Republic of Rwanda

TECHNOLOGY ACTION PLANS FOR CLIMATE CHANGE MITIGATION and ADAPTATION

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LIST OF ACRONYMS

ABFD: Abu Dhabi Fund for Development

AfDB: African Development Bank

APH: Air Preheated Exhaust gases

BADEA: Arab Bank for Economic Development in Africa

BRALIRWA: Brasserie et Limonaderie du Rwanda

BSP: Biomass-fired Steam Power

BTA: Biogas Thermal Applications

CC: Climate Change

CCGT: Combined Cycle Gas Turbine

CCGT: Combined Cycle Gas Turbine

CCI: Cross Cutting Issues

CCS: Carbon Capture, Storage and Sequestration

CH_4: Methane Gas

CO: Carbon Monoxide

CO_2: Carbon Dioxide

CSP: Concentrated Solar Power

CTB: Cooperation Technique Belge

ESMAP: Energy Sector Management Assistance Programme

EU: European Union

EWASA: Energy, Water and Sanitation Authority

GEF: Global Environmental Facility

Gg: Gigagrams

GHG: Green House Gases

GIZ: Germany International Cooperation

GoR: Government of Rwanda

GWh: Gigawatt hour

HRSB: Heat Recovery Steam-Gases Boiler

IGCC: Integrated Gasification Combined Cycle

IRENA: International renewable energy agency

JICA: Japan International Cooperation Agency

KOICA: Korea International Cooperation Agency

KWh: Kilowatt hour

MINAGRI: Ministry of Agriculture and Animal Resources

MINECOFIN: Ministry of Economic Development and Finance

MINEDUC: Ministry of Education

MINICOM: Ministry of Commerce

MININFRA: Ministry of Infrastructure

MINIRENA: Ministry of Natural Resources

MWh: Megawatt hour

MWP: Mini Wind Power

N_2O: Nitrous Oxide

NOx: Oxide Nitrogen

PHEV: Plug-in-hybrid Electric Vehicles

PSH: Pumped Storage Hydropower

PV: Photovoltaic

RAB: Rwanda Agriculture Board

RDB:Rwanda Development Board

REMA: Rwanda Environmental Management Authority

RENGOF: Rwanda Environmental NGOs Forum

RNRA: Rwanda Natural Resources Authority

RURA: Rwanda Utility Regulatory Agency

SHP: Small Hydropower

SNC: Second National Communication on Climate Change under the UNFCCC

SONARWA: Société Nouvelle d'Assurance du Rwanda

SOx: Sulphuric Oxides

TNA: Technology Needs Assessment

UNEP: United Nations Environmental Programme

UNFCCC: United Nations Framework Convention on Climate Change

URC: UNEP Risoe Centre

WB: World Bank

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FOREWORD

Technology transfer has been under focus since the Rio Summit in 1992, where issues related to technology transfer were included in Agenda 21 as well as in the United Nations Framework Convention on Climate Change.

Technology Need Assessment (TNA) project in Rwanda was intended to produce four main reports notably TNA, Barrier Analysis & Enabling framework, National Technology Action Plans (TAPs) and Project Ideas for each prioritised technology.

The review of the four reports was carried out at different levels. At the national level, the reports were reviewed by the TNA Steering Committee, National TNA Team members and other different stakeholders from the energy and the agriculture sectors. At the internationally level, the review was carried out by experts from Environment et Développement du Tiers Monde (ENDA) and UNEP Risø Centre.

The ultimate goal of these reports is to guide political decision makers and national planners on selected economic sectors with highest vulnerability characteristics to the effects of climate change. They further highlight most appropriate technologies which would support these sectors and the country in general, to mitigate or adapt to the effects of climate change.

On behalf of the Government of Rwanda, I thank all stakeholders from public and private sectors who participated in different consultation and validation meetings held to evaluate the selection and prioritization of the sectors and technologies. Their inputs were invaluable and deeply appreciated. Lastly, I extend my gratitude to the Global Environmental Facility (GEF) for providing financial support. I also thank the UNEP Division of Technology, Industry and Economics, the UNEP Risoe Centre and ENDA for their technical support and guidance.

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EXECUTIVE SUMMARY

1. Technology Action Plans for the Energy Sector

With reference to the national energy policies and development priorities, the milestones projected for the energy sector in Rwanda are particularly in line with climate change mitigation actions. Currently about 57% of consumed primary energy comes from direct use of wood fuels against 23% from charcoal, 11% from petroleum products and 4% from electricity. By the year 2030, the contribution to the energy sector from the biomass (charcoal, wood fuels), methane gas and electricity will be respectively about 29%, 60% and 11%. Such a target is achievable through strategic actions like replacement of imported petroleum fuels used for electric power generation in Rwanda, wider use of renewable energy resources, exploitation of geothermal resources to generate at least 310 MWe of electric power before the end of year 2017, effective development of Kivu methane gas to provide liquefied gas for industrial and domestic purposes (100 million of Nm^3 of methane every year, in addition to an electricity production of about 100 MWe by the end of year 2013.

As a positive result of applying appropriate climate change mitigation programs, the GHG emissions will be limited to 6460 Gg CO_2-eq, 3304 Gg CO_2-eq, and 669 Gg CO_2-eq respectively from households ,transport and industries instead of 9122 Gg CO_2-eq ,6021 Gg CO_2-eq and 710 Gg CO_2-eq in case of a business-as-usual scenario. Through the Energy Sector Strategic Plan, a component framework of the EDPRS economic growth for the period 2008-2012, key measures were set up: diversification of energy sources, reduction of cost of energy supply, increase of access to electricity, enhancing energy security, establishing the environmental sound sustainable systems of energy production, and promotion of efficient use of energy. However, there exist barriers which may hamper the implementation of identified technologies. They include:

- Limited number of qualified technicians and experts in energy sector, low involvement of private sector in the energy business in general, including development and diffusion of technologies,
- High interest rates (about 18%), short periods of loans reimbursement, difficult terms and conditions and heavy guarantees,
- Limited information on facilities regarding grants and opportunities of the carbon credit market,

- Missing preliminary phase regarding the pilot projects for new technologies,
- Limited access to loans and leasing programs,
- Missing regulations for renewable energy resources

Proposed measures to overcome main barriers include:

- Set up an appropriate unit for research and training related to the issues of the energy sector to overcome the limited number of qualified technicians and experts in energy sector;
- Enact a law on incentives (feed-in tariffs, exemption of overall taxes and fees for mitigation technologies) and provision of subsidies for promotion of renewable energy technologies in order to enhance the involvement of private sector in the energy business through the development and diffusion of technologies;
- Introduction of specific soft loans for the mitigation technologies and lowering the loan interest rate(below 10 %) , instead of the current high interest rates (about 18%), increase loan-reimbursement periods , introduce fair terms and conditions and reasonable guarantees ;
- Effective provision and use of grants and low-carbon credits for contributing to the promotion and diffusion of renewable energy- based technologies in Rwanda; further increasing benefits from the non-carbon funds;
- Provision of subsidies for setting up and installing pilot projects for the R&D and demonstration purposes, especially for the case of new technologies;
- Set up a special fund for promoting investment in energy development and attracting the private sector;
- Establishment of legal and regulatory frameworks for concessions and exploitation of renewable energy resources such as large solar options and geothermal.

Specific actions proposed for the small hydropower SHP technology are in line with the identified 333 sites including 109 pico/micro-hydropower sites for which a preliminary design was tendered in March 2012.

Therefore there is a need for:

- The Formation of a network of small size companies in hydropower subsector;
- Setting up a particular insurance for handling the hydrological risks;
- Setting up a research unit for establishing a map and database for un-gauged rivers;

- Establishment of a databank on the base-flow of rivers and streams;
- Delivering incentives and subsidies to the promoters of the small hydro and new in-stream hydrokinetic systems;
- Setting up an appropriate unit of training and capacity building with a link to other renewable energy resources;
- Collaboration with the IRENA and ADFD for access to soft loans.

The Proposed action plans for Kivu methane CCGT with CCS will be guided by the following specific solutions: Set up a network of stakeholders; Law on applying the CCS option; Law of shared Kivu methane; Control of evolution of methane resources extraction; Subsidies for combining CCS with CCGT; incentives for the liquefaction of Kivu methane; Regular training and capacity building in CCGT and CCS technology; Award to innovative options of efficient exploitation of Kivu methane.

A list of suggested action plans for the development of geothermal power technology will be linked to the implementation of the following measures: Setting up an industrial association of private promoters; linking to the international geothermal networks; making available a framework for subsidies and incentives for interested private investors ; establishing a law on the geothermal extraction and use; monitoring the geothermal resources and providing information on identified potential sites and reservoirs; installing the pilot projects for R&D;; technical assistance mainly in preliminary investigation and exploration for geothermal resources.

Action plans proposed for the PHEV (the Plug-in Hybrid Electric Vehicles) technology will be influenced by particular conditions of introducing such a new transport option in Rwanda. Appropriate actions are mainly the set up of an industrial network for converting old vehicles into PHEV options; a law on bonus schemes; a law on incentives to the PHEV sub-sector; mechanisms for the investment in infrastructure for PHEV innovation (recharging stations); delivery of subsidies to suppliers; exemption for taxes and fees; leasing programs; grants to local industrial units for PHEV components; promotion of CDM and low carbon market credits to PHEV developers.

Proposed action plans for the Large Solar PV are expected to result in installing PV plants connected both to the EWSA grid and to mini-grids. Implementation of the following actions will be required: creation of networks of all key players in solar energy; a law and regulation on long term incentives and taxes exemption; reviews of tariffs and access to grid networks; access to subsidies, soft loans and leasing programs are required before reaching the stage of economy of scales/to handle the high initial capital cost; a centre for training and research applied to solar and renewable energy exploitation; benefits from carbon market credits and awards for innovations in deployment of solar products for large scale scenarios in Rwanda.

All actions are expected to be funded mainly by the GoR (Government of Rwanda), partners such as the GEF, the African Development Bank, the World Bank and particularly the private sector benefiting from soft loans and other facilities through the local banks. Costs have been estimated from existing documentation with link to energy projects and data established by ESMAP through their analysis of different feasible energy technologies.

2. Technology Action Plans for the Agriculture Sector

In Rwanda, agriculture is the most important sector as it sustains the life of the majority of the Rwandan population. In 2009, the population engaged in agriculture was estimated at 80% of the total population which was 9, 5 million at the time. The agriculture contribution was 34% to GNP and 71% to export revenues. In addition, it is the main source of revenues for 87% of the population and it is thus considered to be the country's economic-growth engine. The same sector being the most vulnerable to adverse effects of climate change, five technologies have been selected in order to assist the country in general and the agriculture sector in particular to adapt to those effects. Selected technologies include: Seed and grain storage, Agro forestry, Radical terraces, Drip irrigation and Rainwater harvesting.

General barriers to transfer and diffusion of selected technology options and measures to overcome them have also been identified. They mainly include: Existence of gaps and/or lack of technical skills and knowledge, high cost of technology implementation and limited access to funds and limited awareness about the benefits of the technologies and limited rural infrastructure.

Proposed measures to overcome these barriers are: The creation of awareness among farmers about technology benefits, provision of technical skills and knowhow for technology diffusion and deployment including installation and maintenance, rural infrastructure development, tax exemption, subsidies, incentives, reduction of interest rates and facilitation to access funds by creating agriculture funding institutions. Action plans have been designed for all five technologies. Details are provided for objectives, activities, legal and institutional framework, timeframe, source of funds which have similarities for all the five technologies. The budget is also estimated and success indicators are proposed for each technology.

Seed and grain storage

Objectives are: Increase awareness, improve local expertise and reduce initial investment cost. Related activities include: Selection of sites and construction of demonstration seed and grain storage systems, Organizing and directing training sessions on the installation and maintenance of seed and grain storage systems, mobilization of local manufacturers, Creation of new rural feeder roads and improvement of existing ones.

The budget is estimated at $ 80 100 000 with local and international funding. Success indicators include: One demonstration site per rural province (4 in total) is constructed, 400 technicians are well trained about the function, installation and maintenance of seed and grain storage systems, existence of at least one local manufacturer of component of modern seed and grain storage system and at least 50 km of new rural feed roads are developed and 500 km of existing roads are improved.

Agro forestry

Objectives are: Improve local expertise, raise awareness and reduce initial investment. Related activities include: Production of training materials and awareness- raising materials, organizing and directing training sessions for agro extension agents, provision of support to the rehabilitation of existing agro forestry research sites, installation of agro forestry demonstration sites, organizing and directing farmers study tours, creation of tree seed stands in every district and production of seedlings.

The budget is estimated at $ 4 950 000 with local and international funding. Success indicators include: Training and awareness-` raising materials are available, 1 agro extension agent per sector is trained on the development and functions of integrated agro forestry systems, at least three existing agro forestry research sites are rehabilitated, existence of at least one well developed agro forest demonstration site per province (5 country wide), all farmers associations/cooperative leaders have at least visited one successful agro forestry site, existence of one tree seed stands in every district, existence of one agro forestry nursery per sector in rural sectors.

Radical terraces

Objectives are: Reduce initial investment, improve local expertise, and increase acceptability of radical terraces within communities. Related activities include: Mobilization of local manufacturers, provision of compost, organizing and directing technical training for extension agents, farmers associations' leaders, preparing and directing awareness campaigns.

The budget is estimated at $ 2 300 000 with local and international funding. Success indicators include: Existence of at least five manufacturers of basic tools, 8000 ha of newly established radical terraces are treated with compost, at least one agro extension agent per sector is trained, farmers and all farmers' associations/cooperatives leaders are trained on radical terraces preparation and maintenance, farmers are aware about benefits of radical terraces.

CHAPTER I: TECHNOLOGY ACTION PLAN FOR THE ENERGY SECTOR

1.1 Actions at Sector Level

1.1.1 Sector description

With reference to the national energy policies and development priorities, the milestones projected for the energy sector in Rwanda are among others in line with climate change mitigation actions. The targets listed below are considered as essential for further sustainable development of energy sector. Among others, exploitation and use of methane gas is expected to result in a new figure for energy for cooking: by the year 2030, contribution by biomass (charcoal, wood fuels), methane gas and electricity will be respectively about 29%, 60% and 11%. Such a target is achievable through strategic actions like:

- Replacement of imported petroleum fuels contributing to electricity generation in Rwanda;
- Wider use of renewable energy resources like exploitation of geothermal resources to generate at least 310 MWe of electricity before the end of year 2017;
- Effective development of Kivu methane gas to produce liquefied gas for industrial and domestic purposes (100 million Nm^3 of methane every year) in addition to electricity production expected to rise from the actual 3.6 MWe by the pilot project to about 100 MWe by the end of year 2013.

