Energy Sector Working Paper

National Strategy on Climate Change and Low Carbon Development for Rwanda

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Executive Summary

"The vision of the energy sector is to contribute effectively to the growth of the national economy and thereby improve the standard of living for the entire nation in a sustainable and environmentally sound manner"

This paper is one of nine sector working papers written as part of the process of developing a National Strategy on Climate Change and Low Carbon Development for Rwanda. It follows on from the Baseline Report produced in February 2011 which provides the local context for each sector, including current programmes and development plans. This paper focuses on Energy while the other working papers cover Water, Agriculture, Land, Forestry, Transport, Built Environment, Mining and Finance. The paper should be read in conjunction with the Strategic Framework including a vision for 2050, objectives, guiding principles and enabling pillars. The aim of each paper is to identify the vulnerabilities and opportunities facing the sector, to review global best practice and relevant case studies, and to propose an action plan for addressing climate change and low carbon development in the short, medium and long term. This action plan is put forward to stakeholders in Rwanda for review and comment. As the title suggests, the working papers are aimed at prompting discussion with stakeholders, rather than being the final word. The sector working papers, strategic framework and stakeholder input will be used to compose the final Strategy in July 2011.

Increasing the supply, access and stability of electricity supply in Rwanda is essential for both economic growth and achieving the Millennium Development Goals. As such it has been prioritised in the Economic Development and Poverty Reduction Strategy by the Government of Rwanda. At present, energy is used predominantly for cooking in the form of biomass. Electricity makes up 3% of primary energy use and access levels are low at 10.5% of the population. The main focus of the National Energy Policy and National Energy Strategy produced by the Ministry of Infrastructure is on reduction of biomass use and increasing supply and access to electricity. Currently, electricity is generated at nearly equal levels from hydropower and diesel-fuelled power plants. The high level of diesel-powered generation in the electricity mix means that Rwanda is dependent on imported diesel and heavy fuel oil which places high demands on Rwanda's foreign exchange reserves. In addition it means that Rwanda's economy is highly vulnerable to oil price spikes. These factors push up the price of electricity in Rwanda. The dependence on hydro power leaves the energy sector vulnerable to the potential effects that climate change will have on rainfall and river flow patterns.

Rwanda has significant domestic energy resources which should be utilised. A number of these are low carbon and resilient to changes in climate and will be suitable for climate finance. At present, the Government of Rwanda is working to implement an ambitious electricity generation program which includes a diverse mix of generation sources including hydropower, geothermal, methane gas to power, solar, biogas and waste to energy projects as well as peat and diesel power. The Government of Rwanda aims to have a generation capacity of 1000 MW by 2017, up from 95 MW at present. This is combined with national grid extension plans to give grid access to 50% of the population, an extension of 2,100 km, by the same year.

The implementation of the electricity generation plan is currently hindered by significant gaps in capacity, a lack of institutional and legal frameworks, low investments and data gaps. In addition, the plans involve the development and expansion of new technologies such as methane gas and geothermal and resources shared by other countries, for example hydropower. The Government of Rwanda is working well to overcome these issues.

This working paper aims to review the energy sector in Rwanda along with global best practice and instructive case studies. It draws on this review to propose a strategic framework for addressing climate compatible and low carbon development including the various options that could be implemented in order to achieve the long-term vision of the energy sector laid out in Box 1.

Three focus areas were identified from the vulnerabilities and opportunities that the sector faces in Rwanda; large-scale generation, or national security, small scale generation, or social security and implementation challenges. A number of policies and actions were identified for each focus area that could be utilized to facilitate the transition to vision 2050. These will be briefly summarized here.

In order to improve implementation effectiveness capacity needs to be built both within the central Ministry and at a local level. Technical, legal and financial capacity must be developed to enable the sustainability of the sector. This can be done through a variety of measures including through University courses, industrial placements and through skills transfer from international experts within Rwanda during on-project training. Studies should be conducted to ensure the optimum capacity building schemes are developed and monitoring schemes to determine effectiveness should be implemented. In the long-term, if technical capacity development is maintained, Rwanda has potential to be a regional hub of renewable energy technology knowledge. Links between the research institutes in Rwanda, the Government and industry should be studied so that the best ways of linking the three to enable effective, relevant research and communication of this research are identified.

