describes the sectors and regions of the country which are exposed to climate change risks and vulnerabilities.

Table 1: A summary of overall sectoral vulnerability index of the country

Impacts of Climate Change	Vulnerable Sector	Critical vulnerable areas/ Regions
Temperature rise and drought	○ Agriculture (crop, livestock, fisheries) ○ Water ○ Energy ○ Health	○ North-west
Sea Level Rise (Coastal Inundation, Salinity Intrusion)	○ Agriculture (crop, livestock, fisheries) ○ Water (water logging, drinking water) ○ Human settlement ○ Energy ○ Health	○ Coastal Areas ○ Islands

Floods (river floods, flash floods)	○ Agriculture (crop, livestock, fisheries) ○ Water (urban, industry) ○ Energy ○ Health ○ Infrastructure ○ Disaster	○ Central Region ○ North East Region ○ Char lands
Cyclone and Storm Surge	○ Marine fisheries ○ Infrastructure ○ Human settlement ○ Life and property	○ Coastal and Marine Zone
Erosion and Accretion	○ Infrastructure ○ Human Settlement	○ Char lands ○ Coastal areas

Source: NAPA, 2005

a) Agricultural and food security

About one-quarter of the country's GDP comes from agriculture, which makes the country's economy. Agriculture sector in Bangladesh that contributes 20.16% (estimated in 2009/10) of the country's GDP and creates employment of 43.6 % (Bangladesh Economic Review 2010) of country's population, is relatively sensitive to existing and impending disasters. Rise in temperature will decrease rice production around 16 percent, wheat and potato production also will be reduced significantly. Besides, changes in temperature, humidity and radiation, will have greater effects on the incidence of insect pests, diseases and microorganisms, which has direct bearing on crop yield. Already Bangladesh is under risks of food deficit, suffering further decreasing food security due to damage by disasters and gradual degradation of the production systems caused by climate (and variability) change.

Several studies have been conducted in Bangladesh to assess the vulnerability of food grain production to various climate scenarios. One such study noted that a 4^{o}C increase in temperature would have a severe impact on food production in Bangladesh, resulting in a 28% reduction for rice and a 68% reduction for wheat. Temperature and rainfall changes have already affected crop production in many parts of Bangladesh, and the area of arable land has already decreased. Increased salinity levels will reduce fresh water availability for irrigation, while growing drainage congestion problems will result in longer periods of flood inundation. This will reduce the areas suitable for rice production. Under a moderate climate scenario, the decline in yields due to salinity intrusion could be 0.2 Mt, which increases to 0.56 Mt under more severe scenarios. In addition, increased coastal morphological dynamics will contribute to the existing problem of loss of valuable agriculture land due to erosion.

A geographical distribution of drought-prone areas under climate change scenarios shows that's the western parts of the country will be at greater risk of droughts, during both the Kharif [1]and pre-Kharif[2] seasons. It is found that, under a moderate climate change scenario,

[1] Kharif crops are usually sown with the beginning of the first rains in June and July, during the south-west monsoon season.

[2] Pre Kharif season refers to the months from March to May. Usually pre-Kharif periods become vulnerable to drought at varying degrees

Aus[3] production would decline by 27 percent while wheat production would be reduced to 61 percent (Karim et al. 1999). Under a severe climate change scenario (with 60 percent moisture stress), yield of *Boro* might reduce by 55-62 %. Moisture stress might force farmers to reduce the area for *Boro*[4] cultivation. The shortening of the winter season is resulting in a decline in production of winter crops, particularly potatoes.

Table 2: Intensity of impacts on different sectors due to Climate Change

Physical Vulnerability Context								
Extreme Temp	Sea level rise		Drought	Flood		Cyclone and Storm Surges	Erosion and Accretion	Sectoral Vulnerability Context
	Coastal inundation	Salinity Intrusion		River flood	Flash flood			
+++	++	+++	+++	++	++	+++	_	Crop Agriculture
++	+	+	++	+	+	+	_	Fisheries
++	++	+++	_	_	+	+++	_	Livestock
+	++	_	_	++	+	+	+++	Infrastructure
++	+++	++	_	++	+	+	_	Industries
++	+++	+++	_	++	_	+	_	Biodiversity
+++	+	+++	_	++	_	++	_	Health
-	-	_	_	_	_	+++	+++	Human Settlement
++	+	_	_	+	_	+	_	Energy

Source: NAPA 2005

b) Climate change impacts in water sector: SLR and salinity intrusion

Water-related impacts of climate change will likely be the most critical concern for Bangladesh in terms of urgency, severity, and economic consequence. Bangladesh, as a deltaic country, drains huge catchment's water (92% of water that Bangladesh drains is from outside the country). There shall be more water during monsoon and less water during dry season. There shall be more floods, droughts, water logging, drainage congestion, storm surges, salinity intrusion, and river bank erosion. Climate change will have its profound impacts on the water resources of Bangladesh. Variability in climate can affect several vital sectors that are the major water users, including agriculture, domestic/municipal, fisheries, navigation, industry and environment (Ahmed, A.U., 2006). Climate change has the potential to inundate coastal areas and cause severe adverse impacts on rainfall patterns.

[3] The rice varieties in the country are grown in three different seasons, locally called Aus, Aman and Boro. The Aus season starts in April and continues till August

[4] The Boro season refers to the cultivation takes place from December to May

Several research and studies on Bangladesh indicate that during the period 2030 to 2050 sea level may rise between 14 cm to 32 cm, and up to 88 cm by the yeas 2100 (Agrawala et al., 2003). The net change in sea-level is likely to be determined by interplay between sedimentation, compaction, tectonic subsidence and actual rise in sea level along the coast line of the country.

Another study conducted by the CEGIS (CEGIS 2006) on Bagerhat, Khulna and Sathkhira considered the sea-level rise scenarios of 32cm and 88 cm in the year 2050 and 2100 respectively. This study also noted that the salinity front will move towards inland with Sea Level Rise (SLR); the low saline areas (0-1 ppt) will decrease from 11% to 9% and 4% but high saline areas (20ppt-25ppt) will increase from 13% to 16% and 18% with the 32 cm and 88 cm SLR respectively. Salt water intrusion from sea level rise in low-lying agricultural plains, along with other hazards, could lead to 40 percent decrease in food grain production.

A projection has been made based on the number of the affected population, extent of affected area and population density of the inhabitable part of the country . This states that in the year 2100, only 122,483 square kilometers land area of Bangladesh out of current 147,570 square kilometers will remain inhabitable. Without inundation the usual population growth trend, population density would be about 1,440 per square kilometer. But inhabitable land area will be reduced, and 1,735 people will have to be accommodated per square kilometer land area (Global climate change: health impact on Bangladesh, 2009).

c) Impact on health

Bangladesh is vulnerable to outbreaks of infectious, waterborne and other types of diseases (World Bank 2000) and climate plays an important role in the seasonal pattern and temporal distribution of infectious and water-borne diseases like malaria, dengue, cholera and other diarrheal diseases; and heat waves and flooding can have severe and long-lasting effect (Rahman 2008). Similarly, increase in surface temperature would virtually help parasites such as mosquitoes, which may lead to increase malaria and dengue fever. In Bangladesh, annual increase of the incidence of malaria and diarrhea has been observed. A study conducted by Climate Change Cell (CCC, 2009b) indicates that the climatic factors including temperature (maximum and minimum), rainfall (annual and seasonal) and salinity concentration are factors of causing diarrhea, skin disease, kala-azar etc.

d) Impact on livelihoods

Climate change may affect the poor and the marginalized professional groups through changes or depletion in common property resources such as fisheries, rangeland or forest which they depend on for their livelihoods (DFID 2004). Different marginalized professional group like small holders and subsistence farmers, pastoralists and artisanal fisher folk will suffer complex and localized impacts of climate change (Easterling et al., 2007) as they have limited adaptive capacity and highly exposed to extreme events.

Changes in water temperature, precipitation and oceanographic variables, such as wind velocity, wave action and sea level rise, can bring about significant ecological and biological changes to marine and fresh water ecosystems and their resident fish populations (Cheung et al., 2009; Westlund et al., 2007), directly impacting peoples, whose livelihoods depend on those ecosystems. Extreme weather events may also disrupt fishing operations and land-based infrastructure while fluctuations of fishery production and other natural resources

can have an impact on livelihoods strategies and outcomes of fishing communities (Iwasaki et al., 2009).

In the coastal areas of Bangladesh, the estimated number of households depending on fisheries approximately ranges between 140,000 and 160,000. In recent years, the fishing communities, who depend on fishing from the estuarine and territorial waters of the Bay of Bengal, are being compelled to refrain from fishing in the peak fishing season as the frequency and intensity of 'rough sea events' increased resulting from the increase of sea surface temperature (SST), which is most likely to be aggravated by the climate change. The entire coastal zone is prone to violent storms and tropical cyclones during pre-monsoon and post-monsoon seasons. In the Bay of Bengal, cyclones usually form under some metrological conditions; the important one is the prevalence of 27 degree Celsius temperature in an extended sea surface area creating huge volume of water vapor. Meantime, a number scientific study have confirmed that there has been a gradual rise in sea surface temperature along the northern Indian Ocean which covers the Bay of Bengal region.

The 4th Assessment Report of the IPCCC has also confirmed a net rise of about 0.6 to 0.7 degrees Celsius over Asia during the past five decades. The rate of change in the sea surface temperature during 1961-2001 also shows a similar trend. Khote (2005), who analyzed paradigm shift in seasonal Sea Surface Temperature Anomaly after 1975, further established a relative linkage between global warming and recent gradual increase of (SSTA) which has been observing in the coastal region of the North Indian Ocean i.e. in the vicinity of the Bay of Bengal. This increase in SST favors formation of increased number of low pressure system in the Bay of Bengal, which, in turn, disfavors the fishers preventing them to sail for fish.

f) Impact on overall growth and development

The causes and consequences of climate change are deeply intertwined with global pattern of inequality, which also over the period structurally made countries poor, such as Bangladesh, where around 160 million people live their lives confronting with social injustice, economic disparity and poverty. Bangladesh has a per capita Gross Domestic Product (GDP) around 700 $ and have very low levels of capital, human and technological development.

Country's existing concerns about food security, water scarcity and energy are made all the more difficult by climate risks that will challenge the goals of inclusive and environmentally sustainable economic growth. Likewise, the social and economic dimensions of climate change will result in unprecedented development and security challenges to the efforts of LDCs towards growth and development; this situation also would hold back the achievement of MDGs, especially the goals of eradicating poverty, combating communicable diseases, and ensuring environmental sustainability etc. Major incidents that would affect the poverty reduction strategies and MDGs achievements are; (i) inundation or submersion of low-lying coastal areas due to sea-level rise and displacement of huge population; (ii) incremental cost of disaster risk reduction and financial loss due to increased level of disasters; (iii) intrusion of salinity and thereby scarcity of drinking water; (iv) reduction in crop production which is around up to 30-50 %; and (v) increasing health hazards. Table 3 describes how the likely impacts of climate change in country's major development sector will halt back achieving MDGs.

Table 3: Likely Implications of Climate Change for Realizing the MDGs

Millennium Development Goals	Likely impacts of climate change
Eradicate extreme poverty and hunger (Goal 1)	- Climate change is projected to reduce poor people's livelihoods needs such as food, health, water, homes, and infrastructures by way of impacting the livelihoods assets and further exacerbating the vulnerability context - Climate change is altering the path and rate of economic growth due to changes in natural systems and resources, infrastructure, and labor productivity. A reduction in economic growth directly impacts poverty through reduced income opportunities - Climate change is projected to alter regional as well as national food security.
Health-related goals: - Combat major diseases - Reduce infant mortality - Improve maternal health (Goals 4, 5 and 6)	- Direct effects of climate change include increases in heat related mortality and illness associated with heat waves (which may be balanced by less winter cold-related deaths in some regions) - Climate change may increase the prevalence of some vector - borne diseases (for example, malaria and dengue fever), and vulnerability to water-, food- or person-to- person borne diseases such as cholera and dysentery - Children and pregnant women are particularly susceptible to vector- and water-borne diseases. Anemia – resulting from malaria – is responsible for a quarter of maternal mortality - Climate change is likely to result in declining quantity and quality of drinking water, which is a prerequisite for good health, and it may also exacerbate malnutrition – an important cause of ill-health among children – by reducing natural resource productivity and threatening food security.
Achieve universal primary education (Goal 2)	- Links to climate change are less direct, but loss of livelihoods assets (social, natural, physical, human and financial capital) may reduce opportunities for full-time education in numerous ways. Natural disasters and drought reduce children's available time (which may be diverted to household tasks), while displacement and migration can reduce access to quality education opportunities
Promote gender	- Climate change is likely to exacerbate current gender

equality and empower women (Goal 3)	inequalities. Depletion of natural resources and decreasing agricultural productivity may place additional burdens on women's health and reduce time available to participate in decision-making processes and income-generating activities - Climate-related disasters have been found to impact more severely on female-headed households, particularly where they have fewer assets to support their livelihoods
Ensure environmental sustainability (Goal 7)	- Climate change will alter the quality and productivity of natural resources and ecosystems, some of which may be irreversibly damaged, and these changes may also decrease biological diversity and accelerate further the existing rate of environmental degradation
Global partnerships (Goal 8)	- Global climate change is a global issue and response requires global cooperation, especially to help developing countries to adapt to the adverse impacts of climate change. But, because of the impacts of climate change in the developed world as well, part of the development assistance which could have been set aside for the development of the developing countries is likely to be used responding climate change impacts back home, thus affecting the aid flows to the developing countries.

Source: Adopted from 'Climate Change Strategy for South Asian Region' World Bank 2009

3.2 An overview of country's development priority in the context of sustainable development goals

Over the past 40 years since independence, Bangladesh has increased its per capita income by more than 130 %, cut poverty by more than half, and is well set to achieve most of the millennium development goals. Some of the underlying specific achievements include, reducing total fertility rate from 7.0 to 2.7; increasing life expectancy from 46.2 years to 66.6 years ; increasing the rate of economic growth from an average rate of 4% in the 1970s to 6% in the 2000s; increasing the savings and investment rates from below 10 percent each in the 1970s to 24 percent (investment rate) and 28 percent (savings rate) in the financial year 2010 (FY10); achieving gender parity in primary and secondary education; and more than tripling of the production of rice (from 10 million metric tons in FY73 to 32 million metric tons in FY10) thereby achieving near self-sufficiency in normal production years.

Even with this past progress, Bangladesh remains a low income country with substantial poverty, inequality and deprivation. An estimated 60 million people are living below the poverty line with a significant proportion living in female-headed households , in remote areas, and consisting of the socially excluded and other vulnerable people. These people,

and among them especially women and children, are also disproportionately affected by natural disasters and the adverse effects of climate change.

The broad development goals underlying the Perspective Plan mentioned earlier in line with the Sixth Five Year Plan (2011-2015) include:

- Building a secular tolerant liberal progressive democratic state
- Promoting good governance and curbing corruption
- Promoting sustainable human development
- Reducing the growth of population
- Instituting a prudent macroeconomic policy mix
- Promoting a favorable industrialization and trade policy regime
- Addressing globalization and regional cooperation challenges
- Making available adequate infrastructure
- Ensuring adequate supply of electricity and fuel
- Achieving food security

Recognizing the need to overcome the long -term development challenges, the Government adopted the Vision 2021 and the associated Perspective Plan 2010-2021 that have set solid development targets for Bangladesh till the end of 2021. Vision 2021 lays down a development scenario where citizens will have higher per capita income leading to higher standard of living, better education and social justice with more equitable socio-economic environment and the sustainability of development will be ensured through better protection from climate change and natural disasters.

Against the backdrop of poverty reduction, employment and growth rate targets, set in Vision 2021, the Sixth-Five-Plan (2011-2015) endeavors to initiate the transition to the higher growth path. This growth path, while ambitious, is achievable through a strategy that transforms Bangladesh from a rural agro-based economy towards an urban manufacturing-based economy. The driving force for the strategy will be the deepening of a labor-intensive export-oriented manufacturing sector, and a much more diversified, commercially motivated agricultural sector.

In the pursuit of the above broad development goals, the following aspects will factor in prominently in the context of climate resilient development planning:

a) **Acceleration of economic growth and employment:** Economic growth and its composition will matter for job creation. Acceleration of the economic growth rate will require a substantial increase in the rate of investment from the present 24 percent of GDP level. Much of the higher investment will need to be deployed to reduce and eventually eliminate the infrastructure constraint (primarily power and transport) and to strengthen human development.

b) **Sustaining Bangladesh's Agrarian Economy:** A strong agriculture is fundamental to poverty reduction and for food security. With land increasingly becoming a constraint for a growing population and urbanization pressure, enhancing the

productivity of land is a must. The emphasis on productivity improvements will be consistent with the need to ensure food security. R&D in agriculture and infusion of new technologies at community level would be essential to achieve the goal of food security.

c) **Gradual Transformation of Agro-based Economy to Manufacturing and Service Sector:** Transforming Bangladesh's agrarian economy into a modern manufacturing and service based economy is a long-term challenge. Yet, this is needed to achieve a faster pace of growth and good job creation. The focus on manufacturing does not mean neglect of agriculture. It is simply recognition of two important points. Firstly, the rapid expansion of agriculture is limited by the availability of land, which is a fixed factor, and by demand (food tends to have low income elasticity). And secondly, the increase in average labor productivity will require a strategy to withdraw labor from activities e.g. agriculture to higher productivity activities e.g. manufacturing and modern services.

c) **Power Sector Reforms:** The annual loss to production and income from power outages could well exceed 0.5% of GDP per year. The availability of domestic primary fuel supply is decreasing such that it is forcing severe measures like shutting down fertilizer factories, rationing gas supplies for household and transport uses, and keeping idle installed power units.