Focussing on the cross-cutting nature of climate change mitigation, a number of additional specific objectives have been planned. One can mention among others the restoration of destroyed sections of forests of Gishwati,Virunga park and Nyungwe park for further sustainability of natural carbon sinks and sequestration of CO_2 from different sources.

Given that the transport sub-sector is one of key development priorities in Rwanda, mitigation approaches such as the combined technology of PHEV based on using both electric motors and efficient internal combustion engines are also targeted. Indeed such an interesting option will require a wider development of renewable energy resources-to-electric power projects backed among others through the low carbon credit market. This can/will include the small and large hydropower, geothermal, conventional solar, concentrating solar and waste-to-energy options within the context of the current 25 projects under the CDM (Clean Development Mechanism) program in Rwanda.

In fact and with reference to official documents, the rate of access to electricity services within the context of climate change mitigation projected to the year 2030 is expected to be at least 60% in rural areas (i.e. 36% of the total Population) and 100% in urban areas. The urbanization rate will reach 60% for a population estimated to be 18.5 million; the number of households is expected to be about 3 522 000. As a successful result of applying appropriate climate change mitigation programs, the GHG emissions will be limited to 6460 Gg CO_2-eq, 3304 Gg CO_2-eq, and 669 Gg CO_2-eq respectively from households ,transport and industries instead of 9122 Gg CO_2-eq ,6021 Gg CO_2-eq and 710 Gg CO_2-eq in case of a business-as-usual scenario (MINIRENA, 2011).

The implementation of the objectives above requires specific policies and actions under the responsibilities of ministerial departments, public agencies and private sector. Existing public agencies are mainly EWSA (energy, water and sanitation agency) with a specific role of implementation of the energy objectives but also RURA (Rwanda utility regulatory authority) as a regulator for key issues like energy prices, licenses to energy developers, providers and investors and capacity-building for more expertise, design, elaboration of project proposals, audits, management and planning of finances and evaluation of energy projects.

In addition to such institutions, the RDB (Rwanda Development Board) plays an important role. It encourages private investors to form public-private partnership (PPP) to gain support through finance, economic incentives and subsidies availed to the private sector as an energy user and developer. Particular issues regarding environmental and climate change impacts due to energy development are handled by REMA.

More recently updated frameworks and policies have been established. The Rwanda Vision 2020 is focusing on a long term development program in addition to the VUP (vision 2020 “Umurenge” program), an EDPRS flagship component. Regional cooperation in energy sector is channelled through existing energy master plans of the EAC (East African Community), COMESA (common market in east and southern Africa), NELSAP (Nile Equatorial Lakes Subsidiary Action Plan, a component of the NBI, i.e. Nile Basin initiative) EGL (“Energie des Grands Lacs”, a unit of CEPGL, i.e. Communauté Economique des Etats des Grands Lacs) and SINELAC (“Societé Internationale d’Electricité des Grands Lacs”).

In addition to the above brief description of the energy sector in Rwanda and with reference to the document on national energy policy and strategy, we present below the five prioritized technologies through this third stage of the TNA project.

Table 1: Relevant laws, policies and strategies in the energy sector

Name	Year or period	Main content
EDPRS(economic development and poverty reduction strategy)	2008-2012	Through the Energy Sector Strategic Plan, a component framework of the EDPRS economic growth for the period 2008-2012, key measures were set up: diversification of energy sources, reduction of cost of energy supply, increase of access to electricity, enhancing energy security, establishing environmentally sound sustainable systems of energy production, promotion of efficient use of energy.
EPS(national Energy Policy and Strategy)	2012-2017	The national Energy Policy and Strategy is a new instrument through which energy sector will be periodically reviewed and updated accordingly within Rwanda's long term plans and strategies aiming at creating sustainable environment for the provision of reliable and affordable energy supplies for all Rwanda needs and to all population, both in rural and urban areas.
Rwanda Vision 2020	2005-2020	More recently updated frameworks and policies have been established. The Rwanda Vision 2020 is focusing on a long term development program in addition to the VUP (vision 2020 "Umurenge" program), an EDPRS flagship component.

Table 2: Summary of energy technology targets

Technology	Current orientation	Targets
SHP	Small hydropower opportunities have been inventoried, showing a high number of potential sites: about 333 including 109 pico/micro-hydropower sites for which a preliminary design was tendered in March 2012 and for a capacity of 9.3MWe by April 2013(EWSA, 2012).	There is also a short-term development plan for five mini-hydropower projects which will be installed for up to a total power capacity of about **17.4 MWe** during the period 2013-2015 as follows: By the end of the year 2013, Rukarara II for an output of **2MWe**; in the year 2014, RukaraIV for **5 MWe** but also Ntaruka II for **2MWe** and Giciye for **4.5MWe**; By the end of 2015, Akanyaru for **3.9MWe**. These projects will be jointly funded by the Government and the private sector (MININFRA, 2011).
Kivu methane CCGT with CCS	A number of companies are interested in investing in the sub-sector of the Kivu methane gas: RIG (Rwanda investment Group), Israel Africa Ltd, Locally the private sector is expected to be sponsored by the Government of Rwanda with support by international institutions. An agreement has been signed by the private investors for a 100 MW_e project.	Other projects are targeted for effective implementation before the end of year 2017 for a total of 310 MW_e: Not only electricity is projected, but liquefaction and distribution of gas for heat use are also planned (MININFRA, 2011). The application of Kivu methane CCGT with CCS technology is suggested for an efficient performance meeting mainly the climate change mitigation requirements.
Geothermal	The case of geothermal is particularly different from the above two prioritized technologies.	A 10MWe pilot electric power plant will be installed soon before the end of 2013 in the area of the Volcano Karisimbi.

	Its development has not yet started.	Then over the period 2013-2017, four geothermal-to-electric power projects are targeted for a 75MWe capacity each (MININFRA, 2011).
PHEV	The PHEV (plug-in hybrid electric vehicles) is a potential pilot technology selected for a further contribution in reducing the GHG emissions by the road transport sub-sector in Rwanda. It is a well known mitigation option, but due to a number of strategic reasons, its diffusion and deployment have not yet reached a sufficient degree of penetration in the market of any country. It is hence a coming new option for Rwanda. into the rotation energy, is about 75%.	With reference to the strategies towards the application of climate change mitigation scenarios for the sub-sector of road transport in Rwanda, electric vehicles and more efficient gasoline and diesel engines have been suggested (REMA, 2010). Recharging the batteries is a process expected to be achieved through stations connected to an electric grid preferably using electricity generated by renewable energy resources. Therefore, geothermal, solar and hydropower options will be the most appropriate solutions to such a requirement for deploying the PHEV technology in Rwanda.
Large solar PV	Regarding the technology relying on Large Solar PV systems, lessons learnt from countries where solar systems are connected to electric utility grids prove that such an option is commercially new on the energy market**.** Recently, large solar PV plants have been installed mainly in USA, Canada, and Europe: the electric capacity for each plant ranges between 9MWe and 143MWe.	New targets for the solar PV are especially the large scale option. In fact where the small solar PV products are popular, the diffusion of large scale options is potentially facilitated, mainly due to the modular character of the PV systems. For instance a large 5 MWe solar PV plant can be assembled by use of modular units of 73 kWe each. The required land surface is about 532 m^2 for a PV efficiency at least equals 14%, an inverter efficiency of 85% (DC to AC), a total incident radiation of 526 MWh/year, i.e a total incident solar global radiation of

	The large scale solar PV technology is not yet introduced in Rwanda even though small solar PV systems are familiar to a wide range of particular end-users, such as schools and health centres.	about 55 MWh/year (ESMAP, 2007).

1.1.2 General barriers and proposed measures

A summary on general barriers and specific measures to remove the barriers hindering the development and diffusion of prioritized mitigation technologies is presented below in table1 and table2.

Table 3: General barriers and proposed measures

Barriers	**Measures**
Limited number of qualified technicians and experts in energy sector	Set up an appropriate unit for research and training related to the issues of the energy sector
Low involvement of private sector in the energy business in general, incuding the development and diffusion of technologies	Enact a law on incentives (feed-in tariffs, exemption of overall taxes and fees for mitigation technologies) and provision of subsidies for promotion of renewable energy technologies
High interest rates (about 18%), short period of loan reimbursement , difficult terms and conditions and heavy guarantees	Introduction of specific soft loans for the mitigation technologies and reduction of the loan interest rate: below 10 %
Limited information on facilities regarding grants and opportunities of the carbon credit market;	Effective provision and use of grants and low-carbon credits aiming at contributing to the promotion and diffusion of renewable energy- based technologies in Rwanda;
Missing preliminary phase regarding the pilot projects for new technologies	Provision of Subsidies for setting up and installing pilot projects for the R&D and demonstration purposes especially for the case of new technologies
Limited access to loans and leasing programs	Set up a special fund for promoting investment in energy development and

	attracting the private sector
Missing regulations for renewable energy resources	Establishment of legal and regulatory frameworks for concessions and exploitation

1.2 Action Plans for Small Hydropower SHP Technology

1.2.1 About the SHP technology

In addition to conventional hydropower systems the new option of the in-stream hydrokinetic turbine (HKT) is also possible especially for the sites presenting small head drops or streams and rivers crossing the flat lands: case of Akanyaru, Nyabarongo and Akagera river basins along some areas in Rwanda.

The design is based on the Kaplan or Francis Turbine, a self excited induction for the pico-hydropower systems, the lifespan of about 15 years and 30 years respectively for the pico and micro scales, and the capacity factor i.e. operational time duration per day of about 60%.

The SHP technology is quite a suitable renewable energy-based and affordable solution; the estimated capital costs (ESMAP, 2007) are as follows for the SHP technology based on the pico/micro scales: in the year 2015, about 1 470 USD/kWe, 2 550 USD/kWe and 2 450 USD/kWe respectively for the capacity of 0.3 kWe, 1 kWe and 100 kWe; these, against 1 560 USD/kWe, 2 680 USD/kWe and 2 600 USD/kWe in the baseline year 2005.

In case of a mini-hydroelectric power system of 5 MWe, the capital cost was about 2 370 USD/kWe in the year 2005 and will slightly decrease down to 2 250 USD/kWe by the coming year 2015.

Probable generating costs for a 100 kWe power plant is expected to be about 11 US cents/kWh (with 13% for O & M costs and 87% for adjusted capital cost) in coming year 2015 (ESMAP, 2007).Compared to a 5 MWe mini-hydropower (7 US cents/kWh), the generating cost is higher for the Pico/micro-hydropower; but the SHP option has an advantage of presenting a high number of potential sites within the rural areas. The progressive development of the SHP technology in such areas will result in a decreased dependence on fossil fuels, diesel engine power generators and on wood fuels (to some extent).

There are also some social and economic benefits; for instance, as the rural population gets motivated to resettle in the grouped villages and Umudugudu-based settlements, modern facilities like charging phones, internet and TV access are expected to become available due to a wider diffusion of small hydropower systems in rural areas. This has the potential to stem the exodus from rural to urban areas. Due to such promotion of wider exploitation of water resources for the electric power generation, small scale business and factories will follow and increase incomes towards a better GDP. In addition, it will result in increased rate of access to electricity services and creation of jobs in small villages and towns.

1.2.2 Targets for SHP transfer and diffusion

With reference to the national energy policy and strategy (MININFRA, 2011), targets projected for the diffusion of the SHP technology are mainly as follows:

- Promotion of private sector participation in hydropower production at large and small scales;
- The delivery of licenses for small hydropower projects;
- Exploitation of higher number of small hydropower sites so that additional power of 75 MWe can be installed between 2011 and 2017;
- Promoting the legal and regulatory frameworks of micro-hydropower and mini grids under the monitoring of EWSA ;
- Financing and investing through IPP (Independent Power Producers) negotiation between EWSA and local promoters and community–based associations or cooperatives.

1.2.3 Barriers to diffusion of Small hydropower (SHP)

Table 3: Main economic and financial barriers for SHP

Barriers	Elements of barriers	Presentation and dimension
Limited financial facilities	High cost of equipment	Due to absence of local industry for electronics and machinery, equipment for hydro plants is imported.
	Limited financial capacity of private sector	The number of private investors in energy sector and particularly in power production, supply and distribution is still low due to their limited financial capacity
	High cost of construction and installation	Due to among others the morphology, topography and land slope, construction of small hydropower plant is expensive; it seems to be the case for instance for new project of Rukarara (8 Megawatt) in the southern province and Keya (2.2 Megawatt) in Northern-West Rubavu district.
	Low access to loans	High interest rates , often exceeding 18%; Short period of loan reimbursement ; Difficult terms and conditions and heavy guarantees

Table 4 : Non financial barriers for SHP

Barriers	**Elements of barriers**	**esentation and dimension**
Limited Knowledge for design and management	Seasonal shortage of designed discharge	Small Hydropower do not have dams and reservoirs for storage and regulation; During dry period, only the base flow component is available in river and stream flow; Records and historical data for small rivers are not available.
	Limited expertise for training the local trainees	Design of hydro plants require a multidisciplinary team; Difficulty in design for rivers with unknown water levels and streams; unknown tools for modeling and estimating data
	Seasonal floods and damage of installed components of power plant	In addition to seasonal decrease in water resources (example in year 2004 for Mukungwa and Ntaruka power plants), floods and landslides damaged the hydropower plants (case of Keya plant where the river Sebeya is often flooding and has started to destroy the structure of fixed penstock pipe of one kilometer length)
Low participation of private sector	Incentives for developers are missing	Mechanism and frameworks for delivering the incentives are selective

1.2.4 Proposed action plan (TAP) for SHP

Table 4: Detailed action plan for the transfer and diffusion of small hydropower technology

Measure	Justification	Responsible	Activities	Time frame	Estimated cost (USD)	Sources of funds	Success indicators	Risk indicators
A1. Formation of a network of small size companies in hydropower subsector	Opportunities of local development of industry and manufacture of some components of hydropower plants :generators, turbines, electro-mechanics	Private sector; MINICOM; EWSA	-Inventory of all companies involved in hydropower -Seminar and formation of an industrial association -Installation of a unit for assembly and production of hydropower components and machinery.	5 years	900,000	GoR; GTZ;CTB		Established network is set alone and companies are not meeting; Local developers are not buying local products;

