Kingdom of Bhutan

TECHNOLOGY NEEDS ASSESSMENT AND TECHNOLOGY ACTION PLANS FOR CLIMATE CHANGE ADAPTATION

"March 2013"

National Environment Commission
Royal Government of Bhutan

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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 Risoe Centre (URC) in collaboration with the Regional Centre (from the corresponding region), 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 National Environment Commission, Royal Government of Bhutan.

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Supported by:

FOREWORD

PRIME MINISTER

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Royal Government of Bhutan

28 March, 2013.

Foreword

Bhutan, with its commitment to preserve the natural environment, has been actively participating in the fight against one of the most pressing challenges of the current times, the climate change. The country has undertaken the Technology Needs Assessment process to identify, evaluate, and prioritize technologies that fit in the overall development context of the nation while allowing the country to adapt to and mitigate climate change. At the Conference of Parties (COP) 14 in 2008, the Poznań Strategic Programme on Technology Transfer was adopted as a step towards *scaling up the level of investment in technology transfer in order to help developing countries address their needs for environmentally sound technologies.* As part of this programme, in 2010, on behalf of Global Environment Facility (GEF), the United Nations Environment Programme (UNEP) started the implementation of Technology Needs Assessment (TNA) for 36 countries.

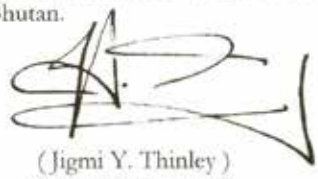
Taking forward its commitment at the international forums, I am pleased that the National Environment Commission (NEC) Secretariat has completed the Technology Needs Assessment for Climate Change (TNA) and that it led to the formulation of a Technology Action Plan (TAP) for implementation of the prioritized technologies for adaptation and mitigation. These initiatives fit in the larger scheme of things that we are pursuing for low-carbon and climate-resilient development and will contribute to the development of the 11th Five Year Plan of the country, to be finalized soon.

As a party to the UNFCCC, Bhutan is fully committed to developing and implementing policies, programmes and projects to address the many challenges posed by climate change. We have also adopted a new Economic Development Policy in 2010, which embraces the concept and principles of green economic development. We are now formulating a national strategy for low-carbon and climate-resilient development.

Application of collective knowledge and skills is crucial in developing solutions for combating the challenges of climate change. In this regard, I am encouraged to note that various stakeholders not only from government agencies, but also from the civil society and private sector have been involved in the TNA process and have contributed extensively in selecting the prioritized technologies, identifying the key barriers to technology development and deployment, preparing the Technology Action Plans for overcoming the identified barriers and identifying the implementable project ideas for each technology. I would like to commend all the individuals and organizations that have contributed to the TNA process particularly, the TNA Taskforce members, the respective government departments and agencies and the National Environment Commission for effectively leading this exercise.

I look forward to seeing the findings and recommendations of the TNA project feed into the national strategy for combating climate change in Bhutan.

Tashi Delek !



(Jigmi Y. Thinley)
Prime Minister, and
Chairman of NEC

PREFACE

Given Bhutan's vulnerability to the impacts of climate change, the nation has accorded climate change a high priority. The nation's commitment to remain carbon neutral while ensuring overall social-economic development reflects its vision to address the challenges of climate change and move towards a sustainable future.

The challenges of addressing climate change, particularly by developing and least developed countries have been recognized at various international forums. Technology transfer as a vital instrument to overcome these challenges has been identified by the UNFCCC in Article 4.5. Subsequently, the need and importance of technology transfer has been reiterated at various Conference of Parties (COP) of the UNFCCC. At COP 14 in 2008, the Poznań Strategic Program on Technology Transfer was adopted as a step towards *scaling up the level of investment in technology transfer in order to help developing countries address their needs for environmentally sound technologies.* As part of this programme, in 2010, on behalf of Global Environment Facility (GEF), the United National Environment Programme (UNEP) started the implementation of Technology Needs Assessment (TNA) for 36 countries.

Bhutan has undertaken the TNA process to identify, evaluate, and prioritize technologies that fit in the overall development context of the nation while allowing the country to combat climate change. The National Environment Commission Secretariat is the nodal agency for the TNA project and has constituted a TNA Task Force involving representatives from various sectors to provide inputs to the TNA project and most importantly in preparing the Technology Action Plan for identified technologies.

In the Part I of the TNA report, for each prioritized sub-sector in climate change adaptation and mitigation one technology was prioritized based on a technology prioritization framework prepared through secondary research and rigorous stakeholder consultation. Part III of the TNA report, is the Technology Action Plan reports covering each adaptation and mitigation technology, in a way to reflect the prioritized measures required to enhance technology diffusion and overcome barriers identified in Part II of the TNA report. The current report brings together the key highlights of the barrier analysis and enabling framework report (Part II), in a way to present the Action Plan for technology diffusion. The Technology Action Plan is reflective of the national priorities of the Royal Government of Bhutan.

Ugyen Tshewang, PhD
Secretary
National Environment Commission

ACKNOWLEDGMENT

The National Environment Commission Secretariat (NECS) sincerely acknowledges the Global Environment Facility (GEF) for the financial support provided for the Technology Needs Assessment (TNA) project in Bhutan. We would also like to thank UNEP Risø Centre (URC) and Asian Institute of Technology (AIT) for their technical guidance during the course of the TNA. The NECS is particularly grateful to Mr. Gordon Mackenzie, TNA country coordinator for Bhutan, for coordinating all the activities between the NECS, AIT and URC.

We would like to thank all the TNA taskforce members for their valuable contribution in prioritization of sectors and technologies, and for their comments on the draft report.

Further, we express our sincere appreciation to Emergent Ventures India and Norbu Samyul Consulting for facilitating the TNA process and putting together the TNA report.

ABBREVIATIONS

BAFRA	Bhutan Agriculture and Food Regulatory Authority
DOA	Department of Agriculture
EVI	Emergent Ventures India
FYP	Five-year plan
GHG	Green house gas
IPCC	Intergovernmental Panel on Climate Change
ITPGRFA	International Treaty on Plant Genetic Resources for Food and Agriculture
JICA	Japan International Cooperation Agency
MOAF	Ministry of Agriculture and Forests
MCDA	Multi-criteria Decision Analysis
NABARD	National Bank for Agriculture and Rural Development
NAPA	National Adaptation Programme of Actions
NBC	National Biodiversity Centre
NEC	National Environment Commission
NECS	National Environment Commission Secretariat
NSC	National Seeds Centre
PGR	Plant Genetic Resources
RDC	Research and Development Centre
RNR	Renewable Natural Resources
SALT	Sloping Agriculture Land Technology
TAP	Technology Action Plan
TNA	Technology Needs Assessment
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
USAID	U.S. Agency for International Development

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Part III
Technology Action Plan Report

Executive Summary

In the Part I of the TNA report, for each prioritized sub-sector in climate change adaptation one technology was prioritized based on a technology prioritization framework prepared through secondary research and stakeholder consultation. As a precursor to developing detailed technology action plans of the identified technologies, it was imperative that key barriers be identified which the action plan should address. Thereby, the Part II of the TNA report highlights the key barriers in adoption of the adaptation technologies and outlines an enabling framework for addressing these barriers.

Building on the Part I and Part II of the TNA reports,this report presents the Technology Action Plan for each adaptation technology identifying the prioritized measures required to enhance technology diffusion. The current report brings together the key highlights of the barrier analysis and enabling framework report, in a way to present action plan for technology diffusion. The Technology Action Plan contained in the current report is reflective of the national priorities as those highlighted in the Government of Bhutan documents as well as those felt most urgent by TNA Taskforce members and Bhutanese experts.

A brief of the Technology Action Plan for each sub sector in adaptation is summarized below:

Agriculture

Development and promotion of drought and pest resistant varieties of crops has been selected as the appropriate technology measure in agriculture sector for adaptation to increasingly variable climate linked with global climate change phenomenon. The chapter outlines a brief description of the sector followed by a brief summary of the barriers to technology diffusion. In order to overcome the barriers to technology development and diffusion, strengthening the current institutions with human resources and required facilities for accelerating R&D for developing new varieties and preserving traditional varieties has been highlighted to be most important and immediate step. This followed by capacity building of RDCs to undertake extension services for diffusion of seeds is the need of the hour, to overcome the shortfalls in the extension services. Strengthening the current community based model of farming, financial support for upgrading R&D equipment, development of human resources and technical knowledge, strengthening the current seeds rules and regulations, undertaking pilots and conducting awareness campaigns are some of the other actions points deemed essential to spread the use of drought and pest resistant varieties of crops.

Water

The primary focus of water resource sector in the face of accelerated climate change phenomenon is the development and adoption of technologies that result in efficient water use. For this purpose sprinkler and drip irrigation has been identified as potential technologies. In order to overcome the barrier of lack of technical expertise and human resource capacity in assisting the diffusion of this technology, strengthening the current institutions in terms of human resources and technical expertise is the immediate action required. This is to be done by introducing training and capacity building programmes for district engineers, regional RDCs engineers, farmers and extension agents. Demonstrating the technology through pilots is also required to increase the confidence of farmers in the technology. Introduction of financial incentives to overcome the high costs associated with these systems such as a fiscal subsidy is required to support adoption of these technologies by farmers, coupled with increasing the access to finance for the agriculturalists.

Natural disaster and infrastructure

In the Natural Disaster and Infrastructure Sector, climate-resilient farm road has been identified as the prioritized technology. Rationalizing the budget for farm road development in accordance with technical standards, strengthening inter-agency coordination, institutional strengthening of engineering divisions, climate resilience mainstreaming in road development policies and guidelines, conducting sensitization, advocacy and awareness building activities to support climate resilient farm road development, pilot projects, strengthening technical know-how and skills etc. are among the other action points for development and construction of climate resilient farm roads in the country.

Chapter 1 Technology Action Plan for Agriculture Sector

1.1 Actions at Sectoral level

1.1.1 Sector Description-Agriculture

Agriculture is the mainstay of the Bhutanese economy, with the sector contributing 16.8 percent to Bhutan's GDP in 2010 (National Statistics Bureau, 2011). More than 60 percent of the Bhutanese population still depends on the agriculture sector which is mostly subsistence in nature (Labour Force Survey, 2011).

However, due to the mountainous terrain, only about 2.93 percent of the land is under cultivation (National Environment Commission, 2011). Bhutan's agricultural diversity in the agro-ecological zones is quite varied and covers a range of climatic zones. The main crops in Bhutan are rice, maize, potato, wheat, buckwheat, barley and millet.

The agriculture sector in Bhutan is particularly sensitive to the impacts of changing climate, which can induce themselves in two ways:

- Direct effects from changes in temperature, precipitation or carbon dioxide concentrations resulting in changes in crop productivity, soil fertility and frequency of infestation by pests, insects, diseases or weeds
- Indirect effects through climate change induced natural disasters such as floods, landslides, hailstorms etc. These have been addressed in the section on Natural Disasters and Infrastructure.

Bhutan's National Adaptation Programme of Action (NAPA) (2006) lists the following vulnerabilities faced by agriculture sector to climate change:

- Crop yield instability- Loss of production and quality (due to variable rainfall, temperature)
- Decreased water availability for crop production
- Increased risk of extinction of already threatened crop species (traditional crop varieties)
- Loss of soil fertility due to erosion of top soil and runoff
- Loss of fields due to flash floods, landslides and rill & gully formation
- Crop yield loss (flowers and fruit drop) to hailstorms. Deteriorated produce quality (fruits and vegetables) due to untimely incessant heavy rains and hailstorms
- Delayed sowing (late rainfall)
- Damage to crops by sudden early (paddy) and late spring (potato) frost
- Outbreak of pests and diseases in fields and during storage where they were previously unknown
- Damage to road infrastructure and hence food security

A country road map paper prepared by the Ministry of Agriculture and Forests ahead of the Bhutan Climate Summit 2011 identifies climate change as one of the major threats of food security in the country and thereby includes a National Food security Program with an overall goal of ensuring availability of safe and quality food at affordable prices. Under this program, a Food Availability Program has been prepared with the goal of increasing crop production through development of improved varieties, breeds, and management technologies. One of the key strategies to achieve this goal is through evaluation and adoption of genetic resources resistant to biotic and a-biotic stresses including drought, pests and diseases. Some work on climate resilient technologies (drought tolerant varieties, disease resistant varieties) particularly on rice and maize have already been carried out.

The sector is also governed by several policies and acts which are the guiding documents. A brief of key policies and acts is provided in the Table 1 below.

Table 1: List of Agriculture Policies, Acts and Regulations in Bhutan

S. No.	Name	Date Effective	Agency	Contents
1.	The Seeds Act of Bhutan	July 2000	Department of Agriculture, Ministry of Agriculture and Forests.	An Act to regulate import and export of agricultural seeds, to prevent introduction of plant pests and diseases and to promote seed industry in the country aimed at enhancing rural income and livelihood.
2.	Seeds Rules and Regulations of Bhutan	2006	Ministry of Agriculture and Forests	Implement the provisions contained in the Seeds Act of Bhutan
3.	Renewable Natural Resources (RNR) Research Policy of Bhutan	2012	Ministry of Agriculture and Forests	The policy focuses on new ways to coordinate, prioritize, plan and programme, organize, finance, manage and implement RNR research to prepare the system and its clients for the challenges of the 21st century.
4.	Plant Quarantine Act of Bhutan	1993	Ministry of Agriculture and Forests	The purpose of this Act is to:- · prevent the introduction of pests not already present or widespread in the country; · control those pests already in the country · provide facilities for services for import and export of plants and plant products;
5.	Plant Quarantine Rules of Bhutan	2003	Ministry of Agriculture and Forests	In order to implement the provisions contained in the Plant Quarantine Act of Bhutan

The agriculture sector of the country is overall governed by the Ministry of Agriculture and Forests (MOAF). The Bhutan Agriculture and Food Regulatory Authority (BAFRA) is the body looking into regulatory issues. In addition, there is the National Seeds Centre (NSC) which is a quality control centre for seeds development, which is under the Ministry of Agriculture and Forests. The National Seeds Centre has a Technology Release Committee, which is primarily an approval providing body for new technology development. After receiving the approval by Technology Release Committee, the particular technology is then sent to NSC for multiplication. It looks into generation and maintains germplasm.