Every 1% of GDP growth is estimated to lead to a growth of 1.4% in electricity demand in a typical developing country. For a 5-6% typical annual economic growth rate, this would imply a need for close to 7-8% growth in electricity supply. Rural electrification ratio expanded rapidly since the early 1990s, growing from 10 percent in 1994 to 37% in 2008. Yet, this is still amongst the lowest in developing world.

Due to the severity of the power crisis, the Government has been forced to enter into contractual agreements for high-cost, temporary solutions, such as rental power and small IPPs, on an emergency basis, much of it diesel or liquid-fuel based. This has imposed tremendous fiscal pressure, as budgetary transfers are routinely made to the power sector in order to enable it to stay current on payments to power suppliers. The Government is aware that precious resources are being diverted to cover operating losses of the utility that arise from purchasing short-term high cost power, which is not sustainable for the financial health of the sector in the long run. Therefore, the longer term strategy embedded in the SFYP power sector plan is to use budgetary allocations to promote low-cost, sustainable expansion of power generation, transmission, and distribution capacity.

d) **Managing the land constraint:** Being one of the most densely populated countries of the world, Bangladesh has to properly manage scarce land resources. Efforts to reduce the growth of population will help, but better management of land is of utmost importance for sustaining rapid growth in Bangladesh. Sound land management also has a direct effect on people's welfare and poverty reduction. Landless farmers are amongst the poorest of the poor. The rapidly expanding slum population and rising land prices in urban areas are indications of increasing difficulties Bangladesh faces in providing people with proper shelter.

Bangladesh has been loosing its precious land resources because of conversion of agricultural land to multiple uses (e.g. housing, unbanization) river erosion and sea level rise. In the severe climate scenario I meter sea level rise will permanently destroy extensive and highly productive low-laying coastal areas that are home to millions of people who will have to be relocated permanently.

e) **The urbanization challenge:** Bangladesh has been experiencing rapid increase in its urban population ever since its independence in 1971. Urban population as a percentage of total population increased from around 8 % to nearly 23 % during 1974-2001 periods. By the year 2015, nearly one-third or 33% of the population of Bangladesh will be living in urban areas. Along with other extreme weather events like flooding and tropical cyclone, sea-level rise is an impending threat to the coastal areas in Bangladesh that would force physical dislocation of more than 35 million people who may find their ways to the urban areas for shelter and income opportunities.

The phenomenal rate of urbanization is posing a major development challenge. The cities and towns of Bangladesh, numbering more than 525, suffer from acute problems of deteriorating infrastructure in the form of poor housing, inadequate and unsafe drinking water, poor drainage and sewerage facilities, log-jam of urban transport and pollution. This situation is going to get worse under climate change scenario as it is already manifested by drainage congestion, urban flooding and the heat stress.

The role of urbanization in transforming traditional societies can hardly be over-emphasized. The emerging socio-economic situations in developing countries like Bangladesh have made this ample clear. In Bangladesh, cities and town are playing a crucial role in the country's socio-economic development despite the adverse socio-economic and environmental consequences resulting from rapid growth of these urban centers. At present, urban dwellers constitute about 30 percent of the total populations of Bangladesh, but their contribution to GDP is more than 60 percent indicating that the productivity of labor in urban areas is much higher than in rural areas.

3.3 Framing climate change resilient sectoral strategies and action plan in the context of country's development priorities

Planning Commission of Bangladesh is the central planning body responsible for macro and micro economic plans and policies i.e. National Five Year Plan and Annual Development Plans. When this comes to a sectoral policy and plan, the ministries are responsible for the policy formulation, planning, evaluation and execution.

In this perspective, Ministry of Environment and Forests of the Government of Bangladesh is mandated according to prevalent rules of business of the Government is to look after and take action regarding climate change. Therefore, in line with the country's development priorities, the government prepared Bangladesh Climate Change Strategy and Action Plan (BCCSAP) in 2009 that outlined six thematic areas to address climate change vulnerabilities in different sectors. BCCSAP is a 10-year programme (2009-2018) to build the capacity and resilience of the country which will contribute to the achievement of country's long-term

development goal. Table 4 describes the sectoral strategies and action plan on climate change adaptation measures those, in turn, will contribute in achieving country's long-term development goals.

Table 4: Sectoral strategies and action plan in line with the long-term development priorities

Long-term development priorities (Sixth Five-year Development Plan 2011-2015)	Sectoral strategies and action plan e.g.,BCCSAP 2009
The urbanization challenge	Theme 1: Infrastructure Proposed relevant actions: i) Undertake strategic planning of future infrastructure needs, taking into account the likely a) future pattern of urbanization and socioeconomic development; and b) the changing hydrology of the country because of climate change.
Acceleration of economic growth and employment Sustaining Bangladesh's Agrarian Economy	Theme 1: Food security, social protection and health Proposed relevant actions: ii) Increase the resilience of vulnerable groups, including women and children, through development of community level adaptation, livelihood diversification, better access to basic services and social protection (e.g., safety nets, insurance) and scaling up. iii) Develop climate change resilient cropping systems (e.g., agricultural research to develop crop varieties, which are tolerant of flooding drought and salinity, and based on indigenous and other varieties suited to the needs of resource poor farmers) fisheries and livestock systems to ensure local and national food security
Acceleration of economic growth and employment Sustaining Bangladesh's Agrarian Economy	Theme 1: Food security, social protection and health Proposed relevant actions: iv) Increase the resilience of vulnerable groups, including women and children, through development of community level adaptation, livelihood diversification, better access to basic services and social protection (e.g., safety nets, insurance) and scaling up. v) Develop climate change resilient cropping systems (e.g., agricultural research to develop crop varieties, which are tolerant of flooding drought and salinity, and based on indigenous and other varieties suited to the needs of resource poor farmers) fisheries and livestock systems to ensure local and national food security

3.4 Identification of Climate Change Adaptation Priorities in the context of development goals

The development priorities that have been identified are interlinked for the ultimate objective to accelerate the economic growth aiming at increasing employment, and income keeping social justice, safeguarding food security, and maintaining environmental integrity. In attaining these objectives, the development priorities focus on addressing an array of challenges that fall in realm of traditional economic sectors in Bangladesh such as Finance, Planning, Commerce, Agriculture, Water, Environment and Forests, Energy, Transport, Industry, Land, Disaster, Local government, and Health. There are sub-sectors, or inter-sectoral overlaps that can be brought into prominence in the light of the climate change adaptation and mitigation for consideration such as the climate change impacts in the coastal areas, the challenges in the rapidly growing urban areas, protection of land as spatial consideration and also for quality, infrastructure development under various sectors for roads, railways and waterways, managing the natural resources and the ecosystem including the biodiversity, and also the social goals of the vision 2021 and the Sixth–Five-Year-Plan including the MDGs.

The clustering of the priority development areas in economic, social and environmental considerations cannot be done in exclusivity, ignoring sectoral overlapping. However the following table gives a clustering of some of the major sectoral functions based on where the major thrust of the activities lie. The clustering has been done through an exercise and consultation with the working group members. At the onset, development priorities are identified and listed down from the country's development policies and strategies e.g. vision 2021, Sixth Five-Year Plan, BCCSAP, Poverty Reduction Strategies etc.

A total of 24 development priorities are listed down in Table 5, which again are prioritized through an exercise of putting score, ranges from 1 to 5, to the each priority by a wide range of stakeholders. The development priority that scored the highest is marked as priority 1. Following the prioritization of the development priorities, they are grouped into three categories on the basis of their economic, social and environmental considerations.

Understanding development priority through the scoring, is critical to indicate priority area for action to achieve sustainable development in the concern sector under the overall develop planning of the country. Such prioritization would be the basis for taking action for the most priority areas as well as designing and planning action in the specific sector.

Table 5: Identification of Climate Change Adaptation Priorities in the context of development goals

		Development Priority
Economic	Poverty Eradication	Priority 1
	HRD for productivity improvement	Priority 11
	Increase employment opportunity	Priority 5
	Accelerate growth for rural non-farm sector	Priority 13
	Land management	Priority 16
	Protection of coastal areas	Priority 9; will complement in implementing priority 2
	Manage river system and water bodies to prevent land loss	Priority 10
	Urban management	Priority 16
	Infrastructure development for disaster risk reduction and water sector management	Priority 4, will complement in implementing priority 2, priority 7, priority 9, priority 10 and priority 16
	Ensure food security	Priority 2
	Ensure energy security	Priority 3
	Disaster management	Priority 7
Social	Expanding of social safety net coverage	Priority 6
	Invest in human resource development	Priority 17
	MDGs related to social aspects	Related to priority 6
	Achieve economic and social well-being of all citizen of the country	Priority 14
	Ensure livelihood security of the marginalized sector of population	Priority 15
Environmental	Integrate the environmental/Climate Change issues in all policy and plans and living condition of slums	Priority 8
	Conserve biodiversity and control air/industrial pollution, improve solid waste management	Priority 11
	Improve water quality	Priority 12
	Provide Safe Water, Sanitation and maintain healthy Environment for all	Related to Priority 6
	Ensure environment friendly transport in Bangladesh	Related to priority 3 and 16
	Ensure conservation measures for economic and efficient use of energy	Related to Priority 3
	Protect wetland/mangroves, saline water intrusion	Related to Priority 9

CHAPTER 4: TNA for adaptation

4.1. Sector prioritization for climate change adaptation

4.1.1 Prioritized Sectors/ Sub-sector for adaptation

Poverty eradication is the top most development priority of the Government of Bangladesh. Bangladesh, as a country, is striving to accelerate economic growth and substantially eradicate poverty by 2021 but avoiding the harsh environmental price many countries have paid in the pursuit of growth [Ministry of Environment and Forest (MoEF, 2009)]. To achieve this goal management of sectors like infrastructure development and management of water resources to save the country's major development sectors from the projected negative scenario of climate change impacts like sea level rise, erratic rainfall, flooding, drought etc. is essential.

To complement to the country's development priority e.g. poverty reduction and attaining food security, the following sectors/ sub-sectors require technological support for climate change adaptation; these are, **climate-smart agriculture technology development and dissemination, infrastructure development for water resources management and disaster risk reduction.** Technological support in this sector will contribute in implementing other development priorities like ensuring food security, land management, disaster risk reduction, protection of wetland/mangroves and agricultural land from the intrusion of saline water. Table 6 describes scale of vulnerability of the major development sectors to the impacts of climate change.

Table 6: Sectors with high adaptation significance

Sectors	Scale of vulnerability
Agriculture	About one-quarter of the country's GDP comes from agriculture, which makes the country's economy. Agriculture sector in Bangladesh, which contributes 20.16 (estimated in 2009/10) % of the country's GDP and creates employment of 43.6 % (BER 2010) of country's population, is relatively sensitive to existing and impending disasters. The country will face significant reduction in productivity and annual crop loss by erratic weather pattern e.g. and also by slow climatic onset e.g. drought. Several studies have been conducted in Bangladesh to assess the vulnerability of food grain production to various climate scenarios. One such study noted that a 4^{o}C increase in temperature would have a severe impact on food production in Bangladesh, resulting in a 28% reduction for rice and a 68% reduction for wheat. Under a moderate climate change scenario, *Aus* production would decline by 27 percent while wheat production would be reduced to 61 percent (Karim et al. (1999). Under a sever climate change scenario (with 60 percent moisture stress), yield of *Boro* might reduce by 55-62 %. Moisture stress might force farmers to reduce the area for *Boro* cultivation. The shortening of the winter season is resulting in a decline in production of winter crops, particularly potatoes.
Health	Bangladesh is vulnerable to outbreaks of infectious, waterborne and

	other types of diseases (World Bank 2000) and climate plays an important role in the seasonal pattern and temporal distribution of infectious and water borne diseases like malaria, dengue, cholera and other diarrheal diseases; and heat waves and flooding can have severe and long lasting effect on health (Rahman 2008). In Bangladesh, annual increase of the incidence of malaria and diarrhea has been observed. A study conducted by Climate Change Cell (CCC, 2009b) indicates that the climatic factors including temperature (maximum and minimum), rainfall (annual and seasonal) and salinity concentration are factors of causing diarrhea, skin disease, kala-azar[5] etc.
Coastal Infrastructure	Several studies indicated that the coastal zone vulnerability would be acute due to the combined effects of climate change, sea level rise, subsidence, and changes of upstream river discharge, cyclone and coastal embankments (WB, 2000). Four key types of primary physical effects i.e. saline water intrusion; drainage congestion; extreme events; and changes in coastal morphology have been identified as the key vulnerabilities in the coastal areas of Bangladesh (WB, 2000). Elevation of maximum areas of Bangladesh is less than ten meters above sea level, with almost 10% of the country below 1 meter, which makes this area extremely vulnerable to increasing high tides. The effects on the coastal areas will be severe due to the erosion, coastal land subsistence, siltation of river estuaries, reduced sedimentation, water logging, and saltwater intrusion in combined with the expected sea-level rise by an average of 2-3 mm per year during the first part of this century. Climate change induced high intensity events pose huge treats to existing physical infrastructures. Damage to national highways due to flood alone is estimated 1011 and 3,315 kilometers by the year 2030 and 2050 respectively. The corresponding damage to embankments is estimated 4,271 and 13,996 kilometers by the year 2030 and 2050 respectively. The aggregated damage of health centers and hospitals due to floods; cyclones, sea-level rise and salinity intrusion are estimated 1,682 and 5,212 respectively, for the above two time horizons (Ahmed, A. U., 2006). Increased erosion and accretion (an increase of land by the deposit of waterborne sediment), inundation and cyclones have the adverse impact and are the causes of damage of infrastructures. Furthermore, investment in infrastructure, roads etc, can in itself aggravate the problem with water-logging by reducing the natural drainage capacity. The coastal zone is most prone to suffer from such problems.
Water resources	Water-related impacts of climate change will likely be the most critical

[5] **Kala-azar:** A chronic and potentially fatal parasitic disease of the viscera (the internal organs, particularly the liver, spleen, bone marrow and lymph nodes) due to infection by the parasite called Leishmania donovani.

	concern for Bangladesh in terms of urgency, severity, and economic consequence. Bangladesh, a deltaic country, drains huge catchment's water (92% of water that Bangladesh drains is from outside the country). There shall be more water during monsoon and less water during dry season. There shall be more floods, droughts, water-logging, drainage congestion, storm surges, salinity intrusion, and river bank erosion. Climate change will have its profound impacts on the water resources of Bangladesh. Variability in climate can affect several vital sectors that are the major water users, including agriculture, domestic/municipal, fisheries, navigation, industry and environment. Climate change has the potential to inundate coastal areas and cause severe adverse impacts on rainfall patterns.

Following identification of sectors with high adaptation significance, sub-secors of each sector are listed down. The sub-sectors under each sector are scored categorically on the basis of their economic, social and environment priorities and putting numeric value ranges from 1 to 5.

Table 7: Sector rating

Sectors	Sub-sectors	Adaptation against the adverse impact of climate change			Adaptation Priority	Total Score
		Relevance with the development priorities				
		Maximize economic dev priorities	Maximize environmental dev priorities	Maximize social dev priorities		
Water Resources (Water sector related infra-structure development and water resource management)	Infrastructure development	4	5	4	5	18
	Resilience against salinity intrusion	3	4	3	3	13
	Tidal system and infrastructures development	4	4	4	5	17
	Monitoring of sea level and coastal morphology	4	4	4	4	16
	Comprehensive Disaster Management	4	4	3	4	15
	Urban Resilience Improvement	4	4	3	4	15
Agriculture	Crop production	4	4	4	5	17
	Fisheries	4	3	3	3	13
	Livestock	4	3	3	3	13
	Forestry	3	3	3	3	12
Health	Public health care	4	2	3	4	13

	Health Education	3	2	4	3	12

Note: **Score 0 represents no benefit; 1 faintly desirable; 2 fairly desirable, 3 moderately desirable; 4 very desirable and 5 extremely desirable.**

In view of the country's strive to undertake climate proofing activities, and to realise the targets set for vision 2021 and the Sixth Five-Year-Plan, the following sector may be considered for this project in the development, diffusion and adaptation of climate change technologies:

- Adaptation technologies for **water sector infrastructure development and management of water resources for enhancing resilience and water security**
- Adaptation technologies for **Agricultural activities, especially crop production** to enhance crop production and food security

On the basis of scores given to different subsectors, the criteria contribution graph is prepared that gives and overview on the contribution of each subsector on the criteria.