A2. Set up a particular insurance for hydrological risk	With link to climate change and variability , seasonal floods can damage infrastructure while shortage of water can result in lowering the performance of hydropower plants(case of shortages of production in year 2004)	MINERENA; MINICOM; MINECOFIN	Negotiation with SONARWA and any other insurance company; Negotiation with the central bank (BNR) for a provision of funds to above companies; Advertisement and information to SHP developers and to their association and external partners	5 years	400,000	GoR	Financial facilitation for compensating any damage are delivered to recipients	Insurance companies not paying in case of damages by climate extreme events;
A3. Set up a research unit for establishing a map and database for un-gauged rivers and streams;	-a high number o streams and small rivers remain un-gauged	EWSA; REMA; National Universi ty of	Elaboration of terms of reference; negotiate a multidisciplinary team of	5 years	400,000	GoR	A map including estimated data for un-gauged river	-Models for un-gauged rivers are not properly applied; Non updated

A4.Establishment of information and database on base-flow of rivers and streams	-need of tools in modeling and forecasting; -understanding the impact of climate change; During the dry periods, only underground flow provides water to hydropower turbines ; therefore , a database (regularly updated) on such resources is required.	Rwanda	consultants at the National University of Rwanda; development of a design model for non gauged rivers; validation of results of research; set up a database; large share and dissemination of the results;					database
A5.Deliver of incentives and subsidies to	-particular small hydropower plants based on	MININFRA; MINIC	Contact international financial	10 years	2 million	World Bank; Gor	-A map river and a databank are	-only a small amount of subsidies are

promoters in Pico hydro and new in-stream hydrokinetic systems	in-stream hydrokinetic require a special support at Rwanda market; -in rural areas, off-electric grids are required; - subsidies and incentives are key tools for a significant attraction of new investors in small hydropower	OM; MINECOFIN	institutions and negotiate soft loans ; establish a particular regulation for incentives and subsidies; distribution of subsidies to inventoried sites eligible to installation of the off-grids				distributed to interested stakeholders and investors -number of new installed small hydro plants	distributed; -
A6.Set up an appropriate unit of training and capacity building in hydropower operations	Skilled expertise is required for hydropower studies and design ;such actions require in	MINEDUC; EWSA; Universities and Colleges	-installation of a joint and shared department of Energy Engineering and Management	10 years	1.8 million	GoR; Koica; GTZ	Number of staff and technicians trained	Long- period training resulted into unemployment; A department of energy is closed

	fact multidisciplinary teams and more availability of local experts		(EEM) - distribution of special grants to students					due to lack of candidates
A7.Collaboration with the IRENA(International Renewable Energy Agency) and others partners	Opportunities of accessing technical assistance and soft loans (2 up to 6% of interest loan) from ADFD (Abu Dhabi Fund for development) via IRENA; access to AfDB (African Development Bank) financial support	MININFRA ; EWSA	Nomination of focal persons in charge of a permanent link with international institutions dealing with the renewable energy facilities; Inventory of such institutions and negotiations for specific agreements and access to funds	10 years	600,000	GoR	Soft loans are made accessible	Banks readjusted and changed the rates of loans before the end of contact;

Above actions are feasible even though some risks are possible: poor maintenance and management of installed projects, limited number of private developers to cover the high number of potential SHP sites in Rwanda. A particular risk is linked to the lack of local market for the potential industry of hydropower equipments.

The hydropower systems at any scale are governed by the variability in hydrological regimes and climate change. The design for un-gauged rivers and streams is not easy. Thus and in addition to the hydropower atlas/map published recently, a more detailed database on integrated water resources and river/ stream sub-basins have to be established. Behavior in drier seasons and information on the minimum base-flow for key representative streams and rivers has also to be investigated and published. For more sustainability of installed hydropower projects, a particular insurance regarding the hydrological risk related to climate change impacts and variability in water resources is required and has to be initiated. Due to the absence of a local industry for electronics and and machinery, all equipments for construction and maintenance of hydropower plants are imported; therefore, there is a need promoting basic units for manufacturing (steel-pipes, electrical components like transformers and generators, water turbines).

1.3 Technology Action Plans for the Kivu Methane CCGT with CCS

1.3.1 About the CCGT with CCS technology

The current Kivu methane power pilot project at Rubona / Gisenyi / Rubavu district is based on the simplified technology of internal spark combustion of methane gas; therefore any future investors can consider the improved option of CCGT technology based on both use of the (GT) gas turbine and the (ST) steam turbine. A unit of carbon capture and storage (CCS) for sequestration of undesirable GHG emission from the CCGT plant can be installed in order to optimize the mitigation scenarios. Therefore, the description presented below is in line with such an improved technology based on a complex system of the GT, the ST and the CCS. Once the CCS components associated to CCGT system are installed, the CO_2 emissions are separated and captured from the flue gases emitted by the CCGT power plants. Then the CO_2 gas is compressed before being transported through a pipelines' network towards a geological reservoir or an ocean or a lake. Note that the storage of CO_2 is cheaper in case of geological options.

The efficiency rate of reduction of CO_2 emissions i.e contribution to GHG mitigation is about 79% (IPCC, 2005). Therefore environmental benefits from use of CCGT with CCS are important. In fact, the GHG emissions produced by methane-based technologies are as follows: about 110 mg/Nm^3 of NO_x i.e lower than the emission standard rated at 125 mg/Nm^3 , about 400 mg/kWh of CO_2 by a CCGT option against 600 mg/kWh in case of a GT system taken alone (ESMAP, 2007).

1.3.2 Targets for transfer and diffusion of Kivu methane CCGT with CCS

Based on the results of surface exploration and the successful 3.6 MWe Kivu methane pilot project plant operational since November 2008, milestones are as follows:

- Negotiate and establish agreements with private sector and international investors for funding projects of 20 MWe to 50 MWe,

-Installation of about 300 MWe by the end of the year 2017 mainly by private promoters under support by the government agencies and donors,

-Negotiation between the governments of RD Congo and Rwanda for developing a joint 200 MWe power plant [1]based on methane gas,

-Liquefaction of methane gas for further replacement of biomass and diesel fuels used in households and industry sector[2].

1.3.3 Barriers to diffusion of Kivu methane CCGT with CCS

Table 5: Economic and financial barriers for Kivu methane CCGT with CCS

Barriers	Elements of barriers	Presentation and dimension
High cost of methane production	High cost of extracting methane gas	The preliminary steps of methane gas from lake Kivu are expensive, installation of appropriate equipment is expensive also; Biogas generation from householders and cooperatives is done in separate sites;
	Additional cost of storage of CO_2 and H_2S	Elimination of associated CO_2 is also an additional cost (especially it is up to 80% of gross mixed gases). It is also the case for H_2S
	High cost of liquefaction (temperature : 168°C below zero)	Transport of gas from production units requires liquefied gas;(it is also the case of use of gas for cooking and for industry purpose as planned by EWSA for the most important consumers like BRALIRWA in North-West and CIMERWA in South-West of the country.

[1] Modalities for such a regional joint venture is yet to be discussed and negotiated through among others the CPGEL (Communauté Economique des Pays des Grand Lacs i.e. Burundi,RD Congo and Rwanda)

[2] Liquefied methane gas (in addition to biogas, solar water heaters, biofuels, electricity) is greatly expected to contribute in reducing biomass use from 555 to 3000 kg-oil –equivalent, respectively from year 2008 to 2020.(MININFRA; 2012).

	High cost of sequestration of exhaust gases	The CCS is yet an expensive technology due to the main stages : separation ,compression ,transport through pipelines and design of geological storage reservoir

Table 6: Non Financial barriers for Kivu methane CCGT with CCS

Barriers	Elements of Barriers	Presentation and dimension
Unfamiliar new technology	Technical and skill limitation	The CCGT is complex and requires highly qualified managers , both gas turbine steam and recovery system are combined for increasing efficiency
	Limited gas production and distribution	CCGT requires enough preliminary production of methane gas from Kivu lake, and biogas from different regions and companies ; Problem of collection and transport of gas is critical and is hindering the development of CCGT technologies in Rwanda.
Conflict with the green policy	Kivu gas is an abundant energy resource and a relatively clean energy compared to the type of more pollutant fuels that it can replace	Even though the methane fuel is not highly pollutant like the petroleum fuels, its exploitation and use require additional and specific actions of sequestration of exhaust gases

1.3.4 Proposed action plan for Kivu methane CCGT with CCS

Table 7: **Technology Action Plan for Kivu methane CCGT with CCS technology**

Measure	**Justification**	**Responsible**	**Activities**	**Timeframe**	**Estimated cost (USD)**	**Source of funds**	**Success indicators**	**Success indicators**
B1.Set up a network of stakeholders	Coordination among interested investors and companies candidates to Kivu methane exploitation; share of information on new options like the CCS and the double use of gas and steam turbines	MININFRA and private sector	Organization of a seminar for all interested investors in Kivu methane; Visits to external existing CCGT and CCS installations and negotiations for joint ventures; Set up a preliminary network between EWSA and the companies already involved in extraction of gas from lake Kivu	5 years	200,000	GoR	Reports on joint meetings ; The number of joint ventures created; Number of visits done abroad and on local Kivu methane units and plants	Low level of lessons learnt from the visits of existing CCGT and CCS, due to non-similarity with the case of Lake Kivu
-B2-Establish a law on	-Necessity of combining CCS to	REMA and	Organization of campaigns for proving the	5 years	400,000	GoR	Published laws in Rwanda	Non operational joint the venture;

applying the CCS option - B3-Law of shared Kivu methane	CCGT for reducing GHG emissions -Need of promoting joint ventures between DRC and Rwanda	EWSA	role of using the CCS technology; Campaigns showing how the efficiency is improved when the gas and steam turbines are combined; Negotiations and discussion through the CPGL for a potential joint 200 MWe plant				official gazette	Law on sharing Kivu methane not easily operational for the countries; The CPEGL is ended while it was expected to be a good tool for negotiations and application of laws
B4-Control of evolution of methane resources and extraction	-Sustainability and variability of renewable resources - avoidance of risk of disturbance of stratification of Lake	EWSA; universities	Establishment of a research unit in charge of monitoring the methane resource and stability of the lake ; Regular records of data and update of the database	20 years	2.6 million	SIDA-SAREC; EU; GoR	Published reports on evolution of extracted methane gas and on renewability of resources of methane gas in lake Kivu	-Stratification and stability of the layers of the lake are affected; A sudden volcanic eruption at the bottom of the lake;
-B5-Subsidies for	-make more affordable these	World bank ;	- Negotiate access to the carbon-credit facilities and	10 years	24 millions		Financial impacts and	The World bank and other donors

combining CCS to CCGT -B6- incentives for the liquefaction of Kivu methane	options -Attract the investors to distribute methane to industries	EWSA	funds for promotion of replacing the petroleum fuels; -Installation of a mini CCGT/CCS pilot plant; - updating the installation of a gas-to-liquid pilot plant near the BRALIRWA (brasseries et limonaderie du Rwanda) in Rubavu district; - Awarding and distributing subsidies and incentives to all companies developing this technology				amount of subsidies delivered ; Number of companies which benefited from subsidies and incentives; Amount of electric power capacity added to the existing capacity	stop the funding once the liquefaction and use of gas in industries are considered as relatively pollutant fuel;
B7-Regular training and capacity building in CCGT and	CCGT and CCS are complex option requiring highly qualified managers and technicians	Universities; REMA; EWSA	-Organization of an annual training session in techniques of CCGT and CCS; -A two-years- visit to	10 years	400,000	GoR; GTZ	Annually number of certificates awarded to technicians	Technicians continue to consider that the CCS is very complex

CCS technology			external CCGT and CCS installations				,stakeholders and staff; Number of local experts who participated in abroad workshops	technology; Foreign units of CCGT and CCS not accepting to share their experience and keeping hidden their knowledge
B6-Award to innovative options of efficient exploitation of Kivu methane	There is a great need in applying CCS presenting lower costs	UNDP; World bank; REMA	-A two-year (day) - seminar for presenting the updated options and innovative CCS options; -Visit to pilot plants by potential developers; - Distribution of awards	10 years	2 millions	EU; JICA; GoR	Number of new types of CCS technology elaborated and successfully tested	

The proposed measures for the Kivu methane CCGT with CCS technology are especially influenced by the process of combining the steam turbine to the combustion gas turbine and capturing the CO_2 emissions before reaching the storage site (a natural or artificial reservoir/lake/geological). Due to the high level of the initial capital cost, appropriate subsidies are required in order to attract the local private sector and the external partners. We have to mention that this technology will succeed in Rwanda if the risk of unfunded component of the CCS is avoided. In fact without the CCS, the Kivu methane looses the eligibility to renewable category and the carbon credits.

Implementation of different phases for such a technology based on the methane gas extracted from deep layers of the Lake Kivu will require a huge budget. Therefore a special fund and grants with link to the low-carbon credit market for covering the particular costs of CCS components can be delivered for further developers and interested investors. Given that the Kivu methane CCGT with CCS technology is complex, its implementation in Rwanda will required both specific incentives (feed-in tariffs, exemption taxes of imported equipments…), organization of regular training and seminars aiming at increasing the number of qualified technicians and managers, a particular law for a future regulation and evaluation of such a shared resource.

1.4 Action plan for geothermal power technology

1.4.1 About geothermal-to-electric power technology

A steam turbine driven by the fluid is connected to an electric generator. A system of conventional condenser and cooling tower fulfills the properties of thermodynamic cycle. Finally, the underground geothermal field is recharged through a reinjection at about 1 km from the position of the drilled hole wells.

For a 200 kWe geothermal binary unit, the capital cost is projected to a probable value of 6 410 USD/kWe in the year 2015 against 3 730 USD/kW in case of a binary 20 MWe plant (ESMAP, 2007). Initial capital costs are among others influenced by an optimal design and choice between the alternatives of an atmospheric exhaust plant and of a condensing plant (UNESCO, 2003).

Regarding the projection for the total average adjusted cost (energy generation cost) for the year 2015, expectations are 14.2 US cents/kWh and 6.3 US cents/kWh respectively for a binary 200 kWe, and a binary 20 MWe (ESMAP, 2007).

