Republic of Rwanda

TECHNOLOGY NEEDS ASSESSMENT-PROJECT IDEAS

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Supported by:

CONTENTS

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: Sulfuric Oxides

TNA: Technology Needs Assessment

TVET: Vocational Education & Training

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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CHAPTER I: PROJECT IDEAS FOR THE ENERGY SECTOR

1.1 Summary of the Project Ideas for the Energy Sector

Projects presented below were identified through an approach based on diversification and availability of resources. The solar PI is expected to be easily replicated due to its simplicity and the opportunity of grid-connection to EWSA network. For the technology of small hydro, about 50 units will contribute in a wider diffusion of rural electrification due to the 224 sites not yet exploited and the huge potentialities in low-head and hydrokinetic scenarios. The 50 modules of geothermal in Bugarama will contribute up to 14 % of rural electrification. Regarding the CCGT with CCS, a 10MW is suggested and its contribution to diffusion of use of Kivu methane gas with the CCS component is due to the satisfactory decrease in GHG emissions at rate of 86 %.For the sub-sector of transport, 5 stations and 50 units of the PHEV are suggested. The diffusion and development of such a new technology in Rwanda are achievable especially due to the expected decrease in consumption of gasoline fuel: 4 times less.

Within the context of the TNA project in Rwanda, five technologies were prioritized and are limited at this stage to electricity and transport sub-sectors. Apart from the SS / MT (small scale / medium term), our process of identifying the projects took in account of all other possible categories for applicability (scale) and availability (term) of technologies as considered and discussed below in table 1.

Table 1: Categories of prioritized technologies

Technology	**Applicability of technology(scale)**	**Availability of technology(term)**	**Category**
Small hydropower	Small scale[SS]	Short term[ST]	SS/ST
Kivu methane CCGT with CCS	Large scale[LS]	Short term[ST] for the CCGT component; Medium term[MT] for the CCS component	LS/ST and LS/MT
Geothermal-to-power	Large scale[LS]	Short term[ST]	LS/ST
PHEV	Small scale[SS]	Long term[LT]	SS/LT
Large solar PV	Large scale[LS] , but also small scale[SS]; in fact solar PV is always a modular system	Short term[ST]	LS/ST as an ensemble of the modular SS/ST

Among these above five technologies prioritized within the context of the nine key criteria discussed in the TNA report and selected under a joint duality of the development priorities and the climate change mitigation obligations, the PHEV is characterized by a medium to long term availability in Rwanda and the CCS component presents a risk of hindering the complex, but greatly useful, methane CCGT with CCS technology. The remaining three technologies, i.e. hydro, geothermal and solar, respond to the short term availability.

Regarding the small hydropower technology, in addition to the high number of potential sites already identified, there is a great opportunity in widening the potentialities through the in-river hydrokinetic turbine (HKT) option. Therefore concrete actions can be oriented to an immediate exploitation of the 224 pico/micro-hydropower sites still unequipped while water resources in Rwanda are quite stable due to a relatively good distribution along the different seasons over the year.

Where the conventional hydropower technology is not suitable because of the absence of a sufficient head level from which water can fall towards the turbine, the HKT can be considered. Therefore the HKT option can be applied to the rivers Akanyaru, Nyabarongo and Akagera even in flat lands of Southern and Eastern areas of the country.

Another asset is the modular character of the solar PV systems through which both the small scale and large scale applicability can contribute to the energy supply at large scale in rural areas where mini-grids are expected to be developed. The particular scenario of connection to the national electric grid is quite feasible and sustainable. Global solar radiation resources are sufficient in Rwanda, very well distributed over the year and spatially equitable and available.

The geothermal technology diffusion in the country is quite possible at short term as far as a pilot plant is projected for this coming year 2013 at Karisimbi volcano area. Even though through the current drilling techniques it is possible to reach a depth of about 10 km, the extraction of geothermal water at lower depths, i.e. presenting lower temperatures, is also an added value due to the opportunity of generating electricity by use of a second working heat fluid characterized by a low boiling temperature point.

The main national targets mentioned in previous reports and referred to in the latest national energy policies and strategies are focused on electricity production up to a capacity of at least 1000 MWe by the year 2017.
Therefore priority on project ideas is given to more available energy resources within the context of diversification: geothermal, Kivu methane gas, solar and hydropower. The approach based on introduction of new technologies influenced also the identification of these project ideas. The diffusion of these projects and their outputs is guaranteed due to mainly the proved sustainability and renewability of the relevant energy resources and the current applicability and adoptability of such technologies.