This paper identifies a number of renewable energy finance sources including a variety of funds, the clean development mechanism and FONERWA. Capacity in accessing the CDM and climate funds should be developed. A number of financial policies that would encourage investment and private sector involvement in renewable energy have been identified. These include feed-in-tariffs for renewable energy generation projects and grant-per-unit sold policies.

A streamlined and effective institutional, regulatory and legal framework will encourage private sector investment in Rwanda. It is highly recommended that the Government of Rwanda continues to conduct research into how the key organizations involved in the energy sector can be streamlined, in particular; MININFRA, RURA and EWSA.

Thorough surveys of all the energy resources in Rwanda should be conducted in order to plan the most cost-effective generation mixes. In addition, increased data on electricity use, demand, energy efficiency and storage requirements should be collected in order to identify the optimum system and monitor the development of the sector.

The plan for increasing electricity supply through large-scale generation projects has several positive features in that they are largely domestic (or shared regionally), from a variety of sources thus increasing climate resilience and, peat excluded, low carbon. Geothermal could be prioritised for development. The move away from fossil fuel dependence could be aided by a strategy including time lines for phase out.

Electricity generation through small-scale generation projects should be increased. In addition to this, increasing access to electricity through local grids and off-grid sources to complement national grid expansion should be assessed as a potentially cost-effective and efficient approach. There have been many benefits identified from distributed power generation. The choice of approach should always be specific to the area in which it is being implemented. Encouraging private sector involvement in small scale electricity generation diffusion into rural areas could be an effective means of increasing access rapidly. This can be done through encouraging the investment of microfinance institutes in renewable energy developers by implementing a grant-per-unit-sold scheme.Removal of import taxes and VAT on renewable technology components and ensuring the implementation of this would be desirable.

For all electricity generation projects ensuring sufficient maintenance and financial sustainability is essential for the long-term generation. Building technical capacity at a local level can enable maintenance to be carried out in a timely and cost-effective manner. Maintenance strategies should be developed as an integral part of all projects. Standards should also be set in order to protect the consumer and build customer confidence. In order to ensure financial sustainability of small scale, local grid generation facilities productive uses of electricity should be built into the design and explicitly considered.

In the medium and long term, new technologies are likely to become feasible and research should be done to investigate potential new technologies feasible for use in Rwanda. Smart grid technology feasibility should be investigated in order to utilize its energy efficiency potential.

Box. 1 Establishing Rwanda's Energy Sector Vision 2050

- **High levels of electricity generation to support a knowledge-based, service sector economy with high levels of growth.**
- **High electricity access levels supporting social security and gender equality.**
- **Energy security secured through a diverse range of renewable energy sources both domestic and regional, enabling an oil price resilient economy**
- **Wide range of resources utilized that are not susceptible to climatic variations giving the energy sector resilience to climate change**
- **Efficient use, production and transportation of electricity**
- **An efficient and effective institutional, regulatory and legal structure**
- **Low cost electricity** generated through utilization of low-cost renewable energy, energy efficiency and low levels of system losses
- **A financially sustainable** energy sector
- **A smart grid network** utilising national grid and distributed local networks where each is most cost effective
- **Extreme weather resistant infrastructure,** through robust planning system and development controls.
- **Well-developed technical capacity** at the local and national level
- **Rwanda as a regional hub** of technical knowledge for renewable energy technologies
- **Regional cooperation** in energy use, research and development

Acronyms/Abbreviations

ARGeo	African Rift Geothermal Facility
BNR	National Bank of Rwanda
CDM	Clean Development Mechanism
CER	Certified Emissions Reductions
CFE	Centre Financier Aux Entrepreneurs
CHP	Combined Heat and Power
DFID	UK Department for International Development
DRC	Democratic Republic of the Congo
EAC	East Africa Community
EB	Executive Board
EDPRS	Economic Development and Poverty Reduction Strategy
EWSA	Energy, Water and Sanitation Authority
FONERWA	National Fund for the Environment
GDC	Geothermal Development Company
GEF	Global Environment Facility
GoR	Government of Rwanda
GTZ	Deutsche GesellschaftfuerTechnischeZusammenarbeit
IPPs	Independent Power Producers
LDCs	Least Developed Countries
MDGs	Millennium Development Goals
MFI	Microfinance Institution
MININFRA	Ministry for Infrastructure
MINECOFIN	Ministry for Commerce and Finance
MNES	Ministry for Non-Conventional Energy Sources
MNRE	Ministry of New and Renewable Energy
NDBP	National Domestic Biogas Programme
NGO	Non-Governmental Organisation
PPA	Power Purchasing Agreement
RECO	Rwanda Electricity Corporation
REMA	Rwanda Environment Management Authority
RIG	Rwanda Investment Group
RWASCO	Rwanda Water and Sanitation Corporation
SHSs	Solar Home Systems
SNV	Netherlands Development Organisation
UBPR	Union des BanquesPopulaires du Rwanda
UECCO	Urambo Electric Consumers Co-operative Society
UNDP	United Nations Development Programme
UNEP	United Nations Environmental Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNIDO	United Nations Industrial Development Organization
UOB	Urwego Opportunity Bank
WCD	World Commission on Dams