Binary plants are elaborated for commercial purposes in small modular units which can hence be assembled into higher capacity units of up to about 110 MWe; Temperature required for the geothermal water brine is about 120 °C to 170 °C for 200 kW up to 20 MWe; lower temperatures are also possible using the working heat fluids which have lower boiling points i.e below 100°C.

1.4.2 Targets for Geothermal transfer and diffusion

- Assessment of geothermal resources mainly in volcanic northern areas and along the whole portion of Rift Valley from the north to the south-West of the country;
- Installation of a pilot project plant of 10 MWe ;
- Generation of about 310 MW of electric power by the end of year 2017;
- Identification of private investors and partners for further financial support.

1.4.3 Barriers to diffusion of geothermal technology

Table 8: **Economic and financial barriers for geothermal**

Barriers	Elements of barriers	Presentation and dimension
Cost of preliminary steps and information on potentialities	Cost of preliminary investigation	Required various studies(geological, chemical, physical, location of wet aquifers and dry hot rocks) are expensive; Potential sites in Rwanda are in the extreme North-West and extreme South-West regions
	Limited incentives and subsidies	Investment in new technology like geothermal has to be associated with wide support for covering the initial capital cost; The initial step of the pilot project is not yet undertaken.
	Cost of validation of result of exploration studies; cost of large campaigns for geothermal	Unless a number of measures and incentives are openly made applicable and available, private investors will continue to hesitate and avoid any involvement in geothermal exploitation and implementation.
	High capital and maintenance costs	The newer the technology, the higher the cost; regional experience from Kenya and Ethiopia is not sufficient for projecting any comprehensive costs of production and maintenance in Rwanda.

Table 9: Non financial barriers for geothermal

Barriers	Elements of Barriers	Presentation and dimension
Stability of infrastructure	Risk of damage by earthquake and other hazardous events	Installation of geothermal power plants is expected along the Rift Valley and high lands in western branch, i.e. volcanic zone and regions with high frequency of earthquake occurrences.
Limited Human resources	Insufficient expertise and skilled technicians	Given that a critical mass of skilled local expertise in geothermal process and exploitation is missing, transfer and deployment phases are weakened.
Limited involvement of private sector	Information on potential resources is not available; Hesitation of private investors	Only surface studies have been achieved; The planned pilot project of 10 MW is still awaited
Conflict with owners of land	Very high density of land occupation by anthropogenic activities	Areas expected to host the geothermal plants are those which are under intensive agricultural activities.

1.4.4 Proposed action plans for geothermal technology

Table 10: **Technology Action Plan for geothermal technology**

Measure	**Justification**	**Responsible**	**Activities**	**Timeframe**	**Estimated cost (USD)**	**Source of funds**	**Success indicators**	**Risk indicators**
-C1-Set up an industrial association of private promoters -C2-Links to international geothermal network	Benefitting from experience of owners of geothermal plants in the region and in Europe, Asia and America will be fruitful	Private sector; EWSA	-Visits to among others Kenyan and Ethiopian geothermal plants; -Participation in summits on geothermal energy	10 years	400,000	GoR; EU; JICA	Reports on visited geothermal plants for instance in Kenya ,Ethiopia, Ireland , Italy and Philippines	-The Rwandan geological conditions are found different from that of Countries from where experience on geothermal is more fruitful
-C3-Make available a regulatory framework for subsidies and incentives for interested private investors	-Any new technology requires particular governing laws -Provision of subsidies and other facilities can result in a positive involvement of	MININFRA; EWSA; MINALOC	-Identification of potential financial partners and investors; -Publish a law for establishing a special fund for subsidies;	10 years	40,000	GoR	Published laws in official gazette; Special laws on geothermal exploration are published;	-Geothermal resources are found insufficient after process of drilling; - Promised subsidies are released;

C4-Establishment of law on geothermal extraction and for concessional agreements	private sector toward a geothermal deployment in Rwanda		- Elaboration of a law and regulatory framework for concessions					
C5-Monitoring the geothermal resources and providing information on identified potential sites	-Up to now , only surface studies have been achieved -Sustainability of resources, once proven, is an attractive factor for public private investors	EWSA; Universities;	-Set up a research and technical team for establishing a geothermal map; - Assessment of potentialities for exploration; -Validation of the predicted power capacity 700MWe; -Carry out studies for options of low temperature geothermal-to-electric power	20 years	4 million	- GoR;	Availed map on geothermal resources; -Updated information and databank on geothermal resources ;	More interesting reservoirs are found in volcanic and vulnerable areas; -Inexistence of deep large reservoirs;
-C6-Installation	-Awareness and	EWSA;	In addition to the	5	30	AfDB;	Two pilot	-lessons leant from

of pilot projects - C7-Special fund and subsidies to private investors	confidence in geothermal business can be increased through RDD pilot plant projects -Particular financial facilities are required in order to face the high costs of both initial capital and maintenance	REMA; FRSP	power pilot project at Karisimbi in the north west , Construction of a pilot project in Bugarama for direct thermal use by CIMERWA(company for cement production, in Rusizi district/southern west); -Negotiation for special funds and subsidies	years	million	BADEA;EU; GoR	projects installed in Bugarama (South –west of country) and in Rubavu district(north-west); -The number of investors in geothermal sector is sufficient the power capacity of 300 MWe is operationalby the year 2017.	pilot projects are not conclusive; - destruction of pilot projects by a sudden earthquake event; Soft loans are not provided.
C8-Organization of regular training and seminars for technician and	In current context of human capacity in Rwanda ,there is a need in increasing the	MIFOTRA; REMA	-Participation of about 4 students in training in Italy at Larderelo,	5 years	340,000	GoR	20 local experts are available by 2017 annually about 4 trained	Newly trained local staff are not employed due to lack of experience;

policy makers	number of skilled staff and policy makers for further deployment and diffusion of geothermal technology		- A 3 months practical training and visits to geothermal plants in Kenya;				technicians and stakeholders deliver a report after the abroad sites' visit	Preference is oriented to international experts
C9-Technical assistance mainly in preliminary investigation and exploration	International cooperation will result in technical assistance from countries where geothermal is historical operational	REMA; MINAFET	-Negotiate a partnership and joint exploration with Kenyan and Ethiopian geothermal companies; -Under the umbrella of international cooperation like JICA, negotiate a particular technical assistance mainly in the process of	5 years	35 million	EU,CTB, GoR	Reports on joint studies ; Published geothermal map and updated information on related geological and volcanic events	

			assessment and exploration					

Regarding the geothermal technology, measures to remove specific barriers will be facilitated due the coming 10 MWe pilot project which is expected to be installed near the volcano Karisimbi. Preliminary studies (geological, chemical, physical, location of wet aquifers and dry hot rock) for investigation and identification of all underground reservoirs of hot water are targeted and have to be conducted and achieved especially in the North-West and extreme South-West regions. A geothermal database and map have to be produced. Appropriate incentives and subsidies have to be openly made applicable and available for attracting the private investors. In fact some key steps of geothermal technology are quite expensive and prohibitive. The regional experience and lessons from Kenya and Ethiopia is not sufficient for projecting any comprehensive costs of production and maintenance in Rwanda.

The installation of geothermal power plants is expected along the Rift Valley and high lands in the Western branch, i.e. volcanic zone and regions with high frequency of earthquake occurrences. Therefore, particular attention and orientation have to focus on the following measures: a special fund for geothermal initiatives, access to carbon credits, installation of a training and research unit for monitoring the geothermal resources and dissemination of lessons learnt from the coming 10 MW pilot project expected in the Karisimbi area.

But it is important to mention that geothermal action plans will probably face the risk of uncertainties in the sustainability of resources and the reservoirs 'capacity: even when the pilot projects are conclusive. In essence, what it is available and sustainable at Karisimbi site in the north –west may not necessary be similar to the situation in the Bugarama area in the south-west.

The mitigation potential and reduction rate for GHG emissions are interesting. In fact, replacing the imported oil fuels for the thermal power plants by the expected geothermal option can result in a reduction rate of about 74%. In case of geothermal resources reaching a temperature of 180 °C and a pressure equals to 8 atmospheres , the geothermal steam is directly passed through the steam turbine; once condensed, water is re-injected into ground for the purposes of recharging the geothermal sources. Such an avoidance of use of the heat exchanger and the hydrocarbon working fluids makes the geothermal technology cleaner in the matter of GHG emissions. Generating electricity energy through such a promotion of exploiting local and reliable green energy resources is considered as a great socio economic benefit for the country. With regards to different planned electricity generation projects, the country could become a medium term exporter of electricity.

1.5 Action plans for the PHEV technology

1.5.1 About the PHEV technology

A plug-in hybrid electric vehicle (PHEV) is equipped with a conventional internal combustion engine and an electric motor. A battery rechargeable through any electric power outlet runs the electric motor while the combustion engine depends on fossil fuels or bio-fuels. In case of fossil fuels, efficient gasoline option is more recommended. For a technology combining such two sources of energy, the amount of CO_2 emissions is lowered due to the decreased amount of fossil fuel consumption.

The source of electricity to which the battery plug is connected for recharging is expected to be a grid preferably based on hydropower, solar, wind and any other non carbon technology. For a recharging frequency of at least 2 times per day, PHEV consumes about 3 liters per 100 km against 4 liters in case of frequency of one charging per day. The overall efficiency of the system "Battery-Electric motor-Wheels" transforming the chemical into mechanical through electrical is about 75%. The efficiency of an internal combustion engine is about 15% in urban areas and 25% in rural or highways.

The initial cost of a PHEV is higher than the conventional vehicles; in fact the PHEV are still limited on international market. However, the operational costs are affordable:

- The cost of the "gasoline-electric" fuel for the PHEV options is 2 times lower than the cost of the conventional petroleum fuel used for common gasoline vehicles;
- The maintenance cost for common gasoline vehicles is about 1.5 times more expensive than the PHEV maintenance.

The **expected** mitigation potential (Reduction of GHG Emissions) is as follows:

- The amount of CO_2 emissions is about 0.11 kg/km for PHEV against about 0.44 kg/km by usual non efficient gasoline vehicles in urban areas;
- In rural areas and highways, CO_2 emission are respectively 0.09 kg/km and 0.26 kg/km for PHEV and usual gasoline vehicles

The introduction of these new vehicles on the local market entails some social benefits. It will stimulate industrialization in setting up local units for manufacturing components of PHEV and their maintenance. This will create more wealth including new jobs.

The economic benefits will come from the increased use of renewable resources and a decrease in importing gasoline and diesel fuels for vehicles. In addition to the potential manufacturing benefits; other economic benefits are linked to the fact that the cost of electricity is lower than the cost of fossil petroleum fuels.

Environmental benefits will be realised from the increased use of such vehicles running on electricity and liquid fuel. This will be considered as an innovative contributor to a significant decrease in GHG emissions from the road transport sub-sector.

1.5.2 Targets for PHEV transfer and diffusion

- Increasing the capacity of transport sector ;
- Substituting imported petroleum fuels by methane gas converted into liquid fuels;
- Developing a market based on efficient gasoline cars;
- Introducing the green transport through the use of biodiesel and deployment of electric vehicles.

1.5.3 Barriers to diffusion of PHEV

Table 11: **Main barriers for PHEV technology**

Type	Barriers	Elements of barriers	Presentation and dimension
Economics and Financial	High cost of purchasing a PHEV	Limited purchasing power of Rwandans	GDP is low : about 275 USD per capita and per year
		Inexistent incentives for promoting new vehicles in compliance with GHG mitigation	Banks , Micro-finances institutions, government agencies for transport sector are not yet sensitized to facilitation for electric vehicles
		Insufficient rates of taxes and fees to conventional pollutant vehicles and second hand vehicles	Market for second hand vehicles is largely developed in Rwanda
		Inexistent local manufacturing units of components for assembling vehicles	Only the process of importation of vehicles fully ready for driving is in place
		Inexistent special externalities applicable against vehicles consuming non efficient gasoline and diesel	A lot of trucks and relatively old mini-bus are highly pollutant and often emitting gases resulting from uncompleted combustion

Table 12: Non financial barriers for PHEV technology

Type	Barriers	Elements of barriers	Presentation and dimension
Non Financial	Market imperfection	Monopoly of conventional gasoline and diesel vehicles	Only a very small number of electric motorcycles are available and optional
		Affordable second hand vehicles	Purchase cost of a new vehicles is almost 2 times more important
		Pilot projects for demonstration are not yet developed	PHEV vehicles are not yet present in Rwanda
		Unexpected competitiveness for PHEV options	Not possible to benefit from inexistent PHEV market; economies of scale don't work
		Inexistent demand for PHEV options	Absence of infrastructure for PHEV battery stations; absence of first steps-actions and promoters
	Legal framework	Only regulation and laws governing conventional gasoline and diesel are operational	GHG emissions from vehicles are not controlled along the road even when exhaust gases are visibly observed
		Penalties and removal of old vehicles are missing	Hesitation in destroying old vehicles is still predominant
	Network of actors	Private sector participation in innovation for transport sub-sector is limited	PHEV technology remains unknown and unfamiliar to public potential purchasers and promoters of distribution of such vehicles
		Limited communication and share of opportunities between PHEV manufacturers and local importers for a step towards introduction of	PHEV options are not considered and only conventional vehicles are imported from Europe and Asia mainly.