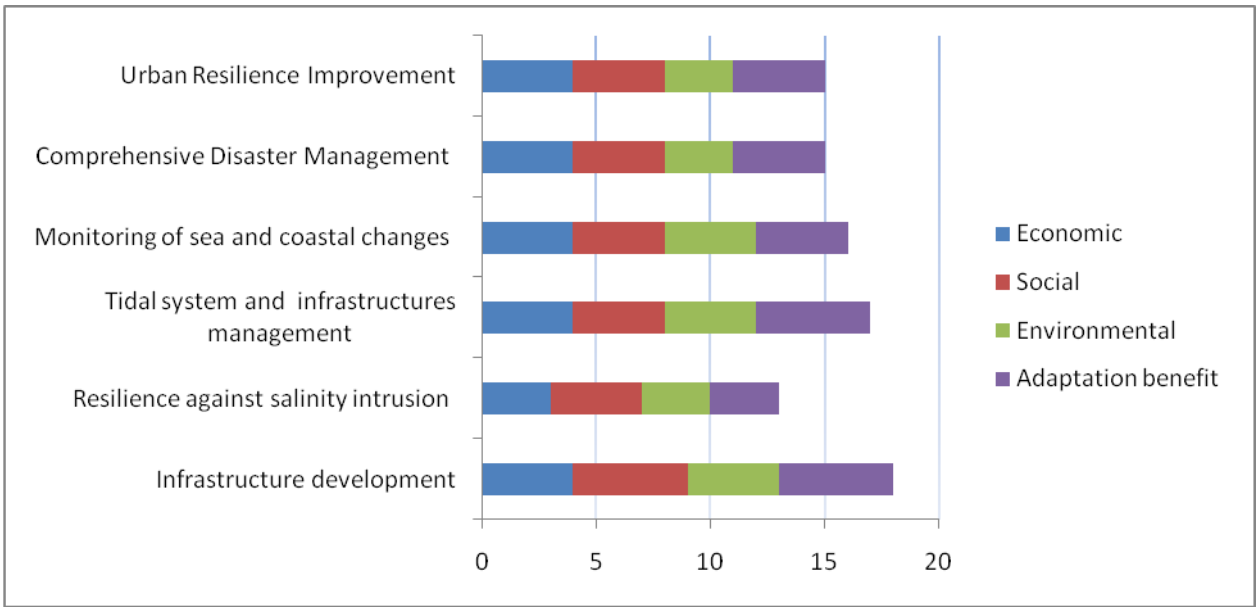

Figure: 4 Criteria contribution graph of the subsectors of water sector

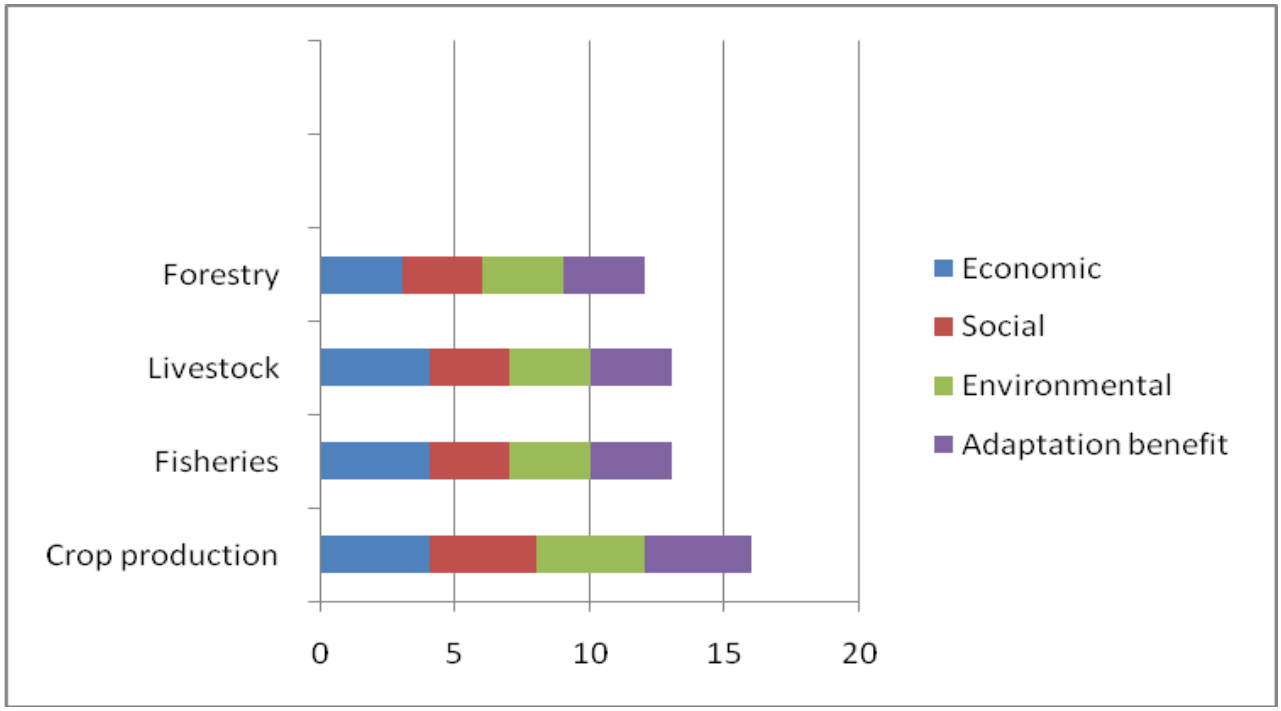

Figure: 5 Criteria contribution graph of the sub-sectors of Agriculture Sector

On the basis of the criteria contribution graphs (Figure 4) Table 8 shows the cumulative score of development priorities of the subsectors of water sector.

Table: 8 Cumulative score clustered under development priorities and adaptation priority of water subsectors

Water		
Subsectors	Development priorities	Adaptation priority
Infrastructure development	13	5
Tidal system and infrastructures management	12	5
Monitoring of sea and coastal changes	12	4
Comprehensive Disaster Management	11	4
Urban Resilience Improvement	11	4
Resilience against salinity intrusion	10	3

As per Table 8, subsectors that got higher cumulative score of development priorities and adaptation priorities have been classified as desirable sub-sectors and presented in Table 9. Sub-sectors with cumulative score of development priorities above 10 and adaptation benefits above 4 are considered extremely desirable water subsectors:

Table 9: Desirability of technological intervention of water subsectors

Water		
Subsectors	Development priorities	Adaptation benefit
Infrastructure development	Extremely desirable	Extremely desirable
Resilience against salinity intrusion	Faintly desirable	Faintly desirable
Tidal system and infrastructures management	Extremely desirable	Extremely desirable
Monitoring of sea and coastal changes	Extremely desirable	Extremely desirable
Comprehensive Disaster Management	Extremely desirable	Extremely desirable
Urban Resilience Improvement	Extremely desirable	Extremely desirable

Similarly, on the basis of the criteria contribution graphs (Figure 5) cumulative score of development priorities of agriculture sector is calculated and presented in Table 10.

Table: 10 Cumulative score clustered under development priorities and adaptation priority of water subsectors

Agriculture		
Subsectors	Development priorities	Adaptation priority
Crop production	12	5
Fisheries	10	3
Livestock	10	3
Forestry	9	3

After calculation of the cumulative score (shown in Table 10), the sub-sectors that got higher cumulative score of development priorities and adaptation priorities have been classified as desirable sub-sectors and presented in Table 11. Sub-sectors with cumulative score of development priorities above 10 and adaptation benefits above 4 are considered extremely desirable water subsectors:

Table 11: Desirability of technological intervention of water subsectors

Agriculture		
Subsectors	Development priorities	Adaptation benefit
Crop production	Extremely desirable	Extremely desirable
Fisheries	Faintly desirable	Faintly desirable
Livestock	Faintly desirable	Faintly desirable
Forestry	Faintly desirable	Faintly desirable

4.1.2 Current status of adaptation technologies in the selected sectors

The Government recognizes that tackling climate change requires an integrated approach involving many different ministries and agencies, civil society and the business sector. There is also a need to strengthen the capacity of Government and other organizations to plan and implement development programs. Development organizations need to strengthen their capacity so that they can implement their regular programs more effectively and rise to the challenge of climate change.

Adaptation Technologies

Over the decades, the Government, with the support of development partners, has invested in:

- Flood management schemes to raise the agricultural productivity of many thousands of hectares of low-lying rural areas and to protect them from severe floods.
- Flood protection and drainage schemes to protect urban areas from rainwater and river flooding during the monsoon season.
- Coastal embankment projects, involving over 6,000 km of embankments and a number of polder schemes, to raise agricultural productivity in coastal areas by preventing tidal flooding and incursion of saline water.
- Over 2,000 cyclone shelters to provide refuge for communities from storm surges caused by tropical cyclones and 200 shelters from river floods.
- Comprehensive disaster management projects, involving community-based programs and early warning systems for floods and cyclones.
- Irrigation schemes to enable farmers to grow a dry season rice crop in areas subject to heavy monsoon flooding and in other parts of the country, including drought-prone areas.
- Agricultural research programs to develop saline, drought and flood-adapted high yielding varieties of rice and other crops, based on the traditional varieties evolved over centuries by Bangladeshi farmers.
- Coastal 'greenbelt' projects, involving mangrove planting along nearly 9,000 km of the shoreline.

These investments in 'climate proofing' have resulted on major impacts on economic growth and poverty reduction. Over the last 10-15 years, the number of fatalities from natural disasters has declined, as the country's ability to manage natural disaster risks has improved and community-based systems have been put in place.

At the same time, Bangladesh has also learnt to adapt new technologies and how to plan and implement the programs with those technologies (e.g. to integrate capture and culture fisheries into the design and operation of flood management projects) by involving communities in planning, construction and management.

CHAPTER 5: Adaptation technology prioritization of water sector

5.1 An overview of possible adaptation technology options in water subsectors

From the sector prioritization exercise, several sub-sectors of water sectors e.g. infrastructure development, tidal system and infrastructures management, monitoring of sea and coastal changes, comprehensive disaster management and urban resilience improvement etc. have been prioritized in order to enable the water sector to adapt to the adverse effects of climate change. Under these subsectors, a number of technological measures have been discussed in the stakeholder consultations, which are described below and also presented in Table 12.

5.1.1 **Improved Embankment Construction:** Most of the existing flood control embankments were designed without berm and without considering the effect of sea-level rise. Mechanical compactions to these embankments were not done during construction. This made embankments less stable and as a result they are vulnerable to breach against high flood and cyclonic/ tidal surge. Solution to the problem is construction of new embankment/ construction of retired embankment/ rehabilitation of embankment with medium and long-term program by traditional and modern technology.

The proposed embankment will provide better stability against sliding and allow no or less seepage during flood and high tide. Further, it will have protection against cyclonic and tidal surge and will require no or less annual maintenance. Social benefits like increased safety of people's life and crops including provision of emergency shelter on the berm at C/S can be achieved against cyclone and tidal surge.

5.1.2 **Rehabilitation of existing Embankments/ dykes and dredging**: All the coastal embankments and sea dykes were constructed under Coastal Embankment Project (CEP) in the early 60's and 70's. Due to prolonged use and weather effects the cross sections of the existing embankments including the crest level have been reduced significantly. In addition, sea-level rise due to global warming effect these embankments and dykes are under serious threats to breach. Solution to the problem is rehabilitation of existing embankments/dykes with medium and long-term traditional and indigenous method.

The proposed embankment rehabilitation will allow no or less seepage during flood and high tide and will provide protection against cyclonic and tidal surge. Further the rehabilitated embankment will require no or less annual maintenance. Social benefits like increased safety of people's life and crops including provision of emergency shelter on the berm at C/S can be achieved against cyclone and tidal surge.

5.1.3. **Saltwater Intrusion barrier:** In the southern part of the country, rivers are closely linked to the sea, are tidal in nature and their water is brackish. The salinity in these rivers increase with the rise in sea level. This effect will be worse if the freshwater flow is less due to drought or human interventions like construction of dams across the rivers in the upstream, etc. The salinity intrusion cannot be protected by constructing barriers across the flowing rivers. Because construction of any barrier across the flowing river will accelerate the siltation process in the river bed starting from the barrier and will create drainage congestion/ water-logging at the upstream

(C/S) area. Research is required to find a good solution and to develop an effective saltwater management.

5.1.4. **Tidal barriers (Sluice gates)**: Most of the sluice gates in the coastal area were constructed under Coastal Embankment Project (CEP) in the early 60's and 70's. Due to prolonged use, and salinity effect the condition of the existing sluices including flap gates have become weak and fragile and lost their draining efficiency. The solution to the problem is construction of new/ rehabilitation of sluice gates with medium and long-term program using traditional/ modern technology.

The advantages of the proposed sluice gate are (i) it will reduce siltation process through river bed erosion, (ii) will increase operating efficiency and (iii) will be durable.

5.1.5 **Tidal river management including computer simulation of tidal flow:** Construction of peripheral embankment along the banks of the coastal rivers under Coastal Embankment Project (CEP) has prevented intrusion of silt laden saline water into the poldered area. Moreover, upstream flow of these rivers reduced drastically due to construction and operation of *Farakka* Barrage. As a result, silt coming up with saline water during high tide in dry season being deposited in the river bed starting from the downstream of the sluice gates. This is the identified main reason of drainage congestion/ water logging in the coastal polders. The solution to this problem is introduction of Tidal River Management (TRM), using indigenous method with medium and long term program.

TRM has the benefits of (i) reducing siltation in the river, increasing drainage capacity and tidal prism, (ii) reducing drainage congestion / water logging within the polder and peripheral rivers, (iii) increasing ground level of the TRM basin.

TRM will provide healthy, productive, economic and agricultural- friendly environment.

5.1.6 **Polder management (rehabilitation and climate proofing):** Construction of peripheral embankment along the banks of the coastal rivers under Coastal Embankment Project (CEP) has prevented intrusion of silt laden saline water into the poldered area. Moreover, upstream flows of these rivers are reduced drastically due to construction and operation of *Farakka* Barrage. As a result, silt is coming up with saline water during high tide in the dry season being deposited in the river bed starting from the downstream of the sluice gates. This is the identified main reason of drainage congestion/ water-logging in the coastal polders. The solution to the problem is medium and long-term indigenous and modern technology though improved planning, design, construction and gate improvement.

Polder management practice will (i) reduce siltation process by river bed erosion and increase tidal prism, (ii) reduce drainage congestion / water logging, (iii) increase ground level of the TRM basin, (iv) provide quick drainage and (v) increase operating efficiency.

Overall polder management will provide healthy, economic and agriculture productive environment. Early cropping in greater areas of the polder will also be possible through polder management.

5.1.7 **Desalinization for drinking water in coastal areas:** Upstream flows in the coastal rivers have been reduced drastically due to construction and operation of *Farakka* Barrage. As a result, saline concentration in the rivers outside and adjacent to polders, have increased significantly during dry season, causing scarcity of drinking water. Solution to the problem is short and medium-term program of desalinization

for drinking water in the coastal areas using indigenous and modern technology.

Desalinization program for drinking water in coastal areas will reduce water-borne diseases and will reduce salt intake and help reducing high blood pressure of the inhabitants.

5.1.8 **Monitoring of sea level rise, tidal fluctuation, salinity intrusion, sedimentation and coastal erosion:** There is no adequate database to ascertain the effect of sea-level rise at different dimensions. It is essential to record the water level, discharge, salinity and sedimentation for monitoring the substantial changes in the respective dimension. This will require medium and long-term programmes with traditional method.

The monitoring program will build up awareness to guide for taking action by the decision-makers to ensure future sustainability. Moreover, the program will help ensuing healthy, economic and agricultural productive environment.

5.1.9 **Comprehensive disaster management incorporating early warning systems and involving community:** In the last decade, the frequency of cyclone and storm surge in the coastal area has increased significantly due to global climate change. The traditional preparedness, warning system and rescue measures against pre- and post cyclonic surge has been proven not adequate and needs improvement and modernization. Coordination and monitoring of pre- and post-disaster activities should be strengthened. This will require medium and long-term program using modern technology.

The program will increase sense of security, reduce magnitude of disaster; reduce casualties and loss of properties and livestock.

5.1.10 **Urban infrastructure improvement:** This implies urban infrastructure improvement to include urban drainage for sustainable urban drainage system. Most of the canals in urban areas of the coastal region have been silted up due to deposition of incoming silt with high tide, twice a day during dry season. The old drainage structures are weaker and fragile due to salinity effect and prolonged use. The solution to the problem can be addressed through medium- and long-term program using traditional technology.

Urban protection technology program will save valuable land and properties, reduce the number of landless people and protect increasing number of poverty affected people.

Table 12: Long list of technologies in water sector

Subsector	Category	Technology
Infrastructure development	Project Implementation	Improved Embankment Construction
		Rehabilitation of existing Embankments/ dykes and dredging
		Tidal barriers (Sluice gates)
Tidal system and infrastructures management	Project Implementation	Polder management (rehabilitation and climate proofing)
		Tidal river management including Computer simulation of tidal flow
		Saltwater Intrusion barrier
Monitoring of	Research and	Monitoring of sea level rise, tidal fluctuation, salinity

sea level and coastal morphologies	knowledge generation	intrusion, sedimentation and coastal erosion
Comprehensive disaster management	Project Implementation	Comprehensive disaster management incorporating early warning systems and involving community
		Desalinization for drinking water in coastal areas
Urban resilience improvement	Project Implementation	Urban infrastructure improvement

5.2 Short listed adaptation technology options in water sector and their adaptation benefits

Following identification of specific adaptation technologies (listed in Table 12), feasibility and urgency of all the proposed technologies have been reviewed and short-listed.

Among 10 technologies, 6 technologies have been short-listed. Technologies, those have been left out of the list, are: Improved Embankment Construction, Polder management (rehabilitation and climate proofing), Saltwater Intrusion barrier and Desalinization for drinking water in coastal areas.

Technologies are rejected in the context of specific reasons, for instance the technology 'saltwater intrusion barrier' has been rejected because salinity intrusion cannot be protected by constructing barriers across the flowing rivers. Because construction of any barrier across the flowing river will accelerate the siltation process in the river bed starting from the barrier and will create drainage congestion/ water logging at the upstream area. Research is required to find a good solution and to develop an effective saltwater management.

