Republic of Rwanda

BARRIER ANALYSIS AND ENABLING FRAMEWORK FOR TECHNOLOGY TRANSFER AND DIFFUSION.

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Disclaimer

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ABBREVIATIONS and ACHRONYMS

APH: Air Preheated Exhaust gases

BRALIRWA: Brasserie et Limonaderie du Rwanda

BSP: Biomass-fired Steam Power

BTA: Biogas Thermal Applications

CC: Climate Change

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

ESMAP: Energy Sector Management Assistance Programme

EWASA: Energy, Water and Sanitation Authority

Gg: Gigagrams

GHG: Green House Gases

GoR: Government of Rwanda

GWh: Gigawatt hour

HRSB: Heat Recovery Steam-Gases Boiler

IGCC: Integrated Gasification Combined Cycle

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

PSH: Pumped storage Hydropower

PV: Photovoltaic

RAB: Rwanda Agriculture Board

REMA: Rwanda Environmental Management Authority

RENGOF: Rwanda Environmental NGOs Forum

RNRA: Rwanda Natural Resources Authority

SNC: Second National Communication on Climate Change under the UNFCCC

SOx: Sulphuric 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

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

This second phase of TNA project is aiming at identification of main barriers hindering the transfer and diffusion of Climate Change mitigation and adaptation technologies. Prioritized technologies were presented in the previous TNA report-1 for both mitigation and adaptation as follows: a) small hydropower, geothermal-to-power, Lake Kivu methane combined cycle gas turbine, Plug-in hybrid electric vehicles and large solar photovoltaic for mitigation; and b) seed and grain storage, agro forestry, radical terraces, drip irrigation and rainwater harvesting for adaptation.

Identification of main measures to remove such barriers for mitigation technologies resulted in a group of solutions and actions linked to key elements of enabling frameworks and policies. These are related to the areas of trade, subsidies, tariff , tax, regulation, public investment, reference and demonstration projects assistance to investors and front runners but also early adopters of technologies. Particular attention was given to barriers related to the national macroeconomic conditions including: inadequate financial options, high initial investment costs, importation duties, limited access to loans and high interest rates.

Comparison of costs and benefits resulted in a clear conclusion of potential application and adoption of all prioritized technologies, especially the new ones expected to be introduced in near future for mitigation. These technologies include geothermal, hybrid electric vehicles and large solar PV

In addition to the fact that all the prioritized mitigation technologies fulfill the key criteria of national priorities up to 2020, the target of GHG mitigation is expected from a diversification approach relying on, among others, exploitation of all available and sustainable energy resources. This is why the Lake Kivu methane gas is expected to play an important role in such a project in case carbon capture and sequestration is taken as an option.

Barrier analysis for the adaptation technologies was also conducted. The following were identified as main barriers which would hinder the transfer and diffusion of adaptation technology options: High initial investment costs, limited technical knowledge, limited awareness about long term benefits of some of the technologies, limited access to funds and high interest rates. It was also found that conducive enabling environments exist which may ease the transfer and diffusion. These include but not limited to: Existence of institutional policies, strategies and political will to subsidize raw agricultural inputs as well as provision of incentives.

CHAPTER 1: ENERGY SECTOR[1]

1.1 Preliminary Targets for Technology Transfer and Diffusion

Within the context of climate change mitigation and TNA project, targets for deployment of prioritized technologies are guided mainly by official documents such as the National Energy Policy and Strategy (MININFRA, 2012), the Rwanda Vision 2020 and the Millennium Development Goals (UNPD, 2005).

For any support to socio economic growth and poverty alleviation, sustainable and affordable energy technologies are required. As presented below the case of Rwanda is really crucial if we refer to some key indicators showing that the level of modern energy consumption is still very low. The annual per-capita primary energy consumption is only 0.17 toe (tone oil equivalent) in Rwanda against 0.16 toe in sub-Saharan Africa and 4.7 toe in industrialized` countries (IMF, 2008). For the case of other Sub-sectors of energy consumption (petroleum, electricity), Rwanda is also still lagging behind. Therefore, the targets below are aiming at improving the status quo so that at least 50% of the population can have access to electricity by the year 2017. As a whole, the cost estimates[2] for the funds required for implementation of the accelerated least cost generation mix from 2011 to 2017 is 5,274 Millions USD.

Regarding the particular sub-sector of electricity, we consider the increase of electricity capacity as a central target and expected outputs are as follows:

- Annual per-capita electric capacity from 5 kW in 2008 to 113 kW in 2020;
- Annual per-capita electric energy from 23 kWh in 2008 to 488 kWh in 2020;
- Rate of access to electricity: from 6% in 2008 to 50% in 2020

The targets above in electricity energy usage are crucial as s Rwanda is still lagging behind in the matter of electricity services. While for instance in Sub-Saharan Africa and in developed countries, average annual per-capita electricity consumption was respectively 478 kWh and 1200 kWh in year 2008; such gaps are still valid up to now[3].

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[1] *All preselected technologies presented in the previous TNA report are feasible options at short/medium term in the context of the timeframe up to year 2030 and mainly through the diversification approach. Within the context of national energy policy for goals up to 2017 in addition to the ranking process and criteria mentioned in TNA report, this stage of barriers analysis is limited to only* ***five*** *options:* ***geothermal, Kivu methane CCGT, hydropower, solar and Plug- in hybrid electric vehicles.***

[2] *Such total capital cost are expected to cover mainly the least cost generation of energy, electrification, petroleum storage , transmission lines, efficiency, biomass conservation and also capacity building.*

[3] *Per-capita electricity consumption is therefore in sub-Saharan Africa 21 times more important (compared to Rwanda); in developed it is about 60 times more.*

1.1.1 Specific targets in geothermal up to 2017

- Assessment of geothermal resources mainly in the 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 MW;
- Generation of about 310 MW of electricity power by the end of year 2017;
- Identification of private investors and partners for financial support.

1.1.2 Specific targets for Kivu methane gas

- Based on the successful 3.6 MW Kivu methane pilot project plant operational since November 2008, negotiate and establish agreements with private sector and international investors for funding projects of 20 MW to 50 MW;
- Installation of about 300 MW by the end of 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 MW power plant based on methane gas;
- Liquefaction of methane gas for further replacement of biomass and diesel fuels used in households and industry sector[4].

1.1.3 Specific targets for small-hydropower

- Promotion of private sector participation in hydropower production at large and small scales;
- The delivery of licenses for small hydropower projects;=--
- Exploitation of a higher number of small hydropower sites so that additional 75 MW 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.

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[4] 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)

1.1.4 Specific targets for PHEV

- 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

1.1.5 Specific targets for solar PV

- 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 kW pilot plant installed near 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[5] standards.

1.2 Methodology and Guidelines

Our methodology, used in the identifying of barriers to acquisition and deployment of energy technologies, in the specifying of appropriate measures and enabling frameworks to succeed in the process of transfer and diffusion, will be influenced by characteristics of targeted technologies. New technologies can obviously require a preliminary phase of share of information about their popularity in developed countries. Inventory for further sustainability of energy resources is also essential.

With reference to guidelines and handbooks designed and published by UNDP and World Bank (UNDP, 2010; ESMAP, 2007), barriers hindering transfer and diffusion of energy technologies can be classified into four main categories: technological, financial, economic and institutional. For each selected and prioritized technology, barriers, measures and frameworks will be identified, analyzed and discussed through consultations with stakeholders expected to play a key role in all phases of the TNA project in Rwanda.

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

According to the observations recorded in countries where our targeted energy technologies have been successful, the range of barriers to transfer and diffusion is large and covers the following issues : a) commercial and competitive aspect , b) skills and knowledge , c) availability of technology products , d) initial capital cost and total production cost, e) institutional framework, f) involvement of the investors and banks,g) access to loans and subsidies , h) access to the national grid and agreements between EWSA as a national utility and private developers, i) type of settlements in rural areas for population, j) importation of products and energy fuels, k) preference in using traditional wood fuels. For better reading, a simplified route cause analysis (diagram of causes, barriers and impacts) will be done for each technology i-e problem tree methodology (refer to annex-I). For each technology, the problem tree will be translated into the solution tree reflecting the transformation of causes into actions to removal of barriers and effects of barriers into results of measures.

1.3 Barrier Analysis and Measures for Large Solar Photovoltaic (PV) Technology

1.3.1 General description of technology

The initial research in PV technology proved that special material of semiconductors convert the sunlight directly into electricity. The process of preparing such materials requires about 1,400 °C., This is why, among other reasons, PV systems are expensive. Worldwide production was only 5 MW in the year 1982 and substantially increased to 385 MW in year 2001. These trends regard mainly small-scale solar PV.

In fact, large grid-connected solar PV technology is relatively new, but highly promising. Solar radiation globally produces about 5 kWh every day per square meter of a receiver surface. Conditions for a proper production of electric power directly connected to national grid, or any mini-grid, are complex. This is due to required agreements between EWSA and the private sector that is expected to invest in large-scale PV systems with 5 MW capacity or more. Characteristics of a 5 MW solar PV plant based on a modular unit of 73 kW [http://www.caddet.org] are roughly as follows:

- ✓ PV area: 532 m^2
- ✓ PV efficiency: 14%
- ✓ Inverter efficiency: 85% (DC to AC)
- ✓ Total incident radiation: 526 MWh/year
- ✓ Total incident: 55 MWh/year; such a modular unit can result in a larger PV plant once about 70 units are assembled and can provide 5 MW

Connection to the national grid is more appropriate for reducing the cost by avoidingthe use of batteries.Thus, the capacity factor equals the daily sunshine duration (in Rwanda about 6 hours). Lifespan of main components is 25 years. There is an optional scenario for reduction of cost involving concentrating solar energy in order to use less size of solar modules (i.e. requirements of about 5 kWh/m^2 for the beam direct normal solar component).

1.3.2 Identification of barriers to deployment of large solar PV

1.3.2.1 Economic and financial barriers

The causes of absence of development and introduction of large solar PV technology are as follows: High initial capital cost of solar product and batteries, fluctuations and inflation affecting the costs of equipments, investors and local developers are not attracted.

Skilled expertise is missing for setting up frameworks related to, for instance, agreements with EWSA for reduction of costs through a direct connection to national electric grid. Another constraint is related to inability to apply research and adopt new options like concentrated photovoltaic and organic solar cells.

The deployment of large solar PV system is also limited by the inexistence of pilot projects for further demonstration beyond the phase of research and development. One of the adverse impacts is the limited diversification of electric energy sources in Rwanda and low exploitation of such a clean resource.

Table 1: Economic and Financial Barriers

Barriers	**Elements of barriers**	**Presentation and dimensions**
Limited penetration into the market	High Initial Capital Cost	The Photovoltaic system compared to other commercial energy technologies remains very expensive; Subsidies and low taxes have not yet resulted in larger diffusion of PV modules in Rwanda; Only some institutions (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 kW 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 for in cash; Lack of access to credit is limiting both investors and end users to small scale size of solar products.
	Weak network and limited update of information on solar products	Poor knowledge in PV sector results in buying non tested solar modules as of now and then, second hand products are taken as new on the local market; new equipments remain expensive; In addition, imported products from Europe, China, USA or Japan to Rwanda,(a landlocked country) are quite expensive due to transport and transaction costs.
	High cost installing private grids	Absence of decentralized mini-grid for distribution of electricity energy is limiting deployment and diffusion of large solar PV system.

1.3.2.2 Non Financial barriers

Table 2: Non Financial Barriers

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 more known and popularised.
	Unfamiliarity with solar PV technology	Design, preparation and implementation of any solar PV project , especially for larger scales, require more skilled labor and expertise which are currently missing for Rwanda ; among others, more special skills in setting up local mini-grids are missing; all phases of installation, operation and maintenance have to refer to 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 is less practical. Power generated is low while its cost of acquisition is high.
	Access to enough land	Due to the limited efficiency of converting solar light into electricity, large land areas are required for installing a large solar PV. Rwanda has the highest density of population in Africa; a situation that renders this application very challenging.
Human and	Limited skilled	Technicians trained for designing and installing the

institutional capacity	expertise	large solar PV plants are very few in Rwanda.
	Non-existent centre for promoting solar application	Expert skills development to properly design and plan for the development and diffusion of the large solar PV systems needs more focus.
Social and cultural behavior	Resistance to change and invest in large solar	The technical benefits from the use and installation of the large solar PV and connection to the EWSA grid are not yet understood; the small sizes are better known and therefore more popular in Rwanda.

1.3.3 Identification of Measures for Large Solar PV

1.3.3.1 Economic and financial measures

Table 3: Economic and financial measures

Elements of Barriers	**Measures**	**Hierarchy of Barriers**
High initial capital cost	Need of different forms of subsidies; More involvement of private sector.	Non-starter (killer)
Limited access to loans and leasing programs	Set up a special fund via the carbon credit market	Crucial
High cost of transfer and transport (transaction)	Application of reduction of taxes and fees	Important
High cost of installing the mini-grids	Special incentives; Option of subsidized mini-grids	Crucial

1.3.3.2 Non financial measures

Table 4: Non financial measures

Elements of barriers	Measures	Hierarchy of barriers
Non-existent feed-in-tariff	Implementation of the policy and agreements for connection to EWSA grid	Crucial
Non-existent local industry for solar and poor commerciality	Set up a partnership between stakeholders for a promotion of local industry in solar and related electronics	Easy starter (insignificant)
Unfamiliarity with solar PV technology	Enhance the capacity building and regular training	Important
Limited access to land	Introduction of CPV(Concentrated solar Photovoltaic) technology in Rwanda	Less important
Low competitiveness	Introduction of mechanism of progressive payment of equipment instead of paying cash (leasing programs); Promotion of solar modules integrated to buildings and adoption of low cost product like the CPV option	Important
Limited capacity of human and institutional	Set up a centre for promotion of solar power systems application; Organization of regular training for technicians	Important
Resistance to move towards large solar	Set up a pilot project of large scale solar PV plant	Crucial

The urgent measures to overcome barriers to diffusion of large solar PV are mainly those which are regarding the higher ranked barriers classified as:”important”, “crucial’ and “killer”. Therefore a special fund via the carbon credit market, subsidies, feed-intariff and capacity building are recommended. A particular centre for promoting the installation and deployment of large solar PV system is required.

For instance, based on experience and lessons from advanced countries, feed-intariff is a successful influence on deployment of large solar PV system. In Germany about 75% of installed PV capacity received such a tariff support (Rickerson et al, 2010) . Instead of EWSA relying on the very small solar PV (250 kW), it is highly recommended to install a larger plant for further demonstration and replication where suitable at a faster pace..

1.4 Barrier Analysis and Measures for Small Hydropower (SHP) Technology

1.4.1 General Description of Technology

The small hydropower technology is a well known mitigation option and suitable for both remote areas and wider distribution through national grids. It is characterized by the following issues:

- The hydropower sector is playing a great role in economic development since the last decades of the 20th century,
- The production of hydro-electricity is based on a simple conversion of water potential energy into electricity by a combined system of water turbines and generators;
- Efficiency of conversion is relatively high, about 60%,
- Use of the Manning equation for designing small hydroelectric power systems driven by water flowing through pipes i.e steel or PVC or concrete penstocks,
- For power capacities less than 600 kW, installed transformers can be very small
- Hydraulic turbines' efficiency: 80%, generators: 90% and transformers: 90%,
- Option of in-stream turbine is appropriate for low lands like in Western Province of Rwanda,
- Design based on the Kaplan or Francis Turbine; self excited induction for pico-hydropower,
- Amount of electricity power is proportional to the head drop and the water flow discharged on turbine,
- Pico-hydro: lifespan is about 15 years,
- Micro-hydro: lifespan is about 30 years,
- The capacity factor i.e. operational time duration per day: about 50% or more according to the local conditions and the size of the demand,
- Power capacity: less than 50 kW for a pico-hydro system and less than 1 000 kW for a micro-hydro plant,
- The electricity output is linked to seasonal variations of water flow and specific designs.

1.4.2 Identification of barriers

1.4.2.1 Economic and financial barriers

Table 5: Main economic and financial barriers

Barriers	Elements of barriers	Presentation and dimension
Limited financial facilities	High cost of equipment	Due to the absence of local industries for electronics and electro-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 limited financial capacity
	High cost of construction and installation	Due to, among other, 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%; Relatively short period of reimbursement of loans; Problematic conditions and heavy guarantees

1.4.2.2 Non financial barriers

Table 6: Non financial barriers

Barriers	**Elements of barriers**	**Presentation and dimension**
Limited Knowledge for design and management	Seasonal shortage of designed discharge	Small Hydropower plants do not have dams and reservoirs for storage and regulation; During dry period, only the base flow component is available in river and stream flows; 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 time frames.
	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 damage 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

1.4.3 Identification of Measures for Small Hydropower

1.4.3.1 Economic and financial measures

Table 7: Economic and financial measures

Elements of Barriers	Measures	Hierarchy of Barriers
High cost of equipments	Promotion of industrial units for manufacturing appropriate steel-pipes instead of importing them (from Tanzania for instance) and for electrical components like transformers and generators but also water turbine for pico and small scales.	Important
High cost of construction and installation, and of preliminary studies	Reinforcement of local expertise and capacity building for high quality in designing small hydropower plants in mountains with high slope and varied geological structure	Crucial
Limited financial capacity	Set up a specialized service facility to access loans focusing on wider development of small hydropower plants; Set up a particular insurance scheme for hydrological risk related to climate change impacts and variability in water resources	Crucial

1.4.3.2 Non financial measures

Table 8: Non financial measures

Elements of Barriers	Measures	Hierarchy Barriers
Fluctuation of water resources	More share and dissemination of information on hydrological changes and risk of damaging the hydropower plants;	Important
Limited skilled expertise (in fact, studies and preliminary design require a multidisciplinary team of	Set up an appropriate and specific unit for training in renewable energy sector and hydropower engineering.	Important

experts)		
Low involvement of private sector	Increase and deliver the incentives	Crucial

The most important barrier to remove is the limited financial capacity of private promoters of small hydropower in Rwanda. Thus, subsidies and acceptable interest rates for payment of loans are the most useful measures for such a technology. Reduction of costs of equipment and maintenance is expected from among other application of specific measures like establishment of a local manufacturer for key equipment as mentioned in the above table.

1.5 Barrier Analysis and Measures for the Combined Cycle Gas Turbine (CCGT)

1.5.1 General Description of Technology

The CCGT plus an optional CCS technology is applicable to the Kivu methane gas in consideration of the following conditions:

- Small amount of Kivu methane gas under extraction since the 1950^{s} for the heat purposes of the brewery BRALIRWA located in the North-West at Gisenyi town in Rubavu District;
- Annual supply: about 1.5 million cubic meters;
- Properties of the gas: mix of CO_2 and CH_4;
- The CCGT is not yet applied in Rwanda; it is also the case for the CCS,
- The CCGT is a combined use of a set of components: gas combustor , gas turbine, heat recovery boiler, steam turbine. It is a reliable commercial,technology.
- The speed of methane resources regeneration rate is relatively limited. The planned speed of extraction can be adjusted to such a process of transformation resulting in renewability of methane gas.
- An amount of air and the methane gas are introduced in a combustor and burned.; The Gas Turbine, driven by gases from a combustor, is mechanically connected to the electric generator. Both heat and electricity are produced.

Such a use of both the gas turbine and steam turbines is commonly named: Combined Cycle Gas Turbine (CCGT). Modular units may range from 1 MW to 10 MW.

How does a CCGT work with both combustion gas turbine and steam turbine?

The methane gas is injected into a combustion chamber and burned. The exting expanding gases drive a gas turbine mechanically connected to a generator for producing electric energy. The waste heat is extracted from the gas turbine and sent to a boiler for producing steam (Heat Recovery Steam – Gas Turbine). The steam, in turn, rotates a turbine (ST) connected to a generator. Specific parameters for a CCGT system are thermal efficiency: 34% for a gas turbine technology and 51% in case of a CCGT. Combustion gas turbine inlet temperature is 1 300 °C while steam turbine inlet temperature is 538 °C. The capacity factor of the CCGT is 80% (i.e. 19 hours) and life spanis 25 years.

The CCS is a set of components with roles of separation and extraction of CO_2 from the CCGT flue gases, its compression and transportation through the pipelines towards a geological system or water body as a final destination for storage.

1.5.2 Identification of Barriers

1.5.2.1 Economic and financial barriers

Table 9: Economic and financial barriers

Barriers	**Elements of barriers**	**Presentation and dimension**
High cost of methane production	High cost of extracting methane gas	The initial steps of methane gas production from lake Kivu are expensive, installation of appropriate equipment is expensive too ; Biogas generation from households and cooperatives is done on separate sites;
	Additional cost of CO_2 and H_2S storage	Elimination of associated CO_2 and HS is also an additional cost (they account for up to 80% of gross mixed gases).
	High cost to achieve liquefaction temperature(-168°C)	Gas from production units has to be transported in a liquefied state ;(it is also the case for gas used in cooking and various industries as planned by EWSA. This will include some of the most important consumers like BRALIRWA in North-West and CIMERWA in South-West of the country.
	High cost of sequestration of exhaust gases	Adopt and apply the cheapest and available techniques for sequestration, removal and storage

1.5.2.2 Non Financial barriers

Table 10: Non Financial barriers

Barriers	**Elements of Barriers**	**Presentation and dimension**
Unfamiliar new technology	Technical and skill limitation	The CCGT is complex and required highly qualified personnel , 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 transportation of gas is critical and is hindering the development of CCGT technologies in Rwanda.
Conflict with the green policy	Kivu gas is a rich resource and a non green energy	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

1.5.3 Identification of Measures for CCGT

1.5.3.1 Economic and financial measures

Table 11: Economic and financial measures

Elements of Barriers	**Measures**	**Hierarchy of Barriers**
High cost of extracting methane gas	Appropriate mechanism of funding CCGT based on Kivu gas is to be setup;	Crucial
Additional cost of storage of CO_2 and H_2S	Instead of reinjection of the CO_2 at 90 m depth in lake Kivu, such a gas can be considered as an input product for industrial units of BRALIRWA for instance ; The H_2S can be used for production of sulfuric acid (H_2SO_4), a useful chemical product for industrial applications in addition to decrease of maintenance of batteries storing energy from solar and wind option;	Crucial
High cost of liquefaction and transport to end users	Consider optional total use of gas for only plants located near extraction units;	Non-Starter (killer)
High cost of sequestration	Adoption of injection and storage in deep layers of the lake	Crucial

1.5.3.2 Non financial measures

Table 12: Non financial measures

Elements of Barriers	Measures	Hierarchy of Barriers
Technical and skill limitation	Practical training in related technology;	Important
Limited gas production and distribution at large scale	Set up a framework for prioritizing the CCGT projects	Important
Conflict with the green policy	Implementation of carbon credit market for applying the CCS scenario	Crucial

Given that a pilot project on Kivu methane-to-electricity power has been installed and is operational since 2009, deployment of CCGT technology requires a special fund for initiating the combined cycle approach . While it is crucial to overcome the barriers related to the issues of costs, it is highly recommended to solve the problem of liquefaction and that of distribution of methane far from the station of production.