In addition, the four RNR Research and Development Centres(RDC) of the MoAF have been historically involved in crop development in general. These centres have developed and released a number of field crop varieties (23 in rice, 5 in maize, 3 in wheat). There are crop breeders working in these centres. However, specific expertise on climate smart agriculture is lacking, which needs to be developed. The National Biodiversity Centre under the Ministry of Agriculture and Forests deals with issues regarding seeds production. It is the focal centre for animal/plant genetic centre (for both new and traditional varieties).

For the distribution of the technologies, each Dzonkhag has extension officer for disseminating seeds varieties. At district level, District Agriculture Officer supported by the Regional RDC coordinates the dissemination. Knowledge of the technology is already raised at the ground level even before the release of the variety. While the country does have an institutional structure in place for development and diffusion of new technologies, but still the diffusion of new varieties remains weak. Therefore, building the dissemination capacity has been the focus of the Ministry of Agriculture and Forests specifically since the past 2-3 years.

Despite being largely an agrarian economy and also having a relatively robust policy and institutional structure governing the sector, there are still barriers dampening the agricultural growth in the country and addressing impacts of climate change on the sector. The institutional capacities of the RDCs are very limited. The research laboratories are outdated with a need for upgrading the equipments and devices. There also existlarge financial gaps, with a need for funds to undertake some vital activities. For instance, the financial capacity of the current institutions is very limited and needs to be increased. There is a need for funding to set up research laboratories, and testing institutions, install latest equipment, enhance the human resource capacity and also build collaborations with international research institutions, if needed. There are also limited storage facilities for food, in the country. Food grain losses are observed to be very high in the old storage facilities built many years ago and there is also high management cost associated with these facilities. Storage facilities for horticulture crops like potatoes and fruits across the country are non-existent, this has an impact on the level of food security in the country.

The small land holdings of farmers often act as a barrier for implementation of certain cropping techniques and patterns. Also the subsistence nature of the farming hinders large scale adoption of new technologies in Bhutan. In addition, with the growing consensus on impacts of climate change, the specific research agenda to address effects of climate change on food security has not yet been included in the main policy domain.

1.1.2 Selected Technology

With the above background, together with extensive stakeholder discussions, in the Part I of the TNA report, 10 technologies for climate change adaptation in Bhutan were shortlisted for the agriculture sector. Out of these, 3 technologies were selected through an extensive multi-criteria decision analysis (MCDA),that was used to prioritize technologies through a process that was country-driven, participatory and involved a number of stakeholders. A three day workshop for criteria weighting and technology prioritization was held at Paro, Bhutan.

Agro-forestry, Development of drought resistant and pest resistant varieties of crops and Sloping Agriculture Land Technology (SALT) were the prioritized technologies for the sector. Further information on these technologies is contained in the TNA report.

Out of these three technologies, development of drought and pest resistant varieties of crops was the technology finalized by the TNA Taskforce for preparation of barrier analysis, enabling framework and technology action plan.

According to NAPA, increased occurrence of pests and diseases in various parts of the country have been observed and climate change is suspected to be a major factor in this regard. Further, studies have shown that majority of the total rice growing areas and 51% of the maize growing areas in the country is still planted with traditional varieties of crops and that there are low adoption rates of improved varieties. In this regard, it becomes important that Bhutan moves towards development of drought and pest resistant varieties of important cereals and horticulture crops to ensure food security at the face of changing climate in the nation.

1.2Action Plan for Drought and Pest Resistant Varieties of Crops

1.2.1 About Drought and Pest Resistant Varieties of Crops

Breeding new and improved crop varieties enhances the resistance of plants to a variety of stresses that could result from climate change such as water and heat stresses and the emergence of new pests. Varieties that are developed to resist these conditions will help to ensure that agricultural production can continue and even

improve despite uncertainties about future impacts of climate change. Breeding for improved performance under environmental stresses involves activities which accumulate favorable alleles (different forms of a gene) contributing to stress tolerance (Clements et al., 2011). In addition to developing new and improved varieties, the management of crops is equally important to prolong resistance. With good biotic stress management plans – resistance can be prolonged otherwise it has been observed that they do not last long.

Development of new crop varieties requires both traditional knowledge in gene-pool as well as utilization of modern biotechnological processes like transgenic crops and molecular breeding. Conventional breeding requires the identification of genetic variability to drought among crop varieties and introducing this tolerance into lines with suitable agronomic characteristics. Although conventional breeding for drought tolerance has and continues to have some success, it is a slow process that is limited by the availability of suitable genes for breeding and largely limited to exploiting the existing genetic variation in crop plants and their very close relatives.

The development of tolerant crops by genetic engineering, on the other hand, requires the identification of key genetic determinants underlying stress tolerance in plants, and introducing these genes into crops. The physiological response of plants to water stress is accompanied by the activation of genes involved in the perception of drought stress and in the transmission of the stress signal. These set of genes are targeted for replication and amplification of their expression in the new breeds. A major reason for the relatively slow progress in conventional breeding responses to the stresses related to climate change arises from the fact that plant adaptations are not likely to be single gene changes and whole metabolic pathways are likely to be involved[1].

1.2.2 Target for technology transfer and diffusion

The target for diffusion of this technology in Bhutan has been primarily based on the national strategy developed by the MOAF. A country road map paper, '*Impact of Climate Change on Food Security*', prepared for*the Bhutan Climate Summit 2011* identifies climate change as one of the major threats of food security in the country and thereby includes a National Food Security Program.

This program has an overall goal of:

- Ensuring availability of safe and quality food at affordable prices through increased production and diversification of food items by instituting efficient distribution net works and regulation of local supply and imports

Under this program, a Food Availability Program has been prepared with the goal of increasing crop production through development of improved varieties, breeds, and management technologies. One of the key strategies to achieve this goal is through evaluation and adoption of genetic resources resistant to biotic and a-biotic stresses including drought, pests and diseases. The country paper also includes a 10 year roadmap for the same. The roadmap includes specific targets for development of drought and pest resistant varieties.

Based on National strategy of MOAF and in line with plans of the ministry under the 11th Five Year Plan, the TNA consultations agreed on following targets for the diffusion of the technology:

- Develop and promote drought resistant rice varieties for low or wet subtropical zones during the period 2013-2018
- Develop and promote drought resistant varieties of spices (cardamom and ginger) for low or wet-subtropical zones during the period 2013-2018
- Develop disease resistant varieties of rice, maize, potatoes, spices and chilies and fodder for high and mid-altitude zones during the period 2013-2018

Work on the main staples of the country (rice and maize) has already been initiated. However, the country aims to also target other important food crops such as wheat, barley, millets, buckwheat etc. as mentioned above. Table 2 shows the details of geographies and traits of selected crops targeted under the TNA. .

[1] For further details on the technology please refer to the technology factsheet of the, 'Technology Needs Assessment and Technology Action Plans for Climate Change Adaptation', National Environment Commission, Royal Government of Bhutan, 2012

Table 2: Crops and geographical area to be targeted for diffusion and transfer of drought and pest resistant varieties

Crops	Districts	Traits	Status
Rice	Thimphu, Paro	Cold tolerance, Blast resistance	Development in process
	Wangdue, Punakha, Tsirang, Dagana, Chukha,	Blast resistance, Sheath Blight resistance	
	Samtse, Sarpang, Samdrupjongkhar	Drought tolerance, Blast resistance	
Maize	Trashigang, Monger, Lhuntse, Yangtse, Samtse, Tsirang, Dagana, Pemagatshel	Disease (GLS, TLB) tolerance, high protein content	Development in process
Wheat	Haa, Paro, Thimphu	Winter hardiness	To be developed
	Punakha, Wangdue, Tsirang, Dagana	Rust resistance	
Barley, buckwheat	Bumthang, Haa	Disease resistance	To be developed
Millets	S/jongkhar, Sarpang, Samtse, Tsirang, Dagana	Rust resistance, High Yield	To be developed

1.2.3 Barriers to the technology's diffusion

Given the current situation in Bhutan with regard to development and diffusion of drought and pest resistant varieties of crops, in the course of TNA process several barriers have been identified. These barriers are either economic barriers or non financial barriers. The non financial barriers are mostly those associated with the limitations of the current institutional structure, the current policy and regulatory framework or those associated with information and awareness with regard to drought and pest resistant varieties of crops. Based on these identified barriers, suitable enabling measures which will assist the country in overcoming these barriers have also been identified. A brief summary of these barriers and enabling measures is presented here below. These enabling measures have further been defined and elaborated on with concrete action for each in the next section of this report.

1.2.1.1 Economic and financial barriers

The key barrier for research and development on drought and pest resistant varieties of crops in Bhutan is the huge investment costs required for setting of research laboratories, development of human resources and for knowledge transfer in the form of exchange programmes, collaboration with international laboratories and universities. The financial capacity of current institutions such the RNR RDCs is very limited to carry out the needed activities. Also, many new varieties of seeds need to be transferred from elsewhere into the country. These would then have to be tested on fields before they are distributed to farmers. All this involves enormous cost which has been identified as a significant barrier, hindering the introduction of this technology in the country. It was emphasized that there are large financial gaps and with needs for funds to undertake some vital activities.

1.2.1.2 Non financial barriers

a) **Institutional barrier**: Among the existing institutions, RNR Research and Development Centres (RDCs) are the oldest dealing with crop improvement research. The National Biodiversity Center (NBC), created in

1998, serves as the focal centre for Plant Genetic Resources (PGR) and conservation of biological resources. RNR RDCs under the Department of Agriculture are actively involved in development and utilization of crop genetic resources in field crops and horticulture. RDCs are assigned specific commodities such as rice, maize, fruits and vegetables to lead research and development of those commodities. RDCs also maintain small germplasm collections and tree mother blocks for their use. The National Seed Center (NSC) also handles large amount of crop germplasm including that of potato.

Although the country has a relatively well-defined institutional structure in place looking at its seeds sector, amongst the existing institutions there is limited human resource capacity to carry out adequate research and development and more importantly extension activities. In addition, synergy amongst institutions is much desired.

b) **Policy, legal and regulatory barrier:** Bhutan's overall legal and regulatory framework is quite favorable towards research and development in crops specifically for developing new biotic and abiotic stress tolerant seed varieties. For instance, the Seeds Act has a clear objective to regulate import and export of agriculture seeds, prevent introduction of plants and diseases and to promote seed industry in the country aimed at enhancing rural income and livelihoods. Similarly, standards and guidelines have already been developed for seed production for implementation by the National Seed Centre. To ensure enforcement of the standards, the Bhutan Agriculture and Food Regulatory Authority (BAFRA) has been made the nodal agency. The IPR related issues are addressed by the Biodiversity Act of Bhutan. Thus there is no direct legal and regulatory barrier hindering the development, production and dissemination of new varieties.

However, the task force members and sectoral experts pointed out that there is a need for a comprehensive agriculture sector policy to be developed to act as an overall guidance document for the sector.

c) **Market barrier:**Access to new seeds of improved strains, especially for the farmers in the remote villages is one of the key barriers in diffusion. Access is an issue largely due to tough topography of the country and is coupled with the limited capacity of the existing institutions to carry out effective dissemination. The Government appointed sales representatives for Geogs(blocks of villages) show less interest in promoting new varieties of cereals particularly rice due to their inexpensive nature, thereby lower incentives for them.

d) **Technical barrier**: Methodologies used for developing new varieties are old and there is heavy reliance on institutes outside the country for germplasm. The research laboratories are outdated and there is a need for upgrading the equipment there. Inadequate manpower and technical skills in crop breeding and germplasm utilization remain a serious impediment. There is also a need to build institutional capacity within the country in the long run to be able to breed new varieties of seeds independently and domestically.

There is also lack of awareness among stakeholders engaged in germplasm development and utilization on recent technology trends and also international treaties and agreements such as Standard Material Transfer Agreements, Cartegena Protocol, and International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA). Information dissemination and sensitization of the technical staff to these, could further R&D in the sector and development of more new varieties.

Also, the subsistence nature of farming along with small land holdings hinders large scale adoption of new technologies.

e) **Social, cultural and behavioral barrier**: In Bhutan, farmers have been developing crop breeds traditionally for generations and hence they may be reluctant to adopt new varieties especially if they require different farming practices and additional investments.

f) **Information and awareness**: There is in general a lack of awareness, education and information disseminated on new available technologies and their benefits to the farmers, which hinders its uptake. Also farmers often are not acquainted with the methods of multiplying new varieties of crops and have to buy new varieties from the market again and again.The recurring cost of purchase of new varieties of

these seeds dissuades farmers from adopting the new varieties, thereby preventing its widespread diffusion.