A list of short-listed technologies is presented in Table 13

Table 13: List of edited technologies

Subsector	Category	Technology
Infrastructure development	Project Implementation	Rehabilitation of existing Embankments/ dykes and dredging
		Tidal barriers (Sluice gates)
Tidal system and infrastructures management	Project Implementation	Tidal river management including Computer simulation of tidal flow
Monitoring of sea level and and coastal changes	Research and knowledge generation	Monitoring of sea level rise, tidal fluctuation, salinity intrusion, sedimentation and coastal erosion
Comprehensive disaster management	Project Implementation	Comprehensive disaster management incorporating early warning systems and involving community
Urban resilience improvement	Project Implementation	Urban infrastructure improvement

5.2.1 Rehabilitation of existing Embankments/ dykes and dredging: All the coastal embankments and sea dykes were constructed under Coastal Embankment Project (CEP) in the early 60's and 70's. Due to prolonged use and weather effects, the cross-sections of the existing embankments including the crest level have been reduced significantly. In addition, sea-level rise due to global warming effect these embankments and dykes are under serious threats to breach. Solution to the problem is rehabilitation of existing embankments/dykes with medium and long-term traditional and indigenous methods.

Important considerations for the improved construction are:

- Redesign of crest level of embankments/dykes incorporating Sea Level Rise (SLR), subsidence and storm surge and providing adequate berm at the C/S.
- Construction of a narrow embankment (ring Bund) at proposed berm level of embankment apart from the main embankment and filling the gap in between by dredged earth. Then additional height at the R/S above the berm level will be constructed.

The proposed embankment rehabilitation will allow no or less seepage during flood and high tide. Further, the rehabilitated embankment will require no or less annual maintenance. Social benefits like increased safety of people's life and crops including provision of emergency shelter on the berm at C/S can be achieved during cyclone and tidal surge.

5.2.2 Tidal barriers (Sluice gates): Most of the sluice gates in the coastal area were constructed under Coastal Embankment Project (CEP) in the early 60's and 70's. Due to prolonged use and salinity effect, the condition of the existing sluices including flap gates have become weak and fragile and lost their draining efficiency. The solution to the problem is construction of new/ rehabilitation of sluice gates with medium- and long-term using traditional/ modern technology.

Important considerations for the new construction/ rehabilitation of sluice gates are:

- Construction of new sluice gates/ rehabilitation should be done incorporating the effect of sea-level rise, subsidence, and cyclonic/ tidal surge.
- Up-gradation of gates and hoists are to be made to utilize full drainage capacity and easier operating system by innovative/ improved design using non-corrosive high strength light materials.

The advantages of the proposed sluice gate are (i) it will reduce siltation process through river bed erosion, (ii) will increase operating efficiency and (iii) will be durable.

5.2.3 Tidal river management including computer simulation of tidal flow: Construction of peripheral embankment along the banks of the coastal rivers under Coastal Embankment Project (CEP) has prevented intrusion of silt laden saline water into the poldered area. Moreover, upstream flow of these rivers reduced drastically due to construction and operation of *Farakka* Barrage. As a result, silt coming up with saline water during high tide in dry season being deposited in the river bed starting from the downstream of the sluice gates. This has been identified as the main reason of drainage congestion/ water-logging in the coastal polders. The solution to this problem is introduction of Tidal River Management (TRM) using indigenous method with medium and long-term program.

Important considerations for the Tidal River Management (TRM) are:

- Identification and assessment of low lying areas within the polder and location of link canal suitable for TRM operation through field survey.
- Assessment of tidal prism, flow velocity, discharge and duration of TRM operation through Model Simulation.
- Planning and preparation of master Plan for TRM and sequential operation of TRM in 145 polders for improved drainage and sediment management, increased navigability of the rivers and raising ground levels of the polders. This is a climate resilient approach for coping with coastal flooding, river sedimentation with the increasing sea level rise and change in precipitation.
- Construction/ rehabilitation of sluice gates incorporating the effect of sea-level rise, subsidence, and cyclonic/ tidal surge.
- Planning and design of up-gradation of gates and hoists to utilize full drainage capacity and easier operating system by innovative/ improved design using non-corrosive high strength materials.
- Installation of up-graded gates and hoists

TRM has the benefits of (i) reducing siltation in the river, increasing drainage capacity and tidal prism, (ii) reducing drainage congestion / water logging within the polder and peripheral rivers, (iii) increasing ground level of the TRM basin, (iv) providing quick drainage and (v) increasing operating efficiency.

TRM will provide healthy, productive, economic and agricultural friendly environment. Early cropping in greater areas would be possible where TRM is accepted.

5.2.4 Monitoring of sea level rise, tidal fluctuation, salinity intrusion, sedimentation and coastal erosion: There is no adequate database to ascertain the effect of sea level rise at different dimensions. It is essential to record the water level, discharge, salinity and sedimentation for monitoring the substantial changes in the respective dimension. This will require medium and long-term programmes with traditional method.

Important considerations for monitoring are:

- Planning, installation of network establishment and monitoring for water level, salinity and sediment measurement.
- Supply & installation of auto gauges at suitable locations.
- Recruitment of manpower

The monitoring program will build up awareness to guide for taking action by the decision-makers to ensure future sustainability. Moreover, the program will help ensuing healthy, economic and agricultural productive environment.

5.2.5 Urban Resilience Development: This implies urban infrastructure improvement to include urban drainage for sustainable urban drainage system. Most of the canals in urban areas of the coastal region have been silted up due to deposition of incoming silt with high tide twice a day during dry season. The old drainage structures are weaker and fragile due to salinity effect and prolonged use. The solution to the problem can be addressed through medium and long-term program using traditional

technology.

Important considerations for the urban protection technology are:

- Identification of the areas vulnerable to cyclonic surge and river erosion of the coastal cities/ towns
- Planning and design of flood wall, spar and river bank revetment works.
- Re-excavation of canals by excavator/manual.
- Rehabilitation of sluices with radial gates
- Monitoring of the stability of flood wall, spur and river bank revetment works.
- Construction /implementation of bank revetment work

Urban protection technology program will save valuable land and properties, reduce the number of landless people and protect increasing number of poverty affected people.

5.2.6 Comprehensive disaster management incorporating early warning systems and involving community: In the last decade, the frequency of cyclone and storm surge in the coastal area have increased significantly due to global climate change. The traditional preparedness, warning system and rescue measures against pre- and post- cyclonic surge has been proven of not being adequate and needs improvement and modernization. Coordination and monitoring of pre-and post-disaster activities should be strengthened. This will require medium and long-term program using modern technology.

Important considerations for the community-based comprehensive disaster management program and early warning system for storm surge and cyclones are:

- Research for development of system management to minimize casualty and loss of properties and livestock against cyclonic surge.
- Development of appropriate and meaningful range & duration of warning system
- Dissemination of forecasting up to the Community level
- Construction/ rehabilitation of Cyclone shelters
- Capacity building

The program will increase sense of security, reduce magnitude of disaster; reduce casualties and loss of properties and livestock.

5.3 Characterization of Short-listed adaptation technology

All the short listed technologies are further categorized on the basis of its availability in time and applicability in scale. The criteria of categorization are short-term, medium-term and long-term and, small scale and large scale.

- The short term is meant that it has proven to be reliable, commercial technology in a similar market mechanism
- The technologies in the medium term would be pre-commercial in that given market context (5 years to full market availability)
- A long term technology would still be in an R & D phase or a prototype
- Small scale technologies are applied at the household and/ or community level, which could be scaled up into a program, and

- All technologies applied on a scale larger than household or community level are considered large scale technologies.

A list of edited technologies with their scale and availability is presented in Table 14.

Table 14: List of edited technologies with their scale and availability

Priority Sector		Technology Identification		
Sector	Sub Sectors	Technology	Scale of application	Short medium and long range availability
Water	Infrastructure development	Rehabilitation of existing embankments/ dykes and dredging	Large Scale	Short Term
		Tidal barriers (Sluice gates)	Large Scale	Short and Medium Term
	Tidal system and infrastructures management	Tidal river management including computer simulation of tidal flow	Large Scale	Short and Medium Term
	Comprehensive disaster management	Comprehensive disaster management incorporating early warning systems and involving community	Small to Large Scale	Short and Medium Term
	Monitoring of sea level and coastal morphology	Monitoring of sea level rise, tidal fluctuation, salinity intrusion, sedimentation and coastal erosion	Small to Large Scale	Short and Medium Term
	Urban resilience improvement	Urban Infrastructure Development	Small to Large Scale	Medium Term

CHAPTER 6: Technology prioritization for Agriculture Sector

6.1 An overview of possible adaptation technology options in agriculture sector (Sector A) and their adaptation benefits

In order to enable the agriculture sector to adapt to the adverse effects of climate change, a number of measures has been discussed in the stakeholder consultations which is to be promoted to enable it to play its role in a context of food security and attaining food self-sufficiency. Various adaptations to climate change for agriculture sector of Bangladesh is identified through review of various documents and consultations which are presented in Table 15 below.

Table 15: Long list of technologies of agriculture sector

Subsector	Category	Technology
Technology development and knowledge management	Varietal development	Development of salinity tolerant rice varieties
		Development of draught tolerant rice varieties
		Development of short maturing rice varieties
Research, Development and Extension services	Project Implementation	Establishment of special agricultural R & D centre
		Technology disseminations for salt and draught tolerant and early maturing rice varieties,
		Plant protection and epidemiological surveillance.
		Training on improved farming practices for crops, irrigation and water management, soil fertility management (conservation and restoration of soil quality) etc.
Management of support sectors	Research and knowledge generation	Polder management
		Development of improved drainage, irrigation and water distribution system
		Land use planning
		Management of water reservoir, infrastructures
		Protection of agricultural land from intrusion of salt water
		Introduction of crop insurance to transfer/ minimize the risk of crop loss and damage

6.2 Short-listed adaptation technology options in agriculture sector and their adaptation benefits

Following the identification of specific adaptation technologies (listed in Table 15),their feasibility and urgency of all the proposed technologies are reviewed and a short-list of their technology is prepared.

Among 13 technologies, 7 technologies have been short-listed. Technologies those are left-out from the list are: Plant protection and epidemiological surveillance, Polder management development of improved drainage, irrigation and water distribution system, protection of

agricultural land from intrusion of salt water and introduction of crop insurance to transfer/ minimize the risk of crop loss and damage.

Technologies are rejected in the context of specific reasons, for instance the technologies e.g. protection of agricultural land from intrusion of salt water and management of water reservoir, infrastructures have been rejected because these will cover by the technologies short-listed in water sector. On the other hand, salinity intrusion cannot be protected by constructing barriers across the flowing rivers. Construction of any barrier across the flowing river will accelerate the siltation process in the river bed starting from the barrier and will create drainage congestion/ water-logging at the upstream area.

Many stakeholders also consented to drop the technology 'introduction of crop insurance to transfer/ minimize the risk of crop loss and damage' from the final list as several attempts of introducing of crop insurance by different organization didn't success. Table 16 below shows the edited technology option of the subsectors of water sector.

Table 16: List of edited technologies

Subsector	Category	Technology
Technology development and knowledge management	Varietal development	Development of salinity-tolerant rice varieties
		Development of drought-tolerant rice varieties
		Development of short-maturing rice varieties
Research, Development and Extension services	Project Implementation	Establishment of special agricultural R & D centre
		Establishment of climate smart Technology Dissemination Center
		Training on improved farming practices for crops, irrigation and water management, soil fertility management (conservation and restoration of soil quality) etc.
Management of support sectors	Research and knowledge generation	Land use planning

6.3 Characterization of Short listed adaptation technology

All the short listed technologies are further categorized on the basis of its availability in time and applicability in scale. The criteria of categorization are short term, medium term and long term and, small scale and large scale.

- The short term is meant that it has proven to be reliable, commercial technology in a similar market mechanism
- The technologies in the medium term would be pre-commercial in that given market context (5 years to full market availability)
- A long-term technology would still be in an R & D phase or a prototype
- Small scale technologies are applied at the household and/ or community level, which could be scaled up into a program, and
- All technologies applied on a scale larger than household or community level are considered large scale technologies.

A list of edited technologies with their scale and availability is presented in Table 17.

Table 17: List of edited technologies with their scale and availability

Priority Sector		Technology Identification		
Sector	Sub Sectors	Technology	Scale of application	Short medium and long range availability
Agriculture	Technology development and knowledge management	Development of salinity tolerant rice varieties	Large Scale	Short Term
		Development of draught tolerant rice varieties	Large Scale	Short and Medium Term
		Development of short maturing rice varieties	Large Scale	Short and Medium Term
	Research, Development and Extension services	Establishment of special agricultural R & D centre	Large Scale	Short and Medium Term
		Establishment of climate smart Agricultural Technology Dissemination Center	Large Scale	Medium Term
		Training on improved farming practices for crops, irrigation and water management, soil fertility management (conservation and restoration of soil quality) etc.	Small to Large Scale	Short and Medium Term
	Management of support sectors	Land use planning	Large Scale	Medium Term

CHAPTER 7: Assessing technologies with Multi-Criteria Decision Analysis (MCDA)

7.1 Criteria and process of technology prioritization

In this exercise, priority technologies have been identified by exploring how investments in technologies for adaptation would improve the situation beyond the baseline situation in these sectors/areas. Improvements have been expressed in terms of development priorities, and adaptation benefits and other environmental impacts, as well as economic and social impacts. Therefore, the main objectives on which a measure or technology are judged include the following:

- Maximize the resilience of the sector and others liable to be impacted indirectly,
- Maximize development priority benefits in terms of environmental, social and economic benefits and minimize adverse impacts due to the measure relative to inaction.

For climate change adaptation technology prioritization, the following criteria have been considered in the discussion and decision making of technology prioritization

Criteria category 1: Contribution to development goals in the light of climate change impact scenarios for the country

Environmental improvement, which includes:

- Reduced environmental hazards
- Efficiency in resource use
- Reduced waste
- Reduced resource use
- Bio-diversity conservation

Social improvement, which includes:

- Health improvement
- Creation of employment opportunity
- Reduced number of displaced people
- Improved quality of life

Economic improvement, which includes:

- Poverty reduction
- Job creation and quality
- Skills improvement
- Enterprise stimulation

Criteria category 2: Reduction of vulnerability to climate change scenarios

- To water shortages, water excesses
- To loss of land
- To increased salinity

Criteria category 3: Costs of technology
- Capital costs
- Operational and maintenance (O&M) costs

7.2 Assessment of technologies: scoring and weighing

7.2.1 Scoring of water and agriculture sector adaptation technology options: Scoring to the listed adaptation technologies of water and agriculture sectors has been done following consultation of the stakeholders of relevant sector. On the basis of the technology information and criteria stated in 'Technology Fact Sheets' and 'Technology Performance Matrix' of each technology, the stakeholders scored each of the technologies for each criteria. The score is given on a scale of 0-100; score '0' is given to the technology option which is least preferred under that criteria and 100 is given to the most preferred option under the same criteria. The other technology options are scored in between 0-100 and relative to highest and lowest scores. The 'Technology Fact Sheets' and 'Technology Performance Matrix' are presented respectively as Annex 1 and Annex 4.

Table 18 below shows the scores of technology options of water sector.

Table 18: Score of water sector adaptation technology options

Technology Options	**Criteria**						
	Capital Costs	O & M Costs	Cost Effectiveness	Adaptation Benefit	Social Benefit	Environmental Benefits	Economic Benefits
Rehabilitation of existing embankments / dykes and dredging	100	100		90	0	80	90
Tidal barriers (Sluice gates)	80	70		0	70	80	80
Tidal river management including computer simulation of tidal flow	0	80		100	70	80	60
Monitoring of sea-level rise, tidal fluctuation, salinity intrusion, sedimentation and coastal erosion	90	100		80	70	0	50
Comprehensive disaster management	90	80		100	90	0	80

incorporating early warning systems and involving community							
Urban Infrastructure Development	0	60		70	70	80	70

On the basis of the stakeholders scoring to each of technology, the least preferred and most preferred technologies have been identified. Technology that scored 100 is considered as most preferred and the technology scored 0 is considered as least preferred.

Table 19 shows the most preferred and least preferred technology options of the water sector.

Table 19: Most preferred and least preferred water sector technology options

Preference	**Criteria**					
	Capital Costs	O and M Costs	Adaptation Benefits	Social Benefits	Environmental Benefits	Economic Benefits
Most preferred	Rehabilitation of existing embankment / dykes and dredging	Rehabilitation of existing Embankments/ dykes and dredging Monitoring of sea level rise, tidal fluctuation, salinity intrusion, sedimentation and coastal erosion	Rehabilitation of existing embankments/ dykes and dredging	Comprehensive disaster management incorporating early warning systems and involving community	Rehabilitation of existing embankments/ dykes and dredging	Rehabilitation of existing embankments/ dykes and dredging
Least preferred	Urban Infrastructure Development	Tidal river management including Computer simulation of tidal flow	Tidal barriers (Sluice gates)	Tidal river management including Computer simulation of tidal flow	Monitoring of sea level rise, tidal fluctuation, salinity intrusion, sedimentation and coastal erosion	Monitoring of sea level rise, tidal fluctuation, salinity intrusion, sedimentation and coastal

						erosion

Scoring of agriculture sector technology options also has been done on scale of 0-100; score '0' is given to the technology option which is least preferred under that criteria and 100 is given to the most preferred option under the same criteria. Table 20 shows the scores of technology options of agriculture sector.