1.6 Barrier Analysis and Measures for PHEV Technology

1.6.1 General Description of 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 station 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 such a technology combining the two sources of energy, the amount of CO_2 emissions is lowered due to the decreased rate 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.

1.6.2 Identification of barriers for PHEV

Like any other technology, transfer and diffusion of PHEV in Rwanda will be faced mainly with barriers related to resistance to change, market failure, limited demand including low financial and purchase capacity. National policy and provision of incentives for such a transport innovation are also needed. Appropriate loans from the banks and leasing programs are also required for promoting the PHEV technology option. Another constraint would be the inexistent infrastructure for recharging batteries.

Reference and pilot projects for a further deployment of PHEV alternative in Rwanda are also missing. For better implementation of GHG mitigation objectives, a diversification approach policy based on efficient gasoline-powered vehicles and electric power, is needed.

1.6.2.1 Economic and financial barriers

Table 13: Main barriers for PHEV technology

Type	**Barriers**	**Elements of barriers**	**Presentation and dimension**
Economic and Financial	High cost of purchasing a PHEV	Limited purchasing power of Rwanda	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 facilitatepurchase of electric vehicles
		Insufficient rates of taxes and fees to conventional pollutant vehicles and second hand vehicles	Market for second hand vehicles is largely developed and dominant 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

1.6.2.2 Non Financial barriers for PHEV

Table 14:Non Financial barriers

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 vehicle is almost twice more costly
		Non-established pilot projects for demonstration	PHEV vehicles are not yet available 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	PHEV options are not

		and share of opportunities between PHEV manufacturers and local importers for a step towards introduction of PHEV in the country	considered and only conventional vehicles are imported from Europe and Asia mainly.
	Human and Institution capacity	Limited technical and skilled human resources	PHEV , technology with potential for GHG emission mitigation, is not yet understood; very limited number, if any, 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 non existent
		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 country producers 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

1.6.3 Identification of Measures for PHEV deployment

1.6.3.1 Economic and financial measures

Table 15: Measures to overcome barriers for PHEV

Category	Measures	Elements	Presentation and dimension
Economics and Financial	Special incentives to suppliers and consumers of PHEV	Incentives to encourage suppliers and promoters of PHEV	Subsidized importation of PHEV options; Exemption from import taxes and fees; Exemption from parking fees
	Bonus	Incentives to consumers	Some bonus subsidies are given to purchasers of PHEV options and efficient gasoline cars emitting less than 150/g.km
	Subsidies for industry of vehicles	Incentives to manufacturing units	Distribution of bonus subsidies for battery and electric motor suppliers and manufacturers ; Subsidies for recharging battery stations for at least a period of the first 3 years of PHEV promotion
	Leasing programs	Special loans for purchase channel	Leasing programs for PHEV consumers; Special fund in case of mini-buses; Leasing program for maintenance services and technical units
	Stopping the use of non efficient vehicles	Discouraging the importation of conventional gasoline and diesel	Increasing import taxes(custom, excise); Establishment of road use fees only for new conventional vehicles;

		vehicles	Increased interest rate
	Subsidies for converting old cars	Incentives for converting pre-owned vehicles into hybrid vehicles	Subsidized maintenance station in charge of facilitating access to converted vehicles
	Use of the carbon market	Carbon credits	All suppliers and consumers of PHEV options benefit from carbon credits

1.6.3.2 Non financial measures

Table 16: Non financial measures

Type	**Measures**	**Elements**	**Presentation and dimensions**
Non Financial	Creation of market for PHEV	Installation of a governmental unit plant for swapping and converting vehicles into hybrid ones	All converted vehicles receive a certification of a swapped vehicle
	Local fabrication of batteries	Development of a local capacity of PHEV market service;	Manufacturing unit of batteries and of H_2S extracted from lake Kivu;
	A manufacture of electric motors	Local production of equipments	Manufacturing unit of electric motors and other key spare parts

1.7 Barrier Analysis and Measures for Geothermal

1.7.1 General Description of Technology

By the year 1870there was discovery of the role of radiogenic heat generated by long-lived radioactive isotopes of Uranium, Thorium and Potassium. In 1942, installed capacity of worldwide geothermal -electricity reached 127 MW as compared to 9,028 MW in year 2003. Geothermal exploitation follows a substantial investigation and exploration before deciding on the type of technology. There are 2 types of technology: Engineering Geothermal System (Hot Dry Rocks) or Naturally Hydrothermal Resources (Wet Rock Technology);

Once a sustainable reservoir of geothermal resources is discovered and drilled whole wells are properly installed, geothermal water brine, at about 180°c and pressure of 8 atmospheres, is extracted. A heat exchange system playing the role of transfer of heat to any selected working fluid is also installed.

- A steam turbine, driven by a heat working 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 whole wells.
- A binary hydrothermal electric power option is based on 2 fluids (1.gothermal steam/ brine and 2. hydrocarbon working heat fluid)
- Working fluids: Kalina water-ammonia mixture; butane; n-pentane
- Capacity range: 200 kW to 20 MW
- Temperature required for the geothermal water brine is about 120 °C to 170 °C
- Flow of fluids: mode of a closed-loop in order to minimize GHG emissions
- Modern drilling can reach a depth of 10 km underground
- Average geothermal gradient: 3 °C/100 m
- Binary plants are elaborated for commercial purposes in small modular units
- For instance in Ethiopia, the installed geothermal-electric power was 8.5 MW in year 2003 against 45 for Kenya; up to now, leading countries are mainly USA (2 800 MW), Philippines (1 905 MW), Italy (862 MW),...
- In case of geothermal resources reaching a temperature higher than 180 °C and a pressure up to 8 atmospheres or more, the geothermal steam can be directly passed through the turbine connected to the generator; then it is condensed and re-injected into deep layers of ground for the recharging purposes; such an avoidance of use of a heat exchanger and a hydrocarbon working heat fluid makes the geothermal technology cleaner without

emission of GHG; instead, for lower temperatures and pressures, the steam is still containing the brine, thus a use of a heat exchanger and a hydrocarbon fluid is required.

1.7.2 Identification of Barriers to geothermal technology

1.7.2.1 Economic and financial Barriers

Table 17: Economic and financial Barriers

Barriers	**Elements of barriers**	**Presentation and dimension**
Cost of first 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 first step of a pilot project is not yet installed
	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 costs; regional experience from Kenya and Ethiopia is not a sufficient basis for projecting relative costs of production and maintenance in Rwanda.

1.7.2.2 Non financial Barriers

Table 18: Non financial Barriers

Barriers	**Elements of Barriers**	**Presentation and dimension**
Stability of infrastructure	Risk of damage by earthquake events 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 lands	Very high density of land occupation by anthropogenic activities	Areas expected to host the geothermal plants are those which are highly covered by agriculture plantations

1.7.3 Identification of Measures for Geothermal

1.7.3.1 Economic and financial measures

Table 19: Economic and financial measures

Elements of barriers	**Measures**	**Hierarchy of Barriers**
Cost of preliminary investigation	Set up a special fund for new technologies and benefit from carbon credits	Non –starter (killer)
Limited incentives and subsidies	Negotiations for different forms of subsidies	Crucial
Cost of validation of results of exploration studies ; Cost of large company for geothermal	Unit of monitoring the geothermal resources and research; proper reinjection of water from plants.; a 10 MW pilot project	Important
High capital and maintenance costs	Access to fund for initial equipment	Non-starter (killer)
Non sufficient expertise and skilled technicians	Capacity building and Training in order to associate a human expertise to the alternative of coming pilot geothermal power plants	Crucial

1.7.3.2 Non financial barriers

Table 20: Non financial barriers

Elements of Barriers	Measures	Hierarchy of Barriers
Risk of damage by earthquake event and others hazardous events	Design and construction taking into account the risk of high vibration; insurance; avoidance of sites with a high potential of landslides and of geological fractures.	Less important
Limited human capacity	Installation of a research centre for geothermal and related disciplines	Crucial
Limited involvement of private sector	Set up an industrial association of private promoters; Make available a legal framework for subsidies and incentives for interested private investors	Crucial
Conflict with owners of lands	Involvement of land owners in sharing the exploitation of geothermal	Important

Measures, actions and solutions expected for removal of economic and financial barriers are linked to a set of financial inputs. They are to be considered from the beginning of the geothermal exploration and cover the crucial cost of drilling and installing of equipment. It is recommended to enhance the capacity building for further establishment of a research and development facility and future management of the pilot –plant project (10 MW).Risk management of potential damage to the proposed plant should also be considered. .

1.8 Linkages of Identified Barriers for the Energy Sector

Apart from the small hydropower, all these prioritized technologies are almost new in Rwanda and require a substantial phase of RDD (research-development-demonstration). There is also a common limitation in a database on energy resources' distribution and availability.

The PHEV barriers are, among others, linked to the low level of deployment of renewable energy technologies.

Table 21: Analysis of Linkages of Barriers for the Energy Sector

Type	**Barriers**	**Linkages**
Economic and Financial	High initial capital cost	Special attention has to be paid to technologies requiring particular equipment due to their costs for acquisition and installation (case of drilling and wells for geothermal; solar collectors; methane and its distribution after liquefaction).
	Low access to loans for investing in energy sector	All technologies are sharing such a financial constraint. Small companies are facing this problem moreespecially for the case of new technologies (CCGT and CCS; geothermal; PHEV). The interest rate is high and a preliminary condition of having a guarantor are constraints common to the diffusion of all these prioritized options.
	-High cost of fuel -High Operation and Maintenance costs	Cost of fuels like biomass and petroleum is high due to limitation in their resources and also their transport from the unit of preparation and treatment to the site of the power plants or centre of consumers.
	Cost of access to lands and wetlands	Technologies facing such a problem are mainly those requiring large size of land for extracting or collecting energy fuel (geothermal; reservoirs for hydropower) or for

		installation of the power plant (large solar PV; solar CSP). For some technologies (geothermal, large hydro) arable land is allocated to power plantsand this can lead to potential conflicts with the agricultural sector.
	High cost of exploitation for access or extraction of fuel	Particularly geothermal and Kivu methane are characterized by high cost of extracting and collecting the intake resource; drilling for the geothermal can require a depth of wells reaching about 3 km and reinjection wells are separated by about 1 km.
	High cost of storage of energy resources and output products	Imported petroleum products, Kivu methane gas -to -power production for industry and cooking, heat energy produced by solar concentrators require large capacity of storage.
Non Financial	Lack of legal statute for promotion of independent or mini-grid connections	Small scale power technologies like solar PV, micro-hydropower are especially affected by such a constraint to transmission, diffusion and distribution of remote power generated; more appropriate facilities are required for attracting private investors and communities.
	Limited local industry for electro-mechanics	All systems of electric power generation require basic equipments which are (almost if not all) imported for the case of Rwanda. One can name turbines (steam, gas), electronics; meters and generators; such a constraint can result among others in high cost of operation, maintenance and in lowered in diffusion of technologies like the Pico/micro/mini hydropower requiring among others importation of pipes.
	Limited human and institutional capacity	All prioritized technologies require a preliminary focus on estimation and studies on

	for private companies and individual producers or developers	sustainability of energy resource fuels, a design for the whole plant, various capacities and enough skilled human staff for maintenance; thus any limited information and weak expertise are affecting all these technologies.
	Limited mechanisms, frameworks and statements for access to subsidies, incentives and carbon credits	Particular technologies facing high cost of newly introduced equipment are most affected by such a barrier to diffusion of energy technologies presented above for this TNA project in Rwanda.
	Inexistent specific joint research/ development in energy sector	This barrier is a cross-cutting issue and, if relevant measures are not strengthened for a further removal, can result in stagnant capacity for design and introduction of new technologies.
	Limited cooperation for the shared electric regional grid interconnection	It is especially regarding hydropower and Kivu methane, two main technologies shared with other countries in the region; such a regional cooperation can transform Rwanda (once production of energy for supply is enough and exceeding the local demand) into an exporting energy.

Table 22: Most important measures for Prioritized Technologies

N°	Technology	Measure n°1	Measure n°2
1.	Geothermal Power	Make available detailed feasibility studies and exploration for further information on geothermal potentialities both for the wet hot aquifers and for the dry hot rocks scenarios	Allocation of benefits from carbon credits to subsidies for investors interested in exploration of geothermal power; lessons from a pilot plant will be useful
2.	Kivu Methane CCGT	Installation of a capacity building towards a wider improved efficiency through combination of the gas turbine, the CHP system of heat recovery and the steam turbine in addition to installation of components for carbon capture and sequestration of exhaust gases	Attracting the local small companies through a delivery of subsidies for joint companies for both electric generation and liquefaction for covering the demand located far from lake Kivu; lessons and experience from Kivu methane pilot plant are awaited
3.	Hydropower(small scale)	Distribution of subsidies facilitating the development of independent mini-grids and assistance in setting up a mini-industry for basic electronics and electro-machinery equipment and devices for better maintenance and diffusion of such a technology; lessons experience from Tanzania where pipes for penstocks are manufactured can be explored;	Incentives and subsidized insurance related to climate and hydrological risks and thus for an insurance supported by government and partners so that the private companies, small developers and cooperative producers can be more attracted
4	PVEH	Provision of incentives to both suppliers; promoters, consumers and manufacturing industrial units of PHEV components	Discouraging the importation non efficient gasoline and diesel vehicles by means of decreasing their costs and

			establishing subsidized purchase cost of PHEV
5	Solar(large PV)	Industrial unit of large solar PV through appropriate subsidies and incentives by both government and partners (local industry for assembling solar cells and for electronics like inverters ; special fund for solar)	Feed –in tariffs and facilities related to direct connection to national EWSA grid in order to avoid use of large field of batteries and to promote the economy of scales through installation of large solar PV

1.9 Enabling Framework to Overcome Barriers

Among prioritized technologies for wider development of energy sector in the context of economic growth, poverty reduction and climate change mitigation, some of them are already planned to be implemented mainly before the year 2017. With reference to the updated National Energy Policy and Strategy additional electric power capacity scheduled for installation is about 150 megawatts per year over the period of 2011 to 2017 so that 1052.4 megawatts will be operational in Rwanda as an added capacity in the year 2017 (MININFRA. 2011).

The top prioritized power technologies are geothermal (310 MW), Kivu methane (295.5 MW), hydropower (75.6 MW for small scale and 161MW for large scale) and peat (200MW); being percentage-wise about 29%, 28%, 23% and 19% respectively. In addition to the above main contributing sources, there are two other minor ones: diesel (10MW) and solar photovoltaic (0.3MW). .

Our discussion on enabling frameworks for overcoming barriers to transfer and diffusion of energy technologies will be limited, below, to only the five above mentioned prioritized options (geothermal, methane, hydropower, hybrid electric vehicles and solar).

Table 23: Addressing Common Barriers to the five prioritized technologies

Type	Common Barriers	Enabling Frameworks	Responsible
Financial	Limited financial capacity of private investors	Framework for benefits from carbon market and credits; a special partnership and joint ventures can be undertaken.	REMA; MININFRA; EWSA, BANKS.
	High tariff of kilowatt-hour generated	Standard Mechanism for increasing efficiency of converting a fuel into electric power (more subsidies and incentives); Laws and agreements with EWSA	EWSA ; RURA; MININFRA ;MINICOM
	High capital cost	Availing a legal statute to facilitate accessing special funds, subsidies, particular loans and incentives to innovators	MINICOM; BANKS; DONORS
	Limited local industry on common devices like turbine ,generators and electronics	Legal framework on research oriented to energy sector and promotion of industrial units for support to the maintenance requirements.	MINICOM; MINEDUC
Non Financial	Limitation in human capacity and expertise	Setting up a network for capacity building and regular training in energy sector especially for design and management of power plants.	MIFOTRA; MININFRA; UNIVERSITIES NGOs
	Limited motivation for joint companies from smaller scale producers	Organization of campaigns, for and seminars for attracting small power producers and investors in different sub-sectors of energy.	PRIVATE SECTOR ASSOCIATION; EWSA
	Limited facilities in research and	Establishment of pilot projects for new technologies;	DONARS; MININFRA;

	development and demonstration	Special fund for key energy options	MINEDUC; REMA
	Resistance to change and limited acceptance of new technologies	Policy on assistance to innovators, early adopters and front-runnors; Policy on inter-agencies coordination; Policy on industrial alliances at local and international level	RDB; RBS; RURA; MINICOM

1.10. Cost/ benefit analysis

Below we present an analysis of costs and benefits for the five prioritized technologies. We considered the generating costs[in: US dollars or cents per kWh] of each technology; in fact such a parameter is calculated through an adjusted initial capital cost extended to the overall lifetime, the fixed and variable operation and maintenance costs and, the cost of energy fuels, if any. The benefits [in: kg/MWh or g/kWh] are related to the contribution of energy technologies to the GHG mitigation applications. Therefore we comparatively analyzed the information resulting from the ratio [in: USD/kg or USD/tonnes] between such costs and benefits.

Annual NPV (net present values) have been calculated for each technology over the lifespan for a discount rate of 10 % both the costs and benefits have been discounted. Considering the double objective of the TNA project aiming at fighting both “against poverty and against the effects of climate change as interrelated efforts” (UNDP, 2010), the prioritized options include the Kivu methane gas CCGT technology improved by the additional CCS option. In addition to such a double worldwide target, it was suggested by the COP 15 at Copenhagen in December 2009 “to accelerate technology development and transfer in support of action on mitigation that will be guided by a country-driven approach and be based on national circumstances and priorities” (UNFCCC, 2009b). Within the context of the TNA project and with targets mitigating the GHG emissions, below we present an alternative of replacing for instance the oil-fired power technology (gas turbine) by low- carbon technologies.

In fact, about e half of total electricity in Rwanda is currently provided by the thermal power plants using imported liquid fuels. From 2005 to 2008, total electricity production was respectively 115.8, 230.4, 248.6 and 276.5 GWh/year. Thus the average increase per year is

40 GWh. Therefore in the coming three years, about 558 GWh, will be required. In case of business-as-usual about 280 GWh will be provided by thermal power plants.

The calculations below, i.e tables 24 and 25, are therefore based on the scenario of replacing thermal power plant (280 GWh) by more clean options.

Table 24: Costs and benefits with link to GHG mitigation

	Small hydropower	**Large solar PV**	**Geothermal**	**Kivu methane CCGT with CCS**
Unit CO_2 emission[kg/MWh]	43	155	197	315
Annual CO_2 emission[megatons]	12	43	55	88
Avoided CO_2 emission[6] [megatons/year]	198	167	155	122
Benefits [10^6 USD/year]	396	334	310	244
Unit generating cost[USD/MWh]	151	616	156	131
Annual generating cost[10^6 USD]	42.3	172.5	43.7	36.7
Benefit-to-cost ratio	9.4	2	7	6.6

[6] Refer to the baseline OIL/DIESEL power plant emitting 750 Kg/MWh , i,e about 210 megatons of CO_2 emission /year

Table 25: Net Present Values (NPV) per each technology for a scenario of replacing 280 MWh from oil thermal power plants

N^{th} year	NPV for Small hydropower [10^6 USD/year]	NPV for Large solar PV [10^6 USD/year]	NPV for Geothermal [10^6 USD/year]	NPV for Methane CCGT with CCS [10^6 USD/year]
1	323	157	238	187
2	293	142	217	170
3	267	129	197	154
4	242	118	179	140
5	220	107	163	127
6	200	97	148	116
7	182	88	134	105
8	165	80	122	96
9	150	73	111	87
10	137	66	101	79
11	124	60	92	72
12	113	55	83	65
13	103	50	76	59
14	93	45	69	54
15	85	41	63	49

Given that the CO_2 emission by oil-fired technology is estimated at about 210 000 tons per year, replacement of such a technology by any renewable option will result in a significant mitigation. With regard to the above results, the best scenario is the replacement of oil and diesel-based power technologies by alternatives presenting the lowest amount of CO_2 emission. The indicative cost of environmental externalities is varying between 2 and 28 USD per ton of CO_2 emissions (IPCCC, 2007). Therefore, In consideration of this minimum 2 USD per ton of CO_2 emission; externalities' costs related to the reduction of GHG emission were agreeable in accordance with the literature related to, among other publications, technical and economic assessment of energy technologies (ESMAP, 2007).

One may wonder how options like geothermal and solar photovoltaic are characterized by an important emission of CO_2. This is due to the process of preparation, treatment and other steps in the overall channel network of fuel production. Thus, it is important to remember that such trends are not affecting the operation process during the lifespan of large solar and geothermal plants.

The NPV calculated for each prioritized technology in the sub-sector of electricity and presented above in table 25 proves that all these options are profitable; therefore their diffusion at large scale in Rwanda is recommended (1.10.6 Cost-Benefit Analysis for PHEV)

Table 26: Operation and maintenance costs of PHEV option

Item	Non Efficient fuel vehicle	PHEV	Savings
Maintenance	17 US cents/km	6.8 US cents/km	10.2 US cents/km
Fuel consumption	2 US cents/km	1.2 US cents/km	0.8 US cents/km
Operating Cost	0.8 US cents/km	0.7 US cents/km	0.1 US cents/km
Tires	19.7 US cents/km	8.7 US cents/km	11 US cents/km
Total	39.5 US cents/km	17.4 US cents/km	22.1 US cents/km

Theabove data are linked to the following approximate Gasoline fuel cost in Kigali(Rwanda) =1.7 US/liter

Average rate of consumption: 10 liters/100km for conventional vehicle and 4 liters/100km for PHEV

Average mileage distance: 50 km/day i.e. 18250 km/year

Average lifespan = 10 years

The fuel consumption item regards only the fossil gasoline fuel; electricity for recharging the batteries is assumed to come from non carbon fuel

Saving from the use of PHEV instead of pollutant GNEF is 22.1 US cents/km i.e. a rate of reduced operation and maintenance cost of 56%.

Table 27: Reduction of GHG emissions costs

	Urban circulation	Rural circulation
Gasoline no efficient vehicle((GNEF)	2.3 US cents/km	1.3 US cents/km
PHEV	0.5 US cents/km	0.47 US cents/km
Savings	1.8 US cents/km	0.83 US cents/km

The above results are based on an average GHG mitigation cost ranging between 20 and 50 USD per ton of CO_2 equivalent (Litiman, 2012); the CO_2 emission is 458 g/km and 105 g/km respectively for the gasoline non efficient vehicle and the PHEV option in case of urban circulation. Regarding the rural circulation, emissions are 262g/km and 95 g/km respectively for GNEF and PHEV options.

The above calculation of cost of GHG emission considered the higher rate (50 USD/tone). Replacement of a GNEF vehicle by a PHEV option results in the savings-related externalities of about 1.8 US cents/km in case of urban circulation. This is justified by the rate of decrease in GHG emission of about 77%. Therefore it is highly recommended to swap from the non efficient cars to cleaner hybrid electric cars. The PHEV technology combined with electricity power generation technologies fully based on non carbon fuels as stated above in the analysis of the four prioritized technologies (geothermal, solar, hydropower and Kivu methane CCGT with optional CCS components); it is expected to play a key role in GHG mitigation in Rwanda.