1.2.4 Enabling measures

Based on intensive discussions with experts, extensive secondary research as well as international experience, measures for building an enabling environment for development and diffusion of the technology in a way to overcome the above barriers have been identified. These measures include:

Economic and financial measures

The new technology development would require huge capital costs to enhance the domestic research and development capacity. The domestic financial resources need to be supplemented by international sources to meet the targets. Financial support needs to be sought for:

- Strengthening of research laboratories, universities and other institutions for R&D.
- Development of human resources and technical knowledge
- Knowledge transfer and exchange programmes

Non financial measures

- **Institutional strengthening**: Strengthening the current institutions (such as NSC, RDCs etc) with human resources and required facilities for accelerating research and development for developing new varieties and preserving traditional varieties. This will help build human and technical capacity of institutes at the central and regional level. Built domestic capacity and ability to develop and produce new varieties domestically, without external dependence. Currently, there is too much of reliance on international germplasm and on conventional methods of crossing are practices domestically to produce new seeds. Capacity building of RDCs to undertake extension services for diffusion of seeds. Currently, the existing institutional capacities are limited to undertake large scale production and dissemination for these varieties to farmers.
- **Building Market support:**Reinforcing the current community based model and up scaling new models for production of seeds. The seed production part has been a major challenge in Bhutan. A well defined community based model will ensure large scale production of improved seeds and also build confidence of farmers in these varieties based due to farmer's direct involvement. This could be ensured by formation and strengthening of community groups by RDCs with support from their outreach centres in different geographical regions for specific crops. It is also important to undertake pilot projects and field testing of new varieties. It is important to test the technologies before a large scale roll out to farmers. This will help make modifications, if required, based on learning of the pilot before a large scale roll out.
- **Policy, legal and regulatory measures:** Modifying the current Seeds Rules and Regulation of Bhutan to also focus on other crops in addition to rice and maize. It is also important to bring to focus through policies and regulation on research and development. Strengthening of these policies would go a long way in creating an enabling environment in development and dissemination of such varieties of crops. The policy structure is in place, but it needs to be strengthened to assist focus on development and dissemination of these varieties. There is also a need to develop a comprehensive agriculture development policy. An overall policy for the agriculture sector, would ensure a combined vision for the sector and avoid overlap of responsibilities between different departments and agencies.
- **Information and awareness creation**: Designing and conducting awareness campaigns to spread information about challenges with existing crops and the need to develop and disseminate new varieties of crops that are pest and drought resistant.

1.2.5 Proposed Action Plan for Drought and Pest Resistant Varieties of Crops

In order to develop action plan for development and diffusion of drought and pest resistant varieties of crops,focused sector specific roundtable discussions were held in Thimphu, Bhutan at NEC office. The

roundtable participants consisted of sectoral experts and representatives from Department of Agriculture under MOAF, Royal Government of Bhutan. Through a technology specific presentation, the roundtable had intensive discussions, which focused on following aspects:

- *Overview of agriculture sector*- discussions were held on relevant institutions, stakeholder networks, policies, acts and regulations governing the sector and likely to facilitate development and diffusions of drought and pest resistant varieties of crops
- *General sector barriers and measures*-this brought forward discussions on general profile of barriers faced in the agriculture sector and the kind of measures that are needed to overcome them.
- *Defining the technology domain:* special focus was given to discussion in terms of defining the technology in a most relevant way given the national circumstances of Bhutan
- *Targets for technology transfer and diffusion*- specific targets were identified for drought and pest resistant varieties of crops. These were based government plans and documents, particularly the 11th FYP and any ongoing or planned government programme for diffusion of these varieties.
- *Barriers to diffusion of drought and pest resistant varieties of crops*- barriers as identified in Part II of the TNA report, were again revisited along with specific enabling measures to overcome them.
- *Proposed Action Plan Framework for Technology development and diffusion*- a draft action plan framework was presented and discussed in detail to aggregate and rationalize themeasures identified to develop national capacities foracceleration of technology development and transfer. The discussion also prioritized and characterized measures for technology acceleration for a national action plan along with estimates of possible technology investment costs.

Based on discussions held at the roundtable, a revised national strategy/action plan was prepared and sent to roundtable participants, especially to the Ministry, for review and comments. Based on which a final prioritized action plan along with national strategy was prepared.

The section brings together the Action Plan which is reflective of the national priorities as those highlighted in the Government of Bhutan Plans, such as the 11th FYP as well as those felt most urgent by TNA Taskforce members and Bhutanese experts.

The Action Plan and thereby the national strategy formulation for the development and diffusion of drought and pest resistant varieties of crops is reflective of national priorities. The budgets of each of these action points are those provided by the Department of Agriculture, Bhutan.

a) Aggregation and rationalization of measures identified for technology acceleration

The list of measures identified for formulation of a national strategy to accelerate the development and transfer of technologies can be seen in Table 3 below.

Table 3: Measures for strategy formulation

Strategic measure	Accelerating innovation RD&D	Accelerating deployment	Accelerating diffusion
Economic and Financial Measure			
Financial support for: **•Strengthening R&D** **•Development of human resources and technical knowledge** **• Knowledge transfer and exchange programmes**	X	X	X
Non Financial Measures			
Institutional			
Strengthening the current institutions for R&D	XX		
Capacity building of RDCs for extension services		X	
Policy, Legal and regulatory			
Strengthen the current Seeds Rules and Regulation of Bhutan and Develop a comprehensive agriculture development policy	X	X	X
Market			
Strengthening of the current community based model and up scaling new models for production of seeds		XX	XX
Pilot projects and field testing of new varieties		X	X
Social, cultural and behavioral			
Awareness campaigns for new varieties		X	X

* Note: This table illustrates for a strategy of acceleration measures according to letters of each square, using the timescale for completion of an action, where:

- Letter "X" refers to measures which need to be started in the short term and carried out within the next five years;

- Letter "XX" refers to measures which can be completed in up to 10 years;

- Letter "XXX" refers to measures longer-term measures which can be planned for completion within 15 years from the current date and also will be used for other technologies below.

b) Prioritization and characterization of technology acceleration measures for a national plan

Based on the barriers and the enabling measures required for deployment and diffusion of drought and pest resistant varieties of crops in Bhutan, the key action points that are essential and immediate are described in Table 4. These action points are organized in priority, in order to convey the importance of action required.

The proposed measures are aligned with the 11th Five Year Plan of Royal Government of Bhutan to ensure that these measures receive required policy and funding support of the Government.

An immediate step for which is strengthening of the current institutions with human resources and required facilities for accelerating research and development for developing new varieties and preserving traditional varieties of seeds. This has been thought to be extremely crucial to solve the larger food security issues as well as combating climate change. Though this process will be a long drawn one, it is important to start moving in the direction by initiating the planning required for this.

Almost in parallel to this step, there is a need to build capacity of RDCs to undertake extension services for diffusion of seeds in order to ensure large scale production and dissemination for these varieties to farmers.As a next step it has been proposed to strengthen the current community based model and upscale new models for production of seeds. It is expected that a well defined community based model will ensure large scale production of improved seeds and also build confidence of farmers in these varieties, due to farmer's direct involvement.

Following this, and in order to provide the financial strength to undertake the identified activities under the current action plan, it has been proposed to establish a seed development fund using both domestic and international funds. The fund can be provided in form of grant and debt for identified activities and could potentially be created under the existing and proposed policies and programs. The fund could be used to finance activities such as strengthening of research laboratories, universities and other institutions for R&D, development of human resources and technical knowledge as well as needed knowledge transfer and exchange.

In line with this, it is also important to strengthen the needed policy and regulatory support. In this context, the current Seeds Rules and Regulation of Bhutan needs to be modified and a comprehensive agriculture development policy to be prepared for Bhutan. In order to build the confidence in new varieties of seeds it is also proposed to undertake pilot projects and field tests of new varieties. While focussing on establishing a strong policy framework, arranging the necessary finance and creating a community based model, it is extremely crucial to conduct awareness campaigns to spread information about challenges with existing crops and the need to develop and disseminate new varieties of crops that are pest and drought resistant.

The importance of each action point along with the timelines and activities, agencies responsible, potential costs along with indicators of success are defined in the Table 4 below.

Table 4: Technology Action Plan based on measures identified for technology acceleration (in priority)

S. No	Measure	Why is it important?	Who should do it?	How should they do it?	Time-scale	Monitoring, reporting and verification for measure	Indicators of Success	Estimated costs (*000 USD)	Potential sources of funding/donors
	Strengthening the current institutions with human resources and required facilities for accelerating **research and development** for developing new varieties and preserving traditional varieties	Help built human and technical capacity of institutes at the central and regional level. Built domestic capacity and ability to develop and produce new varieties domestically, without external dependence. Currently, there is too much of reliance on international germplasm and on conventional methods of crossing are practiced domestically to produce new seeds.	Department of Agriculture (DoA) under the Ministry of Agriculture and Forests (MoAF)	- Hiring the relevant technical experts in key institutes including BAFRA, National Seed Centre, Technology Release Committee and RDCs - Identifying equipments/lab requirements, of the institutions for development of technology - Establishing required facilities either through tie-ups with domestic suppliers or international technology suppliers - Acquisition of latest required lab equipments to further research in related areas - Training and other skill development measures for staff in	2013-2018- the 11th Five Year Plan period	DoA, MoAF	- Number of technical experts appointed by 2018 - Number of training programmes and workshops conducted during the period 2013-2018 - Acquisitions of Lab equipments by 2018 - Number of tie-ups established over the period 2013- 2018	1000	Existing funding programs in Bhutan: Bhutan Trust Fund for Environmental Conservation and UN Capital Development Fund global LoCALprogramme (MoU between UNCDF and GNHC signed); International Adaptation Funding windows: UNFCCC Adaptation Fund; Green Climate Fund; International Climate Fund (UK); International Climate Initiative (Germany); Pilot

			institutes mentioned above Collaboration with regional and international research institutes with the RDCs under DoA by -Establishing tie-ups - Defining scope of tie-ups - Promoting exchange of experts on exchange programmes					Program for Climate Resilience under the Strategic Climate Fund within the Climate Investment Funds Framework; Least Developed Countries Fund. Government budget appropriated for agriculture sector under the 12th Five Year Plan.
Capacity building of RDCs to undertake **extension services** for diffusion of seeds	The existing institutions capacities are limited to undertake large scale production and dissemination for these varieties to farmers.	DoA/RDC	- Design and conduct training and capacity building pogrammes for RDCs and outreach centres focusing on sales representatives and extension officers - Develop extension and communication materials for the training programmes by Hiring consultants or using in-house	2013-2018	DoA/RDC	- Number of training programmes and exposure visits conducted by 2018	500	

			resources - Undertake exposure visits for extension officers sensitizing the existing and new officers to benefits of new technology				
Strengthening of the current community based model and scaling up new models for production of seeds	The seed production part has been a major challenge in Bhutan. A well defined community based model will ensure large scale production of improved seeds and also build confidence of farmers in these varieties based due to farmer's direct involvement.	RDCs/National Seeds Centre	Formation and strengthening of community groups by RDCs with support from their outreach centres in different geographical regions for specific crops.	2013-2018	RDCs	Number of community groups formed in different regions	50
Financial support for: • Strengthening of research laboratories, universities and other	The new technology development would require huge capital costs to enhance the domestic research and development	DoA, MoAF	Establish a seed development fund using both domestic and international funds. The fund can be provided in form of grant and debt for identified	2013-2018	DoA, MoAF	- Creation of a Fund by 2018	100

institutions for R&D. • development of human resources and technical knowledge • knowledge transfer and exchange programmes	capacity. The domestic financial resources need to supplement by international sources to meet the targets.		activities. The fund could be created under the Comprehensive Agriculture Development Policy. Estimate the fund corpus based on targets set - Identifying potential international agencies/funds to be approached - Developing tie-ups with selected agencies - Formalizing the scope of financing and particular financing mechanism to be introduced through such tie-ups				
Policy and regulation development - Strengthen the current Seeds Rules and Regulation of Bhutan. - Develop a comprehensive	Strengthen of these policies would go a long way in creating an enabling environment in development and dissemination of such varieties of crops. The policy	DoA lead agency	Identifying specific areas of regulations to be strengthened and development of the comprehensive policy - Consulting relevant experts for amending policies and developing the	2013-18	DoA	- Policy amendments made by 2015 - Comprehensive Agriculture Development Policy developed by	100

agriculture development policy	structure is in place, but it needs to be strengthened to assist focus on development and dissemination of these varieties. An overall policy for the agriculture sector would ensure a combined vision for the sector and avoid overlap of responsibilities between different departments and agencies.		new policy - Actual amendments of policies in a way to strengthen them			2018	
Pilot projects and field testing of new varieties	Important to test the technologies before a large scale roll out to farmers. Will help make modifications, if required, based on learning of the pilot before a large scale roll out.	RDCs and Dzongkhag	Identifying sites for pilots and field testing - Identifying institutions for conducting the pilots - Seeking source of funding these pilots - Implementing pilots - Monitoring the pilots - Drawing lessons from pilot applications of the	2013-2015	RDCs	Number of pilots implemented by 2015	1000

			drought and pest resistant varieties				
Awareness campaigns to spread information about challenges with existing crops and the need to develop and disseminate new varieties of crops that are pest and drought resistant	It is needed to help farmers and technology providers to overcome traditional practices and habits and thus develop faith in new technologies.	RDCs/Dzongkhag	Design awareness campaign for farmers - Clearly identify elements of such campaign - Develop content of relevance to farmers for such campaigns - Collaborate with village level bodies for proper dissemination of information and conducting such a campaign - Broadcast media - Include successful case studies to sensitize farmers	2013-2018	RDCs/Dzongkhag	- Number of awareness campaigns conducted by 2018	200

c) Finalizing national strategy

Based on priority technology action plans in the sub-sectors, a national strategy and action plan for the drought and pest resistant varieties of cropstargets are presented in Table 5.

Table 5: National Strategy (technology transfer and development for adaptation)

Timescale	0-5 years	5-10 years	10-15 years
Large-scale, medium and short-term technology			
Drought and Pest Resistant Varieties of Crops			
Strengthening the current institutions for R&D	X		
Capacity building of RDCs for extension services	X		
Strengthening of the current community based model and up scaling new models for production of seeds	X		
Financial support for: **•strengthening R&D** **•development of human resources and technical knowledge** **• knowledge transfer and exchange programmes**		X	
Strengthen the current Seeds Rules and Regulation of Bhutan and Develop a comprehensive agriculture development policy		X	
Pilot projects and field testing of new varieties		X	
Awareness campaigns for new varieties	X	X	X

Chapter 2 Technology Action Plan for Water Resources Sector

2.1 Actions at sectoral level

2.1.1 Sector Description-Water Resources

Bhutan's economy is strongly linked to water resources which are vital for many other sectors in the country such as agriculture, hydro power, industry and tourism. On a macro scale the availability of water in Bhutan seems very high (109,000 m^3 per capita); however the major sources for drinking and irrigation water are mainly from local springs, streams and minor east-west tributaries for which no water flow measurement studies exist (National Environment Commission, 2011).