This paper is one of eight sector working papers written as part of the process of developing a National Strategy on Climate Change and Low Carbon Development for Rwanda. It follows on from the Baseline Report produced in February 2011 which provides the local context for each sector, including current programmes and development plans. This paper focuses on Energy while the other working papers cover Water, Agriculture, Land, Forestry, Transport, Built Environment and Mining. Finance and Education are incorporated into the working papers rather than standing alone. The paper should be read in conjunction with the 'thinkpiece' which proposes the Strategic Framework including a vision for 2050, objectives, guiding principles and enabling pillars. The aim of each paper is to identify the vulnerabilities and opportunities facing the sector, to review global best practice and relevant case studies, and to propose an action plan for addressing climate change and low carbon development in the short, medium and long term. This action plan is put forward to stakeholders in Rwanda for review and comment. As the title suggests, the working papers are aimed at prompting discussion with stakeholders, rather than being the final word. The sector working papers, thinkpiece and stakeholder input will be used to compose the final Strategy in July 2011.

2050 Sectoral Vision

The options and recommendations in this report are based around a long-term vision of the energy sector of Rwanda. The key features of this vision include:

- High levels of electricity generation and access cultivating economic growth and development
- Renewable, domestic, low-carbon and climate and oil price resilient electricity sources
- A low-cost, reliable electricity supply
- A financially sustainable energy sector
- Well-developed technical capacity at the local and national level
- Rwanda as a regional hub of technical knowledge for the renewable energy technologies
- Regional cooperation in energy research and development
- An efficient and effective institutional and legal structure

In comparison, at present the energy sector possesses the following key features:

- Low electricity access, particularly in rural areas
- Reliance on biomass for primary energy use
- Electricity sourced from hydro power and diesel-powered generators, therefore susceptible to climate change and oil price shocks
- High electricity costs
- Low technical capacity
- Low institutional and legal capacity

This paper analyses the various options needed to be put in place in order to transition from the present state to the 2050 goal. The GoR has already begun to implement measures that will contribute to achieving the goal and should continue to strive to implement the strategy laid out in the Energy Sector Strategy for 2008 – 2012.

1. Introduction

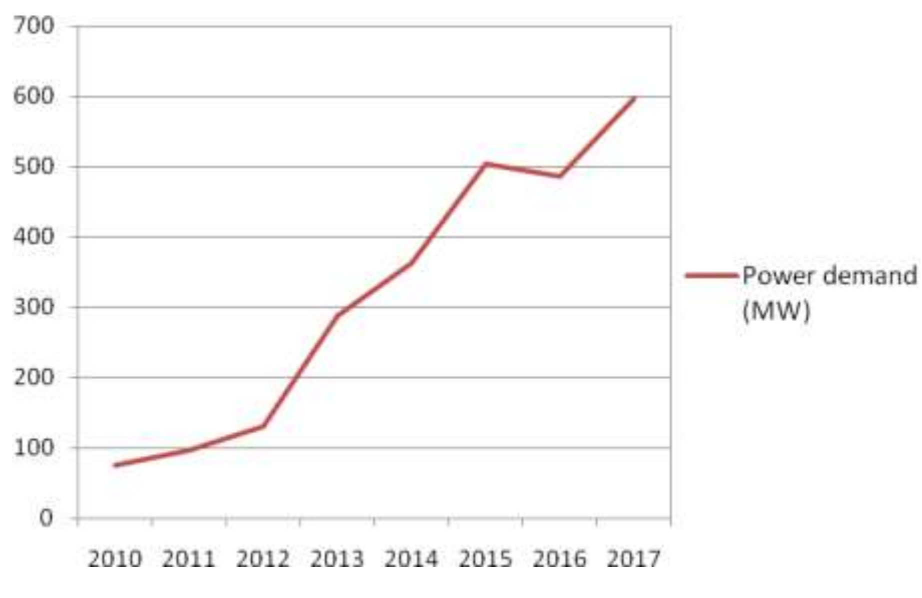
Overview of the Sector

Energy is an essential ingredient for both economic growth and achieving the Millennium Development Goals (MDGs). At present, themain energy source in Rwanda is biomass which makes up 86% of primary energy use[1]. Electricity makes up 3% of primary energy use and access levels are low at only 10.5% of the population. Understandably, a key priority for Rwanda is to increase both generation and access.