1.2. Project ideas for small hydropower technology (SHP)

Table 2: Detailed project idea for small hydropower technology

Introduction	Small hydropower technology is relatively popular in Rwanda even though the number of unequipped potential hydro sites remains high. Among 333 Pico / micro hydropower sites recently identified, there are 109 sites that are under the stage of preliminary design and collection of data since March 2012 (EWSA, 2012). More potential hydro sites are to be added to the above figures in consideration of the option of in-river hydrokinetic turbine (HKT) as presented below. An establishment of 50 pilot plants of HKT options is suggested.
Objectives	To establish and develop in-river hydrokinetic (HKT) pilot plants of modular capacity of 100kWe; To exploit all 224, i.e.67% of the above 333 identified potential micro hydropower sites; To increase the rate of access to electricity services mainly in rural areas by installing 50 units disseminated in different districts. To create employment for Rwandans in the establishment and maintenance of hydropower plants. To boost businesses and manufacturing industries in rural areas through the electrical power supply; To validate collected data and preliminary design; To validate the characterization of all key parameters including discharge , river depth and variability of water resources; To consider the importation of equipment and their installation and to construct electric off-grids ; Optional connection to EWSA grid.
Outputs	50 units in different districts are installed; A total electric energy of about 26.28 GWh per year[1] is added to the existing capacity of Rwanda; About 20 qualified technicians are employed for maintenance of hydro plants; New business and manufacturing are created in rural areas around the projects.
Relationship to country's	Among the 333 potential sites identified by EWSA and MININFRA, only 109 sites are expected to be exploited and to generate electricity in the short term.

sustainable development priorities	By applying these technologies, more potential sites will be developed, which is in line with the plans for the energy companies. By the year 2017 electrification rate is projected to be about 30% instead of the actual 10% (EWSA, 2012) thus improving the development of the country.
Project Deliverables	Development and installation of such electric capacity will result in a change of rural population life standard , increase in business centers, and increased incomes as well as poverty alleviation; Electricity supply in rural areas will be increased and exodus to urban areas will be reduced; Lighting by electricity instead of petroleum fuels at household level and hence contribution to reduction of GHG emissions; Reduction of wood fuels used for cooking services due to use of electricity as indicated in previous reports of this TNA project[1].
Project scope	Exploitation of the hydropower assets will require a step of identifying at least 50 potential sites, collecting data, design process, technical assistance and management works for the 50 hydrokinetic sites totaling up to 5MWe of estimated capacity. The assignment of data collection and the preliminary design will focus on the following issues: Discharge and flow estimation based on appropriate measurements and on existing database from MININFRA, EWSA and MINIRENA(precipitation ,meteorological data ,maps on 1:50,000 with level curves, Modeling and estimation of the river flow-rates going back some years and the near-future forecasts ; Establishment of water catchment area and identification of hydrokinetic potential sites; Establishment and preliminary design through the first parameters of

[1] In addition to liquefied Kivu methane gas, biogas and wood-based fuels, electricity will contribute also to cooking services within the context of climate change mitigation in Rwanda

	hydrokinetic turbine(flow-rate, water velocity and water depth, installed power potential capacity and energy production); Re-evaluation of the technical parameters for different sizes and power standardization(25kWe, 50kWe, 75kWe, 100kWe, 125kWe, 150kWe, 200KWe, 250kWe); Design and elaboration of drawings; elaboration of a list of mechanical and electrical equipment (turbines, generators, channel augmentation, mounting, floatation, power converter, control instruments and protection devices etc) ; Establish a general estimate for investment value; Establish a chart for works implementation; Establish the social environmental impact assessments on the project areas; Establish the final report
Activities	Design and construction of the 50 micro plants at selected sites Installation of the mini-grids and distribution network to end-users
Timeline	2 years
Budget	Initial capital cost : between 3300 USD/ kWe and 7900 USD/ kWe according to specific factors like velocity of water, quality of water, and river depth as considered in the study; the average cost is about 5600 USD/ kWe. The main activities are the design, characterization of key parameters, importation of equipment and their installation; their costs per kWe installed are respectively about 600 USD, 400 USD, 3500 USD and 1100 USD; Total budget required for installation of the 50 pilot projects (total of 5MWe) is hence about 28 millions of USD. Required staff : multidisciplinary team with broad skills in hydrological and electro-technical areas;

	Partnership: required mainly for technical assistance and capital mobilization for overall construction and the purchase of equipment; Source of funds: opportunity of soft loans recently made available by the IRENA (International Renewable Energy Agency) in close cooperation with the ADFD (Abu Dhabi Fund for Development) for a loan interest rate not exceeding 6% ; Subsidies and carbon market credits; Private sector and local banks; Public sector and World Bank.
Evaluation	Every year about 25 hydrokinetic sites are developed and made operational; At the end of the project timeline, about 5MWe are installed for an operating capacity factor of about 0.5; Rural electrification is increased: about 1800 MWh of electric energy is monthly supplied to communities;, about new 25 thousand households are connected to the electrical local off-grids with an average consumption of 72 kWh/month per household;
Challenges	Costs of some equipment and installation of the whole system are expensive and hence not easily affordable by the local interested investors, local communities or cooperatives. Risks of seasonal decrease of the designed water flow discharge of streams or rivers
Assumptions	- Among the 333 potential sites identified by EWSA and MININFRA, only 109 sites are expected to be exploited and to generate electricity in the short term; - The underwater HKT turbines are available on energy equipment commercial market - The private investors are given priority to the soft loans ;

	- EWSA is ready to facilitate any concession and any collaboration between private power companies and local communities
Responsibilities	All preliminary studies and investigation are handled by EWSA while the stages regarding the construction and installation of the hydropower plants will be implemented by private investors under the potential technical assistance from international agencies. The owner companies will handle operational and maintenance services while the communities and other end-users will contribute to the management of the plants; EWSA will supervise the monitoring and evaluation in addition to the on-site management of, and technical assistance to the project, ,for the period duration of the work contract;; Ensure optimal implementation of works by their management contracts with discipline and responsibility, following specific procedures manual; Ensure implementation of management strategy under the action plan without any delays.