Although Bhutan has not experienced severe water shortages in the past, reports of dwindling water sources are increasing and climate change may render the country much more vulnerable. Surveys of local perceptions have reported that people have observed winter flows to be lower than normal in the past 10-20 years. Furthermore, during the mid-term review consultation of the 10^{th} Five Year Plan (March-May 2011), representatives of almost all Dzongkhags raised the issue of acute water shortages for drinking and attributed such recent issues as increasing fallowing of agricultural land in the rural communities to the drying of water sources (National Environment Commission, 2011).

Other projections (IPCC, 2007, cited in National Environment Commission, 2011) indicate that by the 2050s, access to freshwater in Asia will decrease, with increasing extremes of dry and wet periods.With increasing demands for water and also localised vulnerabilities already reported from many parts of Bhutan, adaptation measures have become necessary for both efficient use of water and also dealing with the impacts of climate change on water resources.

In summary, Bhutan's NAPA, 2006 has listed the following vulnerabilities faced by water resources sector:

- Temporal and spatial variation in flow, affecting notably electricity productivity/exports due to disruption of average flows for optimum hydropower generation
- Increased sedimentation of rivers, water reservoirs and distribution network, affecting notably irrigation schemes' productivity as also the agricultural crop yields
- Reduced ability of catchment areas to retain water/ increased runoffs with enhanced soil erosion (deterioration of environment)
- Deterioration of drinking water quality.

The country with its aggressive food self-sufficiency goals and with increased food demand due to population growth, agriculture production has to be intensified on the available land. The challenge of achieving food sufficiency together with the challenge of climate change is thereby necessitating an important role for irrigation facilities in the country. The development of these facilities would play a critical role in increasing yield and food production.

In light of the risks posed by climate change it is greatly realized in the country the need to change the current irrigation practices and adopts measures to adapt to changing climate. It is highlighted that there exist a potential to improve crop yields and water productivity through; (i) improvement/modernization of the existing irrigation systems; (ii) on-farm water management; (iii) provision of water storage facilities; (iv) diversifying the range of irrigated crops; and (v) appropriate technology. These strategies are essential to cope with the changing rainfall and stream flow pattern brought about by climate change.

Currently, the potential to develop irrigation in the country has not been fully realized and expansion of irrigated land will invariably increase the demand for water. Virtually all the irrigation schemes in the country are run-of-the-river type with small open channels conveying water to distant fields. The Government came out with a revised National Irrigation Policy in 2011. Since then the document has been the governing document for the sector. In addition some of the other policies and acts governing the water resources sector particularly agricultural water sector are mentioned in Table 6 below.

Table 6: List of water sector Policies, Acts and Regulations in Bhutan

S. No.	Name	Date Effective	Agency	Contents
1.	The National Irrigation Policy	September 2011	Ministry of Agriculture and Forests.	The document is intended to provide policy direction in the irrigation sub-sector to address its current and future issues. It provides clear direction on the measures that need to be adopted to increase the irrigated area and to improve irrigation water management and optimal utilization of national water resources for crop production.
2.	Bhutan Water Policy	2003	Ministry of Agriculture and Forests	Policy focuses on conservation of water resources and integrated water resources management. It stresses on achieving efficiency in irrigation through applied and adaptive research. The Policy also suggests pricing policies to serve as an economic instrument to enhance efficiency of water use.
3.	Renewable Natural Resources (RNR) Research Policy of Bhutan	2012	Ministry of Agriculture and Forests	The RNR Research Policy of Bhutan responds to the demand in the 10th Five Year Plan of Bhutan and beyond to determine the progress that the research system has made in meeting the objectives set forth in the new areas, and to provide guidance on the management and conduct of RNR research. In doing so, the policy focuses on new ways to coordinate, prioritize, plan and programme, organize, finance, manage and implement RNR research to prepare the system and its clients for the challenges of the 21st century.
4.	The Water Act	2011	National Environment Commission	The Act was enacted with a purpose: · To ensure that the water resources are protected, conserved and/or managed in an economically efficient, socially equitable and environmentally sustainable manner; and · To establish suitable institutions.

The existing institutional structure governing the irrigation sector in the country is as per the National Irrigation Policy 2011. The policy has given mandate to the Ministry of Agriculture &Forests for irrigation development in the country. However, realizing that irrigation development and management would require a multi-sectoral approach, the policy has specific roles and responsibilities for organizations such as the Gross National Happiness Commission, National Environment Commission, Ministry of Agriculture and Forests, RNR Research & Development Centers/RIWaM, Dzongkhag Agriculture Sector, Dzongkhag Engineering Sector, Geog Agriculture Extension Officer and Geog Tshogde.

The irrigation sector in Bhutan however, is fraught with several issues. Irrigation systems currently employed are rudimentary and consist largely of an open earthen channel cut out of the hill slopes.The absence of water storage structures, both at the intake points and within the irrigated areas, makes irrigation systems in Bhutan highly vulnerable to stream flow variations. The acute shortage of professionals and strong institutions in the country is a major impediment for the development, management and implementation of irrigation programs

and activities. The lack of professionals and adequate staff is amplified by the poor quality and state of irrigation infrastructures, and water management.Most of the local Water User Associations (WUAs) are weak and given the human resource constraint support to these organizations have been negligible and ineffective.The greatest bottleneck to proper planning and management of water resources is the dearth of reliable data and information. The hydrological and meteorological data available is limited to few major rivers and watersheds that are of significance to hydropower generation. Research on agriculture water management is at infancy making it difficult to devise appropriate water management interventions. The existence of different agencies under different ministries collecting information and researching on water issues further exacerbates the problem of information sharing. No significant irrigation technologies have been disseminated and local extension agent's knowledge and skills on irrigation is limited.

The high costs associated with new and advanced irrigation systems and in wake of lack of any direct tax exemptions or incentives, the adoption of new systems by farmers remains elusive. There is also general resistance to new technologies from farmers, who are use to old traditional practices coupled with lack of funds to acquire new equipment, further hinders the adoption.

2.1.2 Selected Technology

With the above background, together with extensive stakeholder discussions, in the Part I of the TNA report, 13 technologies for climate change adaptation in Bhutan were shortlisted for the water resources sector. Out of these, 3 technologies were selected through an extensive multi-criteria decision analysis (MCDA), that was used to prioritize technologies through a process that was country-driven, participatory and involved a number of stakeholders. A three day workshop for criteria weighting and technology prioritization was held at Paro, Bhutan.

Micro/mini hydro power, efficient irrigation methods and solar power (rooftop PV) are the prioritized technologies for water resources sector. Further information on these technologies is contained in the TNA report.

Out of these three technologies, efficient irrigation methods more specifically drip and sprinkler irrigation was the technology finalized by the TNA Taskforce for preparation of barrier analysis, enabling framework and technology action plan.

The technology selection was based on the fact that it is aligned with the government's plans to explore improved irrigation methods that are not rain-dependent and lead to water use efficiency.The application of other two technologies (micro/mini hydro power and solar power) is largely dependent on the renewable energy policy that is in draft stages in Bhutan and was therefore not finalized for the preparation of TAP.

2.2 Action Plan for Drip and Sprinkler Irrigation Systems

2.2.1 About Drip and Sprinkler Irrigation Systems

Efficient irrigation methods or technologies include the advanced irrigation systems like sprinkler irrigation and drip irrigation. Sprinkler irrigation is a type of pressurized irrigation that involves applying water to the soil surface using mechanical and hydraulic devices that simulate natural rainfall. The goal of irrigation is to supply each plant with just the right amount of water it needs. Sprinkler irrigation is a method by which water is distributed from overhead by high-pressure sprinklers on risers or moving platforms. Today a variety of sprinkler systems ranging from simple hand-move to large self-propelled systems are used worldwide.

Drip irrigation is based on the constant application of a specific and calculated quantity of water to soil crops. The system uses pipes, valves and small drippers or emitters transporting water from the sources (i.e. wells, tanks and or reservoirs) to the root area and applying it under particular quantity and pressure specifications. Managing the exact moisture requirement for each plant, the system significantly reduces water wastage and promotes efficient use. Compared to sprinklers systems which can provide 75 per cent efficiency, drip irrigation can provide as much as 90 per cent water-use efficiency (Tanji and Kielen, 2002 in Clements et al.,

2011)[2].Drip irrigation is an interesting choice however, one needs to customized it for the given crops and available costs. Taking the advantage of height, gravity dependent drips could be developed in Bhutan to save energy costs.

2.2.2 Target for technology transfer and diffusion

In addition to this ongoing demonstration projects, the DOA is in the process of finalizing the targets and objectives for irrigation as part of the 11th FYP process. The TNA process and consultation with experts, as well, highlighted the targetof increasing area under irrigation by installing new irrigation systems for horticulture (cash) crops. The target is to increase the area by 300 hectares under new irrigation systems from December 2013 to March 2018.

The National Irrigation Policy of Bhutan also aims "***to strengthen technical support services and to develop, promote and disseminate new practices, innovation and technologies that are environmentally sustainable, appropriate, manageable and affordable"*** and in the process introduce and support such technologies as drip and sprinkler irrigation. The Department of Agriculture has budgeted about Nu 50 million (USD 0.9 million) over three years for the transfer and diffusion of the technologies.

The Department has initiated a Decentralized Rural Development Project under the World Bank funding with the objective of demonstrating and promoting drip and mini-sprinkler irrigation technologies to the farmers for cash crop production.

Demonstration plots for sprinkler irrigation tentatively selected through Decentralized Rural Development Project funding (Nu. 5 million) (USD 0.09 million) are as follows:

Table 7: Tentative sites for demonstration of drip and sprinkler irrigation

Sl. No.	Site/location	Target Crop	Dzongkhag
1.	Choekor	Vegetables	Bumthang
2.	Kabjisa	Chili & beans	Punakha
3.	Deothang	Orange	S/Jongkhar
4.	Phangyul	Vegetables/tomato	Wangdue
5.	Patshaling/Gosaling	Citrus	Tsirang
6.	Thangna, Drujeygang	Citrus	Dagana
7.	Phobjikha	Potato	Wangdue

Nu. 5 million (USD 0.09 million) has been allocated for this activity through the DRDP project funding for 2011-2012 FY. Under the project 7 sites spread across the country. Each site will have an area of 2-5 acres. As part of the TNA, it is being proposed to expand the project to include more sites for demonstration of the technology.

2.2.3 Barriers to the technology's diffusion

Given the current situation in Bhutan with regard to development and diffusion of drip and sprinkler irrigation systems, in the course of TNA process several barriers have been identified. These barriers are either economic barriers or non financial barriers. The non financial barriers are mostly those associated with the limitations of the current institutional structure, the current policy and regulatory framework or those associated with information and awareness with regard to efficient irrigation systems. Based on these identified barriers, suitable enabling measures which will assist the country in overcoming these barriers have also been identified. A brief summary of these barriers and enabling measures is presented here below. These enabling

[22] For further details on the technology please refer to the technology factsheet of the, 'Technology Needs Assessment and Technology Action Plans for Climate Change Adaptation', National Environment Commission, Royal Government of Bhutan, 2012

measures have further been defined and elaborated on with concrete action for each in the next section of this report.

2.2.2.1 Economic and financial barriers

The key economic barrier identified for the implementation and diffusion of sprinkler and drip irrigation is the high costs of these systems as compared to traditional irrigation methods. A study in India indicates USD 430 as cost of investment for 1 hectare sprinkler irrigation system (National Bank for Agriculture and Rural Development (NABARD), 2007). Similarly, depending on the crop, the cost of drip irrigation may vary from USD 306 to USD 1800 per hectare (NABARD, 2007)[3].

As per the experts in Department of Agriculture of Bhutan, the cost of these systems in Bhutan would almost be double of those in India due to high transportation and installation costs. And these costs are much higher than those for traditional systems in Bhutan. Such high costs are unaffordable by Bhutanese farmers practicing mostly subsistence agriculture.

Further, access to credit for farmers is another barrier identified for the technology. At present, rural banks in Bhutan such as the Bhutan Development Bank provide loans to farmers at a rate of interest as high as 13%, making it extremely difficult for farmers to avail these loans. In scenario of high costs, lack of any fiscal support and limited access to finance makes the diffusion of these technologies particularly difficult in the country.

2.2.2.2 Non financial barriers

a) **Technical:** The acute shortage of professionals in the country is a major impediment for the development and diffusion of irrigation programs such as those concerned with drip and sprinkler irrigation. Irrigation infrastructure development activities at the Dzongkhag and Geog levels are implemented by few civil engineers who lack technical knowledge and skills in irrigation and agronomy, and are overburdened with other civil construction activities. The lack of professionals and adequate staff particularly dealing and familiar with drip and sprinkler irrigation techniques acts as a major impediment. This coupled with poor efficiency of existing infrastructure for irrigation there is a severe lack of needed experience to design and maintain new systems with very few engineers. The institutions and their human capacity are further constrained to cater to after sales service needs of such systems.

b) **Policy, Legal and regulatory:** environment in the country is not particularly supportive to encourage individual irrigation systems. There is no special focus in current policies on promoting individual irrigation systems, most are focused only on community based models.
In addition given the high costs of these systems, lack of any fiscal incentives in form of tax exemptions or subsidies further discourages farmers in switching to new technologies.

c) **Market:** currently there are no dealers dealing with new technologies and equipment. This is largely because there has been no demand for such systems; thereby the supply could not be developed. Most of these systems are currently being imported from India. No after sales support to these systems further reduces their uptake.

d) **Social, cultural and behavioral:**Water sharing in Bhutan is currently governed by traditional community regulations which are difficult to break, specifically for some areas. Since number of uses will increase, as a result of these technologies, this is likely to create problems.