Finally, for a unit PHEV replacing a conventional non efficient vehicle, the net benefits and savings are about 1693 USD/year in case of an adjusted initial purchase-cost estimated at 4440 USD over a lifespan of 10 years.

Table 26: Estimated NPV for the PHEV technology

N	1	2	3	4	5	6	7	8	9	10
NPV (USD/year)	1539	1399	1272	1156	1051	956	869	790	718	653

The estimated annual NPV for a PHEV unit is presented above in table 26. They are positive and hence the PHEV technology is profitable. Its potential transfer and diffusion in Rwanda can induce and boost the development of renewable energy use.

CHAPTER 2: AGRICULTURE SECTOR

2.1 Preliminary targets for technology transfer and diffusion

2.1.1 Description of targets for prioritized technologies in the agriculture sector

As mentioned in the TNA report, five adaptation technologies were prioritized for the agriculture sector. These include: Seeds and grain storage, Agro forestry, Radical terraces, Drip irrigation and Rainwater harvesting.

2.1.1.1 Targets for seed and grain storage

The target group for the transfer and diffusion of this technology is the farmers' associations/cooperatives in the first place. These 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.

The cost of the deployment of the technology is estimated as follow: To install storage capacity of 60 000 tons with modern and well studied drying area, management offices and other supporting equipment it ranges from $ 480000 to $ 900000 in local conditions. This makes the unit cost range from $ 8 to $ 15 / ton. The transfer and diffusion of the technology should start immediately after the TNA project is concluded.

2.1.1.2 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 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. The average cost to put in place 1 ha of agro forestry plantations is 10 000 $ covering land preparation, seedling preparation (seeds purchasing, tubing, shade construction, nursery maintenance) and baby trees plantation. The transfer and diffusion of the technology should start immediately after the TNA project is concluded.

2.1.1.3 Targets for radical terraces

Radical terraces are ideal for slopes ranging from 13% to 55%, it is estimated that agricultural land with radical terracing potential is owned by 1 000 000 households which 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. The average cost to establish one hectare of radical terraces in Rwanda including labor and basic tools such as picks, shovels etc is $ 1000 tax exclusive. The cost for any additional unit (ha) of radical terracing would cost the same amount as the initial unit. The transfer and diffusion of the technology should start immediately after the TNA project is concluded.

2.1.1.4 Targets for drip irrigation

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 accidental slopes and other areas where the land has been worked so as to be able to cater for agriculture infrastructures. This farming community is estimated at 1 200 000 households which is about 80% of the entire farming community in Rwanda. Looking at the technology diffusion cost, the technology is widely variable; however the cost of a drip irrigation system ranges from US$ 800 to US$ 2,500 per hectare depending on the specific type of technology, automatic devices, used materials as well as the amount of labor required. The transfer and diffusion of the technology should start immediately after the TNA project is concluded.

2.1.1.5 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 make the Rwandan farming community could benefit from the transfer and diffusion of this technology. The installation of one cubic meter in a small sized (240 m^3) runoff pond system costs $ 15. The cost to install one cubic meter in rooftop rainwater harvesting system varies depending on the tank type:

1. With plastic tank: $ 230
2. Stone and concrete tank: $ 220

The transfer and diffusion of the technology should start immediately after the TNA project is concluded.

2.1.2 Methodology

In the first place, literature review was carried out by the consultant in order to list and classify barriers that may hinder the transfer and diffusion of prioritized technologies for the agriculture sector based on guidelines as elaborated and published by the UNDP. Initially, barriers hindering transfer and diffusion of prioritized technologies in the agriculture sector were classified into four main categories: technological, financial, economic and institutional. Being barriers or measures, two types are considered in the context of speed of diffusion;

financial and non financial. Thus for measures we can simplify and consider only two types: financial and non financial measures. Our methodology also considered a consultation process during which listed barriers were discussed among a wide scope of stakeholders including agriculture and finance experts, academics, researchers, NGOs representatives and the media. The consultation was initiated by individual meetings to draft relevant suggestions, and concluded by a workshop where the outcome of individual meetings was discussed and finalized. The workshop was held on 4th September 2012 at Umubano Hotel, Kigali, Rwanda.

2.2 Barrier analysis and possible enabling measures for agro forestry

2.2.1 General description of agro forestry

Agro-forestry is an integrated approach to the production of trees and of non-tree crops or animals on the same piece of land. The 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 uses such as: 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 (climatetechwiki.org).

2.2.2 Identification of barriers for agro forestry

Rwandan agriculture is one of the sectors which are vulnerable to the effects of climate change especially soil erosion as a result of heavy rains. The country holds a total space of 1.4 million hectares with agricultural production potential. The same space can be used for agro forestry development which would help the agriculture sector and the country in general to adapt to the effects of climate change. However, there exist barriers that hinder proper implementation of the technology in Rwanda. The following key barriers have been identified:

1. Agro forestry inputs are not well distributed which makes them not easily accessible to local farmers. These include: seeds, germplasm and credit.
2. Lack of demonstration plots: Farmers are difficult to convince unless they see the advantages of agro forestry. Very few demonstration plots have been established as case studies to generate concrete results

3. There exists gaps of knowledge on agro forestry systems among agriculture extension agents who are in regular contact with farmers.
4. Farmers are not prepared to invest in agro forestry for long term benefits. They prefer immediate benefits
5. There is also lack of infrastructure for handling and processing of existing agro forestry products and lack of marketing services.

2.2.3 Proposed measures to overcome barriers for agro forestry

With respect to barriers translated into causes and effects of not fully adopting agro forestry as an adaptation technology option to climate change in Rwanda, identified measures to overcome the barriers are presented in table 28. Mainly, technical knowledge gaps which exist in the agro forestry industry can be dealt with through training, information sharing workshops and study tours. The legal framework should also be elaborated in order to adapt it to current country needs and priorities.

Table 28: List of proposed measures to overcome identified barriers for agro forestry

Category	Barriers	Measures	Hierarchy of barriers
Technical	Existence of technical knowledge gaps among agro extension agents	Improvement of technical knowledge through training, workshops and study tours to all agro extension agents	Important
Political	Existence of gaps in forestry development legal framework	Revise the legal framework of the agro forestry section by initiating a project aiming at developing specific laws on agro forestry development	Important
Information and awareness	Limited information at farm level	Create awareness among farmers through meetings and community radio	Important
Economic and financial	Inadequate access to credit and high interest rate	Promote access to credit and reduce interest rates by decentralizing agriculture development funds up to	Crucial

		Sector level	
	Relatively high initial investment and absence of immediate economic benefits	Reduction of charges to farmers on initial investment on agro forestry development through provision of inputs such as seedlings.	Non starter

2.2.4 Enabling framework

Through its Strategic Plan for the Transformation of Agriculture (PSTA II), Rwanda has set up several mechanisms that would enable the implementation of technologies which improve agricultural production while sustaining the environment. Different government institutions/agencies have been given different mandates and roles which provide an ideal framework for technology transfer and diffusion among the population. For example ministries are policy makers while government agencies together with local government entities are policy implementers.

Based on the proposed measures, the table below illustrates enabling environment that complements the existing institutional framework in order to overcome identified barriers that may hamper the development of agro forestry in Rwanda.

Table 29: Enabling environment to implement proposed measures to overcome identified barriers for agro forestry

<table>
<tr><th>Proposed measures</th><th>Enabling Environment</th></tr>
<tr><td>Provide training to all agro extension agents:
-Organize seminars
-Conduct workshops
-Organize and conduct study tours</td><td rowspan="4">-MINIRENA
-MINAGRI
-MINALOC
-MINECOFIN
-MINICOM
-RNRA
-REMA
-RAB
-RGB
-RBS
-RCA
-PSF
-Farmers associations/cooperatives
-Research institutions
-NGOs
-National Adaptation</td></tr>
<tr><td>Provide information and create awareness among farmers:
-Create demonstration plots around the country
-Organize and conduct study tours
-Provide awareness materials to farmers associations/cooperatives</td></tr>
<tr><td>Promote access to credit and reduce interest rates:
Create small farmers agro financing institutions</td></tr>
<tr><td>Reduce charges to farmers on initial investment and Educate farmers about multiplied medium to long term benefits of agro forestry systems:
-Provide subsidies for agro forestry inputs
-Tax exemption on imported inputs
-Provide awareness materials</td></tr>
</table>

-Use of media (news papers, radio, TV)	Programs of Action -Policy on agro forestry -Forestry strategy

2.2.5 Cost benefits analysis for agro forestry

Measures

The key barrier to transfer and diffusion of agro forestry islimited adoption of agro forestry systems among farmers.

The target when transferring and diffusing this technology would be to make agro forestry systems fully adoptable within farming communities.

List of alternative measures:

Know how, rural policies, awareness raising, access, subsidies etc

Complimentary measures:

a) Improvement of existing technical knowledge
b) Revision of agro forestry legal framework
c) Creation of awareness among farmers
d) Promote access to credit and reduce interest rates
e) Reduction of charges to farmers on initial investment on agro forestry development through subsidies on inputs (seedlings and fertilizers)

Costs

1. Awareness and knowledge raising among farmers

   Cost of trainers, workshops and training material

In the first year, a starter pack would be made available and be distributed to each of the farming households to allow farmers learn about the benefits of agro forestry.

The cost of a representative pack was estimated at $15 per household including training and information.

The total cost was estimated at: $ 15*1 400 000 households= $ 21 million

2. Subsidies to cover a share of costs on initial investment

Assuming that each household will be 100% provided with seedlings to be planted on 0.01 ha (10 seedlings) at an average cost of $ 0.1 per seedling, the total cost would be: $ 0.1*10*1 400 000= $ 1.4 million

3. Ensure access to available inputs such as seedlings and fertilizers

   Costs related to legal reforms and infrastructure

We assumed this to be part of the overall development agenda and we did not estimate any cost.

Other cost:

These would include labor, land and fertilizers. Regarding labor this is only man power since Rwandan agriculture is human labor intensive. The agriculture land generally belongs to the farmer and in most cases it is inherited from the family. We also assume that most the fertilizers to be used will be organic manure available locally at a negligible cost.

Total costs: (awareness and knowledge raising + subsidies on initial investments cost + related to legal reforms and infrastructure + other costs)

Total costs (USD) $_{\text{year 1}}$: 21 million + 1.4 million + 0 + 0
= 22.4 million

Total costs (USD) $_{\text{year 2}}$: 0 + 1.4 million + 0 + 0
= 1.4 million

Benefits:

Starting in Year 5, one-fourth of the trees will be coppiced annually and sold as building poles for $ 0.40 each.

Assuming that fruit trees will be 50% of the total planted trees and the total number being 14 million per annum, sales of buildings will be:

$ 0.40* ¼ (7 million) = $ 0.7 million from year 5

Starting in Year 7, $5 worth of fruit will be sold each year.

Fruit sales will be:

5$ *7 million tress= $ 35 million from year 7

The discount rate was fixed at 5 % and 9%

Table 30: Net present values for agro forestry

Year	Total Benefits (USD)	Total Costs (USD)	Net benefits (USD)	Discounted net benefits at 5% (USD)	Discounted net Benefits at 8% (USD)
1	-	22 400 000	-	-	-
2	-	1 400 000	-	-	-
3	-	1 400 000	-	-	-
4	-	1 400 000	-	-	-
5	700 000	1 400 000	-	-	-
6	1 400 000	1 400 000	0	0	0
7	37 100 000	1 400 000	35 700 000	27 127 659	20 840 630
8	72 800 000	1 400 000	71 400 000	52 192 982	38 594 594
9	108 500 000	1 400 000	107 100 000	75 316 455	56 603 603
10	144 200 000	1 400 000	142 800 000	96 617 050	66 203 059
NPV				**251 254 146**	**182 241 886**

By Year 10, crops yields (i.e. maize) and revenues on the remaining land will be 22% higher than they would have been without the trees. (Costs of planting and harvesting the maize remain constant.) This assumes an absolute increase in yields of 11% over ten years, compared with a decrease of 11% if the trees had not been planted.

2.3 Barrier analysis and possible enabling measures for drip irrigation

2.3.1 General description of drip irrigation

Drip irrigation is a 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 route area and applying it under particular quantity and pressure specifications. Compared to surface irrigation, which can provide 60 per cent, water-use efficiency and sprinklers systems which can provide 75 per cent efficiency, drip irrigation can provide as much as 90 per cent water-use efficiency (FAO, 2002).

2.3.2 Identification of barriers for drip irrigation

The majority of Rwandan farmers (about 90%) still rely on rain fed agriculture which makes agriculture production much more vulnerable to irregular rainfall and prolonged draughts. With an estimation of 589 000 ha of potential irrigable land, the government of Rwanda through the Ministry of Agriculture has targeted to irrigate at total space of 100 000 ha by 2017 from 18 000 ha in 2011 mostly using flood irrigation which, combined with unreliable precipitation will put more pressure on water resources.

Drip irrigation has been identified as the most efficient technology to assist the agriculture sector/production to adapt to the effect of climate change, especially by reducing water consumption given its 90% efficiency on water use. In local context, barriers to the implementation of the technology have been identified as follows:

Table 31: Identified barriers that may hamper the implementation of drip irrigation in Rwanda

Classification	Barriers	Main characteristics
Financial	High initial investment cost	Drip irrigation components are expensive to purchase
	Difficulties to access funds	Small/medium farming agriculture is not well funded in Rwanda
Economic	Limited private companies dealing in the importation of drip irrigation equipment.	Drip irrigation components/ equipment are only bought on order through few companies which imports them.
	Limited equipment manufacturers in place	No manufacturers of drip irrigation equipment/components are available in Rwanda except for pvc pipes and tanks
Technological	Existence of gaps in technical skills in irrigation	There exist limited local expertise in drip irrigation installation and maintenance.
Natural	Seasonal fluctuation of water availability	Due to changing times of abundant precipitations, rain water resources are no longer reliable which affects rivers and internal lakes levels.
	Elevation of agricultural lands vs common water sources location	It would be more beneficial for Rwandan agriculture to apply drip irrigation on hillside. Given the overall landscape of the country which is hilly it becomes difficult to access water sources which are mostly found in valleys.
	Competition with other water uses	In places where water is more scarce like the north eastern part of the country, there may be competition between agriculture and animals on water resources
Cultural	Irrigation is not given its right value among many of local agriculture practitioners	People do not clearly understand the role that water plays in the plant life and development.

2.3.3 Proposed measures to overcome barriers for drip irrigation

With respect to barriers translated into causes of not adopting drip irrigation as an adaptation technology option to climate change in Rwanda, identified measures to overcome the barriers are presented in table 32.

Table 32: List of proposed measures to overcome identified barriers for drip irrigation

Category	Barriers	Measures	Hierarchy of barriers
Economic & Financial	Few private companies dealing in drip irrigation equipments importation.	Awareness creation with the purpose of creating interest among local importers through improved access to loans at reduced interest rates	Important
	Limited number of manufacturers of drip irrigation equipments	Awareness creation with the purpose of creating interest among local manufacturers by guarantying tax exemption on raw material	Important
	High initial investment cost	Reduce charges to farmers on initial investment of drip irrigation installations through subsidies.	Non starter
	Difficulties to access funds	Facilitate farmers to access funds by creating agriculture funding institutions and reducing interest rates.	Crucial
Technological	Limited of technical skills on drip irrigation	Improve technical skills on drip irrigation through trainings, workshops and study tours	Important
Cultural	Irrigation is not given its right value among many of local agriculture practitioners	Educate local agriculture practitioners about the vital role of water in plant growth and productivity through awareness	Important

		campaigns.	

Table 33 below highlights measures which would assist to overcome identified barriers in implementing drip irrigation.: Local importers and manufacturers would be convinced to import and manufacture drip irrigation equipment by offering them loans at reduced interest rates and through tax exemptions on raw materials.

Through subsidies, charges to farmers on initial investment of drip irrigation systems purchase and installation can be reduced making drip irrigation systems more affordable. Decentralizing agriculture development funds up to sector level would facilitate farmers' to access funds.

Technical skills on drip irrigation can be developed through training, workshops and study tours. Local agriculture practitioners should be educated about the vital role of water in plant growth and productivity by comparing well irrigated crops/fields against non- irrigated crops/fields using demonstration fields.

2.3.4 Enabling framework to implement measures for drip irrigation

Table 33: Enabling environment to implement proposed measures to overcome identified barriers for drip irrigation

<table>
<tr><th>Proposed measures</th><th>Enabling Environment</th></tr>
<tr><td>Create interest among local importers and convince them to import drip irrigation equipment/components by offering them loans at reduced interest rates</td><td rowspan="5">-MINIRENA
-MINAGRI
-MINALOC
-MINECOFIN
-MINICOM
-RNRA
-REMA
-RAB
-RGB
-RBS
-RCA
-PSF
-Farmers</td></tr>
<tr><td>Create interest among local manufacturers and convince them to import drip irrigation equipment through tax exemptions on raw materials</td></tr>
<tr><td>Reduce charges to farmers on initial investment of drip irrigation installations through subsidies</td></tr>
<tr><td>Facilitate farmers to access funds:
-Create agriculture funding institutions
-Reduce interest rates on small and medium sized farming activities</td></tr>
<tr><td>Provide technical skills</td></tr>
</table>

-Organize seminars -Conduct workshops -Organize and conduct study trips on drip irrigation	associations/cooperatives -Research institutions -NGOs
Educate local agriculture practitioners about the vital role of water in plant growth and productivity: -Organize training of trainers through workshops, seminars, show casing, demonstration plots. -Conduct farmers awareness campaign by using awareness materials, the media like news papers (Imvaho nshya), Radio (Rwanda, Contact fm, Flash fm, Salus fm and others)	-National Adaptation Programs of Action -Irrigation and mechanization task force -National water resources management policy -Irrigation master plan -Irrigation strategy -Land policy -Land use master plan -Environmental organic law -Environmental policy

2.3.5 Cost benefit analysis for drip irrigation

Measures

The key barrier to transfer and diffusion of drip irrigation is limited acceptance of drip irrigation systems.

The target when transferring and diffusing this technology is increased acceptance of drip irrigation.

List of alternative measures:

Access to loans, tax exemption, subsidies, know-how, awareness raising

Complimentary measures:

a. Create interest among local importers through improved access to loans at reduced interest rates.

b. Create interest among local manufacturers by guaranteeing tax exemption on raw material

c. Reduce charges to farmers on initial investment of drip irrigation installations through subsidies.
d. Improve existing technical skills on drip irrigation through training, workshops and study tours

e. Educate local agricultural practitioners about the vital role of water in plant growth and productivity through awareness campaigns.

Costs

1. The creation of interest among local importers through improved access to loans at reduced interest rates.

We assume that this programme is included in current planned financial reforms and do not estimate any cost.

2. The creation of interest among local manufactures by guaranteeing tax exemption on raw material.

No cost is estimated since tax exemption on raw material is one of the mechanisms which the government of Rwanda adopted in order to promote the development of the manufacturing sector.

3. Subsidies to cover a share of costs on initial investment.

Assuming that each of the 1.2 million farming households which would directly benefit from drip irrigation transfer and diffusion will be assisted at 50% in order to acquire a drip irrigation system able to water 0.04 ha each year at a cost of $ 1650 per hectare, The total cost would be: [50 % ($ 1650 *0.04)* 1 200 000] = $39 million

4. Improve existing technical skills on drip irrigation through training, workshops and study tours

At the beginning of the programme a starter pack would be made available and be distributed to each of the benefiting households (1.2 million) to allow the community familiarize themselves with the technology.

The cost of the starter pack was estimated at $15 per household including training and information.

The total cost for capacity building is estimated at: $ 15*1 200 000 households
= $ 18 million

Other cost:

These would include system maintenance and other irrigation infrastructures which are estimated at $100 per hectare per year. ($ 0.04*100) * 1200000 households = $ 4.8 million

Total costs: (improved access to loans + tax exemption + subsidies on initial investment + technical skills + other costs)

Total costs (USD) $_{\text{year 1}}$: 0 + 0 + 39 million + 18 million + 4.8 million
= 61.8 million

Total costs (USD) $_{\text{year 2}}$: 0 + 0 + 39 million + 0 + 4.8 million

= 43.8 million

Benefits:

In the first place, the adoption of drip irrigation would allow farmers to harvest four times a year instead of two.

Assuming that corn is produced all over the country with average yields of 5 tonnes per hectare at a price of $60 per ton, it comes to $ 300 of sales of corn per hectare.

Net benefit is estimated at: (sales-inputs and labor)

$300-225= $75 per hectare

Total benefit is: ($ 75* 0.04*1200000 households*2) = $ 7 200 000 per annum

Table 34: Net present values for drip irrigation

Year	Total Benefits (USD)	Total Costs (USD)	Net benefits (USD)	Discounted net benefits at 5% (USD)	Discounted net Benefits at 8% (USD)
1	7 200 000	61 800 000	-	-	-
2	14 400 000	43 800 000	-	-	-
3	21 600 000	43 800 000	-	-	-
4	28 800 000	43 800 000	-	-	-
5	36 000 000	43 800 000	-	-	-
6	43 200 000	43 800 000	-	-	-
7	50 400 000	43 800 000	6 600 000	5 015 197	3 852 889
8	57 600 000	43 800 000	13 800 000	10 087 719	7 459 459
9	64 800 000	43 800 000	21 000 000	14 769 932	10 510 510
10	72 000 000	43 800 000	28 200 000	19 079 837	13 073 713
NPV				**48 952 685**	**34 895 931**

As an adaptation technology option, the key benefits of drip irrigation system are as follows

• It is a convenient and efficient way to supply water directly into the soil along individual crop rows and surrounding individual plant roots.

• It saves money by using water and labor efficiently.

• It can effectively deliver very small amounts of water daily, which can save energy; increase yields and minimize leaching of soluble chemicals.

2.4 Barrier analysis and possible enabling measures for rain water harvesting

2.4.1 General description of rain water harvesting

Rain water 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.

2.4.2 Identification of barriers for rain water harvesting

In Rwanda, most pressure in agricultural water use comes from the continuously increasing irrigated space and this depends on how efficiently water is used. As rainfall becomes unreliable and extreme water conditions intensify, it is becoming a must to expand agricultural irrigated land using harvested rainwater as a water source and using all water harvesting methods which include: runoff ponds, pitting methods, trenching methods etc. Through technology needs assessment, barriers that my hamper the implementation of rainwater harvesting as a climate change adaptation option have been identified as shown in the table below.