Table 20: Score of agriculture sector adaptation technology options

Technology Options	**Criteria**					
	Capital Costs	O & M Costs	Adaptation Benefits	Social Benefits	Environmental Benefits	Economic Benefits
Development of salinity-tolerant rice varieties	90	60	100	0	90	100
Development of drought-tolerant rice varieties	85	70	90	0	80	90
Development of short-maturing rice varieties	80	0	100	80	75	90
Establishment of special agricultural R & D centre	0	70	90	60	0	90
Establishment of climate-smart Agriculture Technology Dissemination Center	80	60	90	90	70	0
Training on improved farming practices for crops, irrigation and water management, soil fertility management (conservation and restoration of soil quality) etc.	100	50	80	70	0	90
Land-use planning	80	80	0	80	70	0

On the basis of the stakeholders scoring to each of technology, the least preferred and most preferred technologies have been identified. Technology that scored 100 is considered and most preferred and the technology scored 0 is considered as least preferred.

Table 21 shows the most preferred and least preferred technology options of agriculture sector.

Table 21: Most preferred and least preferred water sector technology options

Preference	**Criteria**					
	Capital Costs	O & M Costs	Adaptation Benefits	Social Benefits	Environmental Benefits	Economic Benefits
Most preferred	Training on improved farming practices	Development of salinity-tolerant rice varieties Development of drought tolerant rice varieties	Development of salinity-tolerant rice varieties Development of short maturing rice varieties	Development of salinity-tolerant rice varieties	Development of salinity-tolerant rice varieties	Development of salinity-tolerant rice varieties
Least preferred	Land-use planning	Training on improved farming practices	Land-use planning	Establishment of special agricultural R & D centre	Training on improved farming practices	Land-use planning

7.2.2 Weighting of water and agriculture sector adaptation technology options: Following scoring and identification of the most preferred and least preferred technology options weights of each criterion are determined through stakeholders' consultation. For adaptation technologies swing weight has not been considered in determining the weights of each criterion, as most of the criteria do not provide any quantified values of different benefits. Though there have quantified values of capital cost and operation and management cost but these are not comparable as they don't provide any unit cost of the criteria. That's why cost benefit analysis of the technology options also has not been calculated.

After the weights are assigned to the criteria, the weights are normalized by dividing weight of the criteria with the calculated total weight. Calculation of weights and normalized weight has been done in an Excel sheet attached as annex.

7.3 Final decision and results of technology prioritization

After calculation of normalized weights, the overall weighted score has been calculated by multiplying each of the criteria specific weighted score with the normalized weights and then adding all the criteria scores of each technology option.

On the basis of overall weighted score the technology options are prioritized and ranked from high priority to low priority order. For example, water sector technology 'Rehabilitation of existing embankments/ dykes and dredging' got the highest weighted score of 86.1 and comes up a high priority technology. Technology 'urban Infrastructure

development' of water sector got the lowest weighted score of 56.44 and thus considered as lowest priority technology.

Again in regards to agriculture sector technology 'Development of salinity-tolerant rice varieties' got the highest weighted score of 81.92 and comes up a high priority technology. Technology 'Land-use planning' of water sector got the lowest weighted score of 43.86 and thus considered as lowest priority technology.

This is to note that all the short-listed technologies have been listed down as per their order of priority. Given the multi-sectoral impacts of climate change in Bangladesh, the stakeholders emphasized to treat all the technologies equally important and develop action plan for all the technologies.

Table 22 and 23 below shows the prioritized technology options respectively of water sector and agriculture sector.

Table 22: Water sector adaptation technologies as per priority order

Technology	Weighted Score	Priority Order
Rehabilitation of existing embankments/ dykes and dredging	**86.1**	**1**
Comprehensive disaster management incorporating early warning systems and involving community	**75.91**	**2**
Monitoring of sea level rise, tidal fluctuation, salinity intrusion, sedimentation and coastal erosion	**68.66**	**3**
Tidal river management including computer simulation of tidal flow	**65.52**	**4**
Tidal barriers (Sluice gates)	**58.88**	**5**
Urban Infrastructure development	**56.44**	**6**

Table 23: Agriculture sector adaptation technologies as per priority order

Technology	Weighted Score	Priority Order
Development of salinity-tolerant rice varieties	**81.92**	**1**
Development of drought-tolerant rice varieties	**77.17**	**2**
Development of short-maturing rice varieties	**70.39**	**3**
Training on improved farming practices for crops, irrigation and water management, soil fertility management (conservation and restoration of soil quality) etc.	**64.81**	**4**
Establishment of climate-smart Agriculture Technology Dissemination Center	**62.19**	**5**
Establishment of special agricultural R & D centre	**56.08**	**6**
Land-use planning	**43.86**	**7**

CHAPTER 8: Summary / Conclusions

In the context of unprecedented impacts of climate change in Bangladesh, especially to country's strive of growth and development, the first response of facing climate change is undertaking adaptation measures that have to be taken in the very near term. The adaptation measures will involve the use of technology and its management (development, transfer, adaptation, adoption and diffusion). Considering the country's long-term development priorities and strive for poverty reduction and economic growth, this report prioritized water and agriculture sector as the most vulnerable ones where immediate technological measures are required to make these sectors/ sub-sectors resilient to the impacts of climate change. In this context, a number of technology options are discussed, identified and prioritized through a series of consultations both in national and local level. The technology options for water sector include;

a) Rehabilitation of existing embankments/ dykes and dredging,
b) Tidal barriers (sluice gates),
c) Tidal river management including computer simulation of tidal flow,
d) Comprehensive disaster management incorporating early warning systems and involving community,
e) Monitoring of sea level rise, tidal fluctuation, salinity intrusion, sedimentation and coastal erosion and
f) Urban Infrastructure development

On the other hand the technology options for agriculture sector include;

a) Development of salinity-tolerant rice varieties
b) Development of drought-tolerant rice varieties
c) Development of short-maturing rice varieties
d) Training on improved farming practices for crops, irrigation and water management, soil fertility management (conservation and restoration of soil quality) etc.
e) Establishment of climate-smart Agriculture Technology Dissemination Center
f) Establishment of special agricultural R & D centre
g) Land-use planning

References

Ahmed, A.U., (2006). Bangladesh Climate Change Impacts and vulnerability: A Synthesis, Climate Change Cell, Department of Environment, Dhaka.

Agrawala, S., Ota, T,. Ahmed, A.U,.Smith, J. and Van Aalst, M., 2003. Development and climate change in Bangladesh: focus on coastal flooding and the Sundarbans. Organization of Economic Cooperation and Development (OECD) Paris.

Rahman, A. and M. Alam, *Mainstreaming Adaptation to Climate Change in Least Developed Countries (LDCs): Bangladesh Country Case Study.* IIED Working Paper, 2003(2).

Bangladesh Krishi Diary 2010

Bangladesh Economic Review (BER), 2010

CCC, 2008: Climate Change Cell, Department of Environment; Bangladesh Reducing Development Risk in Changing Climate, Dhaka 25 March 2008

CCC 2009b: Climate Change and Health Impacts in Bangladesh. Climate Change Cell, Department of Environment

CEGIS, 2006. Impacts of Sea Level Rise on Land use Stability and Adaptation Options, Draft Final Report. Submitted to the Ministry of Environment and Forests

Cheung WWL, Lam, VWY, Sarmiento JL, Kearney K, Watson R, Pauly D, 2009. Projecting global marine biodiversity impacts under climate change scenarios. Fish and Fisheries, 10 (3): 235-251.

DFID, 2004: Department for International Development (DFID) 2004. Climate Change deepens poverty and challenges poverty reduction strategies, Key Sheet No 01 and 03

Faisal, I. M. and S. Parveen (2004) "Food Security in the Face of Climate Change, Population Growth, and Resource Constraints: Implications for Bangladesh", Environmental Management Vol. 34, No. 4, pp. 487-498.

Iwasaki S, Razafindrabe BHN, Shaw R (2009) Fishery livelihoods and adaptation to climate change: a case study of Chilika lagoon, India. Mitigation and Adaptation Strategies for Global Change 14(4): 339-55

Karim, Z., Hossain, S.G., and Ahmed, A.U. (1999) Climate Change Vulnerability of crop Agriculture in: S. Huq, Z. Karim, M Asaduzzaman, and F. Mahtab (Eds.) Kluwer Academic Publishers, Dordrecht, pp 39-54

Khote, M., 2005. Inter-annual and Decadal Variability of Sea Surface Temperature (SST) Over Indian Ocean, Mausam, 56(4): 804-810.

NAPA, 2005: National Adaptation Programme of Action 2005, Ministry of Environment and Forests, Government of Bangladesh.

Rahman. A. Atik, 2008: Climate Change and its on Health in Bangladesh, Regional Health Forum, Vol 12, No 1, 2008

Shamsuddoha, Md, Khan, SM Munjurul Hannan, Hossain, Tanjir, and Raihan Sajid (2012). Displacement and migration from the climate hot-spots: Causes and Consequences, Center for Participatory Research and Development and ActionAid Bangladesh, Dhaka

Westlund L, Poulain F, Bage H, van Anrooy R, 2007. Disaster response and risk management in the fisheries sector. Rome: FAO.

World Bank, 2000. 'Bangladesh Climate Change and Sustainable Development. Report No. 21104- BD', Rural Development Unit, South Asia Region, The world Bank (WB), Dhaka,

World Bank 2009: South Asia Climate Change Strategy, 2009.

ANNEX 1: Technology Fact Sheets (TFS)

Technology Fact Sheet: Rehabilitation of existing embankments/ dykes and dredging

Sector	**Water/ Infrastructure development**
Technology Name	Rehabilitation of existing embankments/ dykes and dredging
Adaptation Benefits	The proposed embankment rehabilitation will allow no or less seepage during flood and high tide and will provide protection against cyclonic and tidal surge. Further the rehabilitated embankment will require no or less annual maintenance. Adaptation benefits like increased safety of people's life and crops including provision of emergency shelter on the berm at C/S can be achieved against cyclone and tidal surge.
Background/ Notes, Short description of the technology option	All the coastal embankments and sea dykes were constructed under Coastal Embankment Project (CEP) in the early 60's and 70's. Due to prolonged use and weather effects, the cross-sections of the existing embankments including the crest level have been reduced significantly. In addition, sea-level rise due to global warming effect these embankments and dykes are under serious threats to breach. **Solution:** Rehabilitation of existing embankments/dykes with medium and long term traditional and indigenous method
Implementation assumptions, how this technology will be implemented and diffused across the subsector	• Redesign of crest level of embankments/dykes incorporating Sea Level Rise (SLR), subsidence and storm surge and providing adequate berm at the C/S. • Construction of a narrow embankment (ring Bund) at existing height of embankment apart from the main embankment and filling the gap in between by dredged earth to provide berm.
Impact Statements-How this option impacts the country development priority	
Country social development priorities	• Increased safety of people's life and crops against cyclone and tidal surge. • Provision of emergency shelter on the berm during cyclonic/ tidal surge.
Country economic development priorities	• Will reduce import cost of cereal crops • Will reduce loss and damages from the disaster events
Country environmental development priorities	• No or less seepage during flood and high tide. • Protection against cyclonic and tidal surge • No or less requirement of annual maintenance

Costs	
Capital costs	Approximate cost of Earthwork (E/W) construction for the new embankment would be Tk 50 lakh per kilometer. (USD 62500)
Operational and Maintenance costs	Tk 02 lakh per kilometer per year. (USD 2500)

Technology Fact Sheet: Tidal barriers (Sluice gates)

Sector	**Water/ Infrastructure development**
Technology Name	Tidal barriers (Sluice gates)
Adaptation Benefits	The advantages of the proposed sluice gate are (i) it will reduce siltation process through river bed erosion, (ii) will increase operating efficiency and (iii) will be durable.
Background/ Notes, Short description of the technology option	Most of the sluice gates in the coastal area were constructed under Coastal Embankment Project (CEP) in the early 60's and 70's. Due to prolonged use and salinity effect, the condition of existing sluices including flap gates have become weak and fragile and lost their draining efficiency. **Solution** Construction of new sluice gates with medium- and long-term using traditional/modern technology.
Implementation assumptions, how this technology will be implemented and diffused across the subsector	• Construction of new sluice gates/ rehabilitation incorporating the effect of sea level rise, subsidence, and cyclonic/ tidal surge.
Impact Statements-How this option impacts the country development priority	
Country social development priorities	• Increased safety of people's life and crops against cyclone and tidal surge. • Will provide early cropping in greater areas
Country economic development priorities	• Will increase agricultural productivity, which will contribute to the country's goal of attaining food security.
Country environmental development priorities	• Will provide quick drainage • Will reduce siltation process by river bed erosion. • Will increase operating efficiency
Costs	
Capital costs	• Approximate cost of TK 100.00 lakhs per vent; (USD 125000)
Operational and Maintenance costs	Rehabilitation / repair of sluice gate = Tk 25 lakh /per vent (Approx); (USD 31250)

Technology Fact Sheet: Tidal river management including computer simulation of tidal flow

Sector	Water/ Tidal system and infrastructures management
Technology Name	Tidal river management including computer simulation of tidal flow
Adaptation Benefits	TRM has the benefits of (i) reducing siltation in the river, increasing drainage capacity and tidal prism, (ii) reducing drainage congestion / water logging within the polder and peripheral rivers, (iii) increasing ground level of the TRM basin, (iv) providing quick drainage and (v) increasing operating efficiency.
Background/ Notes, Short description of the technology option	Construction of peripheral embankment along the banks of the coastal rivers under Coastal Embankment Project (CEP) has prevented intrusion of silt laden saline water into the poldered area. Moreover, upstream flow of these rivers reduced drastically due to construction and operation of Farakka Barrage. As a result, silt coming up with saline water during high tide in dry season being deposited in the river bed starting from the downstream of the sluice gates. This is the identified main reason of drainage congestion/ water logging in the coastal polders. The solution to this problem is introduction of Tidal River Management (TRM) using indigenous method with medium- and long-term program. **Solution:** • Introduction of Tidal River Management (TRM) using indigenous method with medium and long term program • Medium and long term indigenous and modern technology though improved planning, design, construction and gate improvement
Implementation assumptions, how this technology will be implemented and diffused across the subsector	Important considerations for the Tidal River Management (TRM) are: • Identification and assessment of low lying areas within the polder and location of link canal suitable for TRM operation through field survey. • Assessment of tidal prism, flow velocity, discharge and duration of TRM operation through Model Simulation. • Planning and preparation of Master Plan for TRM and sequential operation of TRM in 145 polders for improved drainage and sediment management, increased navigability of the rivers and raising ground levels of the polders. This is a climate resilient approach for coping with coastal flooding, river sedimentation with the increasing sea-level rise and change in precipitation.

	• Construction/ rehabilitation of sluice gates incorporating the effect of sea level rise, subsidence, and cyclonic/ tidal surge. • Planning and design of up-gradation of gates and hoists to utilize full drainage capacity and easier operating system by innovative/ improved design using noncorrosive high strength materials. • Installation of up-graded gates and hoists
Impact Statements-How this option impacts the country development priority	
Country social development priorities	• Will provide healthy, economic and agricultural productive environment. • Will provide early cropping in greater areas
Country economic development priorities	• Will increase agricultural productivity, which will contribute to the country's goal of attaining food security. • Will reduce economic loss caused by weather extreme events
Country environmental development priorities	• Will reduce siltation process. Will increase river cross section by bed erosion and will increase tidal prism. • Will reduce drainage congestion / water logging. • Will increase ground level of the TRM basin. • Will provide quick drainage • Will increase operating efficiency
Costs	
Capital costs	• Approx cost = Tk 50.00 lakhs/ polder • Approx cost model simulation = Tk 25.00 lakhs/ polder • Approx cost of TRM operation = Tk 1200 lakhs/ TRM basin • New sluices: TK 100.00 lakhs per vent Total: Taka 1375 lakh/ TRM basin; (USD 1718750)
Operational and Maintenance costs	• Rehabilitation / repair of sluice gate = Tk 25 lakh /per vent(Approx) • Approx planning and design cost = Tk 30 Lakhs • Approx cost for installation of up-graded gates & hoists= Tk 3.0 lakhs/ no Total: Taka 58 lakh; (USD 72500)

Technology Fact Sheet: Monitoring sea level, tide, salinity, sedimentation and coastal erosion

Sector	Water/ Monitoring of sea and coastal changes
Technology Name	Monitoring sea-level, tide, salinity, sedimentation and coastal erosion.
Adaptation Benefits	The monitoring program will build up awareness to guide for taking action by the decision makers to ensure future sustainability. Moreover, the program will help ensuing healthy, economic and agricultural productive environment.
Background/ Notes, Short description of the technology option	There is no adequate database to ascertain the effect of sea level rise at different dimension. It is essential to record the water level, discharge, salinity and sedimentation for monitoring the substantial changes in the respective dimension. **Solution:** Medium and long-term program with traditional method.
Implementation assumptions, how this technology will be implemented and diffused across the subsector	Important considerations for monitoring are: • Planning, installation of network establishment and monitoring for water level, salinity and sediment measurement. • Supply & installation of auto gauges at suitable locations. • Skill development
Impact Statements-How this option impacts the country development priority	
Country social development priorities	• Will ensure healthy, economic and agricultural productive environment.
Country economic development priorities	
Country environmental development priorities	• Awareness building to guide for taking action by the decision makers to ensure future sustainability.
Costs	
Capital costs	• Approx cost of planning Tk 50.00 lakh/ polder • Approx cost Tk 5.00 Lakhs/ number for supply and installation of auto gauges Total: 55 lahks/ polder; (USD 68750)
Operational and Maintenance costs	• Approx cost Tk 02.00 Lakhs/ number for operation and management; (USD 2500)