   The subsistence nature of agriculture reduces the viability of these systems. For this technology to be viable it is essential for agriculture to be commercial in nature. In addition there is also an observed general resistance to new technologies from farmers, being used to old traditions and practices.

e) **Information and awareness:** due to limited institutional capacity both at research as well as implementation level for new irrigation systems, there is real dearth of information on better water management techniques, including drip and sprinkler. This lack of information translates into lack of

[3] http://www.nabard.org/modelbankprojects/mi_dripirrigation.asp, last accessed on 15th October 2012

awareness both at the level of researchers, engineers, farmers of new technologies and associated costs and benefits.

f) **Institutional Barrier:** Water management research suffers from shortage of professionals to work on new techniques, leading to a rather slow development and diffusion of new technologies such as drip and sprinkler. As well as implementation of irrigation system suffers due to lack of enough technical staff as Dzonkghag and Geog level.

In addition, existence of different agencies under different ministries collecting information and researching on water issues further exacerbates the problem of information sharing.

2.2.4 Enabling measures

Based on intensive discussions with experts and secondary research, following measures for building an enabling environment for development and diffusion of the technology has been identified:

2.2.4.1 Economic and financial measures

One of the primary ways by which the existing financial barriers for the transfer and diffusion of sprinkler and drip irrigation system could be overcome is the introduction of financial incentives to overcome the high costs associated with these systems. Financial support is essential in short term to enhance uptake of these technologies by commercial farmers and understand the benefits. Such support will also ensure that the pilot projects are replicated on large scale in different parts of the country. In long term once the business case is established such support can be phased out.

Financial incentives could be provided by introducing a scheme on installation of drip/sprinkler irrigation. Such a scheme could provide certain percentage of the total cost of the installation of the irrigation systems as capital subsidy and remaining amount could be sourced through low interest debts and farmer contributions. The subsidy could be provided through a special fund created for promotion of micro irrigation schemes.

Further, at present the loans available to farmers through rural banks such as the Rural Development Bank are offered on high interest thus making them expensive for farmers to avail. In order to improve the access to finance of farmers one of the essential financial measures would be to provide loans to farmers at lower rates of interest through rural and agricultural banks. For this, rural and agricultural banks providing such loans could be identified. The Banks accordingly, could be sensitized on the importance of development and dissemination of the technology. Further incentives could be provided to Banks to provide such loans by introducing re-financing and credit risk guarantee schemes.

2.2.4.2 Non financial measures

Various measures that could be implemented in Bhutan to overcome some of the impending non-financial barriers include:

a) Strengthening institutional support and building technical Capacity

Strengthen the current institutions in terms of human resources and technical expertise. It is Important to overcome the shortage of professionals and strong institutions in Bhutan and promote effective development, management and implementation of irrigation programs and activities. This could be done by first assessing the resource requirement in different level of institutions, designing and conducting training programs on irrigation and water management, designing institutional structure for smoother implementation of micro irrigation schemes.

b) Information and awareness generation

Introduce training, capacity building programmes and awareness campaigns on drip and sprinkler irrigation techniques for district engineers, regional RDCs engineers, farmers and extension agents. It is important to introduce training and capacity building programmes as there is lack of skilled personnel for installation and operation of such technologies. Such programmes will built capacity and also enhance the confidence of the manpower in the technology.

c) Building market support

Undertake pilot projects for technology demonstration and modification. It is important to undertake the required research and test the technology through pilots, in way to suit the local conditions of Bhutan. This is particularly important as there is a risk of damage to the installations during winters for example.

Also given Bhutan's topography and the fact that it is difficult to operate such systems on sloping land, it is crucial to undertake pilots before widespread roll outs of the systems.

2.2.5 Proposed Action Plan for Drip and Sprinkler Irrigation Systems

In order to develop a most relevant action plan for deployment and diffusion of drip and sprinkler irrigation systems focused sector specific roundtable discussions were held in Thimphu, Bhutan at NEC. The roundtable participants consisted of sectoral experts and representatives from Department of Agriculture under MOAF, Royal Government of Bhutan. Through a technology specific presentation, the roundtable had intensive discussions, which focused on following aspects:

- *Overview of the water resources sector-* discussions were held on relevant institutions, stakeholder networks, policies, acts and regulations governing the sector and likely to facilitate the diffusion of drip and sprinkler irrigation systems
- *General sector barriers and measures-* this brought forward discussions on general profile of barriers faced in the water sector and the kind of measures that are needed to overcome them.
- *Defining the technology domain:* special focus was given to discussion in terms of defining the technology in a most relevant way given the national circumstances of Bhutan
- *Targets for technology transfer and diffusion-* specific targets were identified for drip and sprinkler irrigation systems. These were based government plans and documents, particularly the 11th FYP and any ongoing or planned government programme for diffusion of these varieties.
- *Barriers to deployment and diffusion ofdrip and sprinkler irrigation systems-* barriers as identified in Part II of the TNA report, were again revisited along with specific enabling measures to overcome them.
- *Proposed Action Plan Framework for Technology deployment and diffusion*a draft action plan framework was presented and discussed in detail to aggregate and rationalize the measures identified to develop national capacities for acceleration of technology deployment and diffusion. The discussion also prioritized and characterized measures for technology diffusion for a national action plan along with estimates of possible technology investment costs.

Based on discussions held at the roundtable, a revised national strategy/action plan was prepared and sent to roundtable participants, especially to the Ministry, for review and comments. Based on which a final prioritized action plan along with national strategy was prepared.

The section brings together the Action Plan which is reflective of the national priorities as those highlighted in the Government of Bhutan Plans, such as the 11th FYP as well as those felt most urgent by TNA Taskforce members and Bhutanese experts.

The Action Plan and thereby the national strategy formulation for deployment and diffusion of drip and sprinkler irrigation systems is reflective of national priorities. The budgets of each of these action points are those provided by the Department of Agriculture, Bhutan.

a) Aggregation and rationalization of measures identified for technology acceleration

The list of measures identified for formulation of a national strategy to accelerate the development and transfer of technologies can be seen in Table 8 below.

Table 8: Measures for strategy formulation

Strategic measure	Accelerating innovation RD&D	Accelerating deployment	Accelerating diffusion
Economic and Financial Measure			
Introduction of financial incentives to overcome the high costs associated with these systems		X	XX
Increasing access to finance for farmers by providing loans to farmers at lower rates of interest through rural and agricultural banks		XX	XX
Non Financial Measures			
Institutional			
Strengthening the current institutions in terms of human resources and technical expertise		X	XX
Market			
Pilot projects for technology demonstration and modification		X	X
Social, cultural and behavioral			
Introduce training and capacity building programmes on drip and sprinkler irrigation techniques for district engineers, regional RDCs engineers, farmers and extension agents		X	X

* Note: This table illustrates for a strategy of acceleration measures according to letters of each square, using the timescale for completion of an action, where:

- Letter "X" refers to measures which need to be started in the short term and carried out within the next five years;

- Letter "XX" refers to measures which can be completed in up to 10 years;

- Letter "XXX" refers to measures longer-term measures which can be planned for completion within 15 years from the current date and also will be used for other technologies below.

b) Prioritization and characterization of technology acceleration measures for a national plan

Based on the barriers and the enabling measures required for deployment and diffusion of drip and sprinkler irrigation systems in Bhutan, the key action points that are essential and immediateare described in Table 9. These action points are organized in priority, in order to convey the importance of action required.

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The proposed measures are aligned with the 11th Five Year Plan of Royal Government of Bhutan to ensure that these measures receive required policy and funding support of the Government. For large scale deployment, a robust institutional structure is essential; thereby the Department of Agriculture, Ministry of Agriculture and Forest will be the lead agency to drive all the measures and will work closely with regional and local institutions such as RIWaMs, RDCs and extension agents to ensure required planning and implementation support. In this context, strengthening of these institutions in terms of required human resources and technical expertise through proper budget allocation and capacity building and training programs have been proposed.

To provide required market enabling and technology support, pilot projects have been included in the plan which would not only demonstrate the technology but also the financial and institutional structure required for large scale deployment. It is expected that pilots would result into necessary modification of technologies to cater to Bhutan's topography and other implementation constraints.

Finally, deployment of drip and sprinkler irrigation systems in the country requires significant capital support to ongoing agriculture and natural resource management programs. Some of the action points proposed fall under the overarching programs including NAPA, Sustainable Land Management Project and Decentralized Rural Development Project. However, additional funding will be essential for which international adaptation funds would be approached including the Green Climate Fund and Adaptation Fund of UNFCCC and bilateral funds. These funds are proposed to be utilized in a manner which not only addresses the high capital requirement but also the issue of access to finance. In this context, capital support on equipments along with low interest debt to farmers through rural and agriculture banks for purchasing these systems have been proposed.

The importance of each action point along with the timelines and activities, agencies responsible, potential costs along with indicators of success are defined in Table 9 below.

Table 9: Technology Action Plan for water resources sector based on measures identified for technology acceleration (in priority)

S. No	Measure	Why is it important?	Who should do it?	How should they do it?	Time-scale	Monitoring, reporting and verification for measure	Indicators of Success	Estimated costs (*1000 USD)	Potential risks	Potential sources of funding/donors
1	Strengthening the current institutions in terms of human resources and technical expertise	Important to overcome shortage of professionals and strong institutions in the Bhutan and promote effective development, management and implementation of irrigation programs and activities	Department of Agriculture	- Assess the resource requirements in different level of institutions with enhanced focus on local and regional level institutions such as RDCs, Extension officers, Dzongkhag Agriculture Sector, and Dzongkhag Engineering Sector. - Design and conduct training programs on irrigation and water management to develop irrigation professionals and engineers in the identified institutions -Strengthen the institutional	2013-2018	Department of Agriculture	- Additional human resources appointed at different levels by 2018 - Training programs for personnel	100		**Existing funding programs in Bhutan:** **Bhutan Trust Fund for Environmental Conservation and UN Capital Development Fund global LoCALprogramme (MoU between UNCDF and GNHC signed);** **International Adaptation Funding windows:** **UNFCCC Adaptation Fund; Green Climate Fund; International Climate Fund (UK); International Climate Initiative (Germany); Pilot Program for Climate Resilience**

				structure for smoother implementation of micro irrigation schemes. Such structure could include setting up of specific cells in the existing nodal agencies at central, regional and local levels. These cells/units could be responsible for planning, approval, administration, technical support, implementation and monitoring and evaluation.					**under the Strategic Climate Fund within the Climate Investment Funds Framework; Least Developed Countries Fund.** **Government budget appropriated for agriculture sector under the 12th Five Year Plan.**
2	Introduce training and capacity building programmes on drip and sprinkler irrigation techniques for district engineers, regional RDCs engineers,	It is important to introduce training and capacity building programmes as there is lack of skilled personnel for installation and operation of such technologies.	Department of Agriculture, Engineering Division	- Review and assess needs of existing technical staff and farmers - Develop support plans and programs for Training and capacity building for installation and operation and maintenance of the irrigation	2013-2018	Department of Agriculture, Engineering Division	- Training programs conducted by 2018 - Study visits completed by 2018 - Relevant media advertisements and broadcasts organized and aired	200	

	farmers and extension agents	Such programmes will built capacity and also enhance the confidence of the manpower in the technology.		systems - Organize study visits to India and Israel, - Participate in technology exhibitions in other countries - Use the Media (print and A/V) to sensitize on issues of water management and role of such technology in better water management			periodically by over 2013-2018	
3	Pilot projects for technology demonstration and modification	It is important to undertake the required research and test the technology through pilots, in way to suit the local conditions of Bhutan. This is particularly important as there is a risk of damage to the installations during winters	Department of Agriculture, Engineering Division, Ministry of Agriculture and Forests	Design and implement pilot projects through following activities - Evaluate lessons and learning from pilot projects implemented in past or currently ongoing e.g. pilot projects being implemented under the DRDP program funded by the World Bank - Identify sites for pilot projects	2013-2015	Department of Agriculture, Engineering Division, Ministry of Agriculture and Forests	Additional pilots conducted and results documented by 2015	240

	for example. Also given Bhutan's topography and the fact that it is difficult to operate such systems on sloping land, it is crucial to undertake pilots before widespread roll outs of the systems.	across regions in Bhutan - Design pilot specifying type of micro irrigation technology (drip or sprinkler), cash crop, target community, funding required, expected water saving and increase in productivity - Design implementation framework specifying role of institutions at central, regional and local level - Develop strategy for communication and outreach to disseminate project findings among various stakeholders including policy makers and farmers

4	Introduction of financial incentives to overcome the high costs associated with these systems.	Financial support is essential in short term to enhance uptake of these technologies by commercial farmers and understand the benefits. Such support will also ensure that the pilot projects are replicated in large scale in different parts of the country. In long term once the business case is established such support can be phased out.	Ministry of Agriculture and Forests Ministry of Finance	Introduce a scheme on installation of drip/sprinkler irrigation. Such a scheme could potentially provide certain percentage of the total cost of the installation of the irrigation systems as capital subsidy and remaining amount could be sourced through low interest debts and farmers' contributions. The subsidy could be provided through a special fund created for promotion of micro irrigation schemes. - Conduct review of similar schemes in other countries such as India, Israel etc - Conduct a cost benefit analysis of the scheme - Assign budget for	2013-2018	DoA, Ministry of Agriculture and Forests	- Design of the subsidy scheme complete by 2015 - Actual provision of the subsidy to the farmers installing this equipment	300

				micro irrigation scheme and assess the subsidy requirement - Secure funding from domestic and international sources - Develop institutional structure to implement the scheme				
5	Increasing access to finance for farmers by providing loans to farmers at lower rates of interest through rural and agricultural banks	Currently the loans available to farmers through rural banks such as the Bhutan Development Bank are offered on high interest thus making them expensive for farmers to avail.	Gross National Happiness Commission Ministry of Finance and Ministry of Agriculture and Forests	Identify rural and agricultural banks providing such loans - Sensitizing the bank with importance of development and dissemination of the technology. - Suitably incentivizing the banks to provide such loans by introducing re-financing and credit risk guarantee schemes	2013-2018	Ministry of Finance and Ministry of Agriculture and Forests	- Identification and selection of target banks by 2015 - Designing of the loan program by 2016 - Launch of the loan program by 2016	500

c) Finalizing national strategy

Based on priority technology action plans in the sub-sectors, a national strategy and action plan for drip and sprinkler irrigation development targets are presented in Table 10.