1.3 Project Ideas for Geothermal

Table 3: Detailed project idea for Geothermal

Introduction	At ground surface, about 70°C of temperature of geothermal water springs are recorded in Rubavu and Rusizi districts covering respectively the north-west and the south-west areas of the country. For a recorded average geothermal gradient of about 3°C / 100m at various worldwide sites, at 500m down to drilled well a temperature of 85°C can be obtained against 150°C at about 2700m. With reference to geothermal characteristics in Naivasha sub-basin, for instance at Olkaria (Olkaria I for 45 MWe and Olkaria II for 70 MWe), temperatures of steam jets are about 96 and 240 degree Celsius respectively at ground surface and 750 meters underground. – Similarly for such gradient, in Rwanda geothermal sites, a temperature of 150 degree Celsius can be obtained at about 790 meters. Given that the drilling process bears heavily on the initial capital cost of investment and even the maintenance cost, we suggest a binary modular geothermal power unit instead of a conventional steam turbine.
Objectives	To promote the use of geothermal water resources for generating electricity through modular binary systems working within the conditions of low temperatures of the geothermal water available at about 500 meters depth, instead of the conventional steam turbine options requiring a drilled well of 3000 meters i.e. 6 times deeper and equally more expensive; To exploit geothermal resources in Rwanda on a large scale along the Rift Valley branch in Rubavu district, in the Northern-West, and Rusizi district, in the Southern-West. To install 50 modular geothermal power plants in Rusizi, each generating 200kWe.
Outputs	Installed geothermal power plants in Bugarama (Rusizi district): 50 modules of 200kWe each ; Given that the utilization capacity factor can easily reach 80%

	(ESMAP, 2007), electric energy expected annually will be about 70GWh of such a pilot project with a capacity of 10MWe; Such an amount of energy can cover the electricity needs of about 300,000 households' i.e. about 14% of population in rural areas within the scenario of business-as-usual for electricity consumption of 44kWh per capita per year (World Bank, 2010) i.e. about 220kWh for each household.
Relationship to development priorities	With regard to the national energy policy and key targets achievable in the short term , the contribution of geothermal resources to the electricity production is projected to about 310MWe by the end of 2017 i.e. 30% of expected total electricity power capacity; Recently ,geothermal development program was highlighted and a 10MWe pilot project is expected to be launched soon in the Northern Western area (Rubavu district) of the country; Such a scenario of a RD&D stage is in line with the major program of access to electricity services up to 30% of population by the year 2017; Geothermal exploitation is a new option to be introduced in Rwanda ; hence the need for some preliminary stages before any wider deployment and diffusion are undertaken : RD &D systems such as this targeted unit at Bugarama of 10MWe resulting from an assembly of modular systems will assist in establishing proof of concept; In case of installing a 10MWe in Rubavu district and based on conventional steam turbines and a 10MWe in Bugarama and based on a modular binary option at lower temperatures, comparative lessons can be deduced from such different geothermal scenarios.
Deliverables	Introduction and promotion of a modular binary geothermal to electric power are quite important to Rwanda ,a country potentially rich in geothermal water services ;

	A step of RD&D is required to show the low temperature geothermal options capability of meeting the rural needs at affordable cost; The drilled wells are not necessarily deep ; Modular geothermal options will provide direct applications in remote areas; the benefits of both installed mini-grids and direct connections to the national electrical grid are tangible.
Scope and implementation:	The geological and physical studies, preliminary investigations and exploration are important steps for further characterization of geothermal resources and their sustainability in the long term. Once results of exploration and above studies show that the exploitation of geothermal resources is feasible and viable, the next step of testing and confirming the commercial capability is required; Currently, surface exploration has been completed for the North West of the country. A pilot plant with a capacity of 10 MWe is soon to be installed near Karisimbi and commissioned by the end of 2013; Experience and lessons learnt from geothermal power companies in rift valley areas of Kenya and Ethiopia will be helpful; for instance the national KenGen agency (Kenya electricity generating company) has successfully developed the Olkaria geothermal-to-electricity power units; In Rwanda, the targeted areas are mainly the volcanic North West and the low lands of Bugarama in South West where hot spring surface water reaches about 70 degree Celcius.
Activities	-Preliminary studies (geological, physical, chemical); -Assessment of resources (water, temperature, reservoir); -Environmental impact assessment;