Technology Fact Sheet: Comprehensive disaster management involving community-based programs and early warning systems for storm surge and cyclones

Sector	Water/ Comprehensive disaster management
Technology Name	Comprehensive disaster management involving community-based programs and early warning systems for storm surge and cyclones
Adaptation Benefits	The technology will increase sense of security, reduce magnitude of disaster; reduce casualties and loss of properties and livestock.
Background/ Notes, Short description of the technology option	In the last decade, the frequency of cyclone and storm surge in the coastal area has increased significantly due to global climate change. The traditional preparedness, warning system and rescue measures against pre and post cyclonic surgehas been proven of not being adequate and needs improvement & modernization. Coordination and monitoring of Pre-and post-disaster activities should be strengthened. This will require medium and long-term program using modern technology.
Implementation assumptions, how this technology will be implemented and diffused across the subsector	Important considerations for the community-based comprehensive disaster management program and early warning system for storm surge and cyclones are: • Research for development of system management to minimize casualty and loss of properties and livestock against cyclonic surge. • Development of appropriate and meaningful range & duration of warning system • Dissemination of forecasting up to the Community level • Construction/ rehabilitation of Cyclone shelters • Capacity building
Impact Statements-How this option impacts the country development priority	
Country social development priorities	• Will reduce number of displaced and distress people
Country economic development priorities	• Will increase agricultural productivity, which will contribute to the country's goal of attaining food security. • Will reduce economic loss caused by weather extreme events
Country environmental development priorities	• Will reduce environmental pollution and loss of bio-logical resources
Costs	
Capital costs	The program will cost approximately • Tk 50/- lakh for research, • Tk 25/- lakh for development of up-graded warning system,

	• Tk 500/- lakh/ no. for construction of new cyclone shelter, • Tk 50 lakh/ no. for rehabilitation of cyclone shelter, • Tk 1/- lakh/ km for planning and implementation of Eco-friendly landscape & aforestation, • Tk 25/- lakh/ community for provision of renewable energy (solar system) and • Tk 0.5/- lakh/ household for provision of rainwater harvesting & sanitation. Total: Taka 651.5 lakh; (USD 814375)
Operational and Maintenance costs	For capacity building, approximate cost of training, workshop for providing life jacket/ buoy, etc. would be Tk 05/- lakh/ community. (USD 6250)

Technology Fact Sheet: Unban Infrastructure Development

Sector	Water/ Urban resilience improvement
Technology Name	Unban Infrastructure Development
Adaptation Benefits	Urban infrastructure development will save valuable land and properties, reduce the number of landless people and protect increasing number of poverty affected people
Background/ Notes, Short description of the technology option	This implies urban infrastructure improvement to include urban drainage for sustainable urban drainage system. Most of the canals in urban areas of the coastal region have been silted up due to deposition of incoming silt with high tide twice a day during dry season. The old drainage structures are weaker and fragile due to salinity effect and prolonged use. The solution to the problem can be addressed through medium and long term program using traditional technology.
Implementation assumptions, how this technology will be implemented and diffused across the subsector	Important considerations for the urban protection technology are: • Identification of the reaches vulnerable to cyclonic surge and river erosion of the coastal cities/ towns • Planning and design of flood wall, spar and river bank revetment works. • Re-excavation of canals by excavator/manual. • Rehabilitation of sluices with radial gates • Monitoring of the stability of flood wall, spur and river bank revetment works. • Construction /implementation of bank revetment work
Impact Statements-How this option impacts the country development priority	
Country social development priorities	• Number of landless people will be reduced. • Will protect from increasing number of poverty affected people
Country economic development priorities	• Valuable land and properties will be protected.

Country environmental development priorities	• Awareness building to guide for taking action by the decision makers to ensure future sustainability.
Costs	
Capital costs	• Approx cost = Tk 10.00 Lakh/ town identification of vulnerable reaches to cyclonic surge and river erosion • Approx cost of Planning Tk 10.00 lakh/ town • Aprx of re-excavation= Tk.50 lakh/ km • Aprx cost of sluice = Tk 100.0/- lakh/no. • Approx cost of revetment bank = Tk 2000 lakh/ km Total: Taka 2170 lakh; (USD 2712500)
Operational and Maintenance costs	• Approx cost of monitoring = Tk 20.00 lakh/ town (USD 25000)

TECHNOLOGY FACT SHEETS OF AGRICULTURE SECTOR TECHNOLOGIES

Technology Fact Sheet: Development of salinity-tolerant rice varieties

Sector	Agriculture/ Technology development and knowledge management
Technology Name	Development of salinity-tolerant rice varieties
Adaptation Benefits	Coastal farmlands now face loss of rice crop production due to salt water intrusion caused by sea level rise and unusual high tide. This technology will allow protect agriculture based small-holders livelihoods, reduce the number of landless people and protect increasing number of poverty affected people. The introduction of salt-tolerant rice varieties could also help the region cope with another problem — land subsidence.
Background/ Notes, Short description of the technology option	According to the Intergovernmental Panel on Climate Change, Bangladesh is slated to lose the largest amount of cultivated land globally due to rising sea levels. A 1m rise in sea levels would inundate 20 percent of the country's landmass. In recent decades, rising sea levels in the Bay of Bengal have encroached on vast tracts of agricultural land in the south, undermining rice production, a staple part of the Bangladeshi diet. Meantime, thousands of small-scale rice farmers have seen their livelihoods decimated due to the effects of climate change in the low-lying area. With soil salinity spreading fast, the key to survival lies in developing salt-resistant agriculture A new salt-resistant paddy could offer hope to coastal farmers in the coastal regions of Bangladesh whose crops are being affected by increased level of salinity.

	Though the rice variety 'BRRI -47', developed by the Bangladesh Rice Research Institute (BRRI) is claimed to survive high salinity and water-logging but its capacity of salinity tolerance level require to upscale to that this variety could withstand even in higher salinity level.
Implementation assumptions, how this technology will be implemented and diffused across the subsector	Important considerations for this technology implementation and diffusion includes: • Development of improved rice variety • Experimentation of performance in different soil salinity condition • Field experimentation and demonstration • Development of dissemination packages and tools • Monitoring of variety suitability in different coastal regions
Impact Statements-How this option impacts the country development priority	
Country social development priorities	• Number of jobless and unemployed people will be reduced. • Will protect from increasing number of poverty affected people
Country economic development priorities	• This technology will increase rice production and will contribute to country's goal of attaining food security
Country environmental development priorities	• Awareness building to guide for taking action by the decision makers to ensure future sustainability.
Costs	
Capital costs	• Approx cost = Tk 2000.00 Lakh for research and development of new variety • Approx cost for experimentation of the performance new rice variety Tk 500 lakh/ town Total: Taka 2500 lakh; (USD 3125000)
Operational and Maintenance costs	• Approx cost of field experimentation and demonstration = Tk 500.00 lakh • Development of dissemination packages and tools Tk 250 lakh • Approx cost of monitoring = Tk 250.00 lakh/ year Total: Taka 1000 lakh; (USD 1250000)

Technology Fact Sheet: Development of drought-tolerant rice varieties

Sector	Agriculture/ Technology development and knowledge management
Technology Name	Development of drought-tolerant rice varieties
Adaptation Benefits	The northern part of the country facing slow onset of drought that are causing loss of rice crop production and forcing people to migrate in search of alternative livelihoods options.

	This technology will allow protect agriculture based small-holders livelihoods, reduce the number of unemployed people and protect increasing number of poverty affected people.
Background/ Notes, Short description of the technology option	In Bangladesh, drought prone areas are mainly located in the in the Northwestern part, with very severe areas on centered in the *Barind* Tract and adjacent to the upper Ganges-Padma river floodplain areas. A recent study (Shamsuddoha, Md et at 2012) showed that in the drought prone areas small-scale rice farmers are selling out their pieces of land to the big-farm owners who are converting rice-crop land to mango orchards. Thus, agricultural labors are losing their employment opportunity and migrating to the urban growth centers for livings. Therefore, a new drought-resistant paddy could offer hope to the farmers in the drought prone regions of Bangladesh whose crops are being affected by increased level of drought. While,Bangladesh is trying to increase rice production to meet rising domestic demand it is crucial to develop drought-tolerant variety that will give higher yield in upland areas with a little water.
Implementation assumptions, how this technology will be implemented and diffused across the subsector	Important considerations for this technology implementation and diffusion includes: • Development of improved rice variety • Experimentation of performance in different soil salinity condition • Field experimentation and demonstration • Development of dissemination packages and tools • Monitoring of variety suitability in different coastal regions
Impact Statements-How this option impacts the country development priority	
Country social development priorities	• Number of jobless and unemployed people will be reduced. • Will protect from increasing number of poverty affected people
Country economic development priorities	• This technology will increase rice production and will contribute to country's goal of attaining food security
Country environmental development priorities	• This technology will make drought prone areas productive and ensure conservation of biological resources in the drought prone areas.
Costs	
Capital costs	• Approx cost = Tk 2000.00 Lakh for research and development of new variety

	• Approx cost for experimentation of the performance new rice variety Tk 500 lakh Total: Taka 2500 lakh ; (USD 3125000)
Operational and Maintenance costs	• Approx cost of field experimentation and demonstration = Tk 500.00 lakh/ town • Development of dissemination packages and tools Tk 150 lakh • Approx cost of monitoring = Tk 150.00 lakh/ year Total: Taka 800 lakh; (USD 1000000)

Technology Fact Sheet: Development of short-maturing rice varieties

Sector	Agriculture/ Technology development and knowledge management
Technology Name	Development of short-maturing rice varieties
Adaptation Benefits	Introduction of this technology in the specific disaster prone areas will save standing crops from these sudden disaster events. This technology will allow protect agriculture based small-holders livelihoods, reduce the number of unemployed people and protect increasing number of poverty affected people.
Background/ Notes, Short description of the technology option	In Bangladesh, climate change already has affected, and will intensify in future in 2 ways. Firstly, global warming lead to change in precipitation and weather pattern leading agriculture and food security to enormous threat. And secondly, increased number of climate induced disasters in the form of extreme hydro-meteorological events such as flood, drought, salinity ingress, river bank erosion and increased tidal surge leading to destruction of infrastructure, crop production, natural resources, livelihoods and of course the national economy. It has been observed that people of different agro-ecological zones have been experiencing new type of disaster event which they didn't face in the past, at the same time duration of disaster prevalence also has changed or shifted. Different disaster events that damages the standing crops are; a) Dense fog: Damages seasonal crops and seedling beds. b) Erratic rainfall: Damages standing crops, seed beds and sometimes delays cultivation time due to lack of soil moisture content c) Excess rainfall: Damages standing crops, seed beds and sometimes delays cultivation period.

	d) Monsoon flood: Damages standing crops, seed beds e) Storm and hail: Damages standing crop resulting to household level food insecurity Therefore, damages and loss of standing crops from these sudden disaster events could be avoided through replacing the crops with an early maturing variety.
Implementation assumptions, how this technology will be implemented and diffused across the subsector	Important considerations for this technology implementation and diffusion includes: • Development of improved rice variety • Experimentation of performance in different soil salinity condition • Field experimentation and demonstration • Development of dissemination packages and tools • Monitoring of variety suitability in different coastal regions
Impact Statements-How this option impacts the country development priority	
Country social development priorities	• Number of jobless and unemployed people will be reduced. • Will protect from increasing number of poverty affected people
Country economic development priorities	• This technology will increase rice production and will contribute to country's goal of attaining food security
Country environmental development priorities	• Awareness building to guide for taking action by the decision makers to ensure future sustainability.
Costs	
Capital costs	• Approx cost = Tk 2500.00 Lakh for research and development of new variety • Approx cost for experimentation of the performance new rice variety Tk 500 lakh/ town Total: Taka 3000 lakh; (USD 3750000)
Operational and Maintenance costs	• Approx cost of field experimentation and demonstration = Tk 500.00 lakh • Development of dissemination packages and tools Tk 250 lakh • Approx cost of monitoring = Tk 250.00 lakh/ year Total: Taka 1000 lakh; (USD 1250000)

Technology Fact Sheet: Establishment of special agricultural R & D centre

Sector	Agriculture/ Technology development and knowledge management
Technology Name	Establishment of special agricultural R & D centre
Adaptation Benefits	
Background/ Notes, Short description of the technology option	The agriculture sector is vulnerable due to both the primary effects (variation in rainfall and temperature) and secondary effects (drought, flood, cyclone and storm surge, saline intrusion etc) of climate change. In addition, climate change related phenomena such as variation in temperature and rainfall may enhance spread of pest attacks or crop diseases that affect crop production. In the changing climatic context it is necessary to either modify or develop new agricultural (mainly crops) technologies and introduce them at the farmers level. The available technologies in crop agriculture are likely to address current climate variability. To address the long-term impacts and variability, technologies in crop agriculture have to be consistence with the predicted changes in climate system. Meantime, a number of policy and institutional initiatives have been taken on sustainable agriculture technologies and management in order to change from traditional to context specific or climate resilient practices. For instance, the International Rice Research Institute (IRRI), International Center for Agriculture in the Dry Land Areas (ICARDA), International Crop Research Institute for the Semi-Arid Tropics (ICRISAT), International Food Policy Research Institute (IFPRI), International Institute of Tropical Agriculture (IITA) etc. are putting efforts into facilitating increases in productivity and resilience in crop agriculture through technological innovation. Aside with the international effort, it is equally important to strengthen national effort on research and development of climate resilience crop varieties and farming system. This special research and development (R & D) center will develop adaptation technologies that are environmentally sustainable, culturally compatible, socially acceptable, economically feasible and technically viable.
Implementation assumptions, how this	Important considerations for the establishment of

technology will be implemented and diffused across the subsector	special agricultural research and development center: • Research on the development of context specific or climate resilient crop production technologies • Identification of technological needs for sustainable agricultural production in different stress conditions caused by climate change. • Establish a smooth institutional and coordination mechanisms of all the existing agricultural research institutions in country and abroad to consolidate all agricultural success stories on adaptation technologies in government, non-government and private initiatives. • Conduct agricultural and food security related policy research.
Impact Statements-How this option impacts the country development priority	
Country social development priorities	• Will expand agriculture based employment opportunity • Will reduce joblessness of small farm holders and agricultural labors. • Will contribute to country's goal of expanding farm based income and rural poverty eradication.
Country economic development priorities	• Research and development in agriculture will increase rice production and will contribute to country's goal of attaining food security • Will support addressing long-term impacts and variability, technologies in crop agriculture consistence with the predicted changes in climate system
Country environmental development priorities	• Development of appropriate adaptation technologies will optimize utilization of natural resource base • Will support conservation of local level biological resources.
Costs	
Capital costs	• Approx cost = Tk 3000.00 Lakh for Center establishment • Approx cost = Tk 2000.00 Lakh for tools and appliances Total: Taka 5000 lakh; (USD 6250000)
Operational and Maintenance costs	• Approx cost of field experimentation and demonstration = Tk 1000.00 lakh/ year • Development of dissemination packages and tools Tk 250 lakh • Approx cost of HR = Tk 250.00 lakh/ year Total: Taka 1500 lakh; (USD 187500)

Technology Fact Sheet: Establishment of climate-smart Agricultural Technology Dissemination Center

Sector	Agriculture/ Technology development and knowledge management
Technology Name	Establishment of climate-smart Agricultural Technology Dissemination Center
Adaptation Benefits	
Background/ Notes, Short description of the technology option	The dissemination of new technology is an important factor determining the future of climate smart agriculture. Along with the development of innovative agriculture technology is is important to strengthen technology dissemination services so that the farmer is able to make use of the latest agricultural developments so that these serve a useful purpose to the end user. There is also a greater need for coordination between researchers and technology users. Thus, the institution that bridges the gap between farmers and agricultural research scientists is the Agricultural Technology Dissemination Center. This center will establish a formal management mechanism linking scientists or department in charges of different disciplines (though engaged in interdependent tasks) on the one hand to the technology users on the other. The linkage mechanism should be with formal, permanent, mandated, facilitated and designated function. The establishment of an Agricultural Technology Dissemination Centre will provide such a mechanism beyond the individual unit of a research institution to contribute to the dissemination of the information and technical know-how of the climate smart agriculture technologies. The main objective of Agriculture Technology Dissemination Center is to transmit latest technical know-how to farmers. Besides this, the Center also will focus on enhancing farmers' knowledge about crop techniques and helping them to increase productivity.
Implementation assumptions, how this technology will be implemented and diffused across the subsector	The climate smart Agricultural Technology Dissemination Center will provide a ‘single window’ delivery system of the inputs and production technology available from an institution to the farmers and other interested groups. This Center also will facilitate farmer’s access to the institutional resources available in terms of technology, advice, technology products, etc. and will provide mechanism for feedback from the users to the institute.