Currently electricity is generated at nearly equal levels from hydropower and diesel fuelled power plants, around 50% and 45%, respectively [1]. The high level of diesel-powered generation in the electricity mix means that Rwanda is dependent on imported diesel and heavy fuel oil which places high demands on Rwanda's foreign exchange reserves. In addition it means that Rwanda's economy is highly vulnerable to oil price spikes. These factors push up the price of electricity in Rwanda. The dependence on hydro power leaves the energy sector vulnerable to the potential effects that climate change will have on rainfall and river flow patterns.

The Government of Rwanda (GoR) has plans to increase the electricity generating capacity of the country from 95 MW at present to 1000 MW by 2017. At the same time increasing access to 50% of the population and reducing the use of biomass from 86% of total primary energy use to 65%[2]. When increasing electricity generation, the GoR aims to maintain a balance between energy for economic growth and energy for poverty reduction and social objectives.It is predicted that electricity demand will increase as shown in figure 1 resulting from increases in demand resulting from increased access to the national grid to 50% in 2017 and the demand from mining projects outside the Rwandan territory that will be supplied by domestic generation. Domestic demand makes up around 60% of peak demand with cross border mining projects accounting for 20% and sub-regional electricity market making up the remaining 20% [3].

***Figure 1**: Demand forecast for electricity up to 2017 (Source: Draft Electricity Strategic Plan for the Energy Sector: 2011 – 2017 [3])*



The planned increase in electricity generation to meet the increased electricity demand will come from a variety of sources, summarised in table 1, including geothermal, methane, hydropower and peat. In addition, the national grid is to be extended by 2,100 km (700 km of high voltage and 1,400 km of medium voltage)[2]. Further details are given in the Baseline Report.

***Table 1**: Current and planned electricity generation capacity in Rwanda[1]*

Source	Installed Capacity (MW)	Available Capacity (MW)	Planned New Capacity (MW)
Domestic Hydro	26.25	22.9	47.5
Regional Hydro	15.5	14.5	164.97
Micro-hydro	0.7	0.7	50
Domestic Thermal	27.8	27.8	20
Rented Thermal	10	10	-
Solar PV	0.25	0.25	8
Methane	4.2	1.8	300
Geothermal	-	-	310
Peat	-	-	100
Total	84.7	77.95	990.47%

2. Vulnerabilities

As mentioned above, the key vulnerabilities in the energy sector result from the dependence of electricity generation on imported diesel and heavy fuel oil and hydropower.

Given the current high level of hydropower in the electricity generation mix, the sector isvulnerable to the negative effects offuture changes in rainfall and river flow patterns resulting from climate change. Although these changes are at present not yet determined, Rwanda already experiences hydrological variability which results in periodic floods and droughts. These can affect the ability of hydropower stations to work at full capacity. In addition, the growing population is likely to require larger amounts of water, and future land use patterns are likely to have an impact on hydropower potential[4].

The energy sector is also vulnerable to changes in climate in a variety of other ways. The effects largely impact the energy infrastructure, particularly through extreme events such as flooding. These flood events can affect power stations in particular which may have been placed near to rivers in order to use the water for cooling. Extreme events can also effect the transportation of fuel to the power stations [5].

Around 45% of the electricity generation mix is from diesel or heavy fuel oil generators, 100% of which is imported. This dependence on imported diesel and heavy fuel oil ties electricity generation and the Rwandan economy to the price of oil. This is undesirable given the volatility and increasing price of the commodity. Furthermore, the high price of oil means that electricity generated is very costly and must be subsidised by the government in order to make it accessible to consumers. An additional factor related to the dependence on imported diesel and heavy fuel oil in the energy mix is the effect that this has upon Rwanda's trade deficit. The current deficit in trade and services is around US$500 million [2]. A trade deficit of this level is only possible with the continued support of international development partners which allows a higher level of imports to be maintained. Due to the importance of electricity and other uses of petroleum, i.e. transport, for the Rwandan economy and its development imported diesel and heavy fuel oil have a priority call on foreign currency[2]. An increasing dependence on imported energy will limit the availability of foreign currency for the rest of the economy. In addition, when oil price spikes occur, the amount of foreign currency needed to sustain levels of oil imports will increase dramatically impacting on other sectors of the economy [2]. Developing energy from indigenous sources of primary energy can reduce the foreign reserve requirements of the energy sector however if equipment, spare parts and technical input are required from foreign sources there will still be some demand for the foreign exchange reserve.