	-Design and installation of all components of the geothermal unit (drilled wells for extraction of water, heat exchanger, closed loop for fluid circulation, high pressure turbine and generator, injection wells)-Monitoring and evaluation of sustainability of the project.
Timeline	Above overall activities for installation of the 50 sites resulting in a 10MWe capacity are expected to take 5 years.
Budget and resources	Total budget will cover all above activities, purchase of equipment, civil works and other engineering works; Total initial capital cost : 6400 USD per kWh i.e. a total of 64 million USD; The generating costs (adjusted capital cost, operation and maintenance costs) are about 14 US cents per kWh ; Utilization capacity factor: 80% ; Lifespan: 20 years Sources of funds: Opportunities of carbon credits and CDM facilities; Subsidies for encouraging the innovative options of introducing the low temperature-based geothermal-to-electricity power; private sector and joint ventures; World Bank, Public investment, Loans from banks, leasing programs.
Responsibilities and coordination	MINICOM and MINECOFIN: Provision of financial facilities, subsidies and access to soft loans; acting as a guarantor if requested for soft loans from institutions like ADFD via IRENA, AfDB and other international special banks. MININFRA: Coordination of the process of transfer and diffusion of the geothermal-to-power technology; regular organization of training for enhancing

	the capacity building. REMA: Conducting or supervising the environmental impact assessment; approval of such EIA. EWSA: Preliminary studies, exploration, establishment of a database and a mapping system for an updated evolution of geothermal resources. Power companies: Design of the geothermal power plant; concession and exploitation; maintenance.
Challenges	One challenge, among others, is the low geothermal gradients which necessitates drilling very deep wells. The limitations in available financial facilities for implementing the different steps of developing the geothermal project make up another challenge. . There is also a challenging risk of facing unsustainable underground geothermal water resources and a decrease in the designed discharge; such a risk is a result of a mismanagement of the re-injection of water into underground reserves for the process of their recharge.
Monitoring and Evaluation	The indicators of success of such a project are mainly the installed geothermal plant of 10 MWe; the electricity energy distributed to and consumed by the end-users; an effective number of created business units in the commercial and industrial sectors. The benefits from such an installed geothermal plant resulting in a decrease in use of petroleum products and traditional wood fuels for lighting in rural households are hence tangible and measurable. The level of energy security, the amount of energy exported through regional connections to Uganda and Burundi and the rate of contribution through the diversification of the energy mix will be also key indicators of success.

1.4 Project Idea for Kivu Methane CCGT with CCS

Table 4: Detailed project ideas for Kivu Methane CCGT with CCS

Introduction	The project idea proposed for this technology regards the modification of current GT option and the introduction of the CCGT combined to the CCS. Both the CCGT and CCS options are new to Rwanda. They will require a particular attention and specific facilities for installation as pilot projects and for wide diffusion once accepted by different stakeholders and investors.
Objectives	Modification of the existing projects based on the conventional gas combustion technology (GT) and their extension to the CCGT with CSS technology; Installation of a pilot project of 10MWe based on combined CCGT and CCS; Minimizing the amount of CO_2 emissions from the future Kivu methane power plants ; Generation of electricity power only through such a mitigation technology combining both the CCGT and CCS options.
Outputs	A pilot plant generating 10MWe; a change in private investors has resulted in the modification of GT systems, transforming them in CCGT with CCS option; Reduction of the CO_2 emissions from about 600mg-CO_2 / kWh in case of the conventional GT option to 400 mg –CO_2 /kWh by the CCGT option and to only 80mg of CO_2 /kWh by the CCGT combined to the CSS alternative.
Relationship to development priorities	Great efforts are currently focusing on exploitation of Kivu methane gas; The company KPP(Kibuye Power Plant) has developed a pilot project of a 3.6 MWe power plant directly connected to the national grid ; next upgrade is expected by the end of 2013, to about 100MWe plant ; The company REC (Rwanda Energy Company) is targeting a concession of 50 MWe;

	A joint venture between the DR Congo and Rwanda is aiming at installing a 200MWe power plant, but this is still at the level of preliminary discussion; The contribution ratio of Kivu methane gas resources to the targeted 1000 MWe in the year 2017 for Rwanda is targeted to about 30%; Note that the highly efficient CCGT and the recommended CCS technology for the storage of the CO_2 emissions are fully new options in Rwanda.
Deliverables	This project will result in modifying the existing GT option in place for the Kivu methane gas and in an adoption of a mitigation approach based on the CCGT option combined to the CCS technology. In addition, applying the CCS to any energy-related CO_2 emissions will result in a reduction rate of such emissions of at least 85% (IPCC, 2005).
Scope and implementation	The project is aiming at introducing the CCGT for exploitation of the Kivu methane gas and the CSS for handling the CO_2 emissions of energy-related sources; A 10MWe modular power plant is quite feasible : both the GT ,CCGT and CCS are all commercially proven; Exploitation of Kivu methane is now sufficiently tested since 1963 at Rubona station in Rubavu district ; its potential capability of r generating 700MWe up to 50 years is deemed highly feasible; Given that a pilot plant generating 3.6 MWe has been successful, lessons learnt from its management will influence positively the implementation of the CCGT and CCS technologies.
Project activities	The modification of the GT option in place through an introduction of the CCGT combined to a CCS option is a process requiring the following steps: Visit both the installations of CCGT and CCS technologies in countries where these options are operational and successful like China, Germany, Norway and