		PHEV in the country	
	Human and Institution capacity	Limited technical and skilled human resources	PHEV , technology susceptible of resulting in GHG emission mitigation is not yet understood; very limited number of technicians sufficiently skilled in such a technology
		Insufficient institutional capacity	Campaign for promoting PHEV options is not organized; discussion about the PHEV benefits is not undertaken
		Dilemma: non starter , no demand	Nobody is ready to introduce PHEV
	Social and Cultural	Low confidence in PHEV alternatives	Resistance to change and to replacement of conventional vehicles by PHEV ones is potentially hindering the deployment of new transport scenarios
	Research and development	Absence of transfer of knowledge and PHEV technology from producer - countries to local potential consumers in Rwanda	Development of research and development facilities is missing while GHG emission from the fuel combustion for road transport are the highest in energy sector
		Limited focus on replacing fossil fuels by local renewable energy resources	Impacts of imported fossil fuels on energy bill are highly negative

1.5.4 Proposed action plans for the PHEV technology

Table 13: Technology Action Plan for PHEV technology

Measure	Justification	Activities	Responsible	Time frame	Estimated cost (USD)	Sources of funds	Success indicators	Risks indicators
Set up an industrial network for converting old vehicles into PHEV options	Collaboration between promoters of PHEV options and the owners of conventional vehicle is crucial	Feasibility study on conversion of old vehicles into PHEV; -Installation of an industrial unit for conversion	Private sector; MININFRA; MINICOM	10 years	1 million	GoR; JICA	Numbers of swapped vehicles and number of new PHEV units	-Converted vehicles have a small lifespan; - Lack of enough customers
-Law on bonus schemes -law on incentives to PHEV sub sector	Contribution to policy on GHG emission mitigation in transport	- Investigation on lessons and experience from abroad existing PHEV practices; --elaboration of the laws ;	MININFRA; REMA; MINICOM	10 years	40,000	G0R	Published laws in Rwanda Official gazette	Established laws are not properly applied
Mechanism	There is a great	-Installation of	MININFR	5 years,	800,000	GEF;	The number of	-Some

of investment in infrastructure for PHEV innovation (changing stations)	need in installing new stations for recharging batteries and in having a grid supplied with renewable energy	50 pilot stations for recharging batteries of PHEV;	A; REMA; Private sector			WB; AfDB	new stations installed for recharging the batteries of the PHEV electric motors	installed pilot stations do not get sufficient PHEV to be recharged;
-Subsidies' deliver to suppliers; -application of exemption for taxes and fees for only the end-users of the PHEV; -delivering bonus and subsidies to purchasers/end-users	-Encouraging suppliers and promoters of PHEV -Encouraging the importation of PHEV on a large scale -Bonus to PHEV promoters, consumers and increased taxes to those purchasing classic vehicles result in an combined important	-Negotiate and establish a special fund for subsidies and bonus; -Organizing a progressive ending of importation and use of conventional vehicles	MINECOFIN; REMA; MINICOM	5 years	20 million	WB;GEF;EU;GoR	Number of imported PHEV units every year; number of consumers to whom the bonus facilities have been delivered;	Amount of subsidies are covering just the first phase of the activity; -people are not importing enough number PHEV; Preference to use moto-cycles, an transport option very popular in

	factor for promoting the PHEV							Rwanda
-Loans -leasing programs -grants to local industrial units for PHEV components	The purchase channel process for new technology like PHEV requires particular grants and soft loans	-Negotiate the carbon credits facilities, the soft loans, grants and leasing programs; -Installation of a unit for producing or assembling locally the PHEV	RRA ; MININFRA; MINECOFIN; local financial institutions and banks; REMA; MINICOM	10 years	60 million	BADEA ; AfDB; GEF; GoR	Number of consumers , suppliers and companies which benefited from grants and subsidies every year	-in other countries at regional level, other units of PHEV industries are installed
Seminars and workshop for the capacity building in PHEV	The deployment of such a new technology requires a sufficient number of local technicians to deal with the PHEV technology;	-Organization of short training sessions for technicians and stakeholders; distribution of brochures on	REMA; MIMINFRA; RURA; MIFOTRA	5years,	300,000	GoR	Reports on seminars and capacity building sessions; Annually number of technicians and stakeholders	Trained staff and technicians are not fully integrated in the job system;

		PHEV advantage; use of local media					trained; Number of policymakers trained	
-Promotion of CDM and low carbon market credits to PHEV developers	Development of PHEV project through carbon market is part of obligations for GHG mitigation and it is important to access such facilities	-Setting up a service for the carbon credits; -Inventory of all projects eligible to the carbon credits	REMA; RDB; EWSA	5 years	2 million	GEF; WB; EU	The amount of CDM projects initiated and implemented	The process of carbon credits is suddenly stopped due to reasons linked to any misunderstanding between partners and donors

The transfer and diffusion of PHEV technology in Rwanda will require a set of stages including a key phase of RDD (research- development and demonstration) but also an installation of battery stations using preferably electricity generated through renewable energy resources. The risk of poor exploitation and low contribution of renewable energy resources to electricity sub-sector has to be carefully considered. Therefore it will be important to consider the following factors before implementing the specific measures to remove the identified barriers:

- Due to the low Income per Capita (about 275 USD) ,the financial capacity of potential purchasers of the PHEV new vehicles, instead of the most affordable second hand vehicles, is obviously limited;
- The Banks and Micro-finances institutions are not yet sufficiently sensitized to potential facilitation in delivering loans and leasing programs for promotion of electric vehicles;
- A lot of trucks and relatively old mini-bus highly pollutant i.e. often emitting GHG gases resulting from uncompleted combustion cannot be easily swapped with PHEV options;
- Purchase cost of a new vehicles is almost 2 times more important;
- The PHEV is a new technology and not yet introduced in Rwanda;
- Resistance to change and to replacement of conventional vehicles by the PHEV ones is potentially hindrance to the deployment of new transport scenarios.

A set of specific measures are hence required: incentives to encourage suppliers and promoters of PHEV, consumers, and manufacturing units; increased taxes for generic and second hand vehicles; deliver of bonus for PHEV options; provision of subsidies for any local production of equipments like electric motors and other key spare parts; installation of a sponsored unit for a potential conversion of conventional vehicles into PHEV options.

1.6 Action plan for large solar PV technology

1.6.1 About the large solar PV

The costs remain very high: for instance a 5 MWe of PV had its initial capital cost of 7 060 USD/kWe during the baseline year 2005 against the projections for the year 2015 of about 5 000 USD/kWe .The generating costs are projected, for the year 2015, to about 29 US cents/kWh against an average of 42 US cents/kWh in the year 2005 (ESMAP, 2007). The potential installation of remote mini-grids but also the direct connection to the national EWSA grid are appropriate for reducing the costs; avoidance of use of batteries is also a positive factor of the large solar PV.

Another scenario for reducing the capital cost is the use of the optional concentrated solar photovoltaic cells which are in fact characterized by less size of solar modules in line with the coefficient rate of concentrating the direct normal component of solar radiation. The mitigation potential (Reduction of GHG Emissions) is one the highest with regard to other technologies. In fact the solar PV is a non carbon technology and the batteries are not required in case of grid-connected option.

Replacing the existing thermal oil power plants by the large solar PV will result in a reduction of GHG emissions by about 79%. In fact the emission factor of solar PV grid is about 155 kg / MWh against 750 kg/MWh. Another alternative: the development of the solar PV technology on a large scale in Rwanda will result in reducing or avoiding the use of peat resources (GHG emissions of about 1075 kg/MWh) for generating electricity. Finally and in addition to above environmental issues, expected economic benefits are quite significant:

- Promotion of exploitation of local natural resources for electric power generation
- Reduction of exodus from rural to urban areas
- Small scale business and factories are created to generate more wealth.
- Increased rate of access to electricity services, resulting in healthier economy growth.
- Creation of jobs.

1.6.2 Targets for large solar PV transfer and diffusion

- Development of a national strategy for operation and maintenance of large solar PV system
- Exempting all types of solar equipments and components from import duties;
- Basic electrification of all schools, all health centers and all administrative offices in remote rural areas;
- Based on lessons learnt from the 250 kWe pilot plant installed in Kigali at Mount Jali, replication and installation of solar PV connected to the national EWSA grid;
- Development of guidelines on sizing and tender for provision of solar systems with high quality[3] standards.

[3] *Such adequate procurement can also take in account of new solar products more efficient like concentrated solar photovoltaic (CPV)*

1.6.3 Barriers to diffusion of large solar PV

Table 14: Economic and financial barriers for large solar PV

Barriers	Elements of barriers	Presentation and dimensions
high cost of investment and equipments	High Initial Capital Cost	The Photovoltaic systems, compared to other commercial energy technologies remain very expensive; Subsidies and low taxes have not yet resulted in larger diffusion of PV modules in Rwanda; Only some institution(Schools, Health Centers) can just afford an installation of about 3kW for mainly lighting purposes; EWSA installed just only a small plant with a capacity of 250 kWe in Rwanda, near Kigali.
	Limited access to loans from banks and leasing programs	Acquisition of solar modules is limited by the initial capital cost which has to be paid cash; Lack of access to credit is limiting both investors and end users to small scale size of solar products.
	Limited information and network to different manufacturers	Poor knowledge in PV sector results in buying non tested solar modules ; ,very often second hand products are taken for new on local market; new equipment remain expensive In addition, imported products from Europe, China, USA or Japan to Rwanda,(a landlocked country) are quite expensive due to transport .
	High cost installing private grids	Absence of decentralized mini-grid for distribution of electric energy is limiting deployment and diffusion of large solar PV system

Table 15: Non Financial Barriers for large solar PV

Barriers	Elements of barriers	Presentation/ and dimensions
Imperfection of solar market	Non-existent local industry for solar	An initiative of assembling the solar modules was set up before 1993 in Kabgayi headquarters of Catholic Church; it is no longer operational while it was expected to play a key role in making solar cells for local deployment.
	Unfamiliarity with solar PV technology	Design, preparation and implementation of solar PV, especially for larger scales, require more skilled labor and expertise which are currently minimal in Rwanda ; among others, more special skills in setting up local mini-grids are limited; all phases of installation, operation and maintenance lack accurate information on solar resources (variability within the year)
	Low competitiveness	From schools and universities to stakeholders' relative low awareness to solar PV technology, especially for large scale size, is noted; this option is found useful only for very small application of lighting just like the option of simple batteries charged at any available station. Compared to ordinary supply of energy from EWSA, the solar PV supply is negligible l in the context of power generation while its cost of acquisition is relatively high.
	Access to enough land	Due to the limited efficiency of converting solar light into electricity, required land area where to install a large solar PV is also too large for a country with the highest population density in Africa
Human and institutional capacity	Limited skilled expertise	Technicians trained for designing and installing the large solar PV plants are very few in Rwanda
	Non-existent centre for promoting solar application	Knowledge and expertise are limited

Social and cultural behavior	Resistance to change and investing in large solar	Different promoters and developers of solar are still limiting their business to standalone solar systems

1.6.4 Proposed action plans for Large Solar PV

Table 16: Technology Action Plan for Large Solar PV

Measure	Justification	Activities	Responsible	Timeframe	Estimated cost (USD)	Source of funds	Success indicators	Risks indicators
Creation of network of all key players in solar energy	Opportunity of developing a local industry and reduce cost of relevant equipment	-Inventory of all solar companies and investors in Rwanda; - Setting up units for assembling solar modules; - Formation of an solar association with to IRENA	MINICOM; Private sector	10 years	8 million	GoR	-Reports on joint ventures and actions; -Reports on visits done at local level and international large solar plants sites; -A solar industrial unit is operational	-Industrial unit set for solar doesn't attract local purchasers;
Law and regulation on long term incentives and taxes exemption	To handle the high cost of conventional solar components	-Elaboration of road map for the development of the large scale solar PV; -Elaboration of laws and	MININFRA; EWSA; RFPS (FRPS)	5 years	63,000	GoR	-Published laws in official gazette; - A published road map	- Laws are established but incentives are not influencing the diffusion

		regulatory frameworks						
Reviews of tariffs and access to grid networks	Need of agreement between EWSA and developers of large solar PV	-Elaboration of regulatory framework for tariffs, feed-in-tariffs; - Inventory and feasibility study of potential grid-connected PV systems	RURA and EWSA	10 years	63,000	GoR	Number of new developers and companies added to the list of promoters of solar PV systems connected to EWSA electric grid	-Grid-solar connection option is providing ; - Saturation of the EWSA grid and a temporal un-ability to buy solar electricity
-Subsidies -Soft loans and leasing programs; benefits from the carbon credits	-Required before reaching the stage of economy of scale -To handle the high initial capital cost	- Negotiate the access facilities to subsidies and carbon credits; -Set up a fund for soft loans and leasing programs; - Establish the CDM projects	MINECOFIN; MINICOM; Local Banks; International financial institutio	10 years	18 million	GEF; EU; WB	-Annually added power capacity generated by solar PV subsector; - The number of promoters benefitting from financial facilities is significant	-change in interest rate; - inflation ; -Carbon credits limited to small scale solar

			ns; REMA					
Set up a unit for training and research applied to solar exploitation and solar hybrids	Need of well skilled technicians and experts for installation and maintenance of grid and solar components	-Elaboration of design models for solar systems; - Establish a monitoring model of solar resources 'variability and solar components	EWSA; MINEDUC; MIFOTRA; Universities and colleges	5 years,	200,000	GoR	-Number of technicians awarded every year; -Number of jobs created; -Number of new local experts involved in setting up new large solar PV projects	- Uncertainties and climate variability affecting the direct normal radiation and efficiency of concentrators; - in Rwanda: low values of wind for solar hybrids

In addition to the relative familiarity with scale solar PV product on Rwanda market, potential developers of large solar PV technology, if facilitated, will be easily involved in local diffusion of such a technology; therefore the following factors have to considered:

- Existing subsidies and lowered taxes and fees have not yet significantly induced a larger diffusion of solar PV systems in Rwanda; only some institution(Schools, Health Centers) can just afford an installation of about 3kW for mainly lighting purposes;
- The Photovoltaic systems, compared to other commercial energy technologies, remain very expensive, especially the cost of equipment;
- It is important to mention that a private company in close collaboration with EWSA has installed a small solar PV plant with a capacity of 250 kWe directly connected to national electricity grid. Such an approach of grid-connected plants driven by renewable energy resources is quite an interesting step towards the anticipated development of large scale solar PV technology;
- Absence of decentralized mini-grid for distribution of electricity limits deployment and diffusion of large solar PV system;
- An initiative of assembling the solar modules was set up before 1993 in Kabgayi headquarters of Catholic Church; it is no longer operational while it was expected to play a key role in the process of the solar systems development and diffusion in Rwanda;
- Design, preparation and implementation of solar PV, especially for large scales, require more skilled labor and expertise which are currently limited in Rwanda ; among others, more special skills in setting up local mini-grids are minimal; all phases of installation, operation and maintenance lack accurate information on solar resources (variability within the year).

Specific consideration of energy storage is required. It is further necessitated by the potentially high risk of poor diffusion due to a possible poor design and availability limited by the stochastic (random) character of solar energy resources in a cloudy equatorial zone..