Impact Statements-How this option impacts the country development priority	
Country social development priorities	• This technology will facilitate farmer's access to the institutional resources available in terms of technology, advice, technology products,
Country economic development priorities	• Development of farmer's technical know-how on the newly innovated technologies will increase production base, which ultimately increase on-farm employment opportunity and will reduce rural poverty. • Will support addressing long-term impacts and variability, technologies in crop agriculture consistence with the predicted changes in climate system
Country environmental development priorities	• Dissemination of appropriate technologies will increase agricultural production base • Will support conservation of local level biological resources.
Costs	
Capital costs	• Approx cost = Tk 5000.00 Lakh for Center establishment • Approx cost = Tk 2500.00 Lakh for tools and appliances Total: Taka 7500 lakh; (USD 9375000)
Operational and Maintenance costs	• Approx cost of field experimentation and demonstration = Tk 500.00 lakh • Development of dissemination packages and tools Tk 250 lakh • Approx cost of HR and monitoring = Tk 250.00 lakh/year Total: Taka 1000 lakh; (USD 1250000)

Technology Fact Sheet: Training on improved farming practices

Sector	Agriculture/ Technology development and knowledge management
Technology Name	Training on improved farming practices
Adaptation Benefits	
Background/ Notes, Short description of the technology option	Both the extension and dissemination of technology generally were intended to reveal new insights to farmers, to solve practical implementation problems, to provide training and to make means of production available. But 'extension' and 'dissemination' are now often criticized for the linear, unidirectional flow of information between research services and farmers that it implies Imperfections in the technology dissemination system are generally the result of (a combination) the following problems:

	▪ Information dissemination problem: farmers do not know about the technologies. ▪ Training problem: farmers heard about or even saw the innovation but do not know how to implement it. ▪ Technology-fit or enabling environment problem: farmers cannot face the financial and/or labour requirements of the proposed options. Thus, it is important to make shift from the traditional and top-down dissemination approaches to learning approaches, which will (i) increase partnerships among appropriate stakeholder groups along with modifications or changes in rules/norms that enable working in partnership, (ii) make change in the perspective whereby the ultimate user is not the only beneficiary, but all the actors/organizations are beneficiaries – as learners - with their expectations/gains stated explicitly, and (iii) will increase and enable more and appropriate platforms for learning (say, facilitated capacity development exercises/experiments) in different contexts with location-specific partnerships to enable hands on learning, innovation and development.
Implementation assumptions, how this technology will be implemented and diffused across the subsector	Extension and training activities are mainly carried out by government services and NGOs. NGOs provide their services more intensively, but are generally localized. The government extension has a more extensive coverage, but its impact is less felt. Thus, extension and training could apply community led and people centered approached like the training-of-trainers approach, farmer to farmer training, farmers' field school etc.
Impact Statements-How this option impacts the country development priority	
Country social development priorities	• Will ensure active participation of the farmers in introducing climate smart rice crop varieties through workshops, training, demonstration and pilot testing which gives the small farm holders the option to choose the best varieties with low adaptation cost required. • Dynamic skill development through training will empower the small farm holders with the knowledge of improved farming technology • Will reduce joblessness of small farm holders and agricultural labors. • Will contribute to country's goal of expanding farm

	based income and rural poverty eradication.
Country economic development priorities	• Farmer's capacity building on the production technology know how will increase rice production and will contribute to country's goal of attaining food security • Will support addressing long-term impacts and variability, technologies in crop agriculture consistence with the predicted changes in climate system
Country environmental development priorities	• Promotion of appropriate adaptation technologies will optimize utilization of natural resource base • Will reduce the risk of mal-adaptation • Will support conservation of local level biological resources.
Costs	
Capital costs	• Approx cost = Tk 1000.00 lakh for training material development Total: Taka 1000 lakh; (USD 1250000)
Operational and Maintenance costs	• Approx cost of community based group formation and training implementation = Tk 2000.00 lakh per year • Input support Tk 1000 lakh • Approx cost of monitoring = Tk 250.00 lakh per year Total: Taka 3250 lakh; (USD 4062500)

Technology Fact Sheet: Land-use planning

Sector	Agriculture/ Technology development and knowledge management
Technology Name	Land-use planning
Adaptation Benefits	Land-use planning will serve as an important regulation of land use in an efficient and ethical way, thus preventing land-use conflicts.
Background/ Notes, Short description of the technology option	Land-use planning refers to the process by which land is allocated between competing and sometimes conflicting uses in order to secure the rational and orderly development of land in an environmentally sound manner to ensure the creation of sustainable human settlements. In Bangladesh, due to not having land use planning, agricultural lands are often been encroached for residential development, pockets of farmland remain between residential communities. On the other hand, in the coastal areas the agricultural lands, even the coastal swaps and mangrove areas are often converted to shrimp farms. Rapid extension of such shrimp farms are destroying environmental sustainability through increasing soil and surface water salinity and destroying aquatic and terrestrial bio-

	diversity. Again, conversion of agricultural land to residential use removes fertile land from productive agriculture; splits large tracts of agricultural land, thereby reducing its potential for viable farming; and restricts the use of certain production methods etc. In the absence of a land-use policy that reserves specific areas for agriculture, shrimp farms, housing and other commercial activities, it is likely that development control decisions will continue to alienate productive agricultural lands; compromise the economic and financial viability of the agriculture sector; and inadvertently increase the possibility of unsustainable development practices in the long run.
Implementation assumptions, how this technology will be implemented and diffused across the subsector	The process of land use planning consists in the main of the two twin functions of Development/Land use Planning and Development Control. Of necessity, these two functions must be supported by relevant research and mapping which are also major components of the land-use planning process. Land-use planning should be considered as an integral part of the process of national growth and development. Among other things, this process seeks to identify, articulate and satisfy the basic social/human needs of a country's population within the context of available economic/financial resources and technical knowledge.
Impact Statements-How this option impacts the country development priority	
Country social development priorities	• This will ensure utilization of land resources in an efficient and ethical way and will reduce social and political conflict of establishing control over land resources for commercial purpose.
Country economic development priorities	
Country environmental development priorities	• Will support conservation of local level biological resources. • Will stop expansion of shrimp farms in the crop lands which in turn will stop intrusion of saline water in the crop land areas • Will reduce level of pollution in the environmentally fragile areas • Will protect both the aquatic and terrestrial bio-diversity in different agro-ecological zones.
Costs	
Capital costs	• Approx cost = Tk 2000.00 Lakh for the development of land use planning

	• Policy analysis of other development activities Tk 200.00 lakh Total: Taka 2200 lakh ; (USD 2750000)
Operational and Maintenance costs	• Approx cost of policy advocacy and awareness raising Tk 250.00 lakh Total: Taka 250 lakh; (USD 312500)

ANNEX 2: The brief profile of TNA team members

Name	Key Qualification	Project Relevant Experience
Dr. S.M. Munjurul Hannan Khan (National Coordinator)	PH.D. in Natural Resource and Environment Management: Long (more than 15 years) experience in strategy and policy development and implementation related to climate change, biodiversity conservation, natural resource and environment management	Extensive experience in international climate change negotiation process of the UNFCCC process, specifically on adaptation and finance. Actively engaged with national development planning process to achieve sustainable and green development vision. Participated in all negotiation meetings of the UNFCCC and provided technical support to the process as negotiator of the LDCs.
Dr Rezaul Karim (Team Leader)	Ph.D. in engineering; Long (15 years or more) experience in international development support process particularly in relation to environment and sustainable development	Familiar with the international climate change negotiation process especially on technology issues Participated in the inception workshop of the UNEP/GEF Technology Needs Assessment Project in Paris, France in February 2010 Participated in the regional capacity building workshop of the UNEP/GEF Technology Needs Assessment Project in Bangkok, in September 2010 As part of government delegation participated in the climate change negotiation in CoP 13, CoP 14, CoP 15 and CoP 16
Dr M Asaduzzaman	Ph.D. in Economics; Long (at least 15 years) experience of analysis of development problems of growth, and planning in various core national development sectors	Experience with qualitative assessments (e.g., stakeholder consultations, Multi Criteria Decision Analysis) as well as quantitative assessments of technology costs and performance characteristics; Familiarity with the international climate change negotiation process especially on long term vision and adaptation Contributed in the development of Bangladesh Climate Change Strategy and Action Plan (BCCSAP)
Dr Ainun Nishat	Ph.D in Civil Engineering Long years experience in coastal infrastructure	Familiar with current technologies in operation in the country's sectors and the regulatory and policy context for technology transfer; Experience on the technology issues on the climate change adaptation and mitigation

	development planning.	
Dr AKM Saiful Islam	Ph.D in Civil Engineering Extensive experiences in water resources modeling and climate change modeling	Water resources and flood management. Extensive experience in modeling the impacts of climate change
Md Shamsuddoha	M.Sc in Marine Science Hands on experience on climate change adaptation and disaster risk reduction (DRR) measures in the coastal areas.	Experience with participatory processes Familiar with the international climate change negotiation process especially on finance and adaptation As part of government delegation participated in the climate change negotiation in CoP 15 and CoP 16.

Annex 3: List of Stakeholders of different sectors consulted in the process of TNA

List of Stakeholders of Climate change adaptation in agriculture sector

NAME	ORGANIZATION
Mr Khandoker Atiar Rahman	Joint Secretary (Proc), Food Division, Ministry of Food & Disaster Management Government of the People's Republic of Bangladesh Bangladesh Secretariat, Dhaka, Bangladesh
Dr. Ainun Nishat	Vice Chancellor, BRAC University 66 Mohakhali Dhaka 1212 Bangladesh | Ph: +88 (02) 8824051-4(PABX), +88 (02)9853948-9
Mr Naser Farid	Director General Food Planning and Monitoring Unit (FPMU), Ministry of Food and Disaster Management Government of the People's Republic of Bangladesh Bangladesh Secretariat, Dhaka
Dr. Md. Solaiman Ali Fakir	Professor Department of Crop Botany Bangladesh Agricultural University Mymensingh 2202, Bangladesh
Mr Mohammad Abdus Sobhan	Deputy Secretary (Supply), Food Planning and Monitoring Unit (FPMU), Ministry of Food and Disaster Management Government of the People's Republic of Bangladesh Bangladesh Secretariat, Dhaka, Bangladesh
Mr Md. Ruhul Amin Talukder	Food Planning and Monitoring Unit (FPMU), Ministry of Food and Disaster Management

	Government of the People's Republic of Bangladesh Bangladesh Secretariat, Dhaka, Bangladesh
Dr. Md. Golam Ambia	Deputy Director (Monitoring) Department of Agricultural Extension Ministry of Agriculture Khamarbari, Farmgate, Dhaka-1215
Dr. Md. Abdur Rahman Sarkar	Professor Dept. of Agronomy, Bangladesh Agricultural University Mymensingh 2202, Bangladesh
Dr. Abu Saleh Mostafa Kamal	Deputy Secretary (Env-2) Ministry of Environment and Forests Government of the People's Republic of Bangladesh Bangladesh Secretariat, Dhaka, Bangladesh
Dr. Md. Mafizur Rahman	Ministry of Environment and Forests Government of the People's Republic of Bangladesh Bangladesh Secretariat, Dhaka, Bangladesh
Dr. Mazharul Aziz	Dept. Agriculture Extension Ministry of Agriculture Khamarbari, Farmgate, Dhaka-1215.
Md. Rashadul Islam	Director (Deputy Secretary) Climate Change Unit, Ministry of Environment and Forests Government of the People's Republic of Bangladesh Bangladesh Secretariat, Dhaka, Bangladesh
Mr Mostafa Faruk Al Banna	Food Planning and Monitoring Unit (FPMU), Ministry of Food and Disaster Management Government of the People's Republic of Bangladesh Bangladesh Secretariat, Dhaka, Bangladesh
Dr. Ferdousi Begum	Executive Director, Development of Biotechnology & Environmental Conservation Centre (DEBTEC) Apt-11 A, Confidence Tower, 5-Kha, Satmasjid Road, Mohammadpur, Dhaka-1207, Bangladesh
Dr. Shamim Ara Begum	Senior Specialist-Outreach Training, IRRI Bangladesh office House# 9, Road# 2/2, Chairman Bari , Banani, Dhaka-1212, Bangladesh
Ms Shamima Aktar	Amader Gram ICT for Development House # 47, Road # 35/A Gulshan-2 Dhaka 1212, Bangladesh
Ms Ferduhi Sultana Munni	Nahar Health Service & Social Welfare Association 189, West Kafrul, Agargoan Taltola, Dhaka, Bangladesh

Ms Basanti Saha Basanti	OXFAM-GB House-4, Road-3, Block-I. Banani, Dhaka, Bangladesh
Mr Md. Mehedi Masood	Dept. of Agronomy, Bangladesh Agricultural University, Mymensingh 2202, Bangladesh
Mr Mizanur Rahman Bijoy	Coordinator, Climate Change and DRR unit, 29, Ring Road, Shyamoli, Dhaka-1207, Bangladesh
Mr Muhammed Atikul Haque	Research Associate Center for Participatory Research and Development Gulshan-1, Dhaka 1212, Bangladesh
Mr Md. Safiullah Safi	Society for Environment and Human Development 1/1 Pallabi (5th floor) Mirpur Dhaka - 1216. Bangladesh.
Mr Md. Iqbal Uddin	RDRS Bangladesh House 43, Road 10, Sector 6, Uttara,Dhaka-1230 Tel: 880-2-895 4384 - 85

List of stakeholders of Energy Sector

NAME	ORGANIZATION
Mr Md. Mahbub Sarwar	General Manager (Prod. & Marketing) Petrobangla, Petrocentre, 3 Karwan Bazar, Dhaka1215, Bangladesh FAX - 880 2 9120224
Eng. Anwar H. Khan	Director General Hydrocarbon Unit Energy and Mineral Resources Division Ministry of Power, Energy and Mineral Resources BTMC Bhaban (1st floor) 7-9, Kawran Bazar, Dhaka-1215,Bangladesh. Phone : +88 02 9117794, +88 02 8128223, +88 02 8121587, Fax :+88 02 8128224
Mr Md Mehedi Hasan	Hydrocarbon Unit Energy and Mineral Resources Division Ministry of Power, Energy and Mineral Resources BTMC Bhaban (1st floor) 7-9, Kawran Bazar, Dhaka-1215 , Bangladesh. Phone : +88 02 9117794,
Mr Md. Akkas Ali	Petrobangla, Petrocentre, 3 Karwan Bazar, Dhaka1215,

	Bangladesh, FAX - 880 2 9120224
Mr M. Hasan Shahariar	Hydrocarbon Unit Energy and Mineral Resources Division Ministry of Power, Energy and Mineral Resources BTMC Bhaban (1st floor) 7-9, Kawran Bazar, Dhaka-1215, Bangladesh. Phone : +88 02 8128223,
Dr Mizan R Khan	Professor; North South University, Plot 15, Block B, Level 3. Bashundhara, Dhaka 1229. Phone: (88 02) 9885611-20
Mr Abu Syed Md. Faisal	Hydrocarbon Unit Energy and Mineral Resources Division Ministry of Power, Energy and Mineral Resources BTMC Bhaban (1st floor) 7-9, Kawran Bazar, Dhaka-1215 Bangladesh. Phone : +88 02 8121587
Dr M. Asaduzzaman	Research Director; Bangladesh Institute of Development Studies E-17 Agargaon, Sher-e- Bangla Nagar, GPO Box # 3854, Dhaka-1207, Bangladesh Cell: +88 01711 59 50 66 E-mail: asaduzzaman.m@gmail.com Telephone: 880-02-8110759, 9143441-8
Mr Mohammad Iftikhar Alam	Climate Change Unit; Ministry of Environment and Forests Puraton Ban Bhabon, 101, Mohakhali, Dhaka-1212, Bangladesh
Mr Kawser Rahman	Senior Reporter; Daily Janakantha Janakantha Bhaban, 24/A , New Eskatan Road, G.P.O. Box: 3380, Dhaka, Bangladesh
Mr Md. Lovelu Hassan	Climate Change Unit; Ministry of Environment and Forests Puraton Ban Bhabon, 101, Mohakhali, Dhaka-1212
Mr Md. Ziaul Haque	Department of Environment E-16, Agargaon, Sher-e-Bangla Nagar, Dhaka-1207
Mr Md. Akhtaruzzaman	Climate Change Unit; Ministry of Environment and Forests Puraton Ban Bhabon, 101, Mohakhali, Dhaka-1212
Mr ASM Manzurul Quader	Hydrocarbon Unit Energy and Mineral Resources Division Ministry of Power, Energy and Mineral Resources BTMC Bhaban (1st floor) 7-9, Kawran Bazar, Dhaka-1215

	Bangladesh. Phone : +88 02 9117794, +88 02 8128223, +88 02 8121587 Fax :+88 02 8128224
Mr M. Nazrul Haq	Hydrocarbon Unit Energy and Mineral Resources Division Ministry of Power, Energy and Mineral Resources BTMC Bhaban (1st floor) 7-9, Kawran Bazar, Dhaka-1215 Bangladesh. Phone : +88 02 9117794, +88 02 8128223, +88 02 8121587 Fax :+88 02 8128224
Mr Syed Zahirul Alam	Department of Environment E-16, Agargaon, Sher-e-Bangla Nagar, Dhaka-1207
Mr Muhammed Forruq Rahman	Research Associate; Center for Participatory Research and Development-CPRD; House-138, Flat-A6, Road-3, Block-A Gulshan-1, Dhaka-1212 Email: forruqimsf@yahoo.com
Mr ASM Amirullah	Hydrocarbon Unit Energy and Mineral Resources Division Ministry of Power, Energy and Mineral Resources BTMC Bhaban (1st floor) 7-9, Kawran Bazar, Dhaka-1215 Bangladesh.
Mr Md. Shafiqur Rahman	Petrobangla, Petrocentre, 3 Karwan Bazar, Dhaka1215, Bangladesh