The National Energy Policy and National Energy Strategy 2008 – 2012 outlines the GoRs plans for future electricity generation and reduction of biomass dependency. The policies discussed go some way to tackling the vulnerabilities outlined above. However, the goals for electricity generation increase are ambitious and the implementation of the strategy comes with a set of challenges itself.There are a few key implementation challenges that affect the range of electricity generation projects, namely; accessing sufficient funding, developing capacity – technical and legal – and generating an efficient regulatory and legal system. Further data on the sector is also needed in order to effectively plan for the future. There are also a range of challenges associated with each electricity generation method. These vulnerabilities are outlined in table 2.

***Table 2**: Vulnerabilities in the Energy Sector in Rwanda*

Parameter	Vulnerabilities
Economic/ Finance	High electricity costs Lack of finance High up-front costs for many technologies Foreign exchange risks Cost of climate proofing infrastructure Private sector put off by heavy investments and low return rate Private sector put off by large amount of regionally shared resources
Social/ Capacity	Lack of capacity in engineering and technical skills Lack of capacity in accessing climate funding Lack of capacity in dealing with private sector Poorest dependent upon biomass Population growth and economic growth increase demand
Technology/ R&D	Methane – new technology Lack of local equipment, spares Lack of provision for maintenance Easiest and cheapest options used first – increasing technological challenges as time goes on
Political	Regionally shared resources: hydropower and methane Focus on urban/rural Biofuels planned in an area where mechanisation of agriculture is possible
Legal /Institutional	Weak legal frameworks for new resources being developed Tariff structure Little resource management No mechanism for concessions and leases MININFRA focus on implementation and short term ‘fire fighting’, no time or capacity for focusing on long-term and policy-making
Environment /Climate	Future rainfall change Temperature increase Increase in extreme events Peat – land use change effects Biofuels – land use change

	Lake Kivu vulnerable Limited resources
Communication /Information	Need for information on emissions Need for information on efficiency Need for data on energy resource extents Need for rainfall data Potential resistance to new technology such as geothermal

3. Opportunities

Within the energy sector there are also a range of opportunities to reduce vulnerability and achieve the 2050 vision; these are outlined in table 3. There are many potential sources of domestic renewable energy which will enable Rwanda to reduce its dependency upon diesel-powered electricity generation, thus lowering the cost of supply. These sources have the additional advantage of increasing Rwanda's climate resilience by diversifying electricity generation. Many of these renewable energy sources will also allow access to carbon finance. A key opportunity which will be covered in the Built Environment Working Paper but is so vital that it requires mention here too, is the potential for energy efficiency leading to demand reduction. Many of these opportunities have been recognised and incorporated into the National Energy Policy and National Energy Strategy.

***Table 3**: Opportunities in the Energy Sector in Rwanda*

Parameter	Opportunities
Economic /Finance	Domestic renewable energy resources can be exploited instead of the use of diesel generators Climate finance opportunities for renewables Reduction of biomass use allows potential for REDD+ credits Opportunities for encouraging private sector investment in the energy sector
Social /Capacity	Job creation Micro-generation increases rural access Increased electricity access supports gender equality Education and Training - Skills development Health benefits from electricity use and efficient cook stoves Electricity access enables accessibility of MDGs
Technology /R&D	Low technology electrification options available Energy efficient technology
Political	East African Power Master Plan Regional expertise - could create Institutes and Societies for knowledge sharing
Legal/ Institutional	EWSA Opportunity to make efficiency a large part of policy ESMAP and World Bank pilot
Environment /Climate	Energy efficiency Air pollution benefits from renewables Mitigation benefits from renewables
Communication /Information	Public education on efficiency Data gathering on resources and efficiency Data gathering on electricity requirements

4. Sectoral Overlap

Within the energy sector there are several issues that overlap with other sectors; these are shown in table4. The majority of these overlaps will be covered in this working paper, with a few exceptions; the overlaps noted with the Forestry Sector will be covered in the Forestry Working Paper, energy efficiency – a key option for reducing demand and energy security – willbe addressed by the Built Environment Working Paper, and biofuels in the Transport Working Paper.