Specific measures to remove barriers hindering the diffusion of the Large Solar PV technology in Rwanda are mainly as follows: enactment of agreements for connections to the national electric grid; application of the feed-in tariffs; establishment of an updated solar map including the direct beam normal component used as an input i.e. ingredient for the optional concentrated photovoltaic(CPV);provision of subsidies to the developers of the solar mini-grids; Setting up a

partnership between stakeholders for a local solar industry promotion towards mainly an assembly plant ; Set up a pilot project of large scale solar PV plant; Introduction of f payment for equipment in installments instead of paying cash (leasing programs); Promotion of solar modules installed on buildings; subsidies for an introduction of the CPV and CSP (concentrated solar thermo-electric power) products in Rwanda.

CHAPTER 2: TECHNOLOGY ACTION PLAN FOR THE AGRICULTURE SECTOR

2.1 Actions at Sector Level

2.1.1 Sector description

In Rwanda, agriculture is the most important sector as it sustains the life of the majority of the Rwandan population. In 2009, the population engaged in agriculture was estimated at 80% of the total population which was 9, 5 million at the time. The agriculture contribution was 34% to GNP and 71% to export revenues. In addition, it is the main source of revenues for 87% of the population; it is thus considered to be the country's economic growth engine.

Rain-fed agriculture as being practiced in Rwanda is highly sensitive and vulnerable to the effects of climate change.. In fact, food crops and industrial crops growers have a very high degree of sensitivity especially during seasons of frequent and prolonged droughts as well as heavy rains. Indeed, large farmers and rural business people also show a high degree of sensitivity to seasonal prolonged droughts. Nonetheless, they are relatively less vulnerable due to having easy access to financial means and relying on past experiences dealing with and adapting to climate hazards.

Given the fact that agriculture is among the high priority sectors in the country's development plans and programs, several policies and strategies have been put in place to facilitate the sectors' development. Table 17 provides a list of existing laws, policies and strategies in the agriculture sector.

Table 17: Relevant laws, policies and strategies in the agriculture sector

Name	Year	Main contents
National Agriculture Policy	2004	The National Agriculture Policy is a policy which aims at integrating the agriculture sub sectors into the country's development priorities. Considered sub-sectors include: crops production, animal husbandry, and soil and water conservation. The policy categorizes priority commodities to be intensified for crops and animal production.
Strategic Plan for the Transformation of Agriculture in Rwanda-Phase II	2009	The Strategic Plan for the Transformation of Agriculture in Rwanda-Phase II is the second phase of a series of strategies aiming at transforming the agriculture sector through components analysis. It presents current situation and future development targets. The strategy also links the millennium development goals to their agriculture-related targets.
National Seed Policy	2007	The National Seed Policy is a policy which mainly promotes the role of the private sector in seed production and marketing activities; Mechanisms of doing research and variety development; Seed production and conditioning; Seed marketing and constitution of seed security stock; promotion of seed use; financing the private sector; Seed quality control; Seed import and export; Coordination and implementation of the seed policy.
National Post-Harvest Staple Crop Strategy	2011	The National Post-Harvest Staple Crop Strategy is a policy framework that assists the agriculture sector with Strengthening the harvesting, post-harvest handling, trade, storage, and marketing within staple crop value chains in Rwanda, in an effort to improve markets and linkages for farmers, and reduce postharvest losses. The Strategy's fundamental vision is to reduce food insecurity through an efficient post-harvest private sector system delivering staple foods to the people of Rwanda. It mainly contains; its vision, objectives, guiding principles and strategic axes of intervention.

National Agricultural Extension Strategy	2009	The National Agricultural Extension Strategy is a strategy established to develop agricultural extension methods, present characteristics of new orientations as regard to new decentralized extension, the role of different actors in agricultural extension system, functional relationship between the agencies of the Ministry of Agriculture and local administration entities (districts).
Irrigation Master Plan	2009	The Irrigation Master Plan is a national reference irrigation plan which partitions the country into six irrigation domains. Each domain is defined by the category, availability and accessibility of a given water resource vis-à-vis the biophysical and climatic features that influence its mode of abstraction and utilization.
Environmental organic law	2005	The environmental Organic Law is a law that regulates the protection of Environment in Rwanda. It sets out the general legal framework for environment protection and management in Rwanda. It also constitutes environment as one of the priority concerns of the Government of Rwanda. Under the fundamental principle on National Environmental Protection Policy, this law develops national strategies, plans and programs, aiming at ensuring the conservation and use of sustainable environmental resources.
Environmental policy	2003	The environmental policy is a national policy with overall objective of improving the population's wellbeing, judicious utilization of natural resources and the protection and rational management of ecosystems for a sustainable and fair development. The Policy recognizes the adoption of environmental friendly technologies and that the technology constitutes high priority for central and local authorities.
Land policy	2004	The Policy calls for rational use and sound management of national land resources and be based on master plans. The Policy also provides development of land use plans based on suitability

		of the areas/lands/swamps thus distinguishing the different categories of land and their purpose. Regarding the use and management of marshlands, the Policy stipulates that marshlands should be protected for human occupation such as industries and others except after adequate planning and environmental impact assessment.
National Water Resources Management Policy	2011	The "National Water Resources Management Policy" is a policy which aims at fair and sustainable access to water and improvement of the management of water resources, through reforestation on hillsides and water catchments areas.

The above discussed policies and strategies were developed by the most competent authority in collaboration with others stakeholders taking into account the country's needs and relevance of the policy/strategy. There exist mechanisms of policy/strategy review in order to adapt to the most current situation. Rwanda selected agriculture as the adaptation sector mainly based on its high level of vulnerability to the effects of climate change. Technologies were identified and selected for the country in general and the agriculture sector in particular to adapt to the effects of climate change. Below is a brief presentation of the current technology profile, level of employment and future targets.

2.1.2 Current technology profile, employment level and future targets

2.1.2.1 Seed and grain storage

Currently, there exist some seed and grain storage facilities using silos and warehouse technology options. The installed capacity is estimated at 36000 metric tons for silos and 88100 metric tons for warehouses located in different parts of the country.

The target group for the transfer and diffusion of this technology is the farmers' associations/cooperatives in the first place which are considered as ideal for the good management and maintenance of the systems once put in place. Although the number of fully operating farmers associations/cooperatives is not yet well known, it is assumed that the entire Rwandan farming community which is estimated at 1 400 000 households will benefit from seed and grain storage technology transfer and diffusion. Future targets include the installation of additional capacity of 200 000 metric tons by the year 2017.

2.1.2.2 Agro forestry

Agro forestry plantations only occupy ¼ of the available space to be used for the same purpose. Agro forestry systems being suitable for all kind of farming practices, the target group for its transfer and diffusion is the entire Rwandan farming community. It is estimated that all the sub groups (farming communities, associations and/cooperatives) of the 1 400 000 households involved in farming activities will benefit from agro forestry transfer and diffusion.

2.1.2.3 Radical terraces

According to district performance contracts up to 30000 ha of radical terraces were established by June 2012 in all the districts of Rwanda. Radical terraces are ideal for slopes ranging from 13% to 55%, it is estimated that agriculture land with radical terracing potential is owned by 1 000 000 households who are the main part of the Rwandan farming community. For this reason, the transfer and diffusion of radical terracing as an adaptation technology will target 71% of the entire farming community in Rwanda. Specific targets are the establishment of additional radical terraces to cover an estimated space of 7815 ha for the period of 2012/2013.

2.1.2.4 Drip irrigation

The total space currently covered by irrigation is estimated at 200 ha countrywide with the biggest drip irrigation system of 80 ha in the eastern province. Other small installations in place include Agriculture Research Centers and horticulture green houses mainly for flower and tomatoes. The transfer and diffusion of drip irrigation as a technology option for climate change adaption in Rwanda will target farming community populations located in low land regions, the central plateau with no incidental slopes and other areas where the land has been worked so as to be able to receive agriculture infrastructure. This farming community is estimated at 1 200 000 households which is about 80% of the entire farming community in Rwanda. Overall figures of future targets in irrigation are to reach 100000 ha in 2017 from 24000 ha currently in place. These include 65% of marshland irrigation and 35% of hillside irrigation. Drip irrigation falls into the category of hillside irrigation.

2.1.2.5 Rainwater harvesting

Rainwater harvesting infrastructure for agriculture applications is currently estimated at 3089 runoff ponds corresponding to 1235, 5 ha under irrigation. Only around 1% of the total number of beneficiaries has rooftop rainwater harvesting systems mainly for home applications.Rainwater harvesting transfer and diffusion could simply be beneficial to the entire Rwandan population given the country's relatively high precipitation per annum. In fact, rainfall average is 1400 mm per annum with abundant precipitation of 2000 mm in the North western part of the country and low precipitation of 700 mm in the South eastern part of the country. All the 1 400 000 households which make the Rwandan farming community could directly or indirectly benefit from the transfer and diffusion of this technology. Future targets up to 2017 include the installation of 2800 new runoff ponds to be installed at farm level and able to supply water to 1573 ha for irrigation purposes.

2.1.3 General barriers and proposed measures

The most common barrier for the all five technologies prioritized for the agriculture sector is gaps and/or lack of technical skills and knowledge. Crucial ones have also been identified as being: high cost of technology implementation and limited access to funds for all the five technologies. Other barriers include: limited awareness about the benefits of the technologies and limited rural infrastructure.

Proposed measures to overcome these barriers are: the provision of technical skills and knowhow for technology diffusion and deployment including implementation and maintenance, tax exemption, subsidies, incentives, reduction of interests' rates and facilitation to access funds by creating agriculture funding institutions, creation of awareness among farmers about the benefits as well as rural infrastructure development.

2.2 Action Plan for Seed and Grain Storage

2.2.1 Technology description

Seeds and grains are considered to be in storage from the moment they reach physiological maturity until they germinate, are consumed or thrown away because they are dead. Adequate storage helps preserve viability from harvest to sales, protects producers investment, profit and reputation. Cereals, pulses, oilseeds etc. are very important grain products for storage. In fact, good storage helps ensure household and community food security until the next harvest and commodities for sale can be held back so that farmers can avoid being forced to sell at low prices during the drop in demand that often follows a harvest. While considerable losses can occur in the field, both before and during harvest, the greatest losses usually occur during storage. Therefore the basic objective of good storage is to create environmental conditions that protect the product and maintain its quality and its quantity, thus reducing product loss and financial loss. Only well-dried seeds/grains should be stored. Seeds/ grains with moisture in them become damp, moldy and vulnerable to insect attacks.

The establishment of safe, long-term storage facilities ensures that:

Grain supplies are available during times of drought. It is important to be able to store food after harvest so as not to be compelled to sell at low prices. Appropriate storing techniques can prolong the life of foodstuffs, and/or protect the quality, thereby preserving stocks year-round. Seed and grain storage has been established to prepare for droughts, hunger and malnutrition (UNEP, 2010). Grain storage provides an adaptation strategy for climate change by ensuring feed is available for livestock and seed stock is available in the event of poor harvests due to drought (UNEP, 2010). Efficient storage can reduce post-harvest losses and preserve food quantity, quality and the nutritional value of the product (FAO, 2010). Innovations for addressing climate change include technologies for reducing waste of agricultural produce (BIAC, 2009). In fact, the establishment of safe storage for seeds and reserves of food and agricultural inputs are used as indicators of adaptive capacity in the agriculture sector (CARE, 2010).

2.2.2 Targets for seed and grain storage transfer and diffusion

The overall target group for the transfer and diffusion of this technology is the farmers' associations/cooperatives which are considered as ideal for the good management and maintenance of the systems once put in place. Although the number of fully operating farmers associations/cooperatives is not yet well known, it is assumed that the entire Rwandan farming community which is estimated at 1 400 000 households will benefit from seed and grain storage technology transfer and diffusion. Specific target would be that 50% the entire Rwandan community be able to benefit from modern seed and grain storage systems by 2020. It is important to highlight that according to the Rwanda Vision 2020, the population involved in agriculture will decrease from 80% to 60% by the year 2020.

2.2.3 Barriers to seed and grain storage diffusion

Several barriers which would limit meeting milestones and targets during transfer and diffusion of seed and grain storage were identified.. Categories of identified barriers are: Economical, financial and technological.

Economic and financial barriers include high initial investment cost which is related to the high cost of material and components and limited incentives and subsidies. Also, most of the material and components are imported from foreign countries. With the status of Rwanda as a landlocked country, material/components go through delays which negatively affects the delivery time and initial investment cost. Technological barriers are mainly those related to very few technical skills in installation and maintenance of seed and grain storage systems and there is no specific training on installation and maintenance of seed and grain storage systems.

Overall enabling framework which would assist in overcoming the identified barriers and meeting the specified targets and milestones for transfer and diffusion seed and grain storage have also been identified in the previous barriers analysis and enabling frameworks. They basically include already existing environment and other relevant factors to the transfer and diffusion of the technology. First of all, there exist institutions that intervene in the development of the agriculture sector. They mainly include the Ministry of Agriculture and Animal Resources which has the mandate of policy, strategy development and evaluation among others, Rwanda Agriculture Board which mostly deals with research, policy, strategy implementation in general and agriculture technology transfer and diffusion. Other institutions which directly partner with

the above mentioned in the development of the agriculture sector are; The Ministry of Natural Resources, The Ministry of Finance, The Ministry of Trade, Rwanda Natural Resources Authority, Rwanda Environmental Management Authority, Rwanda Cooperative Agency, Rwanda Governance Board, Rwanda Bureau of Standards, Financial Institutions and Research Institutions. Existing civil society partners include NGOs, farmers' associations/cooperatives and local business people (manufacturers, wholesalers and retailers). Other proposed enabling environments include; tax exemptions on imported material to be used in seed and grain storage systems installation, creation of interest among existing local manufacturers by providing incentives and subsidize the agriculture sector.