	Canada. Design of such modification scenario; Install the modified option and develop a 10MWe based on CCGT Develop a new CCGT-CCS for a 10 MWe capacity power plant Evaluate and demonstrate the results through regular seminars and campaigns ; Recommend for adoption and replication of such a combined technology for further Kivu methane projects.
Timeline	The overall project would cover 4 years for completion
Budget and resources	The initial capital costs is about 1040 USD/kW or a total of 10.4 million USD (ESMAP, 2007; IPPC, 2005) Generating costs of 8 US cents / kWh for an utilization capacity factor of 80% (about 19 hours/ day of 24h) and a lifespan exceeding 20 years; Sources of funding: public investments, subsidies, carbon credits, private sector ,loans by local banks, soft loans by international specialized banks of development; Required human resources: a multidisciplinary team covering a wide range of techniques applicable to the CCGT with CCS technologies, from the extraction of the methane gas to the final location of geological storage of CO_2 emissions separated from the flue gases emitted by the power plants; Partnership: particular technical assistance for such a new technology in Rwanda is expected from a variety of sources, including the UNEP
Challenges	Increased cost of investment due to the replacement of the GT option by the CCGT combination to the CCS technology; Difficulties in convincing the investors about financial benefits for the new

	technology option; Limited capacity in accepting new technologies.
Responsibilities and coordination	The action of modifying the GT option is shared and jointly handled by EWSA and the private companies as owners of the current pilot projects; The 10MWe pilot project is initiated by EWSA and can also be jointly shared with private investors ; Due to the CCGT with CCS complex technologies, technical assistance would be sought from development partners.

1.5 Project idea for Plug in Hybrid Electric Vehicles

Table 5: Detailed project idea for Plug in Hybrid Electric Vehicles

Introduction	Given that the contribution to the GHG mitigation has also to come from the road transport, the PHEV (the plug –in hybrid electric vehicles) option was selected for introduction on the Rwandan market. Demonstrative projects have to be set up and intensive campaigns for convincing both the end-users and the intermediate distributors be undertaken. Introducing such a technology in Rwanda is justified by a number of reasons: Importation and consumption of petroleum products for vehicles depletes foreign reserves ; Contribution to the GHG emissions by the transport sub-sector is very high as discussed and indicated in previous TNA report I; Alternative options to replace the fossil fuels used in vehicles are limited in Rwanda.
Objectives	Introduction of at least 50 PHEV for the purpose of demonstration and promotion of such a mitigation technology in the road transport sub-sector; Installation of at least five demonstrative stations for recharging the batteries; Initiatives for a progressive replacement of conventional pollutant vehicles by the PHEV ones; Contribution to the GHG mitigation by the importation of new vehicles meeting the PHEV standards; Decreasing the importation of fossil fuels through the use of electric vehicles
Outputs	Five installed stations for recharging the batteries of the PHEV; Clean vehicles are introduced on the local market.

	Decrease in the use of petroleum fuels by the vehicles and reduction of the GHG emissions; Raised awareness and proven advantages of PHEV ownership in Rwanda
Relationship to development	In the short term, preliminary studies aiming at identifying opportunities for establishing a multi-model system of transport based on efficient technologies are initiated ; In the medium term , set up the transport services relying more on renewable energy resources and responding to the climate change mitigation obligations; In the long term, introduction of more affordable vehicles also accessible to the rural population should be undertaken in consideration of potential future low-cost vehicles. Referring to the current policies and strategies, diversifying the transport options in order to become less dependent on the conventional internal combustion engine technology; Therefore, introduction of technologies based on use of efficient gasoline and electric motors is quite viable and oriented to climate mitigation scenarios. .
Deliverables	At the end of the project, 50 vehicles using both an efficient gasoline internal combustion engine and an electric motor are operational in Rwanda as a pilot project;
Scope and implementation	This project is limited to the provision of 50 PHEV fully operational A preliminary campaign of sensitization will be organized The project at this stage is of a demonstrative nature with a small number of vehicles: just 50 expected to be served by five pilot stations for recharging the batteries; The implementation of this project is possible as far as the budget required is

	affordable;
Activities	The application and implementation of the specific measures for the transfer of PHEV option are as follow: Setting up five stations for recharging the batteries; Organize and conduct awareness campaigns for vehicle consumers and suppliers through a broad campaign for electric vehicles and for more efficient internal combustion engines; Training of technicians on PHEV maintenance Purchase and supply 50 PHEV Monitoring of reduced GHG emissions
Timeline:	Duration of project: 3years
Budget and resources	Cost of one PHEV : about 1500 USD (IPPC,2005); Cost of installing one station : 6000 USD; Cost of operation and maintenance is in link to two liters of gasoline per 100 km in case of a recharging batteries twice per day(IPPC,2010; SSEE ,2011); note that a new ordinary low-carbon vehicle consume about 9 liters per 100km, .i.e. 4 times more. Funds: sources of funds are mainly from the owners of these vehicles, in addition to the subsidies and loans.
Evaluation	Monthly evaluation of performance and consumption of all 50 vehicles; The amount of GHG emissions avoided: using PHEV instead of usual vehicles result in a GHG emissions decrease rate of 75 % , Record of efficient gasoline fuels consumed and electricity delivered by the pilot station ;

	Comparison of consumption vis-à-vis conventional vehicles.
Challenges	The resistance to change and the limited purchasing power of the customers who usually purchase only second-hand vehicles. These are the main barriers which have to be challenged systematically and progressively. Low demand and non acceptance of this new technology by end-users; Non affordable cost for purchasing new vehicles, Compared to the current and popular second-hand vehicles, there is risk of resistance to accept the new type of vehicles; Slow pace in developing the required infrastructure for an acceptable diffusion of the PHEV options on the local market;
Responsibilities	The pilot station can be funded and installed jointly by the public services and the owner of such a station ; The 50 vehicles can be purchased by the public service (MININFRA) and delivered to selected key end-users (sample of governmental staff) at a special cost; The number of f PHEV purchases can be increased through offering bonuses and subsidies The evaluation and monitoring of the PHEV project can be handled by the National Police through its service of Technical Control.