Table 4*: Areas of sectoral overlap relating to the Rwandan Energy Sector*

Parameter	Overlap	Sector
Economic /Finance	Potential for REDD+ financing form reduced deforestation and biomass use	Forests
Social /Capacity	Job creation Education and Training - Skills development Use of electricity over other fuels provides health benefits	Education Education Health
Technology /R&D	Biofuels Energy efficiency and use of renewables Improved cook stoves	Transport Built Environment, Industry/Mining, Agriculture Forests
Political	Use of water resources Land use conflicts: large-scale hydro, peat Competing uses of peat	Water Land Agriculture
Legal/ Institutional	Capacity building Legislation needed to ensure water is used sustainably by all sectors	Education Water, Land, Agriculture, Built Env., Forests
Environment /Climate	Land use changes associated with biofuels Lower deforestation rates associated with move away from reliance on biomass Increased use of water from higher rates of electricity generation Land use changes associated with increased electricity generation: peat, hydro, geothermal	Transport, Land Forests Water Land
Communication /Information	Communication and education on need for energy efficiency Communicate potential to foreign investors Information on deforestation rates for REDD+ Emissions and energy efficiency information needed	Education, Industry Finance Forests Land, Agriculture, Mining/Industry, Built Environment

5. Focus Areas

At present a wide variety of energy generation and efficiency options are being considered[2]. In order to do an in depth analysis a few key options will be focused on in this working paper. These options have been identified from analysing the range of vulnerabilities and opportunities within the energy sector as well as the current strategies laid out by the GoR. The focus areas have been identified with a long-term view in mind. Although at present Rwanda's electricity generation makes up a very small section of primary energy use, with an average annual per capita consumption of 20 KWh compared to a developing country average of 1200 KWh per capita per annum[2], the aim is for access to electricity use to increase rapidly over the next few years. The prominent focus of the GoR's strategic plan for the energy sector is increasing generation and access. As such, the focus of this working paper lies in assessing potential within the energy sector for low carbon climate compatible means of generating electricity.

The energy strategy plan produced by MININFRA identifies two objectives that increasing electricity production and access will accomplish: firstly, increasing economic growth and secondly, furthering social objectives and reducing poverty[2]. The Energy Strategy for 2008 – 2012 identifies four major sources of large-scale electricity generation that can facilitate accelerated economic growth. These four options will be discussed in relation to climate resilience and low carbon growth. In addition, the potential for further development of small-scale electricity generation options will be assessed. Global best practice and case studies will be reviewed in order to provide recommendations for the development of the different energy resources in Section 6.

Table 5 outlines the focus areas and the main related policy options that will be addressed in this working paper. They were identified in respect to the factors outlined in the above two paragraphs. The first focus area is therefore entitled 'Implementation', in this focus area policy options aimed at reducing the challenges identified in the vulnerabilities and opportunities identification process will be reviewed. The remaining two focus areas are entitled National Security and Social Security. Within these two focus areas policy options and electricity generation options that achieve the goals of economic growth and increased access to electricity with the aim of poverty reduction, respectively, will be addressed.

***Table 5**: Energy sector focus areas and key policy options identified for each.*

Focus Area	Options			
Implementation	Finance	Capacity	Institutional/Legal Framework	Data Gathering
National Security	Geothermal	Large-scale Hydro	Methane	Peat
Social Security	Micro/Pico Hydro	Solar PV	Biogas	

6. Review of Best Practice and Case Studies

In order to assist in identifying the best policy options for each focus area a variety of regional and global case studies have been reviewed. A selection of these is outlined below for each focus area.

6.1 Geothermal

Case Study: Kenya

Relevance to Rwanda

- Similar issues related to the rapid growth of demand in comparison to supply
- Great pressure on the conventional sources of energy like hydropower; hydropower in Kenya generates around 60% of the total electricity capacity, similar to Rwanda.

What was implemented?

Kenya was the first African country to use geothermal energy for electric power generation and direct uses. Both public and private sectors are involved in its development. Geothermal power generation currently makes up 17% of total electricity production.