2.2.4 Proposed action plans for seed and grain storage

Table 18: Detailed action plan for the transfer and diffusion of seed and grain storage

Objective	Activities	Legal and Institutions framework	Responsibility	Timeframe	Estimated cost (USD)	Source of funds	Success indicators	Risk indicators
Increase awareness and local expertise	1. Selection of sites and construction of demonstration seed and grain storage systems	-Agriculture policy -Strategic Plan for Agriculture transformation, phase II -National Seed policy -Post harvest staple crops strategy - MINAGRI -MINICOM-MINECOFIN	The Ministry of Local Governance for site selection , the Ministry of Agriculture and the Ministry of Natural Resources for technical	1 year	Based on estimations from the post harvest, handling and storage task force, costs for this activity are estimated at 800000 $ (MINAGRI, 2012)	Funds are expected mainly from local funding institutions such as the Ministry of Finance and local banks. There may be other funding from internation	One demonstration site per rural province - 4 in total are constructed	No plan for site selection
	2. Organizing and directing training sessions on the installation and maintenance of seed and grain storage systems			1 year	The cost for training sessions is estimated at $ 200000. This cost is estimated based on assumptions that 400 technicians will be trained at a cost of $ 500 per trainee.		400 technicians are trained on basic function, installation and maintenance of seed and grain storage systems	No selected candidates yet

Reduce initial investment cost	3. Mobilization of local manufacturers	-MINALOC -MININFRA	expertise and the Ministry of Finance for fund mobilization and allocation	3 years	It is assumed that this activity will be carried out through meetings and the cost is estimated at $ 100000	al partners such as UNEP, the World Bank, the African Development Bank	Existence of at least one local manufacturer of component of modern seed and grain storage system	Actual electrify price is relatively high
	4. Creation of new rural feeder roads and improvement of existing ones			5 years	The estimated cost for this activity is $ 80000000. This cost is delivered from quotations as prepared by HYMMELEC ENGENEERING in 2012.		At least 50 km of new rural feed roads are developed and 500 km of existing roads are improved	No roads have been selected yet

Table 18 illustrates a series of actions/activities planned for the transfer and diffusion of seed and grain storage as an adaptation technology for the agriculture sector. These actions include the construction of demonstration sites to allow the farming community in general and technicians in particular to familiarize with the technology and understand its benefits.

Local manufacturers will also be mobilized as to start produce low cost technology components for cheaper diffusion. For easy decentralization of seed and grain facilities in remote areas with high agriculture production potential, there will be a pilot project on access road construction and improvement.

2.3 Action Plan for Agro forestry

2.3.1 Technology description

Agro forestry is the integration of agriculture and/or farming with forestry so the land can simultaneously be used for more than one purpose. This practice is meant to have both environmental and financial benefits. The presence of trees can provide benefits such as sheltering livestock from the elements and improving the soil so that crops will be more productive. The agro forestry system can also provide a more even income for landowners since all of their income is not tied to a few crops or a single season. Agro forestry can also make it easier for farmers to transition from one type of crop to another as market demand for their products changes.

Agro-forestry is used in almost the whole world where agriculture is practiced. In Rwanda, it is practiced in the agricultural zones which are found in all the provinces. Crops can be grown together at the same time, in rotation, or in separate plots when materials from one are used to benefit another. Agro-forestry systems take advantage of trees for many functions: to hold the soil; to increase fertility through nitrogen fixation, or through bringing minerals from deep in the soil and depositing them by leaf-fall; and to provide shade, construction materials, foods and fuel.

Although agro forestry requires more planning and know-how than simpler land uses given that the system must take into consideration the diverse and sometimes contradictory needs of each component, its environmental and adaptation benefits are many. They include: Increased water infiltration and slow runoff flow, stabilized and protected stream banks from erosion, filtration of pollutants from runoff water, provision of shades to streams for controlling temperature, provision of woody debris that promotes good stream habitat, provision of habitat for wildlife, provision of conduits for wildlife movement, slowing erosive winds and promotes dust deposition, provides visual diversity that improves scenic quality, screening undesirable views.

Socio economic benefits are mainly; creation of jobs in seedling preparation, land preparation, plantation, maintenance and harvesting; creation of investment in forestry production inputs, equipments and production transformation industry. It increases the income earned and inputs saved through improvements in the farm resource base and products for sale. Through increased yields, it provides significant savings for households on fire wood, forage and fertilizer purchase.

2.3.2 Targets for agro forestry

Agro forestry systems being suitable for all kind of farming practices, the target group for its transfer and diffusion is the entire Rwandan farming community. It is estimated that sub groups (farming communities made of households living in the same village, associations and cooperatives) of the 1 400 000 households involved in farming activities will benefit from the transfer and diffusion of agro forestry systems. Specific target would be that agro forestry be integrated on 210000 ha equivalent to 25% of the total arable land in Rwanda by 2020.

2.3.3 Barriers to agro forestry diffusion

Categories of identified barriers are: Political, economical, financial and technical.

Political barriers are mainly related to gaps that exist in forestry development legal framework. In fact the country has neither specific policy nor strategy on agro forestry development. Economic and financial barriers include relatively high initial investment, limited access to credit, high interest rate and the fact that agro forestry systems have no immediate economic benefits. Technical barriers are mainly those related to technical knowledge gaps which exist among agro extension agents and limited information and lack of awareness at farm level.

There also exists overall enabling framework which would assist in overcoming the identified barriers and meeting the specified targets and milestones for transfer and diffusion of agro forestry. They basically include already existing environment and other relevant factors to the transfer and diffusion of the technology. First of all, there exist institutions that intervene in the development of agriculture sector and agro forestry sub-sector. They mainly include the Ministry of Agriculture and Animal Resources and the Ministry of Natural Resources which has forestry development in its attributions. The mandate of these core institutions is policy, strategy development and evaluation among others, Rwanda Agriculture Board and Rwanda Natural Resources Authority / the forestry department which mostly deals with research, policy, strategy implementation in general and agro forestry technology transfer and diffusion in particular. Other institutions which directly partner with the above mentioned in the development of the agriculture sector are; The Ministry of Finance, The Ministry of Local Government, The Ministry of Trade, Rwanda Environmental Management Authority, Rwanda Cooperative Agency, Rwanda Governance Board, Rwanda Development Board, Rwanda Bureau of Standards, Financial Institutions and Research Institutions. Existing civil society partners include

NGOs, farmers' associations/cooperatives and local business people (manufacturers, wholesalers and retailers). Other proposed enabling environments include; tax exemptions, subsidies and incentives.

2.3.4 Proposed Action Plans for Agro forestry

Table 19: Detailed action plan for the transfer and diffusion of agro forestry

Objective	Activities	Legal and Institutions framework	Responsibility	Timeframe	Estimated cost (USD)	Source of funds	Success indicators	Risk indicators
Increase local expertise	1. Production of training materials	-National forestry policy -Agriculture sector transformation strategy-Phase II - MINAGRI -MINICOM -MINECOFIN -MINALOC -MININFRA -RAB -REMA	The Ministry of Local Governance for solving project site related issues, population mobilization and project implementation. the Ministry of Agriculture and the Ministry of Natural Resources for technical expertise and the Ministry of Finance for fund	1 year	50000	Funds are expected mainly from local funding institutions such as the Ministry of Finance and local banks. Other source of funds include the World Bank, the African Development Bank, FAO,	Training material are available	Poor content of the training material

		-RNRA	mobilization and allocation			IFAD and UNEP		
	2. Organize and conduct training sessions for agro extension agents			1 year	400000		One agro extension agent per sector is trained about the development and functions of integrated agro forestry systems	Absence of trained agro extension agents
	3. Provision of support to the rehabilitation of existing agro forestry research sites			2 years	150000		At least three existing agro forestry research sites are rehabilitated	None or not all existing agro forestry research sites are rehabilitated

Raise awareness	4. Production of awareness raising materials			1 year	50000		Awareness materials are produced	Non or incomplete awareness material are produced
	5. Installation of agro forestry demonstration sites			5 years	500000		Existence of at least one well developed agro forest demonstration site per province (5 country wide)	None or some of the proposed agro forestry demonstration sites are installed
	6. Organizing and directing farmers study tours			2 years	1000000		All farmers associations/cooperative leaders have at least visited one successful agro forestry site	None or very few farmers study tour are conducted

Reduce initial investment	7. Creation of tree seed stands in every district			5 years	2000000		Existence of one tree seed stands in every district	None of very few seeds stands are created
	8. Production of seedlings			4 years	1000000		Existence of one agro forestry nursery per sector in rural areas	Nurseries for agro forestry trees do not exist in all rural sectors

The interconnectedness of the components for seed and grain storage transfer and diffusion can be seen from activities dedicated to capacity building such as organizing and directing training sessions for agro extension agents, organizing and directing farmers study tours for better understanding and reception up to activities on actual transfer Production of training materials like the creation of tree seed stands in every district and production of seedlings. In fact, it was seen more relevant to start from informing the people before any other activity is undertaken.

2.4 Action Plan for Radical Terraces

2.4.1 Technology description

Radical terracing refers to a technique of landscaping a piece of sloped land into a series of successively receding flat surfaces or platforms, which resemble steps, for the purpose of more effective farming. This type of landscaping, therefore, is called terracing. Graduated terrace steps are commonly used to farm on hilly or mountainous terrain. Terraced fields decrease erosion and surface runoff retaining soil nutrients. Their environmental benefits and adaptation potential include: Soil erosion control, soil moisture improvement and maintenance, soil fertility improvement and maintenance, arable land (surface) increment, biodiversity conservation and natural hazards (land slide) prevention (MINAGRI, 2009).

Socio economic benefits are mainly; Contribution to the improvement of yields in both quality and quantity by increasing arable surface, soil fertility as well as permanent moisture content. For example potato yields would increase up to 140% on terraced spaces compared to non terraced ones which generate more income to the farmer. The implementation radical terraces are a labor intensive exercise which provides jobs to the local population. They promote investments opportunities in manufacturing tools such as shovels, tridents etc (Mupenzi et al., 2012).

2.4.2 Targets for radical terraces

Radical terraces are ideal for slopes ranging from 13% to 55%, it is estimated that agriculture land with radical terracing potential is owned by 1 000 000 households which make up a big majority of the Rwandan farming community. Radical terraces have already been implemented by individuals and local government entities (districts) but they still cover relatively smaller area of less than 20% of the total potential surface area. Specific target would be that radical terraces be implemented on 294000 ha equivalent to 50% of the total arable land with slopes ranging between 13% and 55% by the year 2020.

2.4.3 Barriers to radical terraces diffusion

Possible barriers which would limit meeting milestones and targets during transfer and diffusion of radical terraces have been identified and reported during barrier and enabling framework analysis exercise. Categories of identified barriers are: Political, economical, financial, technological and cultural.

Political barriers are mainly related to gaps that exist in land management legal framework. The country has neither specific policy nor strategy on radical terracing. Economic and financial barriers include relatively high initial investment, limited access to credit; high interest rate and the fact that radical terraces have no considerable immediate economic benefits. Technological barriers are mainly those related to limited technical skills in terracing and lack of reference information such as slope, soil depth, type etc. Cultural barriers are mainly limited acceptability of radical terraces within some communities due to perceptions that they reduce the size of the farm.

Overall enabling framework which would assist in overcoming the identified barriers and meeting the specified targets and milestones for transfer and diffusion of radical terraces basically include already existing environment and others, relevant to the transfer and diffusion of the technology. First of all, there exist institutions that intervene in the development of agriculture sector and land management. They mainly include the Ministry of Agriculture and Animal Resources and the Ministry of Natural Resources which has land management in its attributions. The mandate of these core institutions is policy, strategy development and evaluation among others, Rwanda Agriculture Board and Rwanda Natural Resources Authority /

the land centre which mostly deals with research, policy, strategy implementation in general and land management technology transfer and diffusion in particular.

Other institutions which directly partner with the above mentioned in the development of the agriculture sector are; The Ministry of Finance, The Ministry of Local Government, The Ministry of Trade, Rwanda Environmental Management Authority, Rwanda Cooperative Agency, Rwanda Governance Board, Rwanda Development Board, Rwanda Bureau of Standards, Financial Institutions and Research Institutions and International agencies. Existing civil society partners include NGOs, farmers' associations/cooperatives and local business people (manufacturers, wholesalers and retailers). Other proposed enabling environments include; tax exemptions, subsidies and incentives.

2.4.4 Proposed Action Plans for Radical Terraces

Table 20: Detailed action plan for the transfer and diffusion of radical terraces

Objective	Activities	Legal and Institutions framework	Responsibility	Timefr ame	Estimat ed cost (USD)	Source of funds	Success indicators	Risk indicators
Reduce initial investment	1. Mobilization of local manufacturer s	-Agriculture sector transformati on strategy-Phase II - MINAGRI -MINICOM - MINECOFI N -MINALOC - MININFRA -RAB -REMA -RNRA	The Ministry of Local Governance for solving project site related issues, population mobilization and project implementation. the Ministry of Agriculture and the Ministry of Natural Resources for	3 years	100000	Funds are expected mainly from local funding institutions such as the Ministry of Finance and local banks. Other source of funds include the World Bank, the African Development	Existence of at least five manufacturers of basic tools	Small number of mobilized local manufacturers
	2. Provision of compost			5 years	1000000		8000 ha of newly established radical terraces are supplied with compost	Shortage of compost
Improve local expertise	3. Organization and conduction of technical trainings for extension agents,			3 years	1000000		At least one agro extension agent per sector is trained farmers and all farmers' associations/coo perative leaders	No trainings are conducted

	farmers association leaders		technical expertise and the Ministry of Finance for fund mobilization and allocation			Bank, FAO, IFAD and UNEP	have at are trained about radical terraces establishment and maintenance	
Increase acceptability of radical terraces within communities	4. Preparation and conduction of awareness campaigns			5 years	200000		Farmers are aware about benefits of radical terraces	Incomplete awareness campaigns are conducted

The mobilization of local manufacturers is the first component in the technology action plan for transfer and diffusion of radical terraces in order to promote local availability of basic tools given their high cost. To make the whole process a success, agriculture extension agents and the representative of the farming community (cooperatives/associations leaders) would benefit from a series of trainings which aims at building their capacity in terms of know how.

2.5 Action Plan for Drip Irrigation

2.5.1 Technology description

Drip irrigation is an irrigation technology based on the constant application of a specific and focused 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. The system should maintain adequate levels of soil moisture in the rooting areas, fostering the best use of available nutrients and a suitable environment for healthy plant roots systems. Its adaptation benefits are found through its ability to manage the exact (or almost) moisture requirement for each plant which significantly reduces water wastage and promotes efficient use.

Environmental wise, drip irrigation minimizes runoff and evaporation, reduces runoff and non-point source pollution, improves groundwater recharge, improves soil quality and retards erosion. Socio economic benefits include but not limited to: The creation of jobs in systems installations and maintenance, promotion of investments in components manufacturing, supply and systems installation, contribution to food security and increment of farmer's income.