Table 35: Identified barriers that may hamper the implementation of rain water harvesting in Rwanda

Classification	Barriers	Main characteristics
Financial & Economic	High cost of RWH systems	RWH systems components are still expensive to purchase
	Difficulties to access funds	Small/medium farming agriculture is not well funded in Rwanda
Technological	Lack of skills and know how in Rain Water Harvesting Techniques	There is no enough local expertise in rain water harvesting systems installation and maintenance.
Natural	Unreliable rainfall	Due to changing times of abundant precipitations, rain water resources are no longer reliable
	Presence of acidic soils	There exists acidic soils in many parts of the country mainly due to over-exploitation of the bed rock.
	Severe soil erosion causing sedimentation and silting	Soil erosion being one of the main environmental degradation issues in Rwanda, rain water harvesting systems especially those using surface runoffs may receive considerable amount of sediments.

2.4.3 Proposed measures to overcome identified barriers for rainwater harvesting

With respect to barriers as translated into causes and effects of not fully adopting rain water harvesting (RWH) selected as an adaptation technology option to climate change in Rwanda, identified measures to overcome the barriers are presented in the table below.

Table 36: List of proposed measures to overcome identified barriers for rainwater harvesting

Category	Barriers	Measures	Hierarchy of barriers
Economic & Financial	High cost of RWH systems	Reduce charges to farmers on the cost of rain water harvesting systems through subsidies	Non starter
	Difficulties to access funds	Facilitate farmers to access funds by decentralizing agriculture development funds up to sector level	Important
Technological	Limited skills and know how in Rain Water Harvesting Techniques	Improve technical skills and know how on Rainwater Harvesting Techniques through trainings, workshops and study tours	Non starter

2.4.4 Enabling framework to implement measures for rainwater harvesting

Table 37: Enabling environment to implement proposed measures to overcome identified barriers for rainwater harvesting

<table>
<tr><th>Proposed measures</th><th>Enabling Environment</th></tr>
<tr><td>Reduce the cost of rain water harvesting systems:
-Promote low cost material through research and show casing
-Empower local manufacturers by providing incentives and tax exemptions on raw materials</td><td rowspan="6">-MINIRENA
-MINAGRI
-MINALOC
-MINECOFIN
-MINICOM
-RNRA
-REMA
-RAB
-RGB
-RBS
-RCA
-PSF
-Farmers associations/cooperatives
-Research institutions
-NGOs
-National Adaptation Programs of Action
-Water policy=Rainwater harvesting strategy-Irrigation strategy
-Irrigation master plan
-
-</td></tr>
<tr><td>Facilitate farmers to access funds:
-Create agriculture funding institutions
-Reduce interest rates on small to medium sized farming activities</td></tr>
<tr><td>Provide technical skills and know how on Rain Water Harvesting Techniques:
-Organize seminars
-Conduct workshops
-Organize and conduct study tours</td></tr>
<tr><td>Promote rain water harvesting systems which minimize evaporation:
- Use of underground storage systems</td></tr>
<tr><td>Minimize soil acidity:
-Lime application</td></tr>
<tr><td>Promote erosion control techniques:
-Construction of radical terraces
-Agro forestry development and diffusion</td></tr>
</table>

2.4.5 Cost benefit analysis for rainwater harvesting

Measures

The key barrier to transfer and diffusion of rainwater harvesting is limited adoption of rainwater harvesting systems among rural communities.

The target when transferring and diffusing this technology is rainwater harvesting systems adoption within rural communities.

List of alternative measures:

Subsidies, access to loans and know- how.

Complimentary measures:

a. Reduce charges to farmers on the cost of rainwater harvesting systems through subsidies
b. Facilitate farmers to access funds by decentralizing agriculture development funds up to sector level
c. Improve technical skills and know how on rainwater harvesting techniques through trainings, workshops and study tours

Costs

1. Subsidies to cover a share of cost on initial investment

It was established that all the 1.4 million households involved in farming activities would benefit from rainwater harvesting. Taking the cost of one cubic meter rooftop rain water collection and storage at $ 220 as a baseline andsubsidies are fixed at 50% of the cost a rainwater harvesting system with a capacity of one cubic meter per household;

Subsidies are estimated as follow:

[50 % (220*0.1) * 1400000 households]

=$ 15 400 000 per annum

2. The facilitation of farmers to access funds/loans

This component appears on the country's development programmes, therefore no cost is estimated

3. Improvement of technical skills and know- how on rainwater harvesting techniques.

We assume that two people per sector will be trained in order to provide needed technical assistance to the farmers. The number of administrative sectors is 418 and the cost to train one person is estimated at $ 2000.

Total capacity building costs are estimated as follow:

2000*2*418

= $ 1 672 000

Other costs: These are related to system maintenance and renovation and are estimated at 5$ installed cubic meter per annum which is $ 5*1 400 000 = $ 7 000 000

Total costs: (subsidies on initial investment + improved access to loans + technical skills + other costs)

Total costs (USD) $_{\text{year 1}}$: 15 400 000 + 0 + 1 672 000 + 7 000 000

= 24 172 000

Total costs (USD) $_{\text{year 2}}$: 15 400 000 + 0 + 0 + 7 000 000

= 22 400 000

Benefits

Harvesting rain waters especially for agricultural purposes would allow farmers to harvest four times a year instead of two.

Assuming that corn is produced all over the country with average yields of 5 tonnes per hectare at a price of $60 per ton which is $ 300 of sales of corn per hectare.

Net benefit is estimated at: (sales-inputs and labor)

$300-225= $75 per hectare

Total benefit is: ($ 75*0.04 ha of irrigated fields per annum*1400000 households*2 additional harvests)

= $ 8 400 000 per annum

Table 38: Net present values for rainwater harvesting

Year	Total Benefits (USD)	Total Costs (USD)	Net benefits (USD)	Discounted net benefits at 5% (USD)	Discounted net Benefits at 8% (USD)
1	8 400 000	24 172 000	-	-	-
2	16 800 000	22 400 000	-	-	-
3	25 200 000	22 400 000	2 800 000	2 491 103	2 223 987
4	33 600 000	22 400 000	11 200 000	9 580 838	8 235 294
5	42 000 000	22 400 000	19 600 000	16 118 421	13 342 409
6	50 400 000	22 400 000	28 000 000	22 134 387	17 654 476
7	58 800 000	22 400 000	36 400 000	27 659 574	21 249 270
8	67 200 000	22 400 000	44 800 000	32 748 538	24 216 216
9	75 600 000	22 400 000	53 200 000	37 412 095	26 626 626
10	84 400 000	22 400 000	62 000 000	41 948 579	28 743 625
NPV				**190 093 535**	**142 291 903**

Other benefits qualified as qualitative/adaptative include; but not limited to:

-High soil erosion reduction potential

High flooding reduction potential

2.5 Barrier analysis and possible enabling measures for radical terraces

2.5.1 General description of radical terraces

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 purposes 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.

According to Mupenzi et al. 2012, radical terraces contributed to increase in the farm productivity, fight against erosion and also contributed to poverty reduction in Rwanda.

2.5.2 Identification of barriers for radical terraces

Radical terraces have been selected as one of the technologies that are most suitable in assisting the agriculture sector and Rwanda in general to adapt better to the adverse effects of climate change. The selection was due to their benefits which include: a) Enabling the development of larger areas of arable land in rugged terrain; b) Facilitating modern cropping techniques such as mechanization, irrigation and transportation on sloping land, c) Increasing the moisture content of the soil by retaining a larger quantity of water, d) Capturing run-off soil which can be diverted through irrigation channels at a controlled speed to prevent soil erosion and others. However, there exists barriers which may hamper their proper implementation in Rwanda as identified in the table below

Table 39: Identified barriers that may hamper the implementation of radical terraces in Rwanda

Classification	Barriers	Main characteristics
Financial & economic	High cost of equipment/tools	The price of hoes, pick axes and other tools that are used in terracing are still expansive at the local market
Technological	Limitation of technical skills in terracing	There exist few experts in terracing techniques
	Limited reference information such as on slope, soil depth, type etc.	Terracing feasibility studies are specific to sites and have only been conducted to terraced sites.
Cultural	Acceptability within communities	Given the long term benefits of terraces, the local population tends to reject their implementation.

2.5.3 Proposed measures to overcome barriers for radical terraces

With respect to barriers translated into causes and effects of not fully adopting slow forming terraces which was selected as an adaptation technology option to climate change in Rwanda, identified measures to overcome the barriers are presented in the table below.

Table 40: List of proposed measures to overcome identified barriers for radical terraces

Category	Barriers	Measures	Hierarchy of measures
Economic & Financial	High cost of equipment/tools	Reduce the cost of equipment/tools by promoting local manufacturers through incentives	Non starter
Technological	Limited technical skills in terracing	Improve technical skills in terracing by organizing/conducting seminars, workshops and showcasing through demonstration plots and study tours	Crucial
	Limited reference information such as slope, soil depth, type etc.	Conduct terracing feasibility studies nationwide through topographical surveys	Important
Cultural	There exist limited acceptability of terraces within communities	Increase the level of acceptability of terraces within communities through awareness campaigns using community radio and demonstration plots	Important

2.5.4 Enabling framework to implement measures for radical terraces

Table 41: Enabling environment to implement proposed measures to overcome identified barriers for radical terraces

<table>
<tr><th>Proposed measures</th><th>Enabling Environment</th></tr>
<tr><td>Reduce the cost of equipment/tools by promoting local manufacturers through incentives</td><td rowspan="4">-MINIRENA
-MINAGRI
-MINALOC
-MINECOFIN
-MINICOM
-RNRA
-REMA
-RAB
-RGB
-RBS
-RCA
-PSF
-Farmers associations/cooperatives
-Research institutions
-NGOs
-National Adaptation Programs of Action
-Land husbandry strategy</td></tr>
<tr><td>Provide technical skills in terracing:
-Organize seminars
-Conduct workshops
-Organize and conduct study tours</td></tr>
<tr><td>Conduct terracing feasibility studies nationwide:
-Mobilize funds
-Hire private firm specializing in pre terracing/topographical surveys</td></tr>
<tr><td>Increase the level of acceptability of terraces within communities by
preparing and conducting terracing benefits awareness campaign using community radio, demonstration plots and study tours.</td></tr>
</table>

2.5.5 Cost benefits analysis for radical terraces

Measures

The key barrier to transfer and diffusion of radical terraces is limited adoption of radical terraces among rural communities.

The target when transferring and diffusing this technology is radical terraces adoption within rural communities

List of alternative measures:

Incentives, know how, baseline surveys, awareness campaigns.

Complimentary measures:

a. Reduce the cost of needed terracing tools through the provision of incentives to local manufacturers
b. Conduct training for skills and know how improvement
c. Conduct surveys in order to have a baseline on which countrywide terracing would be based.
d. Conduct awareness campaigns on the long term benefits of radical terraces
e. Provision of incentives to local manufacturers to reduce the price of basic terracing tools

Costs

1.

It was established that a total of 294 000 ha of arable land needs the establishment of radical terraces.

The cost to establish 1 ha of radical terraces is estimated at $ 1000. The cost of tools (shovels, tridents, etc.) is 40% of the total cost which is $ 400 per hectare. Assuming that manufacturers are provided with incentives totaling 50%, total incentives are estimated as follow:

[50% (400 * 294 000)/10)

= $ 5 800 000 per annum

2. Conduct training for skills and know how improvement

Assuming that a representative starter pack will be given to each of the benefiting households at the beginning of the programme at a cost of $ 17 per household including the cost of establishing demonstration plots,

The total cost for capacity building is estimated at:

$20*1 000 000 = $ 20 000 000

3. Conducting baseline surveys at a cost of $ 200 per hectare

Total cost for baseline surveys are estimated as follow:

($ 200*294 000) / 10 = $ 5 800 000 per annum

4. Conduct awareness campaigns

This cost is not given a numerical value as we assumed that it will be integrated into other agro extension activities

Other costs include labor + other inputs

= [($ 200 * 294000) + ($15*29400)]/10

=$ 6 321 000 per annum

Total cost: (incentives to local manufacturers + capacity building through trainings + conduct baseline surveys + cost of awareness campaigns + other costs including labor and other inputs)

Total costs (USD) $_{\text{year 1}}$: $5 800 000 + $20 000 000 + $ 5 800 000 + 0 + 6 321 000

= $ 37 921 000

Total costs (USD) $_{\text{year 2}}$: $ 5 800 000 + 0 + $5 800 000 + 0 + 6 321 000

= $ 17 921 600

Benefits

Adequate radical terracing results in increment of yield up to 10% for corn and 10% increment of productive space mainly used for agro forestry and forage.

Assuming that all the installed radical terraces are used to produce corn, which gives yields of 5 tonnes per hectare in normal conditions, financial benefits are estimated as follow:

1. Benefits resulting from normal corn yields + increase in yields as a result of radical terraces:

From year 3 there will be:

Sales of normal yields (in the absence of radical terraces)

[$ 60*29400]/10= $ 1764000 per annum

Sales of 10% increase in yields as a result of radical terracing

[10% ($60*294000 ha*5 tonnes)]/10

= $ 882 000 per annum

2. Benefits resulting from increase in productive space:

Assuming that the 10% additional space is used for agro forestry trees at a rate of 1000 trees per hectare with 50% of the trees being fruits trees, benefits are estimated as follow:

From year five, one-fourth of the 50% of all the trees will be coppiced annually and sold as building poles for $ 0.40 each.

{$ 0.40*[50% (294000 ha * 1000)/4]}/10

= $ 1 470 000 per annum

It is assumed that main agro forestry inputs such as seedlings are fully subsidized

Starting in Year 7, $5 worth of fruit will be sold each year.

{$ 5*[50% (294000 ha * 1000]}/10

= $ 73 500 000 per annum

Table 42: Net present values for radical terraces

Year	Total Benefits (USD)	Total Costs (USD)	Net benefits(USD)	Discounted net benefits at 5% (USD)	Discounted net Benefits at 8% (USD)
1		37921000	-		
2		17921600	-		
3	2646000	17921600	-		
4	5292000	17921600	-		
5	9408000	17921600	-	-	
6	13524000	17921600	-		
7	99372000	17921600	81450400	61892401	47548394
8	168756000	17921600	150834400	110259064	81532108
9	245922000	17921600	228000400	160337834	114114314
10	323988000	17921600	306066400	207081461	141894483
NPV				**539570761**	**385089300**

Other adaptation benefits include:

-Soil erosion reduction potential

-Water conservation

-Natural hazards (land slide) minimization.

2.6 Barrier analysis and possible enabling measures for seed and grain storage

2.6.1 General description of seed and grain storage

Good seed and grain storage helps ensure household and community food security until the next harvest. 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 should be stored. Seeds with moisture in them become damp, moldy and vulnerable to insect attacks.

2.6.2 Identification of barriers for seed and grain storage

Rwanda has established a National Post-Harvest Staple Crop Strategy which is a policy framework to assist with strengthening the harvesting, post-harvest handling, trade, storage, and marketing within staple crop value chains. All these are meant to help strengthening markets and linkages for farmers, and reducing post-harvest losses which would compromise food security.

Adequate seed and grain storage being critical in food security, the technology intervenes as one of the techniques used in post harvest and has been selected as one of the technologies that would assist the country in fighting adverse effects of climate change. However, there exist barriers that may hamper the implementation of the technology as presented in the table below.

Table 43: Identified barriers that may hamper the implementation of seed and grain storage in Rwanda

Classification	Barriers	Main characteristics
Financial & economic	High initial investment cost	Although as seed and grain storage system might be cost effective in Rwanda; The installation its components involves high costs
	Delays in material deliveries Limited rural infrastructures such as roads	Most of the materials of the already few installed seed and grain storage systems have been imported. Although there exist efforts in improving rural feeder roads, the overall state of road infrastructure is still bad.
Technological	Lack of technical skills in installation and maintenance of seed and grain storage systems	There are few, if any, experts in seed and grain storage systems

2.6.3 Proposed measures to overcome barriers for seed and grain storage

With respect to barriers translated into causes and effects of rejecting seed and grain storage which was selected as an adaptation technology option to climate change in Rwanda, identified measures to overcome the barriers are presented in the table below.

Table 44: List of proposed measures to overcome identified barriers for seed and grain storage

Category	Barriers	Measures	Hierarchy of barriers
Economic & Financial	High initial investment cost	Reduce initial investment costs through incentives and subsidies	Non starter
	Limited basic rural infrastructures	Improvement of basic rural infrastructures through construction of new rural feeder roads and improvement of existing ones	Important
Technological	Lack of technical skills in installation and maintenance of seed and grain storage systems	Provide technical skills in installation and maintenance of seed and grain storage systems by organizing/conducting seminars, workshops and showcasing through demonstration plots and study tours	Crucial

2.6.4 Enabling framework to implement measures for seed and grain storage

Table 45: Enabling environment to implement proposed measures to overcome identified barriers for seed and grain storage

<table>
<tr><th>Proposed measures</th><th>Enabling Environment</th></tr>
<tr><td>Reduce initial investment costs through tax exemptions on imported material to be used in seed and grain storage systems installation and creation of interest among existing local manufacturers through the provision of incentives</td><td rowspan="4">-MINIRENA
-MINAGRI
-MINALOC
-MINECOFIN
-MINICOM
-RNRA
-REMA
-RAB
--POST HARVEST TASK FORCE
-RGB
-RBS
-RCA
-PSF
-Farmers associations/cooperatives
-Research institutions
-NGOs
-National Adaptation Programs of Action
-Seed policy</td></tr>
<tr><td>Facilitate access to funds by decentralizing agriculture development funds up to sector level and reduction of interest rates</td></tr>
<tr><td>Improvement of basic rural infrastructures through construction of new rural feeder roads and improvement of existing ones</td></tr>
<tr><td>Provide technical skills in installation and maintenance of seed and grain storage systems by organizing/conducting seminars, workshops and showcasing through demonstration plots and study tours</td></tr>
</table>

<u>2.6.5 </u>Cost benefits analysis for seed and grain storage

<u>Measures</u>

The key barrier to transfer and diffusion of radical terraces is limited acceptability of seed and grain storage within rural communities

The target when transferring and diffusing this technology is seed and grain storage systems acceptance within rural communities

List of alternative measures:

Incentives, subsidies, rural infrastructures, know how

Complimentary measures:

a. Reduce initial investment costs through incentives and subsidies
b. Improvement of basic rural infrastructures through construction of new rural feeder roads and improvement of existing ones
c. Provide technical skills in installation and maintenance of seed and grain storage systems by organizing/conducting seminars, workshops and showcasing through demonstration plots and study tours
d. Provision of incentives to local manufacturers and importers in order to make available needed components

Costs

1. The cost establishing an efficient seed and grain storage of one metric tonne in a 60 000 metric tonnes capacity system is $ 15.

Total incentives at 50% rate are estimated at:

[50% ($15*400000)]/10

= $ 300 000 per annum

Subsidies are estimated at:

[50% ($15*400000)]/10

= $ 300 000 per annum

2. The cost of improving rural infrastructures is assumed to be covered under other development programmes and no cost estimates are established

3. Conduct trainings for skills and know how improvement

We assume that two people per sector will be trained in order to provide needed technical assistance to the farmers. The number of administrative sectors is 418 and the cost to train one person is estimated at $ 2000.

Total capacity building costs are estimated as follow:

2000*2*418

= $ 1 672 000

Other costs are related to system maintenance which is estimated at 10% of the total cost of the installation of one metric tonne

= [10 %*(400000*15)]/10

=$ 60 000 per annum

Total cost: (incentives to local manufacturers + subsidies to farmers + infrastructure + capacity building through trainings + other costs which are mainly maintenance costs)

Total costs (USD) $_{\text{year 1}}$: $ 300 000 + $300 000 + 0+ $ 1 672 000 + $ 60 000

= $ 2 320 000

Total costs (USD) $_{\text{year 2}}$: $ 300 000 + $300 000 + 0+ 0 + $ 60 000

= $ 660 000

Benefits

Direct benefits are those related to reduction of post harvest losses. In fact adequate seed and grain storage systems allow farmers to save 60% yields under storage.

Assuming that only corn grains are stored. Direct benefits are estimated as follow:

[60% ($ 60*400000)]/10

= $ 1 440 000 per annum

Table 46: Net present values for seed and grain storage

Year	Total Benefits (USD)	Total Costs (USD)	Net benefits(USD)	Discounted net benefits at 5% (USD)	Discounted net Benefits at 8% (USD)
1	1440000	2320000	-		
2	2880000	660000	2220000	2053654	1903945
3	4320000	660000	3660000	3256227	2907069
4	5760000	660000	5100000	4362703	3750000
5	7200000	660000	6540000	5378289	4452008
6	8640000	660000	7980000	6308300	5031525
7	10080000	660000	9420000	7158054	5499124
8	11520000	660000	10860000	7938596	5870270
9	12960000	660000	12300000	8649789	6156156
10	14400000	660000	13740000	9296346	6369958
NPV				**54401961**	**41940057**

The adaptation benefit of adequate seed and grain storage relies in its capacity to ensure food security and availability of quality seeds in case of bad harvests.

2.7 Linkages of barriers identified for the agriculture sector

During barrier analysis exercise, linkages between technologies were identified. The most common barrier for all the five technologies prioritized for the agriculture sector is gaps and/or lack of technical skills and knowledge. High cost of technology implementation has also been identified as a cross cutting barrier for all the technologies. Other barriers include: Difficult access to funds, lack of awareness about the benefits of the technologies and limited rural infrastructures.

Complementarities have also been established between all the five prioritized technologies. In fact, a good agro forestry system would be supported by the establishment of radical terraces for possible extension, especially in the Rwandan context where land size is a crucial problem in agriculture production. On the other hand, radical terraces would benefit from agro forestry systems in the sense that they contribute to soil fertility improvement trough biomass (leaves) fall and decomposition, therefore increasing their productivity. Agro forestry species also contribute to radical terraces slope protection.

Given the general slope of Rwandan agriculture land (13%-55%) and its related impacts such as increased runoff leading to soil erosion and land slide, rainwater harvesting and drip irrigation should be done after radical terraces and agro forestry systems are in place so as to maximize system outputs. Seed and grain storage is here considered most needed once the used of the other four technologies is optimized.

List of references

Antle, J. M., J. J. Stoorvogel and R. O. Valdivia, 2004. Assessing the economic impacts of agricultural carbon sequestration: Terraces and agro-forestry in the Peruvian Andes, Agriculture, Ecosystems & Environment 122(4), 435-445.

BIAC, 2009. Agriculture and climate change, Issues for consideration. Business and Industry Advisory Committee to the OECD, November 2009, Paris, France.

Boldt j, I. Nyagaard, U.E Hansen, S,Traerup, 2012. Overcoming Barriers to the Transfer and Diffusion of Climate Technologies. UNEP Risoe Centre, Denmark.

CARE, 2010. Toolkit for Integrating Climate Change Adaptation into Development Projects, Digital Toolkit – Version 1.0 CARE International, with technical input by the International Institute for Sustainable Development (IISD).

Christian Ngô, 2004. L'Energie, Ressources, Technologies et Environnement, ISBN 210 04 85 989, DUNOD, Paris, France.

CTB, 2011. Wind atlas, Belgium Technical Cooperation, Kigali, Rwanda.