History

To date wells have been drilled at only two sites: at Olkaria, located in the Hell's gate National Park, and Eburru. Exploration first started in 1956 and production started in 1981 when the first plant of 15MW was commissioned in Olkaria I[6].

Electricity Generation

Olkaria I: KenGen operated, 45MWe, 33 wells drilled[7].

Olkaria II: KenGen operated, 105 MWe. Wells drilled between 1986 and 1993 but construction of the power plant was delayed until the year 2000 when funds became available [7].

Olkaria III: The first privately funded and developed geothermal power plant. It is owned by Orpower4, 48 MWe.

Olkaria IV: Expected commission date - January 1st 2013. KenGen operated, 140 MWe [8].

Direct Use

The direct use of geothermal power is limited; there has been only one successful commercial use – the Oserian Greenhouse Project. The project uses steam from an early exploration well; one of the less productive wells that were drilled before a testing phase carried out by INEP/DGEF. It is used to control night-time humidity levels in the greenhouses, thereby alleviating fungal disease.

Lessons

- Need for local community, local government and local private investor participation
- Timely financing of projects is critical
- Early utilisation of exploration wells important in order to create interest
- Technical reviews very important in reducing costs and locating resources
- Can attract foreign investors through incentives such as tariffs.

6.2 Methane

Case Study: Lake Monoun and Lake Nyos, Cameroon

Relevance to Rwanda

There are three lakes in the world that fulfil the conditions necessary for accumulating gases, Lake Kivu being one of them[9].Lake Kivu however is different in terms of carbon dioxide concentration. In the Cameroon lakes, the inflow rate from volcanic activity below the lakes is large in relation to the volume of the lake. In Lake Kivu the inflow is smaller in comparison with the size of the lake.Eruptions from the Cameroon lakes are therefore more frequent and remove the carbon dioxide from the lake before methane can also accumulate. In Lake Kivu, biologic methane production at the bottom of the lake from the carbon dioxide is the main risk for gas eruptions.

Actions Taken

Degassing has been put in place at Lake Monoun which has lowered the gas contents at critical depths. The layering and density gradients have remained in place. Initially the water extraction increased the density gradients and thus the stability at depth, because as water is removed from depth it is replaced by water from above which has a lower gas and salt content. The gas content below the extraction point stays roughly constant because the gas removed is being drawn from water at and above the pipe inlet. This withdrawal feeds the pipe and a new, lower gas concentration water layer subsides from above. As water with lower gas concentrations is fed to the pipe, the rate of extraction decreases because it is the gas pressure in the inlet water which drives the force of exsolution (formation of bubbles) that lifts water up the pipe without any external energy required.

Lessons

- Severe volcanic activity may trigger a large catastrophic eruption, discharging most of the gases from the lake. The probability of such an event is very low[9]
- If gases are removed from the lake the probability as well as the potential consequences will be reduced [10]
- Gas extraction postpones degassing events, but will not remove the hazard completely [9]

- A monitoring programme related to the gas extraction should be put in place to help in clarifying the actions needed [9]
- Gas extraction may add to the risk of a minor eruption that will impact people nearby (or downwind) on the lake and on the closest shore. Everything possible should be done during the implementation to minimize the probability of such events [10]

6.3 Large-Scale Hydro

Case study: World Commission on Dams (WCD)

The WCD has conducted a series of case studies and reviews of dam implementation. From this they produced a series of best practice guidelines for their implementation based upon seven key 'pillars' [11]:

i) Gaining Public Acceptance

- Recognition of rights and an assessment of the risks allows identification and inclusion of stakeholders in decision-making
- Access to information, legal and support for all stakeholders, particularly vulnerable groups
- Demonstration of public acceptance; achieved through agreements negotiated in an open, inclusive and transparent process
- Projects affecting vulnerable groups should be guided by their free and prior informed consent

ii) Comprehensive Options Assessment

- Development, water, food and energy needs and objectives to be identified and assessed before resource development options decided upon
- Environmental and social considerations to be given a high priority along with technical, economic and financial factors
- These needs and objectives should be considered in all stages of planning, design, construction and operation

iii) Addressing Existing Dams

- Opportunities exist to optimize the benefits that can be gained from existing dams by addressing outstanding issues
- A comprehensive post-project monitoring system along with a performance review process needs to be put in place for all dams