Table 10: National Strategy (technology transfer and development for adaptation)

Timelines	0-5 years	5-10 years	10-15 years
Large-scale, short to medium-term technology			
Drip and Sprinkler Irrigation			
Strengthening the current institutions in terms of human resources and technical expertise	X	X	
Introduce training and capacity building programmes on drip and sprinkler irrigation techniques for district engineers, regional RDCs engineers, farmers and extension agents	X	X	
Pilot projects for technology demonstration and modification	X		
Introduction of financial incentives to overcome the high costs associated with these systems.	X	X	
Increasing access to finance for farmers by providing loans to farmers at lower rates of interest through rural and agricultural banks	X	X	

Chapter 3 Technology Action Plan for Natural Resources and Infrastructure Sector

3.1 Actions at sectoral level

3.1.1 Sector Description-Natural Resources and Infrastructure

Bhutan is vulnerable to natural disasters such as floods, landslides, forest fires, droughts, cyclones and windstorms due to its rugged and fragile mountain terrain, complex geological setting, high intensity of seasonal rains, and active tectonic processes taking place in the Himalayas (Ministry of Home and Cultural Affairs Bhutan, 2005). These disasters are likely to become more frequent and more intense with changing patterns of temperatures and precipitation. This is also evident from the Fourth Assessment Report of the Intergovernmental Panel on Climate Change 2007 that states that the tropical cyclones will become more intense with larger peak wind speeds and heavier precipitation. Subsequently, the report also states that extra-tropical storm tracts are projected to move pole-wards which imply that Bhutan may face more frequent and severe impacts of natural disasters. In fact, the severity and frequency of windstorms and flashfloods in Bhutan have increased over the past years due to increasing rainfall and untimely monsoons. Increase in temperature and drought have also increased incidences of forest fire. All these disasters have caused extensive damage to life and infrastructure in the past. For instance, the cyclone Aila of 2009 led to loss of 12 lives and damages to agriculture, roads, bridges, schools, hydro projects, and other infrastructure. In April 2008, windstorm damaged 249 rural houses in lower Trashigang. Lumang gewog was worst hit with 148 households affected. Eight school buildings, four Lhakhangs and one forest office were also damaged by the windstorm (National Environment Commission, 2011).

Given this background, it becomes imperative to strategize adaptation options for natural disasters to prevent the extensive damage that these cause to life and infrastructure. The country's infrastructure is usually built to meet the current climatic conditions and is not prepared to withstand the consequences of climate change events in the form of exacerbated natural disasters in future. For instance, many roads and bridges are washed away and damaged due to landslides and flash floods. A damage assessment done in eastern Dzonghkhags found that almost 22 bridges had been washed away or severely damaged by 2004 monsoons (Ministry of Home and Cultural Affairs Bhutan, 2005).

Bhutan's NAPA, 2006 lists the following vulnerabilities faced by the Natural Disasters and Infrastructure sector:

- Debris covered glaciers forming huge moraine dam lakes that ultimately lead to GLOFs (flash floods and landslides, heavy siltation of the rivers and other geotechnical hazards)
- Natural disasters will affect essential infrastructure:
    - Hydropower systems (generation plants, transmission and distribution infrastructure)
    - Industrial estates
    - Human settlements
    - Historical and cultural monuments: Dzongs, monasteries, chortens etc
    - Public utilities: Roads, bridges, communication

To adapt to the changing climate and its consequent effect on natural disasters, it becomes important that the nation's infrastructure is designed, built, operated and maintained in a way that enables it to withstand current as well as future impacts of natural disasters. For instance, the road network – which forms the veins and arteries of country's socio-economic development structure – is extremely vulnerable to climate impacts because of the mountainous topography, young and highly fragile geologic formation, and intense seasonal rains.

The first road in Bhutan – what is now the Phuentsholing-Thimphu highway – was built in the beginning of 1960s, with the advent of the first Five-Year Plan. Presently, the country's road network extends over 8,300

km. The Royal Government of Bhutan aims to establish a road network that connects all the 205 geogs in order to promote geographically balanced socio-economic development.

According to the Guidelines on Road Classification 2009 by the Ministry of Works and Human Settlement, the road network is classified into the following road types:

(a) National highways
(b) Dzongkhag roads
(c) Farm roads
(d) Thromde roads (urban roads)
(e) Access roads for approach to public and private projects and properties

Road development in Bhutan is governed by a number of legislations and guidelines. The Road Act of the Kingdom of Bhutan 2004 defines the institutional arrangements for administration and control of roads, rights and ownership over roads, financing modalities, and technical standards including traffic safety, environmental safeguards, and geologic stability.To facilitate the integration of environmental considerations, the Department of Roads has formulated environmental codes of practices for road planning, design and construction.

The overall executive and coordination functions for roads are vested in the Department of Roads, Ministry of Works and Human Settlement. Depending on the road type, operational and technical functions are carried out by various agencies in the line ministries and at the dzongkhag level.

While roads in general are vulnerable to climate change in Bhutan, it is the farm roads that are most vulnerable among all road types. This is largely because they are constructed with rudimentary planning and engineering works as a result of limited financial and human resources available for building such roads. On the other hand, farm roads, along with electricity, are among the most critical infrastructure for the enhancement of rural economy and poverty reduction, which is the overarching development goal of government plans and policies. Their importance and relevance go beyond just the purpose of connecting farm lands with the main roads. They also provide access to many rural development infrastructures such as schools, health care facilities, local government offices, and agricultural extension centers, and enhance delivery of public services to the many scattered and remote rural settlements.

Farm roads constitute the largest proportion of all road types, making up nearly 40 percent of the road network in the country (see Table 11 below).

Table 11: Types of Roads in Bhutan (length and % of total road network)

Road type	Length (km)	% of total road network
Primary national highway (incl. expressway)	1,763.39	21.1
Secondary national highway	516.35	6.2
Dzongkhag roads	1,127.00	13.4
Thromde (urban) roads	304.87	3.6
Farm roads	3,289.67	39.2
Other roads (forest roads, access roads, power tiller tracks)	1,380.32	16.5
	8,381.60	**100.0**

Source: Bhutan Road Network Information, June 2011, Department of Roads, Ministry of Works and Human Settlement

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Note: There is slight discrepancy in farm road figures. The national inventory of farm roads, June 2011, by the Department of Agriculture, Ministry of Agriculture and Forests shows a higher figure of 3,665.34 km.

According to the national inventory of farm roads 2011, the existing network of farm roads directly benefits 42,853 rural households. Based on average household size of 4.6 members(Population and Housing Census 2005), this translates to a population of 197,124, which is about 28 percent of the country's projected population of 708,265 in 2011 (the year the inventory was conducted) (National Statistics Bureau). In addition, there are many co-beneficiaries who have not yet been quantified. These include geog government staff, dzongkhag and central government staff who have to undertake work-related travel to rural areas, urban residents who have ancestral homes in the villages, and private entrepreneurs engaged in agricultural business.

The Department of Agriculture, Ministry of Agriculture and Forests, through its Engineering Division provides technical guidance and overall monitoring for implementation of standards for development of farm roads. The Dzongkhag Administrations are responsible for field planning and monitoring of development of farm roads, which are generally contracted out to local private construction companies for construction. Routine maintenance, after completion and hand over of farm roads by private contractors, is to be done by the beneficiary communities. If major maintenance or restoration becomes necessary due to emergency incidents such as flashfloods and landslides, government support is to be provided.

The planning, construction and maintenance of farm roads are to take place according to the Guidelines for Farm Road Development produced in 2009 (first version produced in 2003) by the Department of Agriculture, Ministry of Agriculture and Forests. Table 12 below presents the policies, acts and regulations related to road development in Bhutan.

Table 12: Road sector-related Policies, Legislations and Regulations

S. No.	Name	Date Effective	Agency	Contents
1.	The Road Act of the Kingdom of Bhutan	2004	Department of Roads, Ministry of Works and Human Settlement	The Act *inter alia* defines institutional powers and functions for road planning, construction, and maintenance at various levels, and outlines requisite technical standards, including environmental and geo-technical considerations.
2.	Environmental Assessment Act	2000	National Environment Commission	Makes environmental assessment and environmental clearance mandatory for all policies, plans, programmes and projects, in particular infrastructure development such as roads, which have potentially adverse environmental impacts.
3.	Regulations for Environmental Clearance of Projects	2002	National Environment Commission	As a supporting regulation to the Environmental Assessment Act 2000, stipulates procedures and responsibilities for environmental clearance of development projects, in particular those involving infrastructure development such as roads.

3.1.2 Selected Technology

With the above background, together with extensive stakeholder discussions, in the Part I of the TNA report, 7 technologies for climate change adaptation in Bhutan were shortlisted for the natural resources and infrastructure sector. Out of these, 3 technologies were selected through an extensive multi-criteria decision analysis (MCDA),that was used to prioritize technologies through a process that was country-driven, participatory and involved a number of stakeholders. A three day workshop for criteria weighting and technology prioritization was held at Paro, Bhutan.

Real-time weather stations and weather forecasting (multi-range), climate resilient roads and community-based early warning systems are the prioritized technologies for natural disasters and infrastructure sector. Further information on these technologies is contained in the TNA report.

Out of these three technologies, climate resilient farm road development wasselected as the preferred technology for preparation of barrier analysis, enabling framework and technology action plan under the natural disasters and infrastructure sector. This is because it is aligned with the government's road policy and legislation that advocates environment-friendly road construction. However, implementation of the same in Bhutan so far has been weak because of a number of barriers such as inadequate knowledge, skills, demonstrational measures, and equipment. Creation of a detailed enabling framework and TAP for the technology will definitely help in overcoming many of these barriers and allow it to be scaled up in the nation. Furthermore, the other two top-priority technologies – i.e. real-time weather stations and early warning systems – under this sector were already being planned for implementation through projects supported by the Japan International Cooperation Agency (JICA) and UNDP/GEF/LDCF as a part of the NAPA2 follow-up.

3.2 Action Plan for Climate Resilient Farm Roads

3.2.1 About Climate Resilient Roads

Climate-resilient road development technology refers to a set of technological measures that take into account local climate conditions and vulnerabilities in planning, design and construction. The most effective method of making roads climate-resilient is to anticipate and fully consider climate change impacts during the planning stage and integrate resilience measures in the design using local climate information in combination with geophysical information.

The measures to make roads climate proof are generally classified in the following categories[4]:

Engineering and structural measures: Under these measures the technologies typically include the following:

- Slope stabilization structures such as dry stone wall, gabion wall and jute bag wall. The choice of the structure is dependent on the gradient of the road and road construction materials and *in situ* soil condition
- Paving of roads with durable materials;
- Proper alignment of new roads to avoid vegetative loss, steep gradient and fragile terrain;
- Improved drainage systems to avoid erosion of road materials and the road section/stretch itself. The drainage system includes roadside drainage and cross drainage structures such as cascades, small check dams, culverts and causeway;
- Improved planning of roads with proper cross section and standard dimensions;

[4] http://www2.adb.org/Documents/RRPs/CAM/42334/42334-01-cam-oth-03.pdf

- Improved survey and design techniques with adequate considerations for Environment Friendly Construction Technologies;
- Adequate geological and geotechnical considerations.

Bio-engineering measures: This involves the use of vegetation, either alone or in conjunction with civil engineering structures(Howell, et al)[5] such as small check dams, wall and drains to manage water and debris thereby reducing instability and erosion on slopes (Paudyal 2007)[6]. Bio-engineering measures are also taken during earthwork and excavation activities of road construction. These include among others spreading of top soil, broadcasting seeds, grass slips and seedling of local plants. Typical bio-engineering methods include the following:

Grass Planting- Grass seed is spread or alternatively grass is hand-planted in lines across the slope. This results in slope stabilization by armouring and reinforcing of slopes.

Shrub and Tree Planting- Shrubs or trees are planted at regular intervals on the slope which later create a dense network of roots in the soil supporting the slope.

Brush Layering, Palisades and Fascines- In this system, woody cuttings are laid in lines across the slope usually following the contour which form a strong barrier, preventing the development of rill, and trap material moving down the slope. The system catches debris, armours and reinforces the slope.

Composite Systems- A range of composite systems are also used including live check dams, vegetated stone pitching and planted geo-textiles later supplemented by the vegetation. The composite systems reinforce the soil thereby stabilising the slopes.

Integration of local climate and geologic information in planning and design: This is a critical aspect of climate-resilient road development and will influence the choice and design of civil work structures and bioengineering measures to be put in place.

As a terminology, climate-resilient road development is being introduced recently but conceptually it is not completely new to the country. It has to certain extent existed in the form of "environment-friendly road construction", or EFRC in short, a concept and term that has been in circulation in the country's road construction parlance since 1999. EFRC concept was adopted as an integral component of the Rural Access Project (RAP), started in 1999/2000 with funds from World Bank and technical support of the Netherlands Development Organization (SNV). The RAP has covered more than 250 km of rural roads using EFRC approach and practices, and led to the commencement of a second RAP in 2008. Many other road construction projects have also applied EFRC but largely in partial or piecemeal fashion.

During the course of stakeholder consultations for the Technology Needs Assessment and Technology Action Plan, it was inferred that EFRC was somewhat of a misnomer as road construction can never be environment-friendly but can only go to the extent of employing practices and measures to minimize adverse environmental impacts. 'Climate-resilient road development' was identified as a more suitable terminology for the TNA and TAP.