DAVID Coley, 2008. Energy and Climate Change, Creating a sustainable future, Center for Energy and Environment, Universities of Exeter, Devon, United Kingdom.

FAO, 2010. "Climate-Smart" Agriculture – Policies, Practices and Financing for Food Security, Adaptation and Mitigation, Food and Agriculture Organization, Rome,Italy.

IPCC, 2007 b. Mitigation of Climate Change , the contribution of working group III to the fourth assessment Report, Intergovernmental Panel on Climate Change, Cambridge, United Kingdom.

IPCC, 2007. Climate Change; Fourth Assessment Report, Intergovernmental Panel on Climate Change, Geneva, Switzerland.

MINAGRI, 2007. National Seed Policy, Ministry of Agriculture and Animal Resources, Kigali, Rwanda.

MINAGRI, 2009. Strategic Plan for the Transformation of Agriculture in Rwanda – Phase II (PSTA II), Ministry of Agriculture and Animal Resources, Kigali, Rwanda.

MINAGRI, 2010. National Agricultural Extension Strategy, Ministry of Agriculture and Animal Resources, Kigali, Rwanda.

MINAGRI, 2011. Agriculture Mechanization Strategy, Ministry of Agriculture and Animal Resources, Kigali, Rwanda.

MINAGRI, 2011. National Post-Harvest Staple Crop Strategy, Ministry of Agriculture and Animal Resources, Kigali, Rwanda.

MINAGRI, 2012. Strategic Environmental Assessment of the Agriculture Sector, European Development Fund, Ministry of Agriculture and Animal Resources, Kigali, Rwanda.

MINECOFIN, 2007. Economic Development and Poverty Development Strategy (EDPRS 2008-2012), Ministry of Economic Planning and Finance, Kigali, Rwanda.

MINECOFIN, 2007. Economic Development and Poverty Development Strategy (EDPRS 2008-2012), Ministry of Economic Planning and Finance, Kigali, Rwanda.

MININFRA, 2011. National Energy Policy and Strategy, Kigali, Rwanda.

MINIRENA, 2006. National Adaptation Programmes of Action to Climate Change, Ministry of Natural Resources, Kigali, Rwanda.

MINIRENA, 2009. Five-Year Strategic Plan for the Environment and Natural Resources Sector, Ministry of Natural Resources, Kigali, Rwanda.

MINIRENA, 2011. National Strategy for Climate Change and Low Carbon Development, Ministry of Natural Resources, Kigali, Rwanda.

MINIRENA, 2011. Second National Communication under the UNFCCC, Ministry of Natural Resources, Kigali, Rwanda.

MINIRENA, 2012. Rainwater harvesting and management national strategy, Ministry of Natural Resources, Kigali, Rwanda.

SSEE, 2012. National Strategy on Climate Change and Low Carbon Development for Rwanda, Baseline report, Smith School of Enterprise and Environment, Oxford, United Kingdom.

UNDP, 2011. Handbook for conducting Technology Needs Assessment for climate change, Nov. 2010, New York, USA.

UNEP, 2011. Technologies for Climate Change Adaptation; Agriculture Sector. TNA Guidebook series, UNEP-RISO Center, URC, Roskilde, Denmark.

UNEP, 2011. Technologies for Climate Change Adaptation; Agriculture Sector. TNA Guidebook series. UNEP-RISO Center, URC, Roskilde, Denmark.

UNEP, 2011a. Technologies for Climate Change Adaptation; The Water Sector. TNA Guidebook series, UNEP-RISO Center, URC, Roskilde, Denmark.

UNEP, 2011b. Technologies for Adaptation: Perspectives and Practical Experiences, UNEP-RISO Center, URC, Roskilde, Denmark.

UNEP, 2012. Overcoming Barriers to the Transfer and Diffusion of Climate Technologies, UNEP-RISO Center, URC, Roskilde, Denmark.

UNESCO, 2003. Geothermal Energy, Utilization and Technology, ISBN 92-3-103915-6, Paris, France.

UNESCO, 2003. Geothermal Energy: utilization and technology, United Nations Educational, Scientific and Cultural Organization, Paris, France.

UNFCCC, 2006. Technologies for Adaptation to Climate Change, UNEP-RISO Center, URC, Roskilde, Denmark.

UNIDO, 2005. GIS Application for Monitoring, United Nations Industry Development Organization, Trieste, Italy.

URC, 2011. Diffusion of renewable energy technologies: case studies of enabling frameworks in Developing countries. Technology Transfer Perspectives Press Series, UNEP-RISO Center, URC, Roskilde, Denmark.

World Bank, 2004. Strategic/Sectoral, Social and Environment Assessment of Power Development Options in Burundi, Rwanda and Western Tanzania, Draft Report N°1, SNC – Lavalin International, 015718-0000-40 TR -0002-00/SSEA Project.

World Bank, 2007. Technical and Economic Assessment of off-grid, mini-grid and grid electrification technologies , Energy Sector Management Assistance Program, Technical Paper 121/07, Dec. 2007, World Bank, Washington DC, USA.

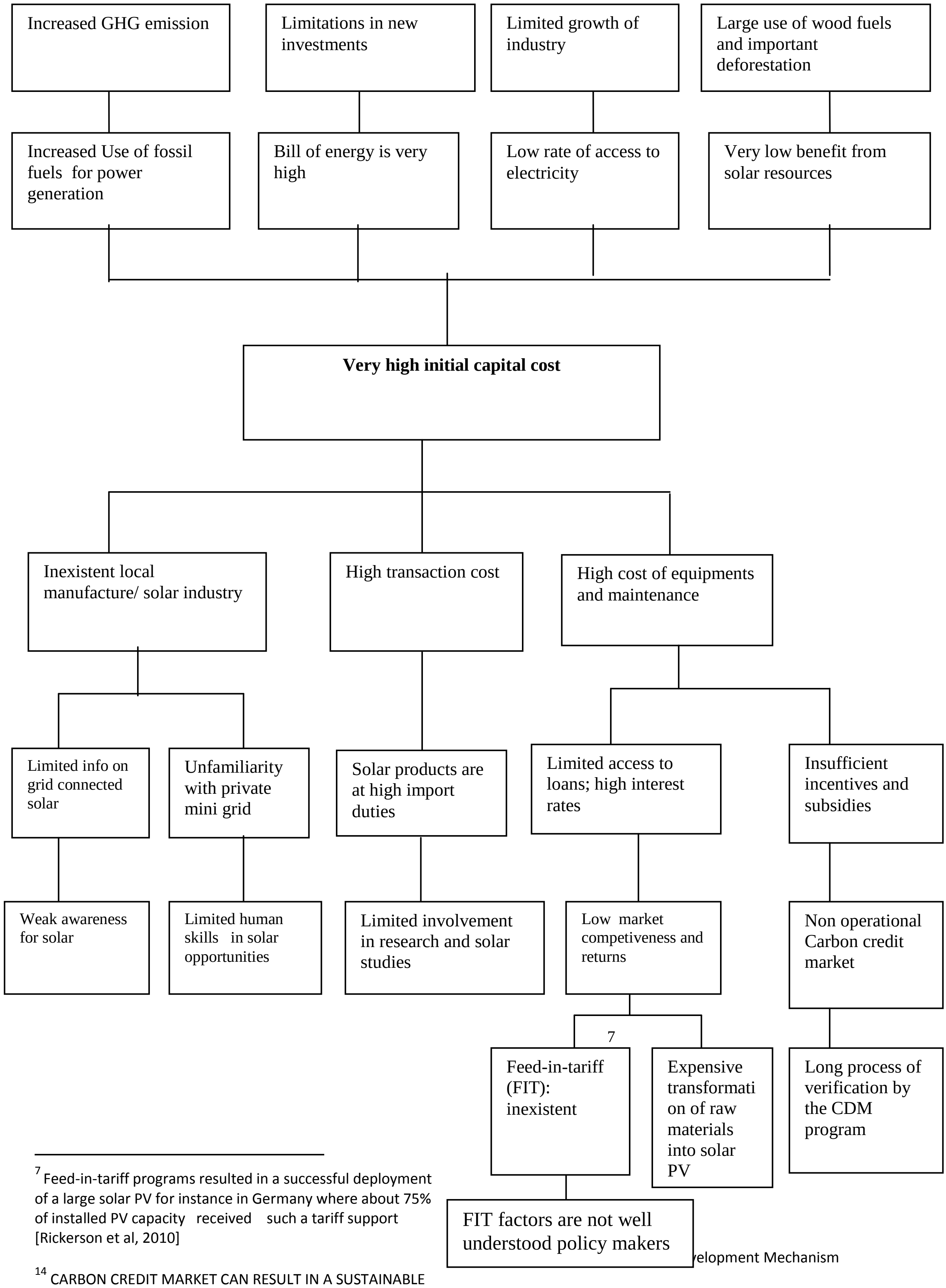
Annexes

Annex 1- Market maps, problem and solution trees

1.1 Energy sector

1.1.1 Problem trees

Large Solar PV Technology

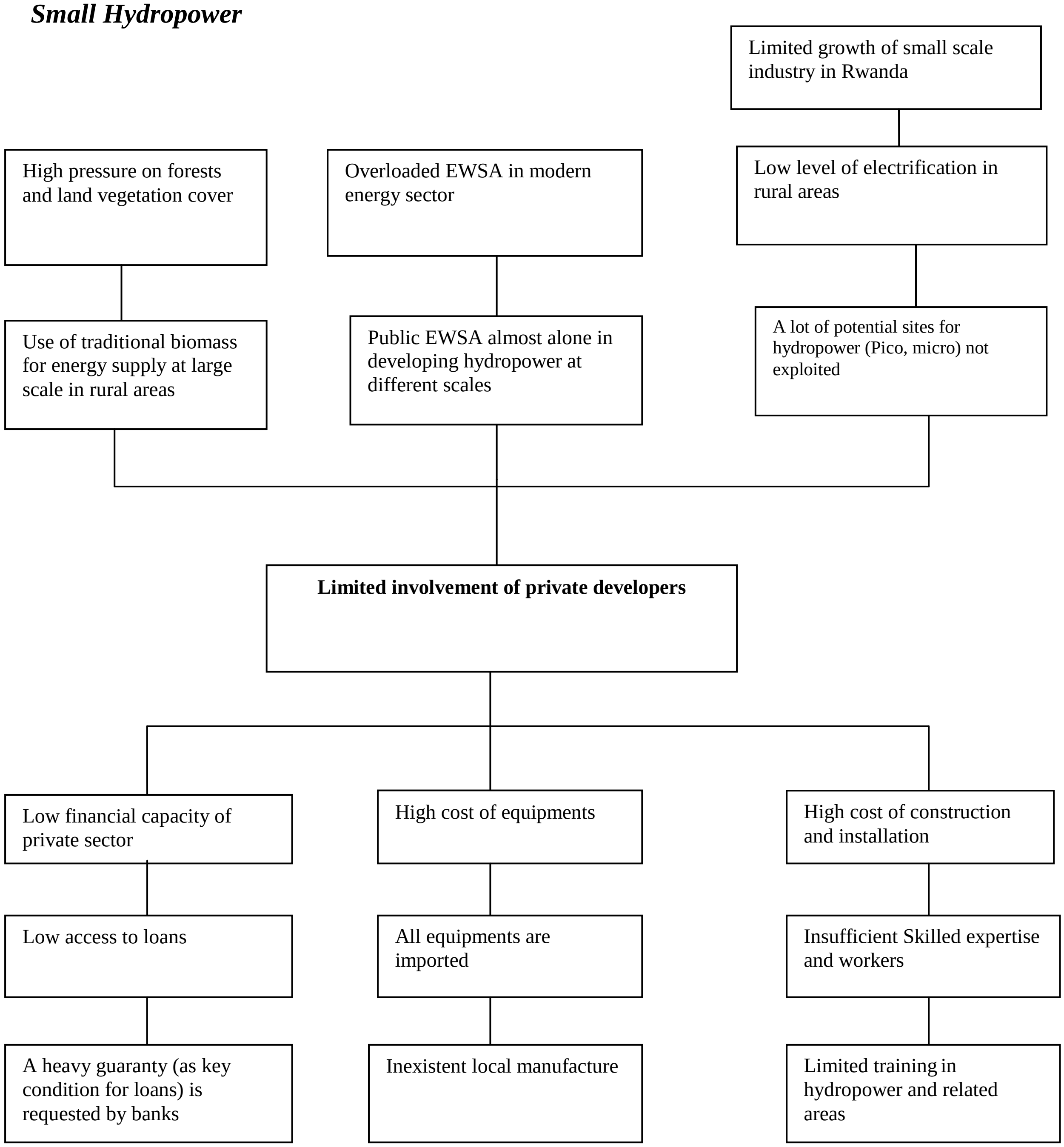


[7] Feed-in-tariff programs resulted in a successful deployment of a large solar PV for instance in Germany where about 75% of installed PV capacity received such a tariff support [Rickerson et al, 2010]

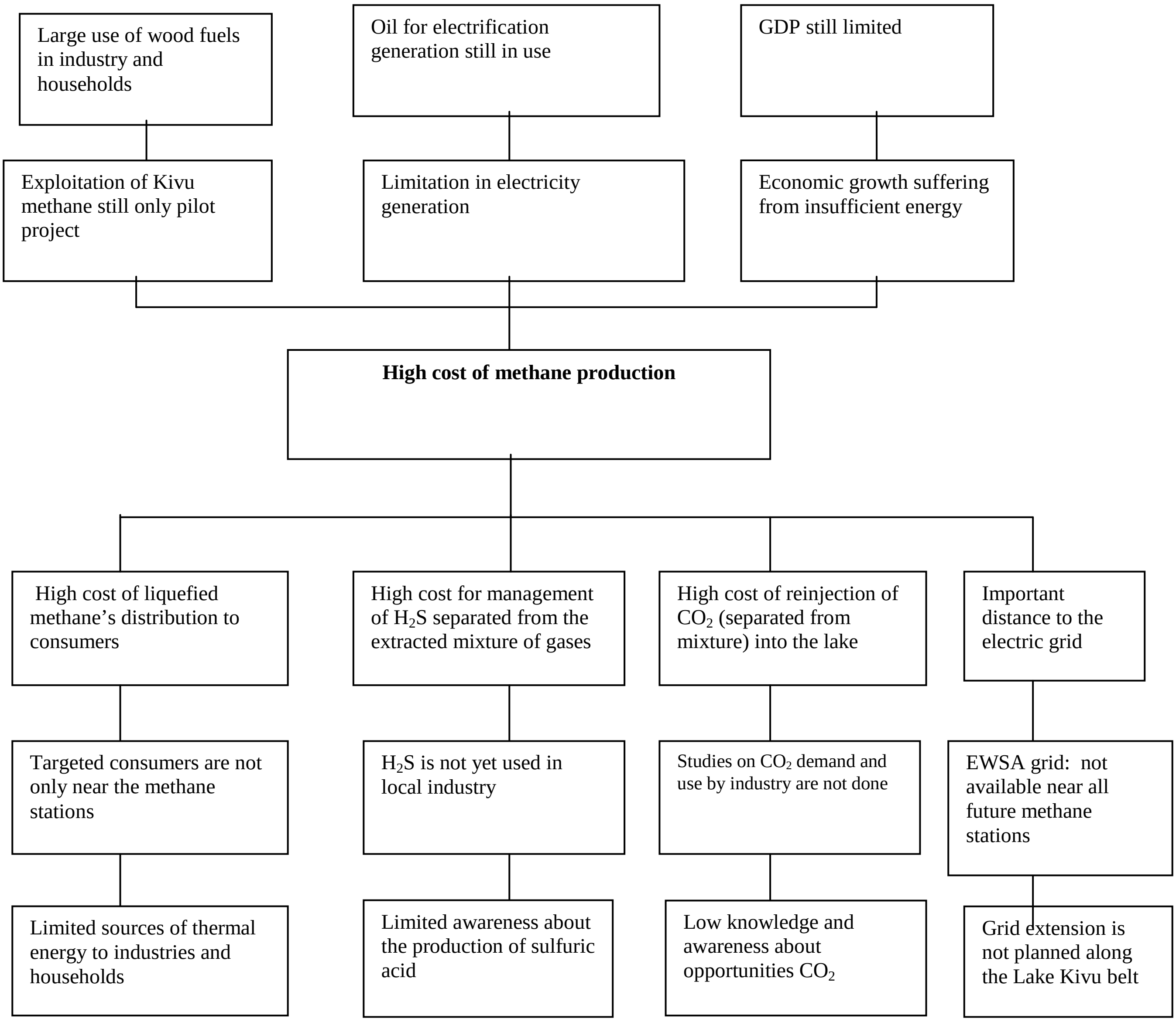
elopment Mechanism

[14] CARBON CREDIT MARKET CAN RESULT IN A SUSTAINABLE FIANANCIAL FACILITIES instead of relying on subsidies and Other support from donors and government

