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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.,

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2011)². Drip irrigation is an interesting choice however, one needs to customize 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 target of 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

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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

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

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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

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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 of drip 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 immediate are 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 12 th 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	

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	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

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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
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				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

Kingdom of Bhutan*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			
<i>Drip and Sprinkler Irrigation</i>			
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	