1.6 Project idea for large solar PV

Table 6: Detailed project idea for large solar PV

Introduction	Within this context of the TNA project, a project idea was suggested based on the extension and replication of more large solar PV systems, also directly connected to the EWSA grid. Selected regions more suitable for hosting such projects are located in the Southern and Eastern Provinces of the country. Special funds can also be negotiated through the IRENA which is in link with the ADFD offering soft loans with an interest rate lower than 6% for renewable energy projects in developing countries.
Objectives	Promotion of the large solar PV plants with connection to the national electric grid for a capacity ranging between 5MWe and 10MWe per each project; Extension and replication of the existing small pilot project (250kWe) installed at Jabana and connected to the EWSA grid; Reinforcement of the solar PV local market which is still limited to small scale applications; Increase of electricity production through solar resources. Elaboration of a regulatory law and framework for provision of subsidies to widen and strengthen the support to the developers of solar energy.
Outputs	Installed large scale solar PV plants connected to the EWSA electric grid; Established agreement between EWSA and energy projects developers; Decreased dependence of energy sector on imported petroleum fuels contributing to electricity generation; The large solar PV technology is known on the Rwanda market. Replication of pilot projects is achieved through the installed transmission and distribution in rural areas.

Relationship to development priorities	The contribution of renewable energy resources to electricity production in Rwanda is more and more targeted and achieved progressively. Recently, the Government of Rwanda secured funds, grants and credit programs for buying solar systems; Application and diffusion of solar options are expected to benefit from the carbon credits; A locally manufactured unit of solar photovoltaic modular systems is targeted (SSEE, 2011); Even though the option on the large solar PV has to be newly introduced, its deployment will benefit from the relatively small 250kWe operational and connected to the EWSA electric grid. With the adoption of low carbon strategy, this technology will contribute to sustainable development and green economy
Deliverables	Installation of a large solar PV as a pilot project for boosting the program of deploying the solar applications, may spur growing confidence and stimulate attraction and involvement by private investors; Any increase in use of renewable energy resources reflects a decrease in GHG emissions due to the substitution effect; Increasing access to electricity and reduce the use of wood and kerosene fuels for lighting and cooking to a lesser extent.
Scope and implementation	The project idea is aiming at installing at least a 5MWe pilot project for such a technology based on the large solar PV connected to the national grid; With reference to large projects of the solar PV operational in Europe and USA , information on lessons learnt from such projects will be of great interest and help; Collection of specific data and a visit to such large projects are necessary; for instance some grid –connected solar PV systems have a size ranging between 10MWe in Bavaria (operational since year 2005, Germany) and 60MWe in Olmedilla (operational since year 2008 in Spain); In addition to opportunities in partnership and technical assistance in the context

	of access to carbon credits, lessons learnt locally will be also of great importance.
Activities	-Negotiation of a partnership and a training-visit at one of the existing large solar PV installed in developed countries: for instance in France at Saint Clar/ Gers(9MWe), Germany at Bavaria (10MWe) , Spain at Murcia(14MWe), Portugal at Amareleja (41MWe) , in France at Toul-Rosieres(143MWe), USA at Las Vegas (18MWe) and even in less sunny Canada at Sarnia/ Ontario (40MWe); -Fund mobilization; -Design and installation of the large PV solar pilot plant; -Negotiation of an agreement for the grid-connected scenario and for particular feed-in tariffs to support the owners of the large solar PV plants; -Collaboration with all districts and selection of lands where to install the large solar plants; note that more suitable lands are found in the South and Western Provinces; -Validation of the existing data sets on the DNI (the direct normal solar radiation component) resources.
Timeline:	Implementation of the technology of large solar PV (5MWe) will require 4 years.
Budget and resources	Initial capital cost : 5500 USD / kWe (ESMAP,2007) Generating cost : 42 US cents /kWh(i.e. the adjusted capital cost, costs of operation and maintenance); Utilization capacity factor : 6 hours per daylight; Lifespan : 20 years ; Sources of fund : private sector companies, subsidies, carbon credits and soft loans from specific banks; Partnership: it is expected from private companies and countries which have got great experience in solar energy subsector;

	Local partnership: EWSA and REMA.
Evaluation	Quantity of MWh of the electricity from the solar PV plant and regularly supplied to the end-users ; Another measurable indicator is the installed solar plant directly connected to the EWSA electric grid; Number of new households or customs connected to EWSA electric services; Amount of additional electricity energy and transmission/distribution lines made available by EWSA; Number of new solar projects candidate for replication as a result of the pilot project success.
Challenges	Affordability and financial capacity regarding high initial cost of solar components; Complications in accessing subsidies and carbon credits specific to the use of renewable energy services; Problem of land acquisition because the conventional solar PV systems require large tracts of land, unless the concentrated solar PV scenario is considered.
Responsibilities	Given that the suggested solar project preferably belongs to a private company or consortium , almost all above activities are handled by the owner ; Subsidies and carbon credits have to be negotiated through the support by the public services; IRENA and ADFD soft loans require the government involvement as a guarantor.