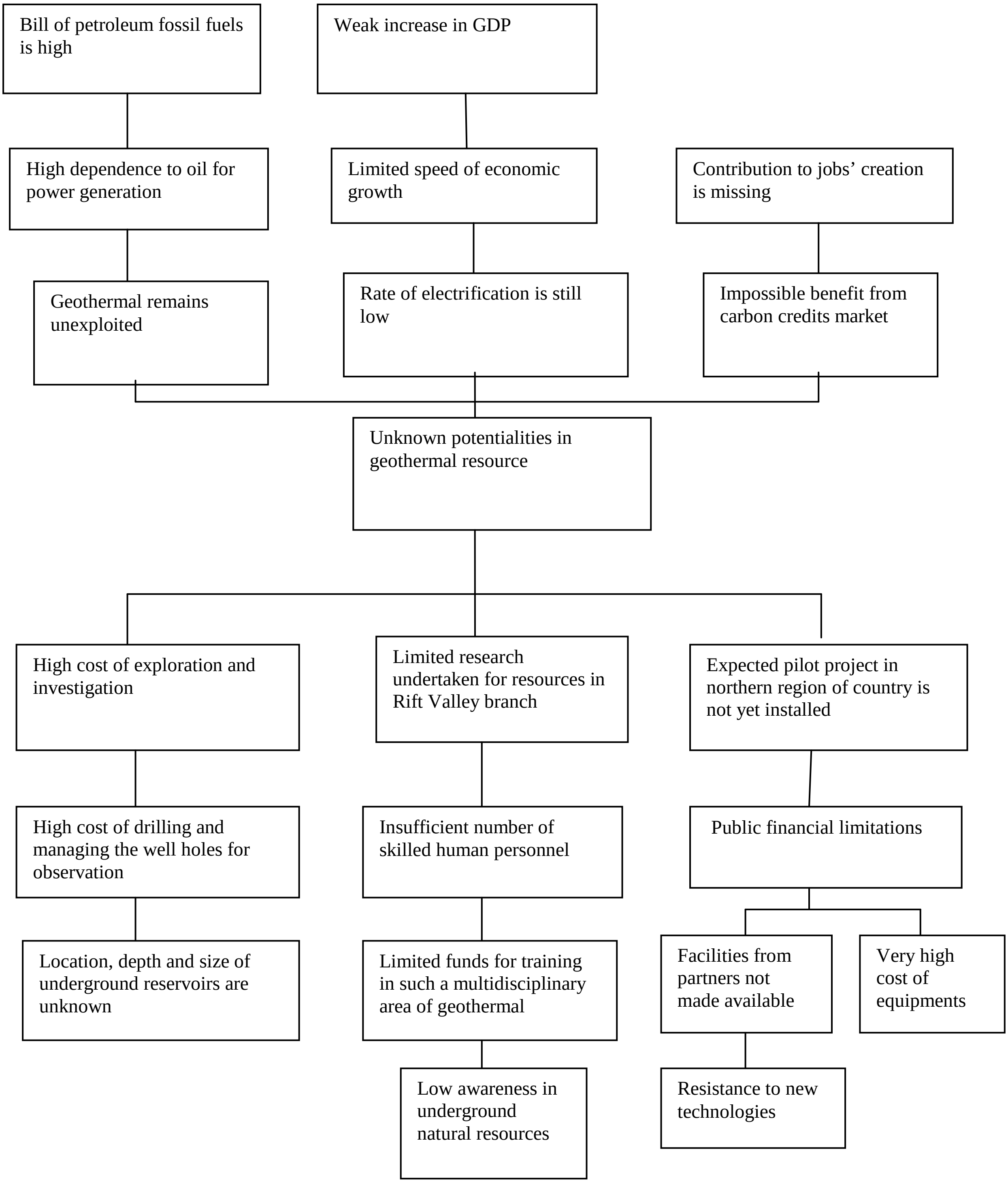
Small Hydropower



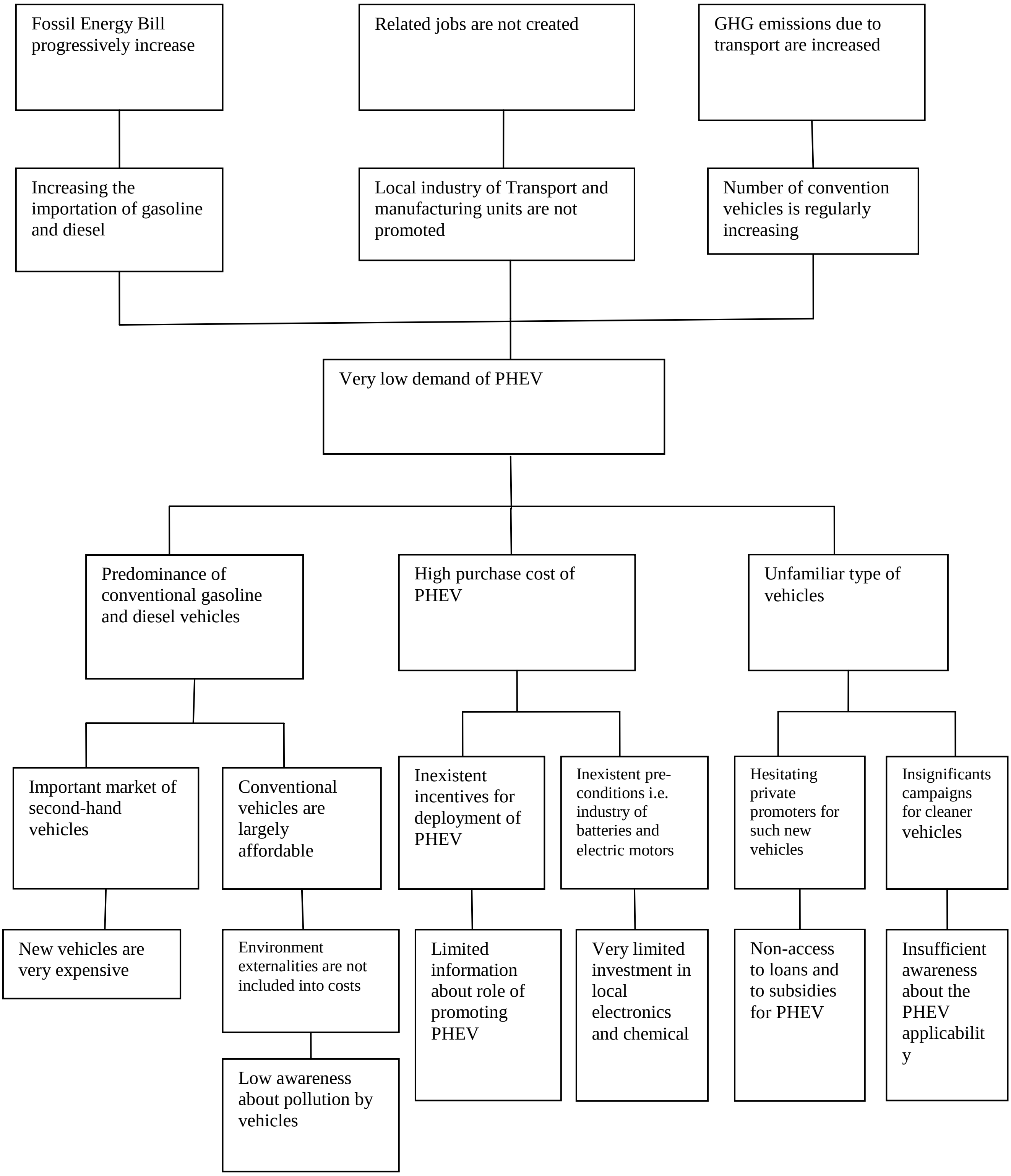
Kivu Methane CCGT



Geothermal

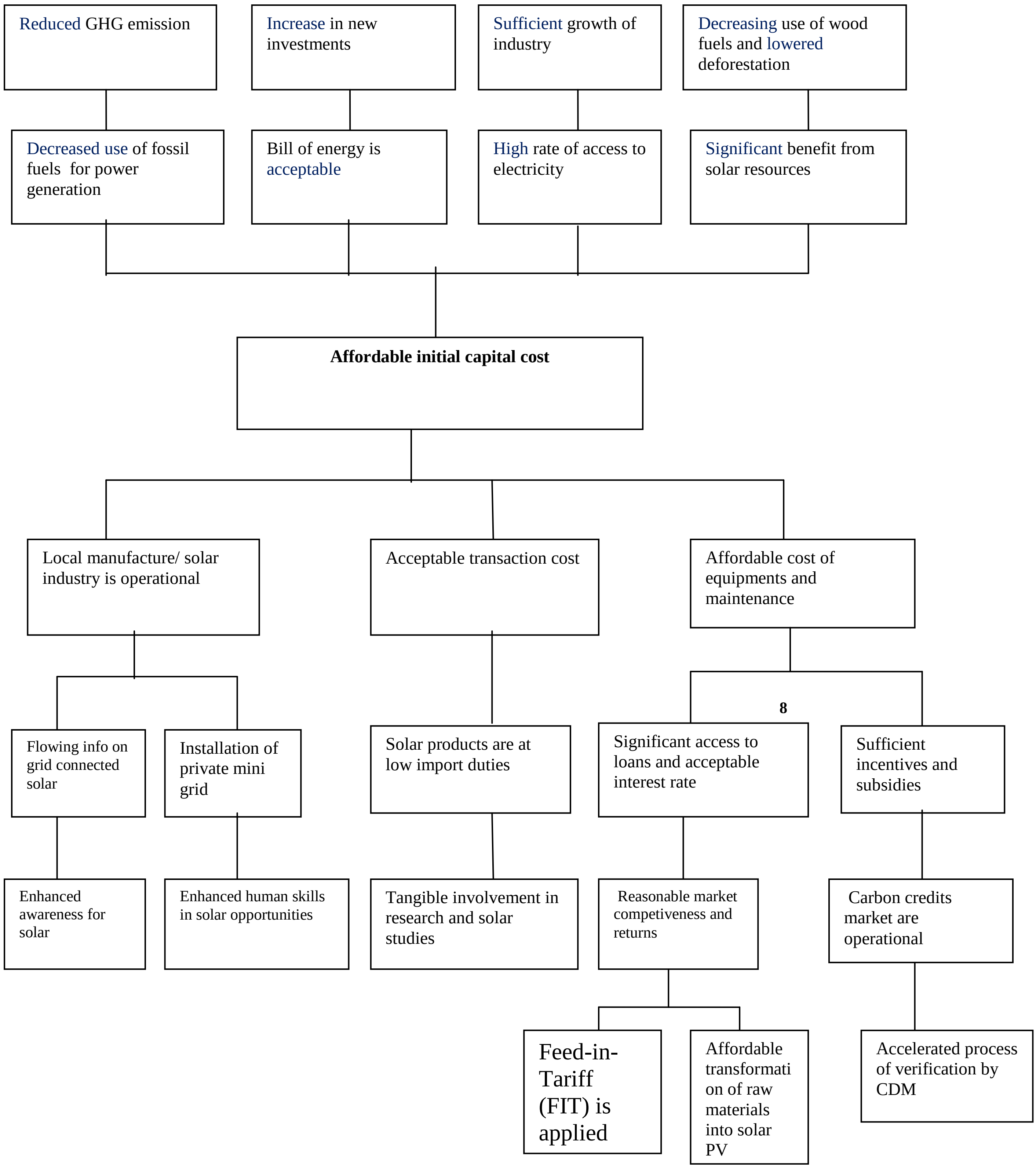

Bill of petroleum fossil fuels is high
Weak increase in GDP
High dependence to oil for power generation
Limited speed of economic growth
Contribution to jobs' creation is missing
Geothermal remains unexploited
Rate of electrification is still low
Impossible benefit from carbon credits market
Unknown potentialities in geothermal resource
High cost of exploration and investigation
Limited research undertaken for resources in Rift Valley branch
Expected pilot project in northern region of country is not yet installed
High cost of drilling and managing the well holes for observation
Insufficient number of skilled human personnel
Public financial limitations
Location, depth and size of underground reservoirs are unknown
Limited funds for training in such a multidisciplinary area of geothermal
Facilities from partners not made available
Very high cost of equipments
Low awareness in underground natural resources
Resistance to new technologies

PHEV


Fossil Energy Bill progressively increase
Related jobs are not created
GHG emissions due to transport are increased
Increasing the importation of gasoline and diesel
Local industry of Transport and manufacturing units are not promoted
Number of convention vehicles is regularly increasing
Very low demand of PHEV
Predominance of conventional gasoline and diesel vehicles
High purchase cost of PHEV
Unfamiliar type of vehicles
Important market of second-hand vehicles
Conventional vehicles are largely affordable
Inexistent incentives for deployment of PHEV
Inexistent pre-conditions i.e. industry of batteries and electric motors
Hesitating private promoters for such new vehicles
Insignificants campaigns for cleaner vehicles
New vehicles are very expensive
Environment externalities are not included into costs
Limited information about role of promoting PHEV
Very limited investment in local electronics and chemical
Non-access to loans and to subsidies for PHEV
Insufficient awareness about the PHEV applicabilit y
Low awareness about pollution by vehicles

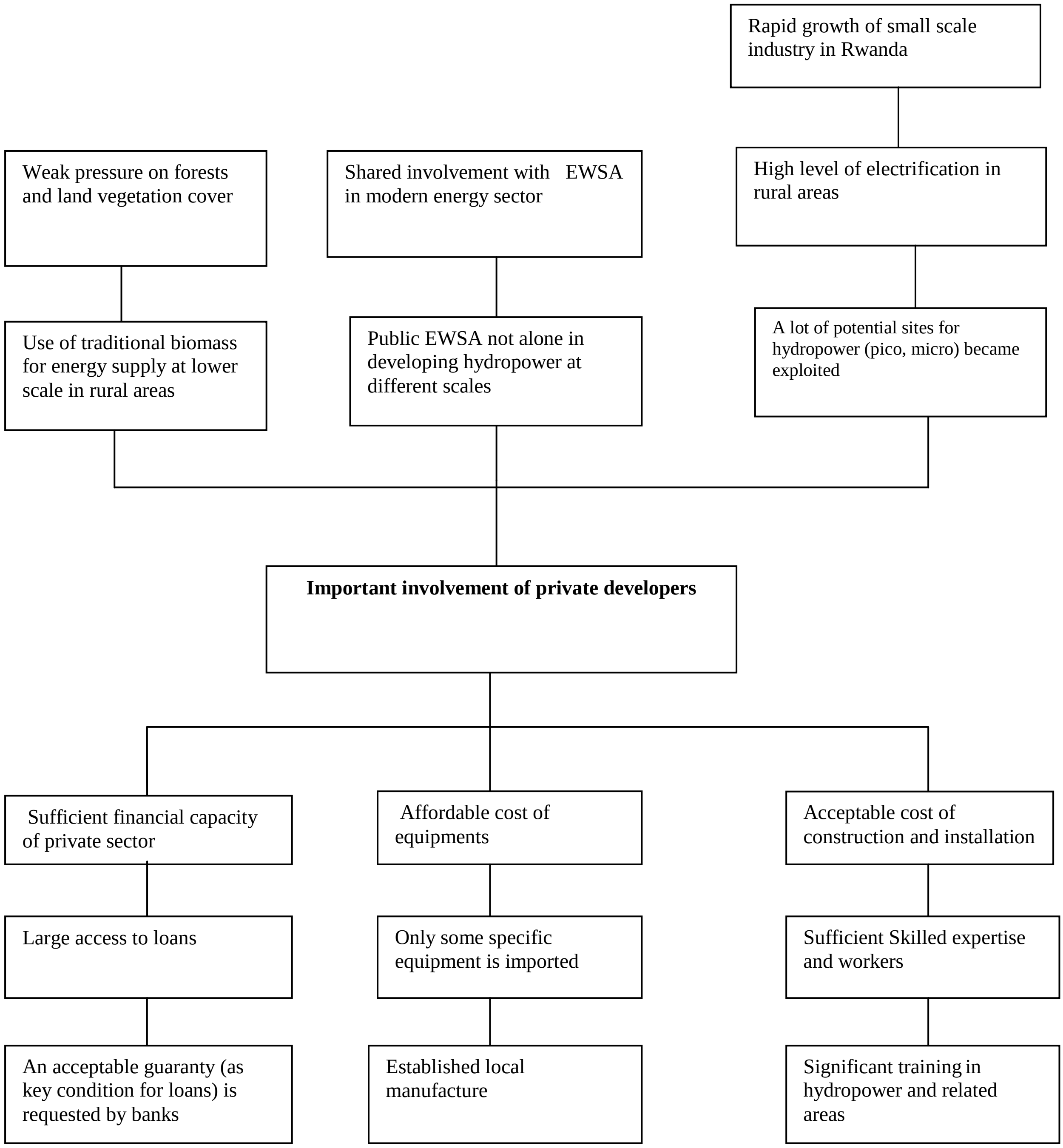
1.1.2 Solution trees

Large Solar PV Technology

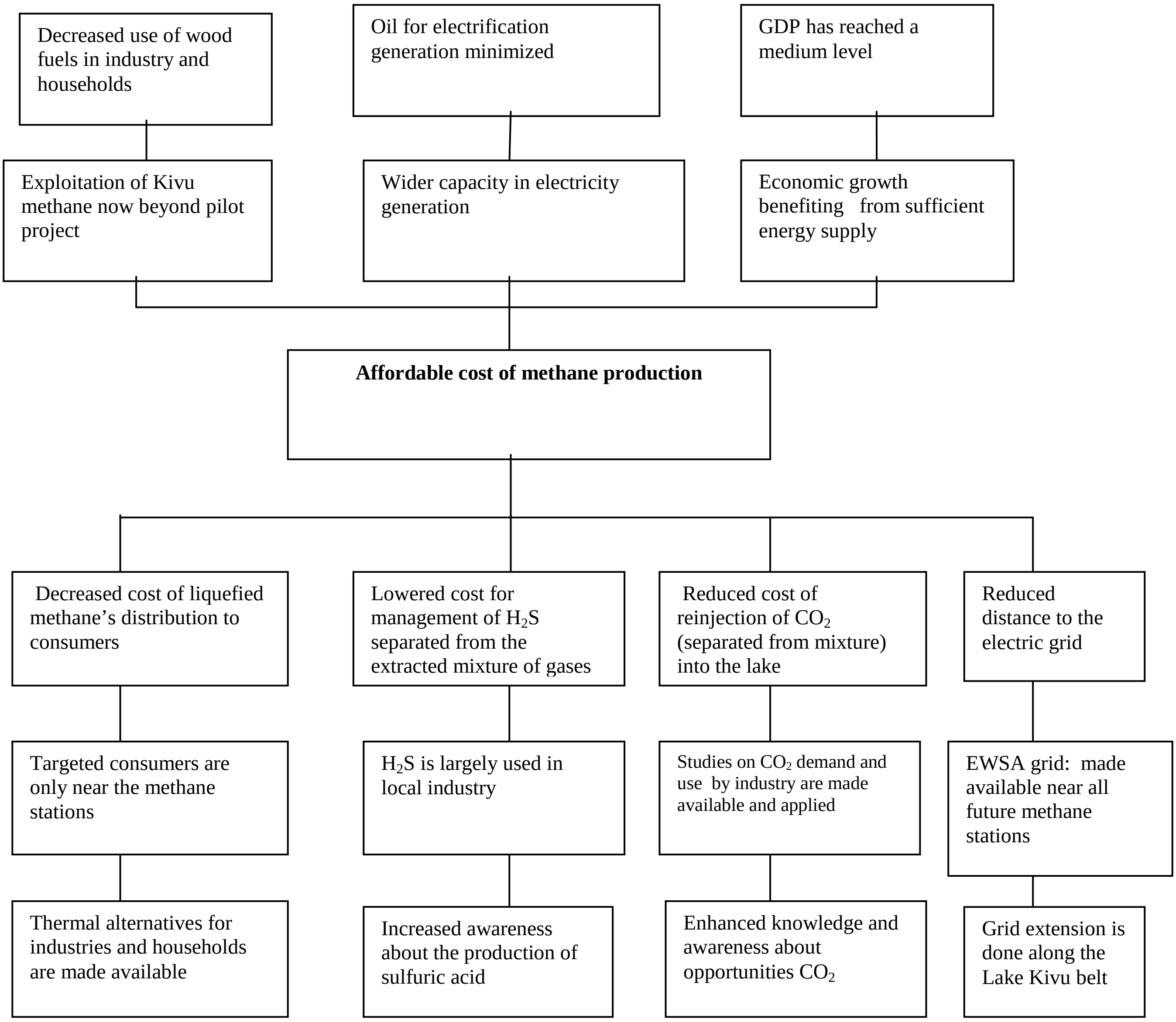


[8] Banks can play a key role in placing a given technology on a competitive and sustainable footing (Sirnivasson, 2009); Cash- payment market is replaced by credit-payment market

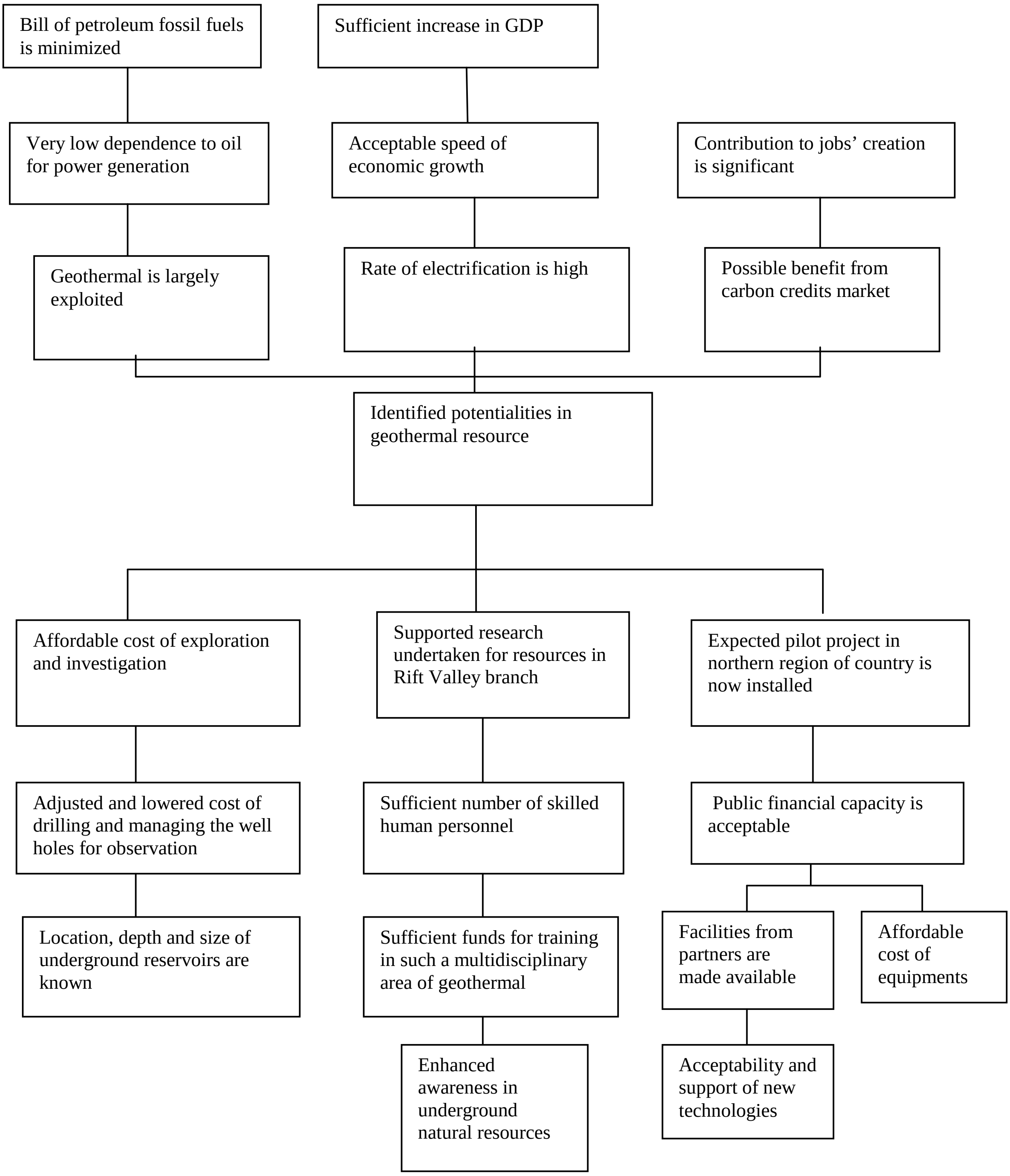
Small hydro power



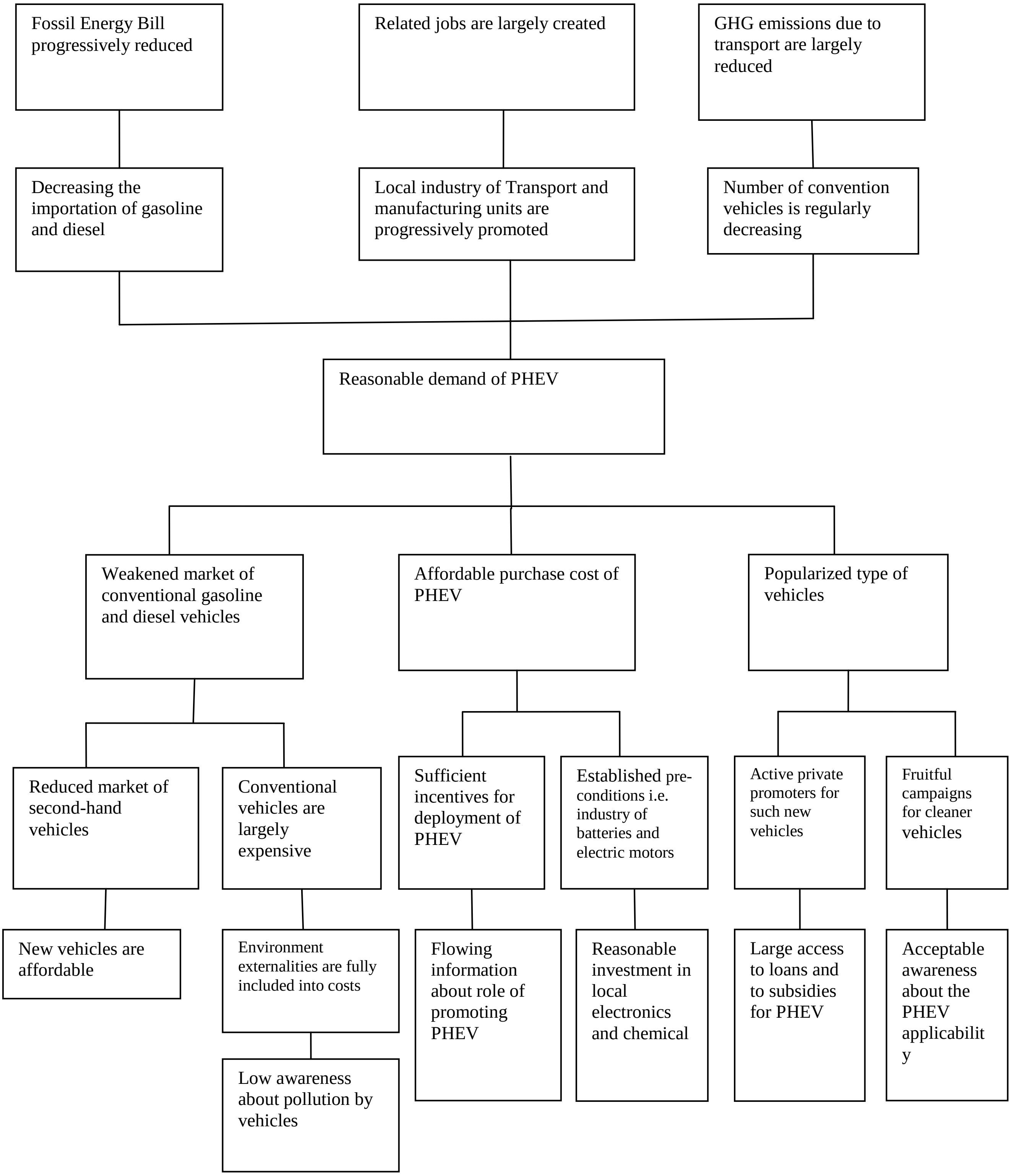
Kivu Methane CCGT



Geothermal


Bill of petroleum fossil fuels is minimized
Sufficient increase in GDP
Very low dependence to oil for power generation
Acceptable speed of economic growth
Contribution to jobs' creation is significant
Geothermal is largely exploited
Rate of electrification is high
Possible benefit from carbon credits market
Identified potentialities in geothermal resource
Affordable cost of exploration and investigation
Supported research undertaken for resources in Rift Valley branch
Expected pilot project in northern region of country is now installed
Adjusted and lowered cost of drilling and managing the well holes for observation
Sufficient number of skilled human personnel
Public financial capacity is acceptable
Location, depth and size of underground reservoirs are known
Sufficient funds for training in such a multidisciplinary area of geothermal
Facilities from partners are made available
Affordable cost of equipments
Enhanced awareness in underground natural resources
Acceptability and support of new technologies