2.5.2 Targets for drip irrigation

Overall targets in the transfer and diffusion of drip irrigation as an adaptation technology have been established in previous reports. These were estimated based on overall number of beneficiaries estimated at 1 200 000 households, 80% of the entire farming community in Rwanda. Specific target would be that drip irrigation be implemented on 20000 ha in the arid region of the country (eastern province) by the year 2020.

2.5.3 Barriers to drip irrigation diffusion

Possible barriers which would limit meeting milestones and targets during transfer and diffusion of drip irrigation have also been identified and reported during barrier and enabling framework analysis exercise. Categories of identified barriers are: Economical, financial, technological, natural and cultural.

Economic and financial barriers include relatively high initial investment, limited access to credit; high interest rate and limited private companies dealing in drip irrigation equipments. Technological barriers are mainly those related to limited technical skills in drip irrigation

systems installation and maintenance. Natural barriers include: Seasonal fluctuation of water availability, elevation of agricultural lands vs common water sources location, competition with other water uses. Cultural barriers are mainly those related to the fact that communities are not familiar with modern irrigarion systems which may result in rejecting the technology.

Overall enabling framework which would assist in overcoming the identified barriers and meeting the specified targets and milestones for transfer and diffusion of drip irrigation basically include already existing environment and others, relevant to the transfer and diffusion of the technology.

First of all, there exist institutions that intervene in the development of agriculture sector and water resources management. They mainly include the Ministry of Agriculture and Animal Resources and the Ministry of Natural Resources which has water resources management in its attributions. The mandate of these core institutions is policy, strategy development and evaluation among others, Rwanda Agriculture Board and Rwanda Natural Resources Authority / the water resources department which mostly deals with research, policy, strategy implementation in general and integrated water resources management technology transfer and diffusion in particular.

Other institutions which directly partner with those mentioned above in the development of the agriculture sector are; The Ministry of Finance, The Ministry of Local Government, The Ministry of Trade, Rwanda Environmental Management Authority, Rwanda Cooperative Agency, Rwanda Governance Board, Rwanda Development Board, Rwanda Bureau of Standards, Financial Institutions and Research Institutions and International agencies. Existing civil society partners include NGOs, farmers' associations/cooperatives and local business people (manufacturers, wholesalers and retailers). Other proposed enabling environments include; tax exemptions, subsidies and incentives.

2.5.4 Proposed Action Plans for Drip Irrigation

Table 21: Detailed action plan for the transfer and diffusion of drip irrigation

Objective	Activities	Legal and Institutions framework	Responsibilities	Timeframe	Estimated cost (USD)	Source of funds	Success indicators	Risk indicators
Make available affordable drip irrigation systems	1. Promotion of local manufacturer	-Agriculture sector transformation strategy-Phase II - MINAGRI -MINICOM -MINECOFIN -MINALOC -MININFRA -RAB -REMA -RNRA	The Ministry of Local Governance for solving project site related issues (land...), population mobilization and project implementation. the Ministry of Agriculture and the Ministry of Natural Resources for	5 years	1500000	Funds are expected mainly from local funding institutions such as the Ministry of Finance and local banks. Other source of funds include the World Bank, the African Development	Drip irrigation components/systems are manufactured locally	Small number of mobilized local manufacturers

			technical expertise and the Ministry of Finance for fund			Bank, FAO, IFAD and UNEP		
Improve local expertise	2. Organizing and directing technical trainings on drip irrigation systems installation and maintenance		mobilization and allocation	3 years	1000000		Existence of local contractors dealing with drip irrigation systems installation and maintenance	No trainings are conducted
Increase acceptability of drip irrigation systems	3. Preparing and conducting of awareness campaigns			5 years	200000		Farmers are aware about benefits of drip irrigation	Incomplete awareness campaigns are conducted

among communities	4. Installation of small scale solar powered drip irrigation systems in remote areas			5 years	5000000		1000 units of small scale solar powered drip irrigation are installed on selected farms in dry regions of Rwanda	No solar powered drip irrigation systems are installed in remote areas

Table 21 illustrates a series of actions/activities planned for the transfer and diffusion of drip irrigation as an adaptation technology for the agriculture sector. These actions include organizing and directing technical trainings on drip irrigation systems installation and maintenance, preparing and conducting awareness campaigns and Installation of small scale solar powered drip irrigation systems in remote areas.

2.6 Action Plan for Rainwater Harvesting

2.6.1 Technology description

Rainwater harvesting is a technology used for collecting and storing rainwater from rooftops, the land surface or rock catchments using simple techniques such as jars and pots as well as more complex techniques such as underground check dams. Commonly used systems are constructed of three principal components; namely, the catchment area, the collection device, and the conveyance system.

Socio economic benefits are mainly; Increased job opportunities, investment opportunities in RWHS components manufacturing, increased number of harvesting seasons and increased income. Environmental benefits include: No need of energy resources and chemicals normally used for clean water production. It reduces demand on rivers and groundwater, large- scale collection of rainwater can reduce run-off and therefore the risk of flooding.

2.6.2 Targets for rainwater harvesting

Rainwater harvesting transfer and diffusion could simply be beneficial to the entire Rwandan population given the country's relatively high precipitation per annum. In fact, rainfall average is 1400 mm per annum with abundant precipitation of 2000 mm in the North western part of the country and low precipitation of 700 mm in the South eastern part of the country. All the 1 400 000 households which makes the Rwandan farming community could benefit from the transfer and diffusion of this technology. Specific targets are the installation of a total capacity of 1 000 000 m^3 country wide by 2020.

2.6.3 Barriers to rainwater harvesting diffusion

Possible barriers which would limit meeting milestones and targets during transfer and diffusion of rainwater harvesting have been identified and reported during barrier and enabling framework analysis exercise. Categories of identified barriers are: Economical, financial and technological.

Economical and financial barriers are mainly related to the high cost of RWH systems, difficulties to access funds and high interest rate. Technological barriers are mainly those related to limited technical skills in rain water harvesting systems installation and maintenance.

Overall enabling framework which would assist in overcoming the identified barriers and meeting the specified targets and milestones for transfer and diffusion of rain water harvesting basically include already existing environment and others, relevant to the transfer and diffusion of the technology.

There exist institutions that intervene in the development of agriculture sector and water resources management. They mainly include the Ministry of Agriculture and Animal Resources and the Ministry of Natural Resources which has water resources management in its attributions. The mandate of these core institutions is policy, strategy development and evaluation among others, Rwanda Agriculture Board and Rwanda Natural Resources Authority / the water resources department which mostly deals with research, policy, strategy implementation in general and integrated water resources management technology transfer and diffusion in particular.

Other institutions which directly partner with those mentioned above in the development of the agriculture sector are; The Ministry of Finance, The Ministry of Local Government, The Ministry of Trade, The Ministry of Infrastructure, Rwanda Environmental Management Authority, Rwanda Cooperative Agency, Rwanda Governance Board, Rwanda Development Board, Rwanda Bureau of Standards, Financial Institutions and Research Institutions and International agencies. Existing civil society partners include NGOs, farmers' associations/cooperatives and local business people (manufacturers, wholesalers and retailers). Other proposed enabling environments include; tax exemptions, subsidies and incentives.

2.6.4 Proposed Action Plans for Rainwater Harvesting

Table 22: Detailed action plan for the transfer and diffusion of rainwater harvesting

Objective	Activities	Legal and Institutions framework	Responsibilities	Timefr ame	Estimat ed cost (USD)	Source of funds	Success indicators	Risk indicators
Improve local knowledge	1. Organizing and directing technical trainings on rain water harvesting systems installation and maintenanc e	-Agriculture sector transformatio n strategy- Phase II - MINAGRI -MINICOM - MINECOFIN -MINALOC -MININFRA -RAB -REMA -RNRA	The Ministry of Local Governance for solving project site related issues (land...), population mobilization and project implementation. the Ministry of Agriculture and the Ministry of Natural Resources for	3 years	800000	Funds are expected mainly from local funding institutions such as the Ministry of Finance and local banks. Other source of funds include the World Bank, the African Development	Existence of local contractors specializing in small to large scale rainwater harvesting systems installation and maintenance	No trainings are conducted
Make available affordable	2. Promotion of local manufactur			4 years	2000000		Rainwater harvesting systems/	No local manufacturers are promoted

rainwater harvesting systems	ers		technical expertise and the Ministry of Finance for fund mobilization and allocation			Bank, FAO, IFAD and UNEP	components are produced locally	
	3. Provision of subsidies for technology acquisition			6 years	10 000 000		Rainwater harvesting systems with a capacity of 1000000 m^3 are installed country wide	Very small capacity of rainwater harvesting system is installed countrywide

The interconnectedness of the components for rainwater harvesting transfer and diffusion can be seen from organizing and directing technical trainings on rain water harvesting systems to the action diffusion through provision of subsidies for technology acquisition. In fact, it was considered more relevant to start with informing and raising awareness of the people before they use the technology.

Actions plans are mainly designed to address the issue of efficient technology transfer and diffusion. They take into account main barriers and proposed measures for best technology implementation. For seed and grain storage, they include: The selection of sites and construction of demonstration seed and grain storage systems, organizing and directing training sessions on the installation and maintenance of seed and grain storage systems, mobilization of local manufacturers, and creation of new rural feeder roads and improvement of existing ones.

The agro forestry technology will be promoted through trainings; awareness raising and creation of seeds/seedlings stands in every district of the country to assist farmers in better understand the benefits of agro forestry and support them in having main basic production inputs. The implementation of radical terraces as a CC adaptation technological option would require actions which include: The Mobilization of local manufacturers, the provision of organic manure, trainings and awareness creation.

Action plans for transfer and diffusion of drip irrigation will be based on different activities including: the promotion of local manufacturers for grip irrigation components, the installation of pilot drip irrigation systems preferably powered by solar panels trainings and awareness rising. Regarding rain water harvesting, actions plans are: Organizing and directing technical trainings on rain water harvesting systems installation and maintenance, promotion of local manufacturers, assistance to farmers for technology acquisition.

Existing interconnectivity between action plans for the all five selected technologies are: the promotion of local manufacturing since most of the technology components are imported which makes them expensive, trainings to improve local knowledge and awareness creation especially among farmers about multiple benefits of the technologies.

3. STAKEHOLDERS CONSULTATION

Key persons in different institutions were approached individually mostly through face to face meetings (see annex 1). This facilitated the drafting of the actions plans for all the selected technologies. After this exercise, the consultation process continued with a wide range of stakeholders during a workshop meeting held on 30th November 2012 at Umubano Hotel, Kigali, Rwanda. Invited were experts in the energy and agriculture sectors with scientific and financial backgrounds, people from the academia, researchers, NGOs representatives and media.

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Annex

Annex 1: List of Involved Stakeholders

Energy sector

N°	Names	Field	Institution
1	Dr. Gasingirwa Christine	Chemistry	MINEDUC
2	Dr. Jean Baptiste NDUWAYEZU	Agro forestry	IRST
3	Dr. Edmond Rwabuhungu	Hydrology / Geothermal	NUR
4	Dr. Ndahayo Fidele	Physics	NUR
5	Eng. NIYONZIMA Steven	Civil Engineering /Environmental	NUR
6	Prof.Dr.Nizurugero Jean	Sociology /socio economics	NUR
7	Dr.Eng. Omar MUNYANEZA	Civil engineering/water engineering	NUR
8	Eng.Fabien MUKUNDUFITE	Power engineering/ renewable energy	NUR
9	Eng. Desire TWUBAHIMANA	Civil engineering	KIST
10	Dr. Telesphore KABERA	Hydro-geology/carbon capture	KIST
11	Eng. Fabien HABYARIMANA	Physics/solar energy	KIST
12	Dr. Cyprien HAKIZIMANA	Environmental chemistry	IRST
13	Eng. Augustin MUNEZERO	Power engineering/ renewable energy	IRST
14	Eng. Felicien NSABUKUNZE	Applied physics /renewable energy	IRST
15	Eng. Francois HABINSHUTI	Civil engineering	IRST
16	Eng. Vincent GASAMAGERA	Physics/ combustible nuts	IRST
17	Prof. Dr. KAREMERA MAREMBO	Physics/solar concentrators	INATEK
18	Dr. Aloys KAMATARI	Environmental Chemistry/	INATEK
19	Eng. Alain Patience NIYIBIZI	Applied physics/Renewable	EWSA

		energy(biogas)	
20	Eng. Charles NYIRAHUKU	Unit of Methane gas ,petroleum, and peat	EWSA
21	Eng. Gaspard NKURIKIYUMUKIZA	Renewable energy	EWSA
22	Eng. Gaetan SAKINDI	Applied Physics/geothermal	EWSA
23	Eng.Oswlald TANGANYIKA	Computer Science	INATEK
24	Dr Mathusalem KANOBANA	Soil Science	INATEK
25	Eng. Edison NIYONTEGEREJE	Power engineering/renewable energy	CIMERWA
26	Eng. Jean de Dieu MUKWIYE	Solar energy	Private sector
27	Dr. Augustin BIZIMANA	Civil engineering/Energy demand	Private sector
28	Eng. Gallican KAYITABA	Architector / energy demand	Private sector
29	Eng. Marcel HABIMANA	Power engineering	MININFRA
30	Eng.Charles KABIRI	Electromechanics	NUR
31	Eng.Onesphore NYAWERA	Computer science	IECO -GAZ .COM ltd.
32	Dr. Fabien TWAGIRAMUNGU	Chemistry/Environment	KIE
33	Eng. Jean BIZIMANA	Electromechanics	EWSA(Keya Small Hydro Power Plant)
34	Eng. Theoneste ISHIMWE	Electromechanics	IRST
35	Eng. Jacques MUNYANDAMUTSA	Electrical	EWSA
36	Eng. Laurent MAJUNE SIBOMANA	Mechanical Engineering	EWSA(Methane Gas Project/Kibuye Power Plant)
37	Eng. Elie KABENDE	Applied physics/R.E	ULK/Gisenyi
38	Eng. Abias UWIMANA	Environmental chemistry	NUR
39	Abbe Eugène URAYENEZA	Sociology	Gisenyi Parish
40	Dr. Froduald MINANI	Mathematics	NUR

41	Eng. Olivier NTIRUSHWA	Power engineering/renewable energy	Kivu Methane Gas

Agriculture sector

No	Names	Affiliation	E-mail
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