CHAPTER 2: PROJECT IDEAS FOR THE AGRICULTURE SECTOR

2.1 Brief Summary of the Project Ideas for the Agriculture Sector

Selected technologies in the agriculture sector have been classified in three categories based on the type of the agriculture input they mainly support as discussed and approved by the TNA stakeholders during a meeting held at Umubano Hotel, on 30th November 2013. The groups are as follows: two technologies on soil/land husbandry which are agro forestry and radical terraces, two technologies on water resources management which are rain water harvesting and drip irrigation and on technology related to post harvest which is seed and grain storage with main feature of enhancing food security. Specific and approved project ideas for the agriculture sector are:

1-Integration of agro forestry and radical terraces in highland provinces of Rwanda: This project idea aims at promoting efficient land management by combining two selected adaptation technology options known to complement each another. The project is expected to result in: Well managed arable land, increased yields and empowered population.

2-Rainwater harvesting for agriculture applications in dry province of Rwanda: This project idea aims at rainwater collection, storage and use for agriculture production in the driest province of Rwanda. The project will combine two selected adaptation technology options known as drip irrigation and rainwater harvesting. Expected results include: Reduced wastage of water resources, more productive land and reduced water related conflicts.

3-Enhance food security through efficient seed and grain storage in Rwanda: This project idea aims at improving food security through modern and efficient seed and grain storage in Rwanda. Good seed and grain 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. Expected results are: Very few if not zero damaged seed and grain storage, timely available seeds for the following planting season and improved food security situation.

In addition to the background information found in the literature, specific project ideas for the agriculture sector were identified and discussed using stakeholder's consultation approach including personal meetings and interviews with workers in the agriculture sector under the TNA project. The content enrichment and approval/validation were carried out during two general stakeholders meetings in Kigali, at Umubano Hotel on 30th November 2012 and 02nd April 2013 respectively.

2.2 Specific project ideas

2.2.1 Project idea for agro forestry and radical terraces:

Table 7: Detailed project idea for agro forestry and radical terraces

Name of Project idea	**Integration of agro forestry and radical terraces in highland provinces of Rwanda**
Introduction	Agro-forestry is used in almost the whole world where agriculture is practiced. In Rwanda, it is practiced in the agriculture 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. 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). This project idea aims at promoting efficient land management by combining two selected adaptation technology options known to complement each another
Objectives	Increase climate resilience through transfer and diffusion of selected adaptation technology options
Outputs	At the end of the project there should be:

	Agro forestry species planted on a 30000 ha of new and existing radical terraces 2. New 10000 ha Radical terraces are prepared
Relationship to the country's sustainable development priorities	This project comes to reinforce already existing government efforts of making Rwanda a food secure country while keeping the environment safe
Project Deliverables	1. Demonstration sites combining the two technologies shall be established in each district of the northern ,western provinces and selected district of the southern province 2. Agro forestry tree species nursery shall be installed in each district of the northern , western provinces and selected district of the southern province
Project Scope	This project will be limited to the northern, western province and the southern provinces
Project activities	1. Organize and direct training sessions for agro extension agents 2. Installation of demonstration sites 3. Organize and direct farmers study tours 4. Production of seedlings
Timeline	5 years
Budget (USD)	The budget for activity number one which consists of organizing and directing training sessions for agro extension agents in all the district of the country is estimated at 100 000USD The installation of at least 12 demonstration sites in districts of the Northern and the Western provinces would cost 850 000USD. Organizing and directing study tours for selected farmers is expected to cost 200 000USD while the production of seedlings is expected to cost 350 000USD.
Measurement/evaluation	One demonstration site is available per district for all the 12 districts of the northern and western provinces as well as selected district of the southern province
Possible complications/challen	Policy limitations: There is neither specific policy nor strategy on land husbandry techniques as well as agro forestry development.

ges	Limited funds are allocated to the development of these technologies. Limited expertise/human resources: There exist gaps of knowledge on agro forestry systems among agriculture extension agents who are in regular contacts with farmers.
Responsibilities Coordination	Ministry of Agriculture shall provide policy guidelines and technical assistance for the diffusion and transfer of the technology. Ministry of Natural Resources shall provide guidance and framework in which the technologies are transferred and diffused and assist in mobilizing and managing needed funds. The Ministry of Local Governance in collaboration with local governance entities, farmers' associations/cooperatives and NGOs shall mobilize local stakeholders. Communities will implement the technologies and apply them efficiently