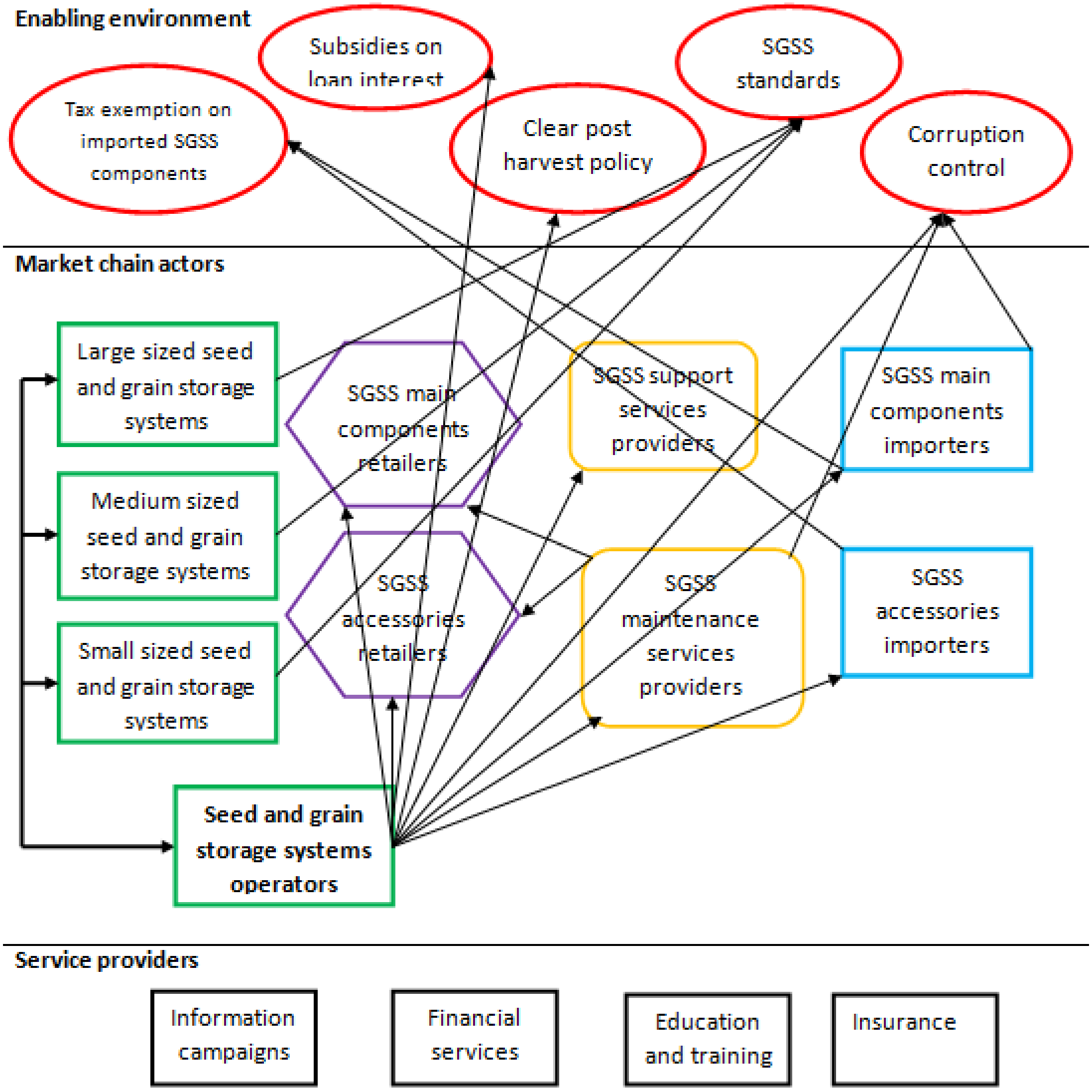
PHEV


Fossil Energy Bill progressively reduced
Related jobs are largely created
GHG emissions due to transport are largely reduced
Decreasing the importation of gasoline and diesel
Local industry of Transport and manufacturing units are progressively promoted
Number of convention vehicles is regularly decreasing
Reasonable demand of PHEV
Weakened market of conventional gasoline and diesel vehicles
Affordable purchase cost of PHEV
Popularized type of vehicles
Reduced market of second-hand vehicles
Conventional vehicles are largely expensive
Sufficient incentives for deployment of PHEV
Established pre-conditions i.e. industry of batteries and electric motors
Active private promoters for such new vehicles
Fruitful campaigns for cleaner vehicles
New vehicles are affordable
Environment externalities are fully included into costs
Low awareness about pollution by vehicles
Flowing information about role of promoting PHEV
Reasonable investment in local electronics and chemical
Large access to loans and to subsidies for PHEV
Acceptable awareness about the PHEV applicabilit y