3.2.2 Target for technology transfer and diffusion

The Road Master Plan (2007-2027), produced by the Ministry of Works and Human Settlement, reflects a national target of 2,654.4 km of dzongkhag roads (formerly feeder roads), 537 km of inter-dzongkhag highways, and 794 km of national highway. The master plan does not project any target for farm roads.

The goal will be to make the whole of country's farm road network climate-resilient. Discussions with representatives from the Department of Agriculture, Ministry of Agriculture and Forests, suggest that the farm road target for 11th Five-Year Plan target (June 2013-July 2018) could be used for the TAP. This target is, however, under discussion at this point in time and expected to be finalized in the next 2-3 months. For pilot projects to implement and demonstrate the full-range of climate-resilient farm road development technology,

[5] http://himachal.nic.in/hpridc/RandD.pdf
[6] http://www.scidev.net/en/features/landslide-victory-bioengineering-in-nepal.html

15-20 km of farm roads, covering construction of new farm roads as well as improvement of existing farm roads, in each Dzongkhag is proposed for the next five-years, coinciding with the 11th Five-Year Plan period. This translates to a national target of 300-400 km of farm roads over a period of five years.

3.2.3 Barriers to the technology's diffusion

Given the current situation in Bhutan with regard to development climate resilient farm roads, in the course of TNA process several barriers have been identified. These barriers are either economic barriers or non financial barriers. The non financial barriers are mostly those associated with the limitations of the current institutional structure, the current policy and regulatory framework or those associated with social, cultural and behavioral barriers with regard to development of climate resilient roads. Based on these identified barriers, suitable enabling measures which will assist the country in overcoming these barriers have also been identified. A brief summary of these barriers and enabling measures is presented here below. These enabling measures have further been defined and elaborated on with concrete action for each in the next section of this report.

3.2.3.1 Economic and financial barriers

The main barrier for climate-resilient farm roads is the huge upfront costs for detailed planning and design, entailing not only well-trained personnel but also advanced survey and engineering equipment, and use of robust construction materials. The Project Appraisal Document of the Second Rural Access Project has cited an additional capital cost of 20-30 percent for roads using EFRC approach and practices. Integrating climate-resilience measures will further raise the cost of building roads. Whilst environmental codes of practice exist for road construction, they are generally not applied unless environmental management costs are built in as in the case of specially funded projects, such as those by the World Bank and Asian Development Bank, where environmental and social safeguards are conditional for securing funds. According to the Guidelines for Farm Road Development, Nu 3 million (around USD 57,000) is estimated for construction of each km of farm road integrating basic environmental measures (World Bank 2006). In practice, that kind of budget is very rarely available for farm road construction. Furthermore, in sites where climate and geophysical conditions are more difficult, even Nu 3 million(around USD 57,000) per km is reportedly far from adequate[7].

3.2.3.2 Non financial barriers

a) **Institutional barrier:** A key institutional issue is the poor coordination and line of communication between the Department of Agriculture/ Ministry of Agriculture and Forests and the Dzongkhag Administrations, where the Dzongkhag Engineers are based work-wise. The Dzongkhag Administrations have no clear institutionalized working linkages with the Department of Agriculture. As a result, coordination between the two agencies has been poor and this has among other things impacted proper implementation of farm road development guidelines and technical standards.

   Most Dzongkhag engineering sections are short-staffed and ill-equipped to carry out proper planning and design of farm roads, and monitor construction work. This constraint is further exacerbated by the lack of knowledge and skills among the private contractors to carry out environment-friendly/ climate-resilient road construction.

   Another major institutional issue is the role of Dzongkhag Administrations in environmental assessment and environmental clearance. Currently, farm roads are planned by Dzongkhag Engineers and Dzongkhag Agriculture Officers and Geog Administrations, environmental assessment and collation of information for environmental clearance of farm roads up to 5 km are done by Dzongkhag Environmental Officers, followed by review of application for environmental clearance by the Dzongkhag Environment Committees. So, the entire procedure of planning, environmental assessment, review, and environmental clearance is housed within a single agency, i.e. the Dzongkhag Administration. This presents a great risk of 'conflict of interests' and undermining the purpose and value of environmental assessment and environmental clearance, which is a crucial procedural

[7]Stakeholder consultation session for TAP for climate-resilient farm road development, 10th October 2012, NECS conference hall.

framework for ensuring that recommended technical and environmental standards are implemented in the development of farm roads.

b) **Policy, legal and regulatory barrier:**Currently, there is no national road development policy. The road master plan (2007-2027) which exists focuses on operational plans and targets for dzongkhag (feeder) roads, inter-dzongkhag highways, and national highway and does not feature other road types. The Road Act 2004 advocates that roads need to be constructed in environmentally sound manner but it lacks comprehensive provisions on how this will need to be implemented.There is no clear-cut policy or legal provision for compensation/ land substitution for acquisition of private land to build farm roads.

c) **Technical barrier**: Environmental codes of practice for roads and highways were developed in 2002, and are inadequate in terms of outlining specific practices for planning and designing climate-resilience in roads. The Guidelines for Farm Road Development 2009 is also deficient when it comes to technical standards for climate proofing of farm roads.

Field interventions that demonstrate the full range of climate-resilient farm road development technology are also limited. Thus, there is insufficient basis on the ground for developing cases for replication and scaling-up.A major technical barrier is also the unavailability of local meteorological data for use in planning and designing farm roads. This is largely due to the limited network of meteorological stations.

d) **Social, cultural and behavioral barrier**: Developing climate-resilient farm roads will require meticulous planning and implementation of construction standards and additional funds than what is normally available. However, public demand for farm roads is enormous. Consequently, ambitious targets for farm roads have been set in the ongoing 10th Five-Year Plan (July 2008-June 2013). These are, in most dzongkhags, not commensurate with the implementation capacity. Nonetheless, due to relentless public demand and consequent political pressure, the attempt is to build more and more farm roads with limited human and financial resources.

Furthermore, there is the misconception that climate-resilient or environment-friendly roads are very expensive and beyond the financial means of a country like Bhutan with scarce budget. This is mostly because lack of life cycle cost analysis or understanding of the analysis while planning for climate resilient farm roads. There is, also, no country-specific evidence providing quantified data of comparative costs and benefits of climate-resilient roads, which can be used to sensitize the stakeholders, and inform investment decisions.

3.2.4 Enabling measures

Based on intensive discussions with experts, extensive secondary research as well as international experience, measures for building an enabling environment for development and diffusion of the technology in a way to overcome the above barriers have been identified. These measures include:

Economic and financial measures to overcome barriers to development and diffusion of drought and pest resistant varieties of crops

It is recommended the budget for farm road development be rationalized in accordance with the technical standards required for climate-resilience. In this respect, the following activities are proposed:

- Review existing costs and budget for farm road development in relation to the recommended technical standards for farm roads, include those required for climate-resilience, and come up with specific recommendations;
- Convene inter-agency meetings/ workshops to discuss the review findings and implementation of recommendations;
- Produce and disseminate farm road budgeting guidelines for implementation together with the technical standards.

Non financial measures

The following measures are recommended to address the non-financial barriers associated with environment-friendly/ climate-resilient roads:

Institutional Measures: Inter-agency coordination and working linkages need to be developed and strengthened, in particular between the Engineering Division, Department of Agriculture/ Ministry of Agriculture and Forests. To achieve this, the following activities are proposed:

- Review existing institutional arrangements for farm road development, analyze the gaps and come up with recommendations for strengthening coordination and institutional linkages;
- Convene inter-agency meetings/ workshops to discuss the review findings and implementation of recommendations;
- Incorporate the recommendations in the Farm Road Development Guidelines.

Institutional capacity of the Engineering Division of DoA/MoAF and Dzongkhag Engineering Sectors will also need to be strengthened. This would involve: staff training for DoA/MoAF and Dzongkhag Engineers; equipment support to the Dzongkhag Engineering Sectors; review of existing staffing structure for engineering works at dzongkhag and development of dzongkhag staffing plan for engineering works based on the scale and nature of work; and deployment of engineering staff according to the dzongkhag staffing plan for engineering works

Policy Measures: Climate-resilience mainstreaming in road development policies and guidelines requires to be enhanced. This will require a review to examine to what existing policies and guidelines relevant to road development address climate-resilience aspect and come up with specific recommendations to comprehensively integrate this aspect in the policies and guidelines.

There is also the need for clear policy/ legal provisions with regards to compensation/ land substitution for private land acquisition for farm roads. It is proposed that a review be carried out to examine the policy/ legal framework for land acquisition and come up with recommendations to address the issue of compensation/ land substitution for private land acquisition for farm roads

Information and Awareness: Information and country evidences to support the case for climate-resilient farm road development need to be developed. To do so, it is proposed that case studies be carried out to examine and highlight comprehensive (economic, social and environmental) costs and benefits of climate-resilient farm roads vis a vis roads that do not integrate climate-resilient measures and environmental standards.

Using the case studies as country evidences, conduct sensitization, advocacy and awareness-building activities for the following (but not limited to) target audiences: (a) policy-makers; (b) parliamentarians; (c) dzongkhag administrations; (d) gewog administrations. In addition, the case studies can be used to produce a video to highlight the various adverse impacts of poorly-built farm roads and the importance and benefits of climate-resilient farm roads, and broadcast it through TV.

Technical Measures: To demonstrate the full range of climate-resilient farm road development technology, pilot projects are proposed. This will entail selection of pilot sites using multiple criteria, including poverty reduction, population size, and climate impacts. It is proposed that the full-range of climate-resilient farm road development technology be implemented in pilot sites at the rate of 15-20 km per Dzongkhag. Targets may include both new farm roads as well as existing farm roads that require to be improved for climate-resilience.

Concurrently, activities will need to be undertaken to strengthen the technical know-how and skills among various people who will have a role in the planning, design and construction of climate-resilient farm roads. This will involve dissemination of technical know-how and skills through training and provision of knowledge resources (toolkit, handbook, reference materials, etc). Target audience for dissemination of technical know-how and skills include private contractors, private engineers, site supervisors and machine operators (Government staff not included here as they can be covered through staff training mentioned as part of institutional strengthening measures).

3.2.5 Proposed Action Plan for Farm Roads Development

In order to develop a most relevant action plan for diffusion of climate resilient farm roads focused sector specific roundtable discussions were held in Thimphu, Bhutan at NEC. The roundtable participants consisted of sectoral experts and representatives from Department of Agriculture under MOAF, Royal Government of

Bhutan and Department of Roads, Ministry of Works and Human Settlement. Through a technology specific presentation, the roundtable had intensive discussions, which focused on following aspects:

- *Overview of infrastructure sector*- discussions were held on relevant institutions, stakeholder networks, policies, acts and regulations governing the sector and likely to facilitate diffusions of farm roads
- *General sector barriers and measures*- this brought forward discussions on general profile of barriers faced in the infrastructure sector and the kind of measures that are needed to overcome them.
- *Defining the technology domain:* special focus was given to discussion in terms of defining the technology in a most relevant way given the national circumstances of Bhutan
- *Targets for technology transfer and diffusion*- specific targets were identified for farm road diffusion. These were based government plans and documents, particularly the 11th FYP and any ongoing or planned government programme for diffusion of these varieties.
- *Barriers to diffusion of farm roads*- barriers as identified in Part II of the TNA report, were again revisited along with specific enabling measures to overcome them.
- *Proposed Action Plan Framework for Technology diffusion*- a draft action plan framework was presented and discussed in detail to aggregate and rationalize the measures identified to develop national capacities for acceleration of technology diffusion. The discussion also prioritized and characterized measures for technology diffusion for a national action plan along with estimates of possible technology investment costs.

Based on discussions held at the roundtable, a revised national strategy/action plan was prepared and sent to roundtable participants, especially to the Ministries, for review and comments. Based on which a final prioritized action plan along with national strategy was prepared.

The section brings together the Action Plan which is reflective of the national priorities as those highlighted in the Government of Bhutan Plans, such as the 11th FYP as well as those felt most urgent by TNA Taskforce members and Bhutanese experts.

The Action Plan and thereby the national strategy formulation for the diffusion of farm roads is reflective of national priorities. The budgets of each of these action points are those provided by the Ministries.

a) Aggregation and rationalization of measures identified for technology acceleration

The list of measures identified for formulation of a national strategy to accelerate the development and transfer of technologies can be seen in Table 13 below.

Table 13: Measures for strategy formulation- Farm roads

Strategic measure	Accelerating innovation RD&D	Accelerating deployment	Accelerating diffusion
Economic and Financial Measure			
Rationalize the budget for farm road development in accordance with the technical standards for climate-resilience	X	X	X
Non Financial Measures			
Institutional			
Strengthen inter-agency coordination and working linkages for farm road development	XX	XX	XX

Institutional strengthening of the Engineering Division of DoA/MoAF and Dzongkhag Engineering Sectors		X	XX
Streamline environmental assessment and environmental clearance procedures at the dzongkhag level so that the risk of 'conflict of interests' is eliminated.		X	X
Policy, Legal and regulatory			
Climate-resilience mainstreaming in road development policies and guidelines	X	X	X
Develop clear policy/ legal provisions with regards to compensation/ land substitution for private land acquisition for farm roads		x	X
Information and Awareness			
Develop information and country evidences to support the case for climate-resilient farm road development	X	X	X
Conduct sensitization, advocacy and awareness-building activities to support climate-resilient farm road development		X	X
Technical			
Pilot projects to demonstrate the full range of climate-resilient farm road development technology, covering construction of new farm roads as well as improvement of existing farm roads that lack climate-resilience.		X	X
Strengthen technical know-how and skills among various people who will have a role in the planning, design and construction of climate-resilient farm roads		X	X

* Note: This table illustrates for a strategy of acceleration measures according to letters of each square, using the timescale for completion of an action, where:

- Letter "X" refers to measures which need to be started in the short term and carried out within the next five years;

- Letter "XX" refers to measures which can be completed in up to 10 years;

- Letter "XXX" refers to measures longer-term measures which can be planned for completion within 15 years from the current date and also will be used for other technologies below.

b) Prioritization and characterization of technology acceleration measures for a national plan

Based on the barriers and the enabling measures required for development and diffusion of farm roads in Bhutan, the key action points that are essential and immediate are described in Table 14. These action points are organized in priority, in order to convey the importance of action required.