2.2.2 Project idea for drip irrigation and rainwater harvesting

Table 8: Detailed project idea for rainwater harvesting and drip irrigation

Name of Project Idea	**Rainwater harvesting for agriculture applications in dry province of Rwanda**
Introduction	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. 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. This project idea aims at rainwater collection, storage and use for agricultural production in the driest province of Rwanda. The project will combine two selected adaptation technology options known as drip irrigation and rainwater harvesting
Objectives	Increase climate resilience through transfer and diffusion of selected adaptation technology options
Outputs	At the end of the project there should be: 1. 500 units of small scale solar powered drip irrigation are installed. 2. A capacity 500 000 m^3 of rainwater harvesting systems is installed.
Relationship to the country's sustainable development priorities	This project comes to reinforce already existing government efforts of making Rwanda a food secure country while keeping the environment safe
Project Deliverables	1. Demonstration sites combining the two technologies shall be established in selected district of the eastern province 2. Drip irrigation units shall be provides to selected communities based on best initiatives in rainwater collection and storage

Project Scope	This project will be limited to selected districts of the eastern province and will only look at solar powered drip irrigation systems and rainwater harvesting
Project activities	1. Organizing and directing training sessions for agro extension agents 2. Installation of demonstration sites 3. Organizing and directing farmers study tours 4. Provision and installation of drip irrigation units
Timeline	4 years
Budget (USD)	Extension agents shall be trained on the transfer and diffusion of rainwater harvesting and drip irrigation. The cost of this activity is estimated at 150 000USD. Six demonstration sites in the most dry districts of the eastern province (Bugesera, Gatsibo, Nyagatare) shall be installed at a cost of 300 000USD. Study tours for selected farmers shall be organized and conducted at a cost estimated at 150 000USD. Drip irrigation units shall be provided and installed at a cost of 400 000USD
Measurement/evaluation	One demonstration site is available in selected district of the eastern province and drip irrigation units are provided and installed for selected farming communities
Possible complications/challenges	Limited funds are allocated to the transfer and diffusion of the technology Limited human resources/expertise is locally available to the development of drip irrigation Silting and sedimentation may compromise rain water harvesting and storage
Responsibilities	Ministry of Agriculture shall provide policy guidelines and technical assistance for the diffusion and transfer of the technology. Ministry of Natural Resources shall provide guidance and framework in which the technologies are transferred and diffused and assist in mobilizing and manage needed funds. The Ministry of Local Governance in collaboration with local governance entities, farmers' associations/cooperatives and NGOs shall mobilize local stakeholders. Communities will implement the technologies and make sure that it is used efficiently.

2.2.3 Project idea for seed and grain storage

Table 9: Detailed project idea for seed and grain storage

Name of Project Idea	**Enhance food security through efficient seed and grain storage in Rwanda**
Introduction	Cereals, pulses, oilseeds etc. are very important grain products for storage. While considerable losses can occur in the field, both before and during harvest, the greatest losses usually occur during storage. This project idea aims at improving food security through modern and efficient seed and grain storage in Rwanda. In fact, Good seed and grain 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.
Objectives	Increase climate resilience through transfer and diffusion of selected adaptation technology options
Outputs	At the end of the project there should be: 1. At least 80 000 metric tons capacity is installed
Relationship to the country's sustainable development priorities	This project comes to reinforce already existing government efforts of making Rwanda a food secure country while keeping the environment safe
Project Deliverables	1.Trained personnel on efficient seed and grain storage systems installation and maintenance 2. Seed and grain storage units at community level
Project Scope	This project will be limited to selected districts in the whole country based on their production potentials and harvesting situations
Project activities	1. Organizing and directing training sessions on the installation and maintenance of seed and grain storage systems 2. Mobilize the community about the importance of using efficient seed and grain storage 3. Select sites in all 4 rural provinces (Eastern, Western, Northern and Southern) and construct demonstration seed and grain storage systems
Timeline	3 years

Budget (USD)	The cost of organizing and directing training sessions is estimated at 200 000USD. The mobilization of the population about the importance of using efficient seed and grain storage systems through awareness campaigns and study tours would cost 200 000USD The construction seed and grain storage facilities at four selected sites with a capacity of 20 000 metric tons each would cost 1 600 000USD
Measurement/evaluation	Efficient seed and grain storage units are available at 4 selected site The population understands the importance of using efficient seeds and grain storage systems
Possible complications/challenges	Limited funds allocated to the implementation of seed and grain storage systems Limited human resources/expertise are locally available There may delays in material deliveries since most of them are imported especially silos
Responsibilities	Ministry of Agriculture shall provide policy guidelines and technical assistance for the diffusion and transfer of the technology. Ministry of Natural Resources shall provide guidance and framework in which the technologies are transferred and diffused and assist in mobilizing and manage needed funds. The Ministry of Local Governance in collaboration with local governance entities, farmers' associations/cooperatives and NGOs shall mobilize local stakeholders. Communities will implement the technologies and make sure that it is used efficiently.

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Annex1: List of Stakeholders

Energy sector

Nº	Names	Fields	Institutions
1	Dr. Gasingirwa Christine	Chemistry	MINEDUC
2	Dr. Jean Baptiste NDUWAYEZU	Agroforestry	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 energy(biogas)	EWSA
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

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