List of stakeholders: Water Sector

NAME	ORGANIZATION
Mr. Aparup Chowdhury	Joint Secretary (Env.) Ministry of Environment and Forests Government of the People's Republic of Bangladesh Building # 6, Level # 13 Bangladesh Secretariat, Dhaka
Mr Mir Sajjad Hossain	Members Joint River Commission 72, Green Road, Dhaka 1215, Bangladesh Phone: +88-02-9121165 (Member) Fax: +88-02-9121596 Email: jrcombd@gmail.com

Annex IV

BANGLADESH

Dr. Monowar Hossain	Executive Director Institute of Water Modeling, House-496, Road-32, New DOHS, Mohakhali, Dhaka-1206, Bangladesh
Dr. KB Sajjadur Rashid	Retired Professor, University of Dhaka Dhaka, Bangladesh
Dr. Rezaur Rahman	Institute of Water and Flood Management (IWFM), Bangladesh University of Engineering and Technology (BUET), Dhaka, Bangladesh
Dr Fazle Rabbi Sadek Ahmed	Director- Climate Change Department of Environment Agargaon, E-16, Agargaon, Shere Bangla Nagar Dhaka 1207, Bangladesh Phone: +88-02- 8181778 (Office)
Mr Md Sarafat Hossain Khan	Director,Planning-1, Bangladesh Water Development Board 8th Floor WAPDA Building Dhaka,Bangladesh. Tel : 880 - 2 - 9553118 , 9550755
Mr Abu Nayeem Md. Maruf Khan	Senior Assistant Secretary Ministry of Environment and Forests Government of the People's Republic of Bangladesh Building # 6, Level # 13 Bangladesh Secretariat, Dhaka
Dr. Sheikh Mahabub Alam	Director Research, Dhaka School of Economics Bangladesh Economic Association Bhaban 4/C Eskaton Garden Road (3rd Floor) Dhaka 1000, Bangladesh Phone: 880-2-9359628-9
Mr Manjur Murshed Zahid Ahmed	Institute of Water Modeling, House-496, Road-32, New DOHS, Mohakhali, Dhaka-1206, Bangladesh
Mr Abu Saleh Khan	Institute of Water Modeling, House-496, Road-32, New DOHS, Mohakhali, Dhaka-1206, Bangladesh
Dr Emaduddin Ahmad	Consultant Institute of Water Modeling, House-496, Road-32, New DOHS, Mohakhali, Dhaka-1206, Bangladesh
Ms Amala Das	SDS – Shariatpur Plot#30A, Road#4, Sector#3. Uttara Model Town, Dhaka-1230, Bangladesh Phone#8912840
Mr Malik Fida H Khan	Center for Environmental and Geographic Information Services, CEGIS

	House-6, Road-23/C, Gulshan-1. Dhaka-1212, Bangladesh
Mr Md Abdullah Al Baki	BRAC (Disaster, Environment & Climate Change) 66 Mohakhali Dhaka 1212, Bangladesh
Md. Rafiqul Alam Siddique	Climate Change Unit, (Ministry of Environment and Forests) Mohakhali Ban Bhaban, Ministry of Environment and Forests, Mohakhali, Dhaka, Bangladesh
Ms Shakila Yasmin	Climate Change Unit, (Ministry of Environment and Forests) Mohakhali Ban Bhaban, Ministry of Environment and Forests, Mohakhali, Dhaka, Bangladesh
Mr Abu Mostafa Kamal Uddin	United Nations Development Programme_ UNDP UN Offices, 18th Floor IDB Bhaban, Agargaon, Sher-e-Bangla Nagar, Dhaka 1207, Bangladesh
Ms Shamima Nasreen	Climate Change Unit, (Ministry of Environment and Forests) Mohakhali Ban Bhaban, Ministry of Environment and Forests, Mohakhali, Dhaka, Bangladesh
Mr Md Rezaul Alam	Local Government Engineering Department Level-5, LGED Bhaban, Agargaon, Sher-e-Bangla Nagar, Dhaka-1207, Bangladesh
Mr Md Iqbal Hossain	Executive Engineer Barind Multipurpose Development Authority _BMDA Dhaka, Bangladesh
Mr Prodip Kumar Biswas	PSO, Water Resources Planning Organization (WARPO), (Ministry of Water Resources) House-103, Road-1, Banani Dhaka, Bangladesh
Mr Mohammad Alamgir	PSO, Water Resources Planning Organization (WARPO), (Ministry of Water Resources) House-103, Road-1, Banani Dhaka, Bangladesh
Ms Farhana Akter Kamal	Institute of Water Modeling, House-496, Road-32, New DOHS, Mohakhali, Dhaka-1206, Bangladesh
Mr Abu Saleh Khan	Institute of Water Modeling, House-496, Road-32, New DOHS, Mohakhali, Dhaka-1206, Bangladesh
Mr Saleh uddin Khan	Center for Environmental and Geographic Information Services (CEGIS)

	House-6, Road-23/C, Gulshan-1. Dhaka-1212, Bangladesh
Mr Nabir Mumnun	Research Officer Bangladesh Centre for Advanced Studies-BCAS, House 10, Road 16A, Gulshan-1, Dhaka-1212, Bangladesh
Mr Abid Anwar	WaterAid, House 97/B, Block-A, Banani, Dhaka 1213, Bangladesh
Mr Saif Uddin	Center for Natural Resource Studies-CNRS, House No. 13 (4th & 5th Floor), Road No. 17, Block D, Banani, Dhaka 1213, Bangladesh Tel: +88-02-9886514 Fax: +88-02-9880928,
Mr Niaz Mahmud	BRAC Center 75 Mohakhali, Dhaka, Bangladesh

List of stakeholders: Cross cutting sectors

NAME	ORGANIZATION
Dr S M Munjurul Hannan Khan	Deputy Secretary; Ministry of Environment and Ministry of Environment and Forests Government of the People's Republic of Bangladesh Building # 6, Level # 13 Bangladesh Secretariat, Dhaka Phone: +880 2 7167472 (Office)
Dr Khabir Uddin	Professor; Department of Environmental Sciences, Jahangirnagar University, Savar, Dhaka-1342, Bangladesh
Dr Abdur Rob Mollah	Chairperson ; Nature Conservation Management NACOM, House # 41/1, Road # 1, Block – A, Niketan, Gulshan-1, Dhaka -1212, Bangladesh Phone: + 88-02-8832073 (Office)
Mr Mohammed Solaiman Haider	Deputy Director,Department of Environment, E-16, Agargaon, Shere Bangla Nagar Dhaka 1207, Bangladesh, Phone: +88-02- 9662142(Res))
Mr Mohammed Zakaria	Executive Chairperson; GonoGobeshana o Unnayan Foundation (GoUF), House # 1-E-6, Road # 7/A (New), West Dhanmondi, Dhaka - 1209, Bangladesh. Phone: +8808115962, (office)
Mr Tanjir Hossain	Deputy Manager; ActionAid; Bangladesh Country Office, House # 8, Road # 136, Gulshan – 1, Dhaka- 1212, Phone: +88(02) 8837796, 9894331, 8835632(office)
Mr Md Saud Bin Hossain	ChnageMaker, House 8, Road 13, Suite F-3 Dhanmondi Dhaka, 1209 , Bangladesh

Annex IV

BANGLADESH

Mr Haradhan Banik	Deputy Chief Conservator of Forests, Forest Department, Banabhaban, Agargaon, Dhaka-1207, Bangladesh, Agargaon, Dhaka Phone: +88-02- 8181148 (Office)
Dr Tapan Kumar Dey	Conservator of Forests, Forest Department, Banabhaban, Agargaon, Dhaka-1207, Bangladesh Phone: +88-02- 8181142(office)
Mr Syed Nazmul Ahsan	Deputy Director, Department of Environment, Agargaon, E-16, Agargaon, Shere Bangla Nagar Dhaka 1207, Bangladesh Phone: +88-02- 8181778 (Office)
Mr Dildar Ahmed	Development of Biotechnology & Environmental Conservation Centre (DEBTEC), Apt-11 A, Confidence Tower, 5-Kha, Satmasjid Road, Mohammadpur, Dhaka-1207, Bangladesh Cell Number: +880 1713 017 705
Mr Rashiduzzaman Ahmed	Nature Conservation Management –NACOM, House # 41/1, Road # 1, Block – A, Niketan, Gulshan-1, Dhaka - 1212, Bangladesh Phone: + 88-02-8832073 (Office)
Mr Ajit Kumar Das	Member (Tech) Bangladesh Space Research & Remote Sensing Organization (SPARSO), Agargaon, Dhaka Phone: + 880-2-9113329 (office)
Mr Md. Kamruzzaman	IUCN Bangladesh Country Office House #16, Road #2/3, Banani, Dhaka 1213. Phone: (+8802) 9890423, 9890395 or 9852743 (Office)
Mr Md. Mahmudun Nabi Khan	Concern Worldwide Bangladesh Country Office, House - 15 SW (D), Road – 7, Gulshan -1, Dhaka – 1212, Bangladesh Phone: 880-2-8811469, 880-2-9881325 Fax: 880-2-8817517
Mr Moklessur Rahman	Center for Natural Resource Studies House-19/B, Road-16, Block-B , Banani, Dhaka-1213, Bangladesh Phone: +88-2-9886514 (Office)
Mr Mostafa Rahman	Center for Natural Resource Studies House-19/B, Road-16, Block-B, Banani, Dhaka-1213, Bangladesh Phone: +880-2-9886514(Office)
Mr Gazi Sipon Hossain	Climate Change Cell; Department of Environment, , E-16, Agargaon, Shere Bangla Nagar Dhaka 1207, Bangladesh Tel: 88 02 9103655, 8121821, 9115120

Annex IV

BANGLADESH

Mr Ashraful Amin	Climate Change Unit; Mohakhali Ban Bhaban, Ministry of Environment and Forests, Mohakhali, Dhaka, Bangladesh
Mr Istiakh Sobhan	IUCN Bangladesh Country Office House #16, Road #2/3, Banani, Dhaka 1213 Phone: (+8802) 9890423, 9890395 (Office)
Mr Md. Mesbabul Alam	Department of Environment, E-16, Agargaon, Shere Bangla Nagar Dhaka 1207, Bangladesh, Phone: +88-02- 9662142(home)
Mr Md. Sanoar Hossain	Department of Environment, E-16, Agargaon, Shere Bangla Nagar Dhaka 1207, Bangladesh
Ms Sabnam Sarmin	Research Associate; Center for Participatory Research and Development , House # 138, Road # 3, Niketan, Gulshan 1, Dhaka-1212 Phone: +88029860042(Office)
Mr Hasibul Islam	ActionAid Bangladesh House # 8, Road # 136, Gulshan – 1, Dhaka-1212, Phone: +88(02) 8837796, 9894331(Office)
Mr Ifhtekharul Islam	WaterAid Bangladesh, House No: 97/B, Road No: 25, Banani, Dhaka-1213, Bangladesh Phone: +88-028819521, 880-2-8815757(Office)

Annex 4: Performance Matrix of the technology options

Table: 24 Performance Matrix of the priority technologies of water sector

SL	Technology Options	Costs in Taka and USD (1 USD =Tk 80)		Benefits			
		Capital Costs	O &M Cost	Adaptation Benefits	Social Benefits	Environmental Benefits	Economic Benefits
	Rehabilitation of existing Embankments/ dykes and dredging	Tk 50.00 lakh per kilometer. (USD 62500)	Tk 02.00 lakh per kilometer per year. (USD 2500)	Very High	High	Very High	Very High
	Tidal barriers (Sluice gates)	TK 100.00 lakh per vent (USD 125000)	Tk 25.00 lakh /per vent (USD 31250)	High	Medium	High	High
	Tidal river management including Computer simulation of tidal flow	Tk 1375.00 lakh/ TRM basin (USD 1718750)	Tk 58.00 lakh /per vent (USD 72500)	Very High	Low	Very High	High
	Monitoring of sea level rise, tidal fluctuation, salinity intrusion, sedimentation and coastal erosion	Taka 55.00 lakh/ polder (USD 68750)	Tk 02.00 Lakh/ number/year (USD 2500)	High	Medium	Low	Low
	Comprehensive disaster management incorporating early warning systems and involving community	Taka 651.50 lakh (USD 814375)	Tk 05.00 lakh/ community. (USD 6250)	Very High	Very High	High	High
	Urban Infrastructure Development	Tk 2170.00 lakh/ town (USD 2712500)	Tk 20.00 lakh/ town (USD 25000)	High	High	High	High

Table: 25 Scoring for the initial list of the priority technologies of water sector

Technology Options	**Criteria**					
	Capital Costs	O& M Costs	Adaptation Benefits	Social Benefits	Environmental Benefits	Economic Benefits
Rehabilitation of existing Embankments/ dykes and dredging	100	100	90	0	80	90
Tidal barriers (Sluice gates)	80	70	0	70	80	80
Tidal river management including Computer simulation of tidal flow	0	80	100	70	80	60
Monitoring of sea level rise, tidal fluctuation, salinity intrusion, sedimentation and coastal erosion	90	100	80	70	0	50
Comprehensive disaster management incorporating early warning systems and involving community	90	80	100	90	0	80
Urban Infrastructure Development	0	60	70	70	80	70

Annex IV

BANGLADESH

Table:26 Most preferred and least preferred technology of water sector

Preference	**Criteria**						
	Capital Costs	O & M Costs	Cost Effectiveness	Adaptation Benefits	Social Benefits	Environmental Benefits	Economic Benefits
Most preferred	Rehabilitation of existing Embankments/ dykes and dredging	Rehabilitation of existing Embankments/ dykes and dredging Monitoring of sea level rise, tidal fluctuation, salinity intrusion, sedimentation and coastal erosion		Rehabilitation of existing Embankments / dykes and dredging	Comprehensive disaster management incorporating early warning systems and involving community	Rehabilitation of existing Embankments/ dykes and dredging	Rehabilitation of existing Embankments/ dykes and dredging
Least preferred	Urban Infrastructure Development	Tidal river management including Computer simulation of tidal flow		Tidal barriers (Sluice gates)	Tidal river management including Computer simulation of tidal flow	Monitoring of sea level rise, tidal fluctuation, salinity intrusion, sedimentation and coastal erosion	Monitoring of sea level rise, tidal fluctuation, salinity intrusion, sedimentation and coastal erosion

Annex IV

BANGLADESH

Table: 27 Performance Matrix of the priority technologies of agriculture sector

SL	Technology Options	Costs in Taka and USD (1 USD =Tk 80)		Benefits			
		Capital Costs	O & M Costs	Adaptation Benefits	Social Benefits	Environmental Benefits	Economic Benefits
01	Development of salinity tolerant rice varieties	Tk 2500.00 lakh (USD 3125000)	Tk 1000.00 lakh (USD 1250000)	Very High	High	High	Very High
02	Development of drought tolerant rice varieties	TK 2500.00 lakh (USD 3125000)	Tk 800.00 lakh (USD 1000000)	Very High	High	Medium	Very High
03	Development of short maturing rice varieties	Tk 3000.00 lakh (USD 3750000)	Tk 1000.00 lakh (USD 1250000)	Very High	Medium	Medium	Very High
04	Establishment of special agricultural R & D centre	Taka 5000.00 lakh (USD 6250000)	Tk 1500.00 Lakh (USD 187500)	Very High	Medium	Low	High
05	Establishment of climate smart Agriculture Technology Dissemination Center	Taka 7500.00 lakh (USD 9375000)	Tk 1000.00 lakh (USD 1250000)	Very High	High	Low	High
06	Training on improved farming practices for crops, irrigation and water management, soil fertility management (conservation and restoration of soil quality) etc.	Taka 1000.00 lakh (USD 1250000)	Taka 3250.00 lakh (USD 4062500)	Very High	High	Low	Medium
07	Land use planning	Tk 2200.00 lakh (USD 2750000)	Tk 250.00 lakh (USD 312500)	High	High	High	High

Annex IV

BANGLADESH

Table:28 Scoring for the initial list of the priority technologies of agriculture sector

SL	Technology Options	Criteria					
		Capital Costs	Operation & Mgt Costs	Adaptation Benefits	Social Benefits	Environmental Benefits	Economic Benefits
01	Development of salinity tolerant rice varieties	90	60	100	0	90	100
02	Development of drought tolerant rice varieties	85	70	90	0	80	90
03	Development of short maturing rice varieties	80	0	100	80	75	90
04	Establishment of special agricultural R & D centre	0	70	90	60	0	90
05	Establishment of climate smart Agriculture Technology Dissemination Center	80	60	90	90	70	0
06	Training on improved farming practices for crops, irrigation and water management, soil fertility management (conservation and restoration of soil quality) etc.	100	50	80	70	0	90
07	Land use planning	80	80	0	80	70	0

Table :29 Most preferred and least preferred technology of agriculture sector

Preference	Criteria					
	Capital Costs	O & M Costs	Adaptation Benefits	Social Benefits	Environmental Benefits	Economic Benefits
Most preferred	Training on improved farming practices	Development of salinity tolerant rice varieties Development of drought tolerant rice varieties	Development of salinity tolerant rice varieties Development of short maturing rice varieties	Development of salinity tolerant rice varieties	Development of salinity tolerant rice varieties	Development of salinity tolerant rice varieties
Least preferred	Land use planning	Training on improved farming practices	Land use planning	Establishment of special agricultural R & D centre	Training on improved farming practices	Land use planning

Annex IV

BANGLADESH