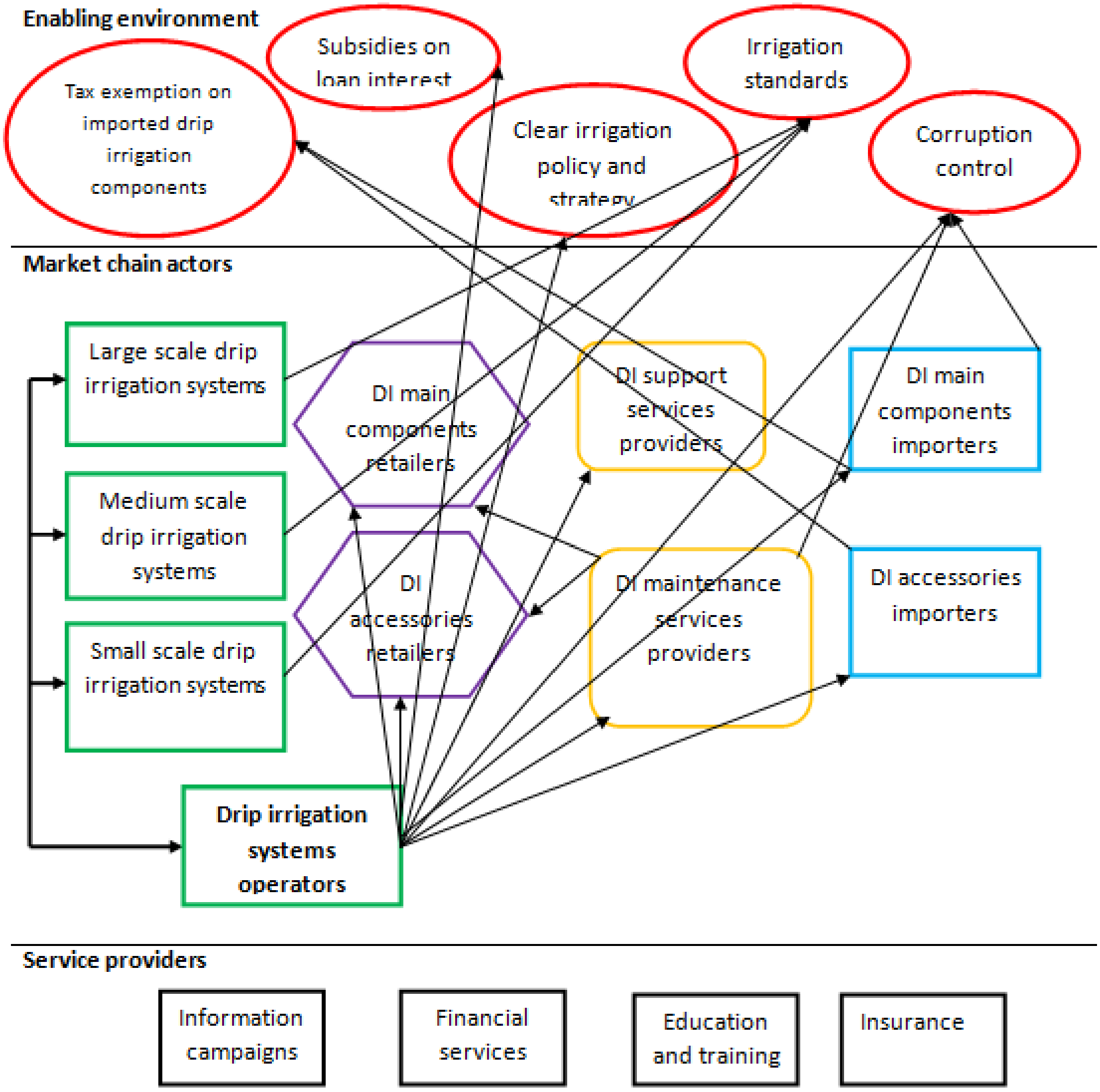
1.2 Agriculture sector

1.2.1 Market maps

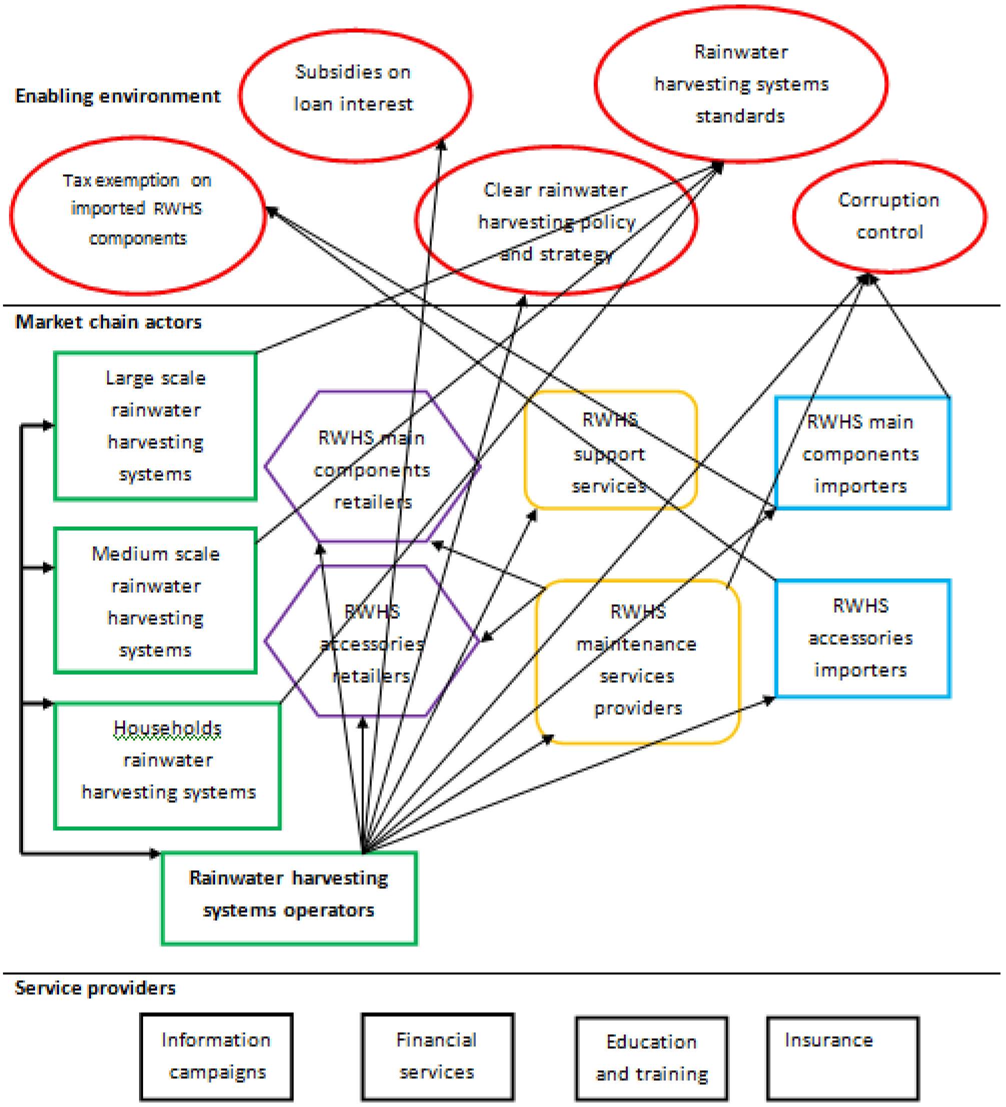
Seed and grain storage



Drip irrigation



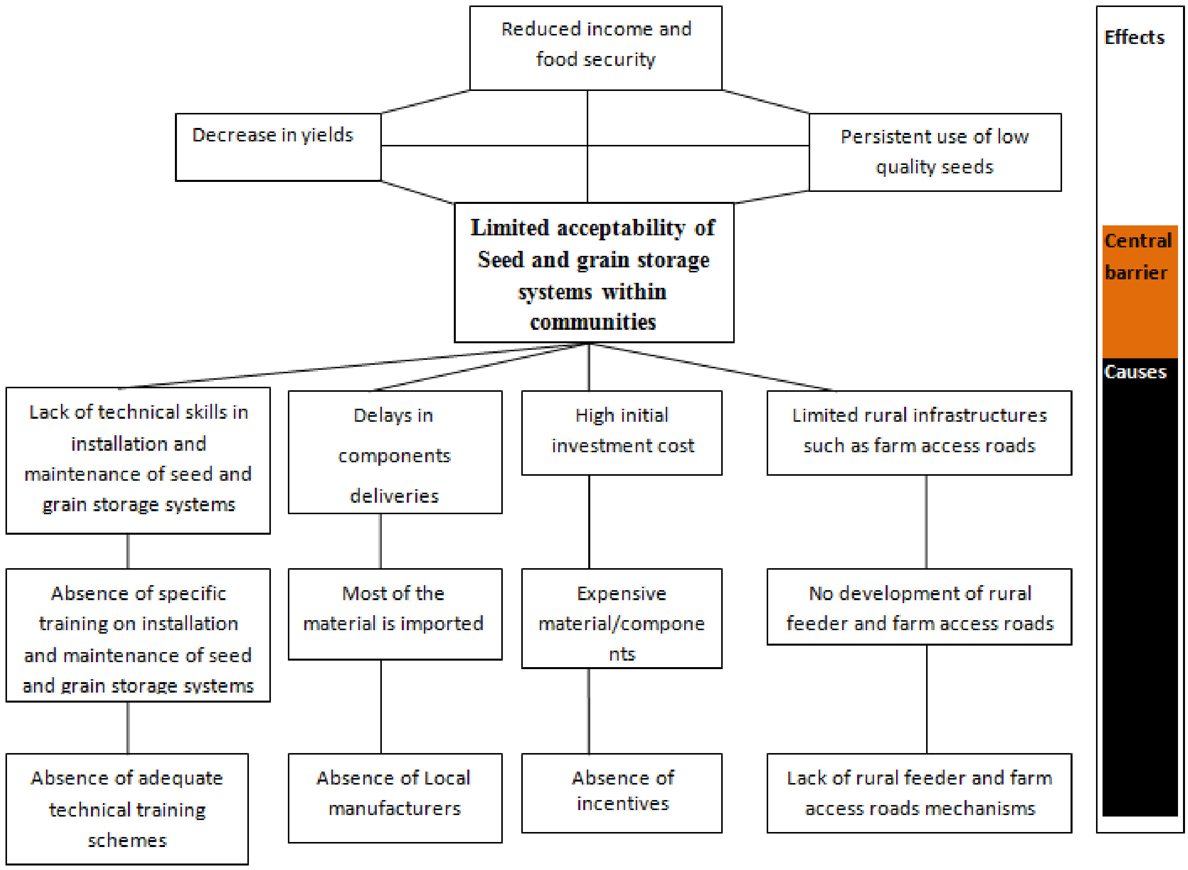
Rainwater harvesting



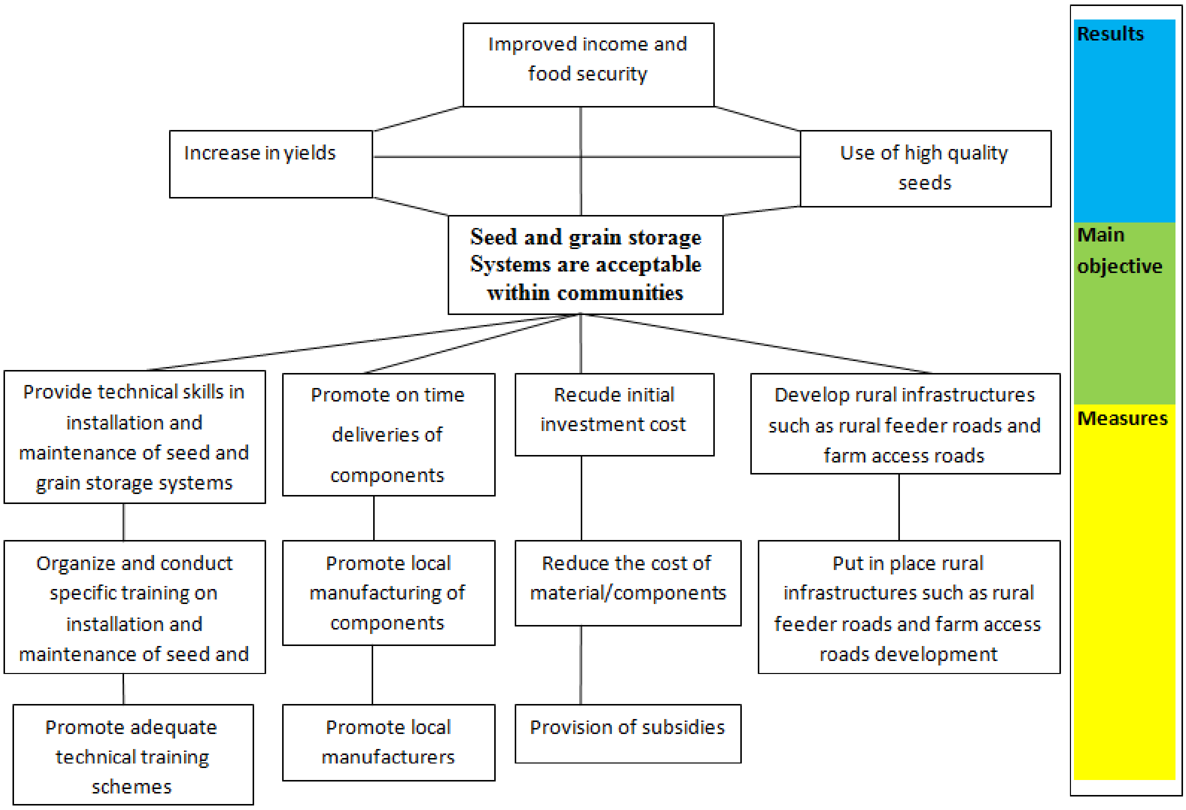
1.2.2 Problem and solution trees

Seed and grain storage

Problem tree

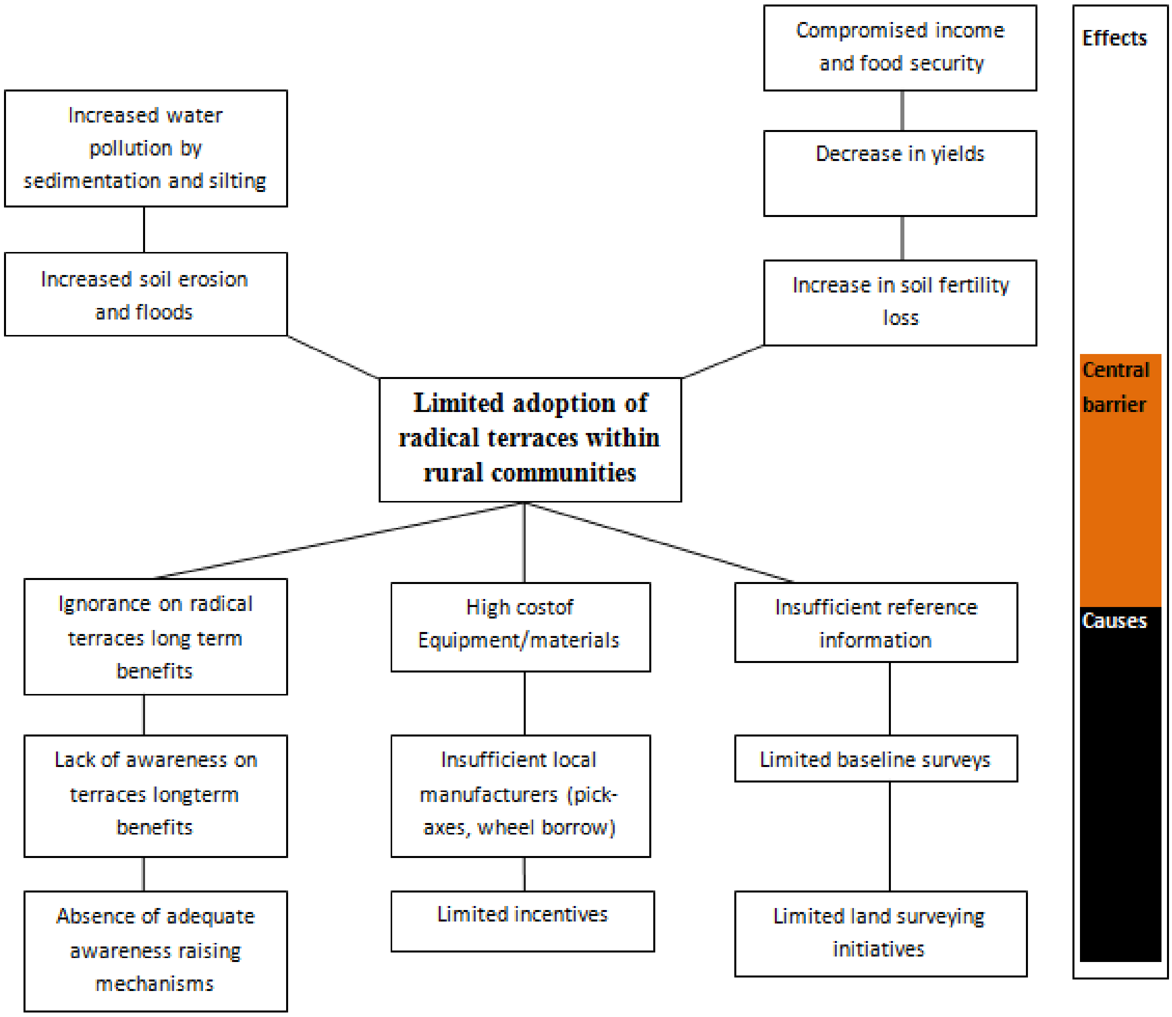


Solution tree

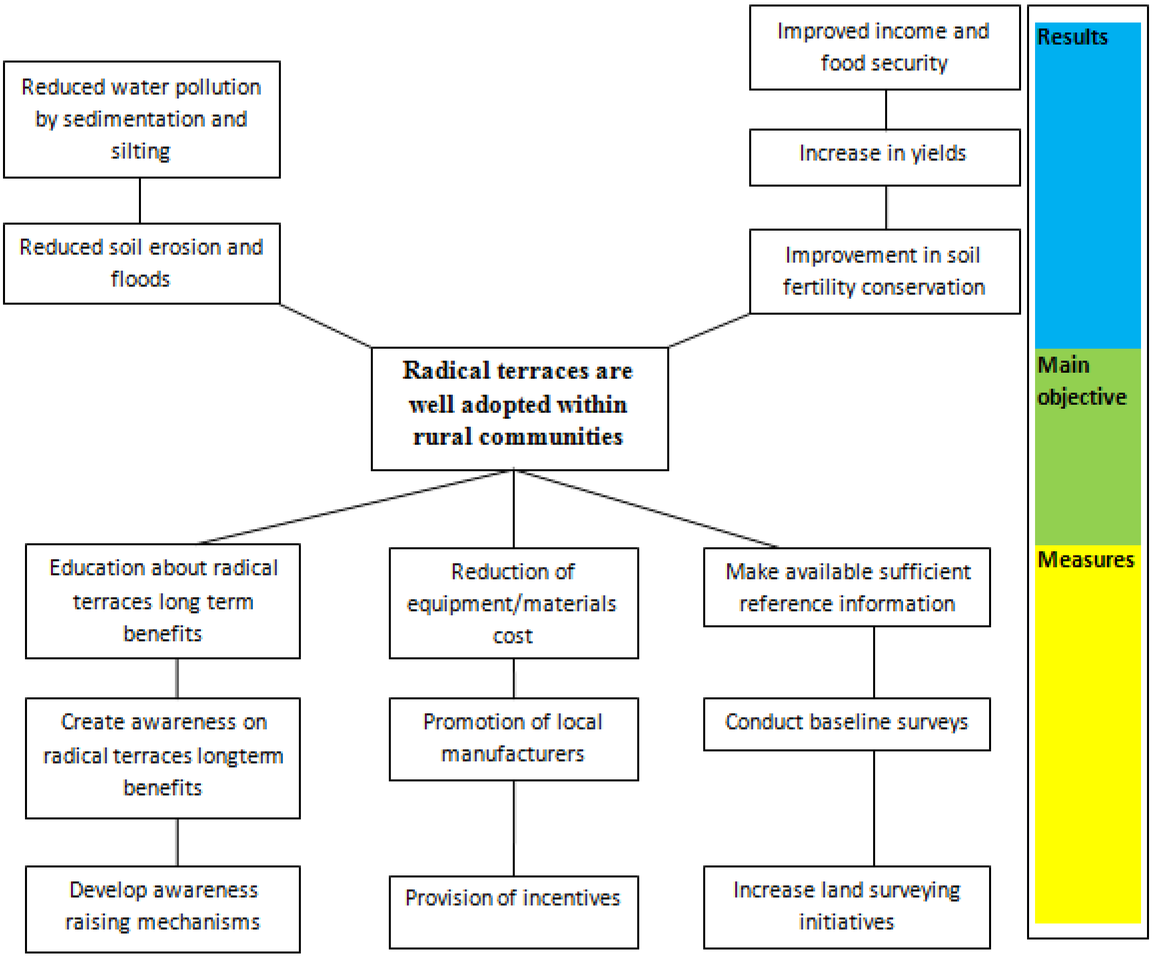


Radical terraces

Problem tree

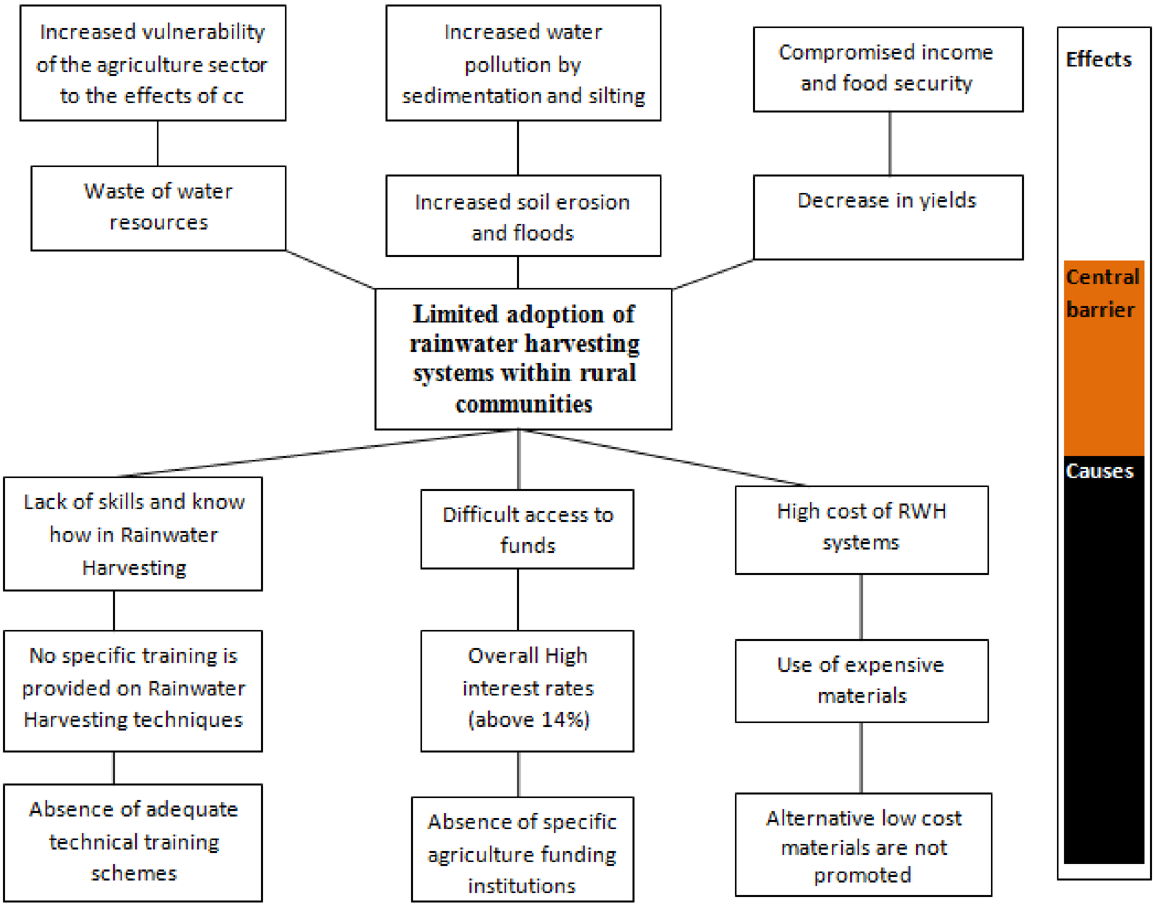


Solution tree

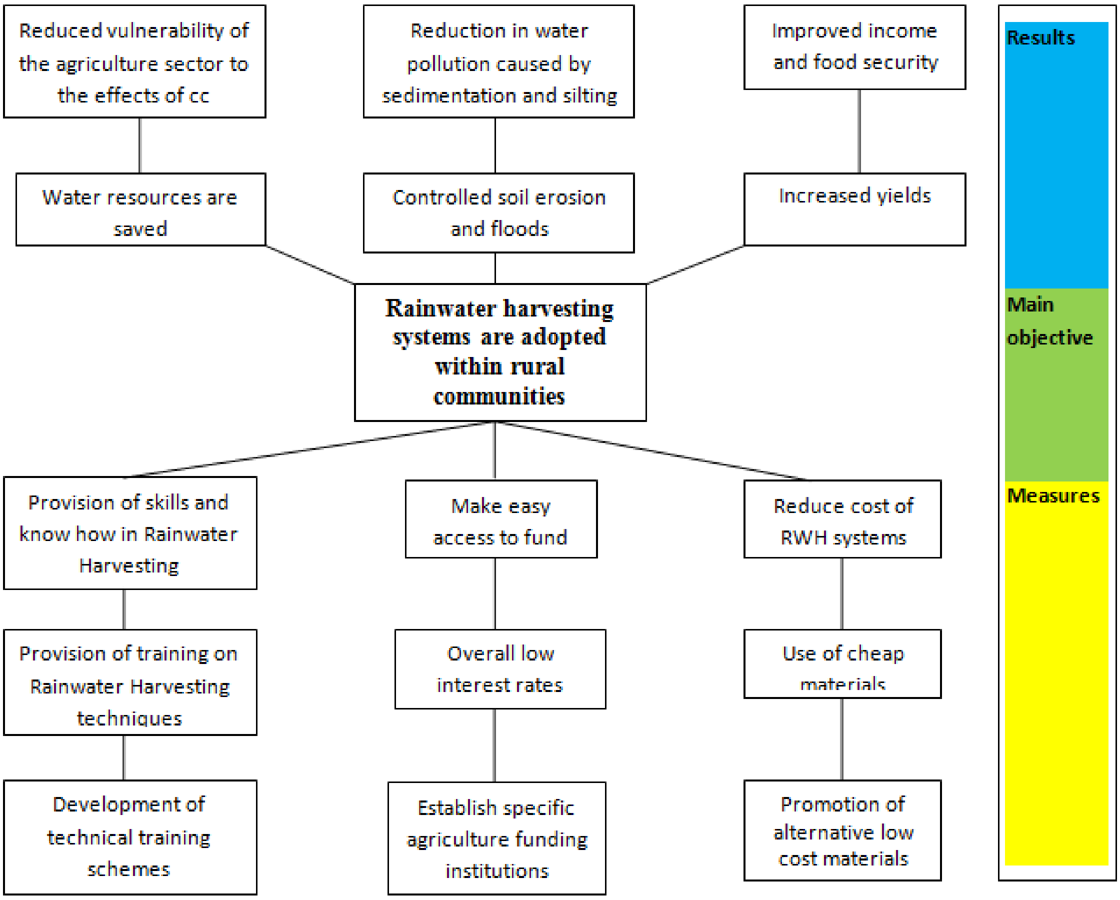


Rainwater harvesting

Problem tree

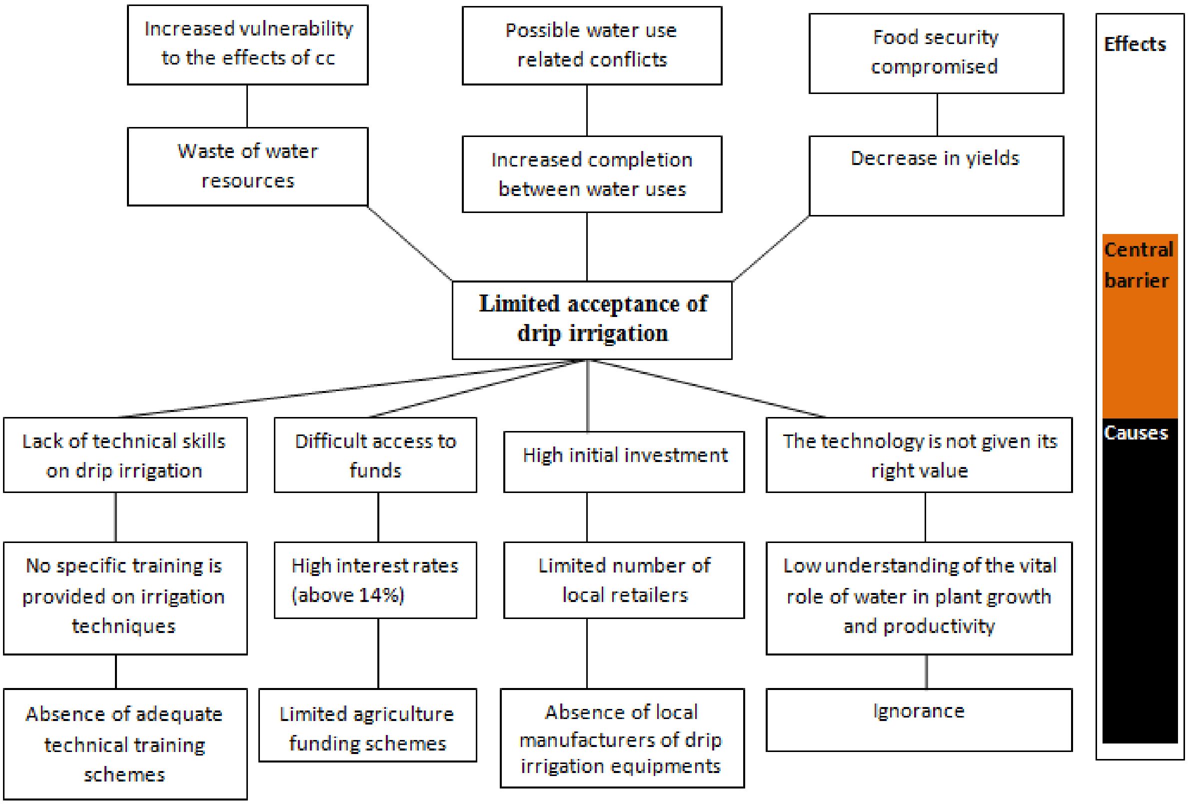


Solution tree

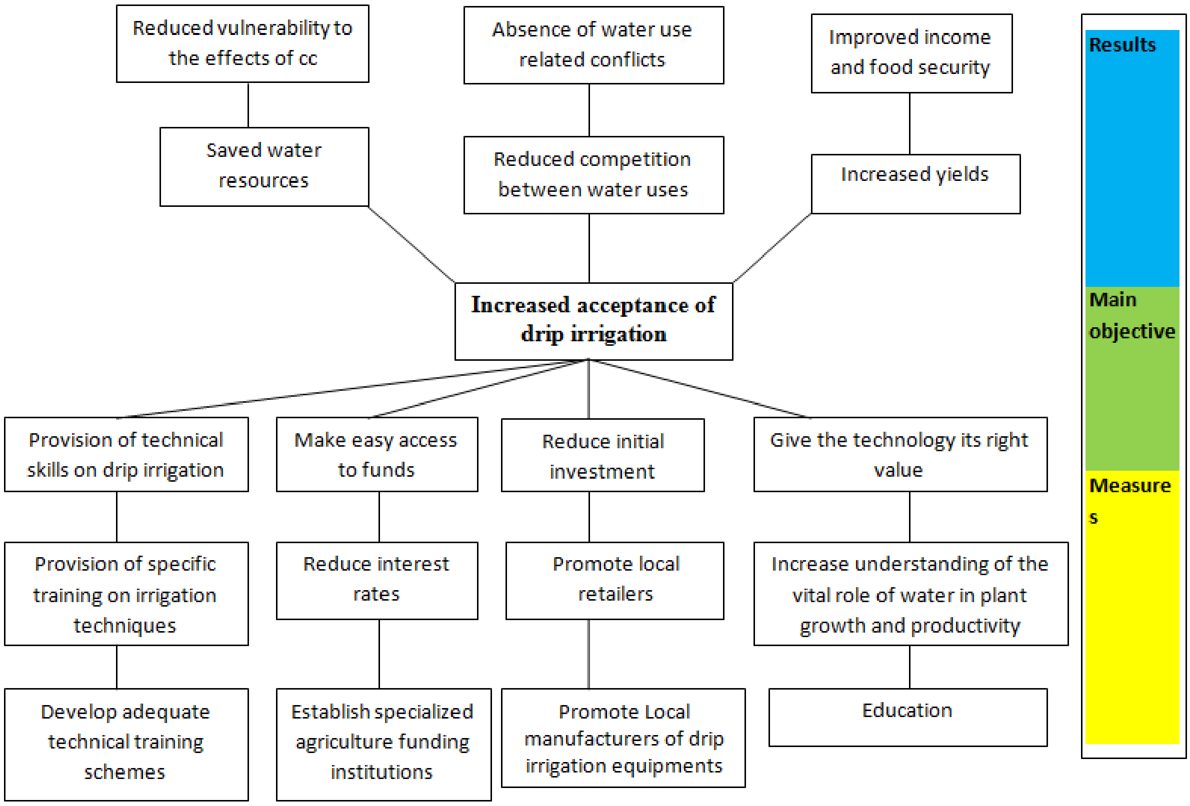


Drip irrigation

Problem tree

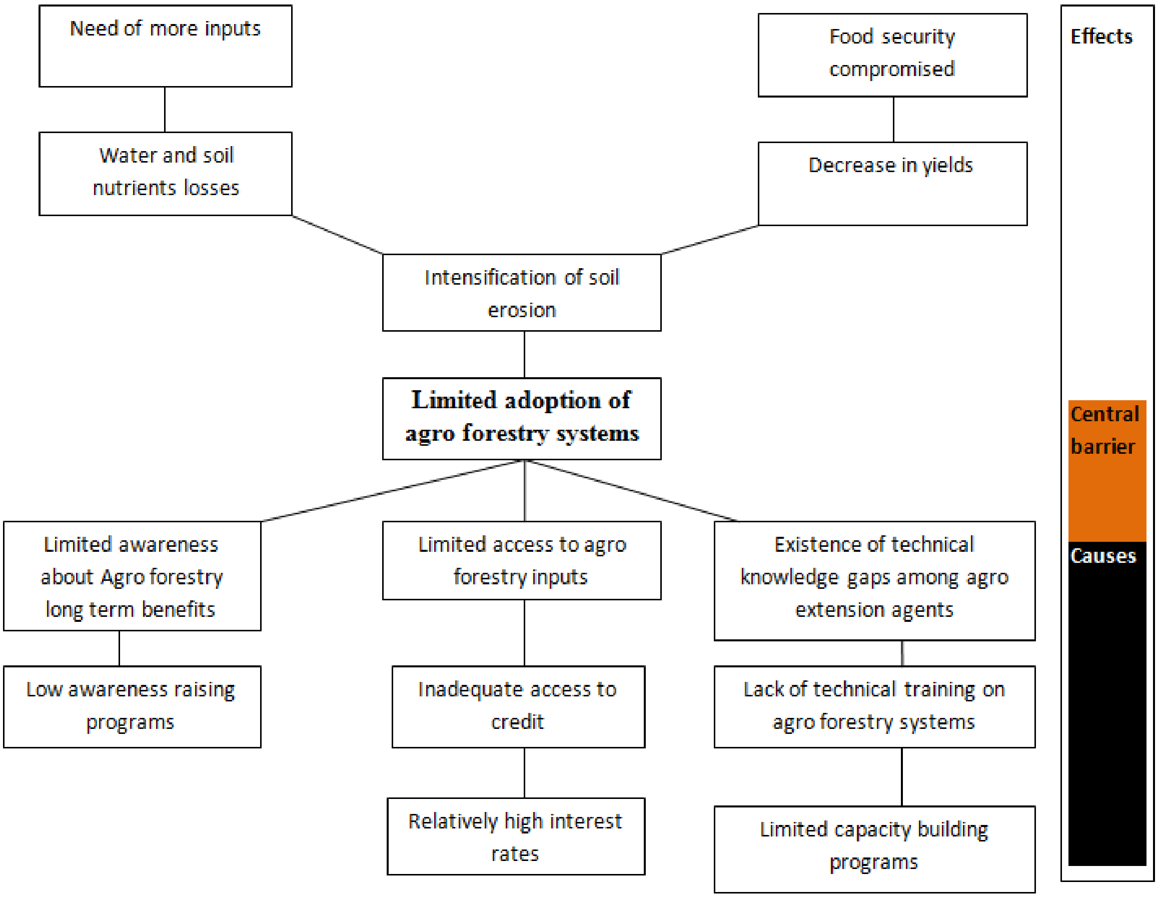


Solution tree

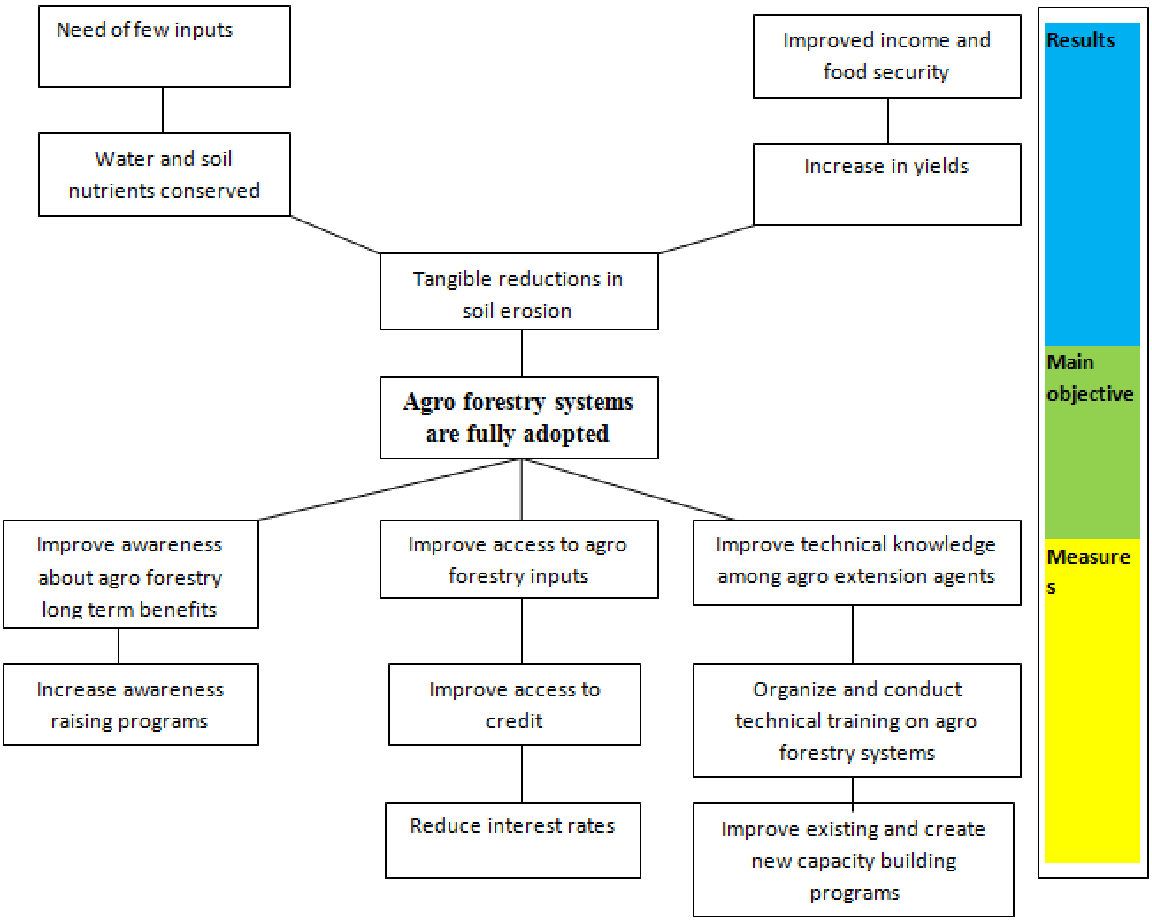


Agro forestry

Problem tree



Solution tree



Annex 2- List of involved stakeholders and their contacts

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