The proposed measures are aligned with the 11th Five Year Plan of Royal Government of Bhutan to ensure that these measures receive required policy and funding support of the Government.

The Action Plan Table constitutes of 10 key measures:

- Rationalization of the budget for farm road development in accordance with the technical standards for climate-resilience;
- Strengthening inter-agency coordination and working linkages for farm road development;
- Institutional strengthening of the Engineering Division of DoA/MoAF and Dzongkhag Engineering Sectors;
- Streamlining environmental assessment and environmental clearance procedures at the dzongkhag level so that the risk of 'conflict of interests' is eliminated;
- Climate-resilience mainstreaming in road development policies and guidelines;
- Development of clear policy/ legal provisions with regards to compensation/ land substitution for private land acquisition for farm roads;
- Development of information and country evidences (cost-benefit analyses) to support the case for climate-resilient farm road development;
- Sensitization, advocacy and awareness-building activities to support climate-resilient farm road development;
- Pilot projects to demonstrate the full range of climate-resilient farm road development technology, covering construction of new farm roads as well as improvement of existing farm roads that lack climate-resilience;
- Development of technical know-how and skills among various people who will have a role in the planning, design and construction of climate-resilient farm roads.

The rationale, implementing agency(ies), approach, timeframe, indicators of success, and indicative budget for the aforesaid measures are outlined in the following table:

Table 14: Technology Action Plan for farm roads development based on measures identified for technology acceleration (in priority)

S.No	Measure	Why is it important?	Who should do it?	How should they do it?	Time-scale	Monitoring, reporting and verification for measure	Indicators of Success	Budget (000' USD)
1.	Rationalize the budget for farm road development in accordance with the technical standards for climate-resilience	Inadequate budget compromises the implementation of recommended technical standards, which in turn leads to poor quality of roads and consequently higher costs of maintenance and restoration	DoA/MoAF, MoF, GNHC	§ Review existing costs and budget for farm road development in relation to the recommended technical standards for farm roads, including those required for climate-resilience, and come up with specific recommendations; § Convene inter-agency meetings/ workshops to discuss the review findings and implementation of recommendations; § Produce and disseminate farm road budgeting guidelines for implementation together with the technical standards.	2013-2014	MoAF, MoF, GNHC	Number of farm roads constructed with adequate budget for climate-resilience	35
2.	Strengthen inter-agency coordination and working linkages for farm road development	Weak institutional linkages and coordination between DoA/MoAF and Dzongkhag Administrations have led to non-conformity with guidelines and standards for farm road development	DoA/MoAF, MoWHS, Dzongkhag Administrations/ MoHCA	§ Review existing institutional arrangements for farm road development, analyze the gaps and come up with recommendations for strengthening coordination and institutional linkages; § Convene inter-agency meetings/ workshops to discuss the review findings and implementation of recommendations; § Incorporate the recommendations in the Farm Road Development Guidelines	2013-2015	MoAF and MoWHS	Level of coordination between DoA/MoAF and Dzongkhag Administrations	13
3.	Institutional strengthening of the Engineering Division of DoA/MoAF and Dzongkhag Engineering Sectors	The institutional capacity of DoA/MoAF and Dzongkhag Engineering Sectors is limited for climate-resilient farm road development	MoAF, MoWHS and RCSC,	§ Staff training for DoA/MoWHS and Dzongkhag Engineers § Equipment support to the Dzongkhag Engineering Sectors § Review of existing staffing structure for engineering works at dzongkhag and development of dzongkhag staffing plan for engineering works based on the scale and nature of work § Deployment of engineering staff according to the dzongkhag staffing plan for engineering works	2013-2018	MoAF and MoWHS	§ Proportion of staff in DoA/MoAF and Dzongkhag Engineering Sectors with improved knowledge and skills	420

							for climate-resilient farm road development § Staff strength of Dzongkhag Engineering Sectors proportionate to the scale and nature of works	
4.	Streamline environmental assessment and environmental clearance procedures at the dzongkhag level so that the risk of 'conflict of interests' is eliminated.	Existing in-house procedures of planning, environmental assessment, review, and environmental clearance (for farm roads up to 5 km) within the Dzongkhag Administration present the risk of 'conflict of interests' and undermining the value and purpose of environmental assessment and clearance	NECS and DoA/MoAF	§ Review existing procedures for environmental assessment and environmental clearance, and come up with recommendations to streamline the procedure to remove the risk of 'conflict of interests'; § Revise the procedures as per the recommendations, and incorporate these revisions in all relevant guidelines and planning frameworks.	2013-14	NECS	Effectiveness of environmental assessment and clearance procedures in improving the quality of farm roads	15
5.	Climate-resilience mainstreaming in road	Current policies and guidelines for roads cover environmental management in generic sense but do not sufficiently address	MoAF, GNHC, NEC	Examine to what existing policies and guidelines relevant to road development address climate-resilience aspect and come up with specific recommendations to comprehensively integrate this	2013-2015	GNHC and NEC	Coverage of climate-resilience aspect in	15,000

	development policies and guidelines	climate resilience aspect in specific terms.		aspect in the policies and guidelines			policies and guidelines relevant to roads	
6.	Develop clear policy/ legal provisions with regards to compensation / land substitution for private land acquisition for farm roads	Ambiguity in policy/ legal provisions with regards to compensation/ land substitution for private land acquisition for farm roads is an impediment to proper alignment and planning of farm roads	NLC, MoAF, GNHC	Examine the policy/ legal framework for land acquisition and come up with recommendations to address the issue of compensation/ land substitution for private land acquisition for farm roads	2013-2015	NLC and GNHC	Existence of clear policy/ legal provisions on compensation/ land substitution for private land acquisition for farm roads	15
7.	Develop information and country evidences to support the case for climate-resilient farm road development	The need to strengthen information, which is currently weak, to support the case for climate-resilient farm road development	DoA/MoAF	Conduct case studies to examine and highlight comprehensive (economic, social and environmental) costs and benefits of climate-resilient farm roads vis a vis roads that do not integrate climate-resilient measures and environmental standards.	2013-2015	MoAF	Availability of information and country evidences to comprehensively support the case for climate-resilient farm road development	60
8.	Conduct	The need to create larger and	DoA/MoAF	§ Using the case studies as country evidences, conduct sensitization, advocacy and awareness-	2015-	MoAF	Level of	100

	sensitization, advocacy and awareness-building activities to support climate-resilient farm road development	deeper understanding of the comparative advantages of climate-resilient farm roads, and influence the public and political opinion for moderation of road construction targets commensurate with available human resource and financial capacities		building activities for the following (but not limited to) target audiences: (a) policy-makers; (b) parliamentarians; (c) dzongkhag administrations; (d) gewog administrations; § Using the case studies, produce a video to highlight the various adverse impacts of poorly-built farm roads and the importance and benefits of climate-resilient farm roads, and broadcast it through TV.	2018		awareness and support for climate-resilient farm roads at the level of policy-makers, parliamentarians, and local governments.	
9	Pilot projects to demonstrate the full range of climate-resilient farm road development technology, covering construction of new farm roads as well as improvement of existing farm roads that lack climate-resilience.	The need to demonstrate the technology and provide the ground basis for replication and scaling-up, and to influence future policy work	DoA/MoAF and Dzongkhag Administrations	§ Select pilot sites using multiple criteria, including poverty reduction, population size, and climate impacts. § Implement the full-range of climate-resilient farm road development technology in the pilot sites at the rate of 15-20 km per dzongkhag. Targets may include both new farm roads as well as existing farm roads that require to be improved for climate-resilience.	2013-2018	MoAF and GNHC	Number of climate-resilient farm roads established in the field	18,000

10.	Strengthen technical know-how and skills among various people who will have a role in the planning, design and construction of climate-resilient farm roads	The need to strengthen technical knowledge and skills for climate-resilient farm road development	DoA/MoAF and Dzongkhag Administrations	Disseminate technical know-how and skills through training and provision of knowledge resources (toolkit, handbook, reference materials, etc). Target audience for dissemination of technical know-how and skills include private contractors, private engineers, site supervisors and machine operators (Gov't staff not included here as they can be covered through staff training mentioned as part of institutional strengthening measures)	2013-2018	MoAF	Proportion of private contractors, private engineers, site supervisors, and machine operators with technical knowhow and skills for climate-resilient farm roads	300
								18,973

Acronyms used in the table: DoA- Department of Agriculture; **GNHC-** Gross National Happiness Commission; **MoAF-** Ministry of Agriculture and Forests; **MoF-** Ministry of Finance; **MoHCA-** Ministry of Home and Cultural Affairs; **MoWHS**- Ministry of Works and Human Settlement; **NEC-** National Environment Commission; **NLC-** National Land Commission; **RCSC-** Royal Civil Service Commission.

c) Finalizing national strategy

Based on priority technology action plans in the sub-sectors, a national strategy and action plan for the climate resilient farm roadtargets are presented in Table 15.

Table 15: National Strategy for Farm roads (technology transfer and development for adaptation)

Timeline	0-5 years	5-10 years	10-15 years
Large-scale, short-term technology			
Rationalize the budget for farm road development in accordance with the technical standards for climate-resilience	X		
Strengthen inter-agency coordination and working linkages for farm road development	X		
Institutional strengthening of the Engineering Division of DoA/MoAF and Dzongkhag Engineering Sectors	X	X	X
Streamline environmental assessment and environmental clearance procedures at the dzongkhag level so that the risk of 'conflict of interests' is eliminated.	X	X	
Climate-resilience mainstreaming in road development policies and guidelines	X		
Develop clear policy/ legal provisions with regards to compensation/ land substitution for private land acquisition for farm roads	X		
Develop information and country evidences to support the case for climate-resilient farm road development	X		
Conduct sensitization, advocacy and awareness-building activities to support climate-resilient farm road development	X	X	
Pilot projects to demonstrate the full range of climate-resilient farm road development technology, covering construction of new farm roads as well as improvement of existing farm roads that lack climate-resilience.	X		
Strengthen technical know-how and skills among various people who will have a role in the planning, design and construction of climate-resilient farm roads	X		

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Annex I. List of Stakeholders consulted

Several stakeholders were consulted in the process of preparation of the current Technology Action Plan Report. The list of stakeholders consulted along with their details is provided below.

S. No.	Name	Organization	Type of Consultation	Topics consulted for
1.	Birkha B. Chhetri, General Secretary	Association of Bhutanese Industries	Roundtable discussions and one on one interview	Industries
2.	Chhimi Dorji, Deputy Executive Engineer	Department of Hydro Meteorology Services	Roundtable discussions and one on one interview	Water, Agriculture
3.	Chhimi Rinzin, Chief Agriculture Officer	Department of Agriculture	Roundtable discussions	Agriculture
4.	Dawa Chogyel, Deputy Chief Environment Officer (EU-DOI),	Ministry of Economic Affairs	Roundtable discussions	
5.	G K Chhopel, Chief, Water Resources Division	National Environment Commission Secretariat	Roundtable discussions and one to one interview	Water
6.	Tek Nath Kararia, Civil Engineer	Thimphu Thromde	Roundtable discussions	Waste
7.	Gyembo Tenzin, Deputy Executive Engineer	Department of Agriculture	Roundtable discussions	Agriculture
8.	Jigme Nidup, Senior Environment Officer	National Environment Commission Secretariat	Roundtable discussions	Farmroads
9.	K. P Bhandari, DGM (plant)	SKW Tashi Metals	Roundtable discussions	Industries
10.	Karma Pemba, Chief Transport Officer	Road Surface and Transport Authority	Roundtable discussions and one to one interview	Transport
11.	Karma Tshethar	Department of Agriculture	Roundtable discussions	Agriculture
12.	Kunzang Choden, Senior Research Officer	Council of RNR Research in Bhutan	Roundtable discussions and one to one interactions	Water, Agriculture
13.	Nima Dorji, Engineer	Department of Agriculture	Roundtable discussion	Water, Agriculture

14.	Namgay Thinley, Deputy Chief Horticulture Officer	Department of Agriculture	Roundtable discussion	Agriculture
15.	Prem P. Adhikari, Senior Transport Officer	Road Safety and Transport Authority	Roundtable discussion	Transport
16.	Sherab Jamtsho, Deputy Executive Engineer	Department of Renewable Energy	Roundtable discussion	Industries
17.	Subarna Sharma, General Manager	Ugen Ferro Alloy Pvt Ltd	Roundtable discussion	Industries
18.	Tashi Dorji, Head of Administration	SKW Tashi Metals	Roundtable discussion	Industries
19.	Tashi Wangdi, Senior Manager	Bhutan Ferro Alloys Ltd	Roundtable discussion	Industries
20.	Tenzin Khorlo, Chief Environment Officer	National Envrionment Commission Secretariat	Roundtable discussion	Waste
21.	Thinley Dorji, Chief, Compliance Monitoring Division	National Environment Commission Secretariat	Roundtable discussion	
22.	Trashi Namgyel, Hydromet Officer	Department of Hydro Meteorology Services	Roundtable discussion	Water
23.	Tshering Yangchen, Assitant Environment Officer	Thimphu Thromde	Roundtable discussion	Waste
24.	Yeshey Penjor	Independent consultant	Roundtable discussion and one to one interview	Waste
25.	Tshering Wangchuk, Program Officer		Roundtable discussion	
26.	Tshewang Lhamo, Environment Officer		Roundtable discussion	