iv) Sustaining Rivers and Livelihoods

- Dams can transform landscapes and create risks of irreversible impacts, the effects on ecosystems at river basin level are important to understand as well as how community livelihoods depend upon them
- Avoiding the impacts through good site selection and project design should be a priority
- A national policy should be developed for maintaining rivers with high ecosystem functions in their natural state

v) Recognising Entitlements and Sharing Benefits

- People affected by a project should benefit from it; all people must be satisfied that moving from their current context and resources will improve their livelihoods
- Impacts assessment should include all people at the reservoir, upstream and downstream whose properties, livelihoods are affected
- Mutually agreed and legally protected benefit sharing mechanisms need to be negotiated to ensure implementation

vi) Ensuring Compliance

- Compliance to a set of clear guidelines that should be adopted by sponsoring, contracting and financing institutions should be subject to independent and transparent review
- A Compliance Plan should be prepared for each project prior to commencement
- Costs for establishing compliance mechanisms should be built into project budget

vii) Sharing Rivers for Peace, Development and Security

- Storage and diversion of water in transboundary rivers is often a source of tension between countries
- National water policies should make specific agreements in shared river basins
- Agreements should be negotiated on the basis of good faith among Riparian States. They should be based upon principles of equitable and reasonable utilisation, no significant harm and prior information

Case Study: Transboundary Regional Water Management Cooperation in Central Asia

Relevance to Rwanda

Management of a resource shared between multiple countries.

Description

Turkmenistan, Uzbekistan, Kazakhstan, Kyrgyzstan and Tajikistan share the same water resource around which multiple environmental problems exist. The downstream countries have abundant natural energy resources but depend upon the upstream countries for a clean and reliable water resource [12]. The situation could have been a potential cause of conflicts; however, instead they entered into an agreement on 'Cooperation in the Joint Use and Protection of Water Resources of Interstate Significance'. The Central Asian states pledged "strictly to observe the coordinated procedures and established rules on use and protection of water resources," while recognising the Aral Sea as of common interest to the five countries[12]. Whilst there have been significant problems, and this is far from a best practice case in many ways, the states were able to enter into an agreement in which the upstream countries benefited from the energy resources of those downstream in exchange for protection of the water resource [12].

Lessons

- As a result of the individual pursuit of self-sufficiency in water and energy, the countries have invested in costly solutions instead of adhering to the mutual interdependence of the water and energy systems [12]
- Can view shared resources not as a problem but as an opportunity for collaboration and economic development

6.4 Peat

Case Study: Finland

Relevance to Rwanda

Finland similarly has large peat reserves and dependency upon imported fuels.

Actions

In Finland, peat is mainly used in energy generation or in horticulture, split 90% and 6-7%, respectively. Peat energy produces around 6% of total energy use. Peat is used to replace imported fuels. Two-thirds of the energy consumed in Finland has been generated with imported fuels. At present, peat is used in around one hundred larger applications [13].

While peat diversifies the country's domestic energy supply, it is not environmentally sustainable, therefore presenting a problem for another of the country's goals. In Finland, the use of peat can produce greenhouse gas emissions exceeding 10 million tonnes of carbon dioxide per year [14].

Lessons

- Peat can bring energy security benefits by reducing dependence on imports
- However, it also releases high amounts of CO_2 and is environmentally unsustainable

6.5 Distributed Power

Case Study: India

Relevance to Rwanda

Similar levels of rural electrification and need for rapid increase in electricity generation.

Description

Rural electricity supply in India has low penetration rates as well as low service; only 31% of the rural households have access to electricity, and the supply suffers from frequent power cuts and high fluctuations in voltage and frequency. The demand-supply gap is currently 7.8% of average load. A major challenge in the development of the power sector is the poor financial state of the utilities. This is due to the lack of adequate revenues and state subsidies for supply to the rural subscribers [15].

One potential solution could be decentralized power generation close to the rural load centres. A case study-based analysis was undertaken to investigate what the impact of a decentralised biomass-based power generator would be in the Tumkur district, Karnataka [15]. It was found that there was a significant improvement in the voltage profiles and reduction of technical distribution losses using this method. This suggests that rural micro-grids or rural electricity co-operatives would be beneficial. This improvement of the quality of the electricity supply also means that tariffs could be altered without consumer complaints in order to make the electricity system more financially sustainable [15].

Lessons

- Distributed power can be effective alternative to grid expansion

6.6 Solar PV

Case Study: India

Relevance to Rwanda

India has low levels of rural electrification.

What was implemented?

The Government initiated a solar programme in 1976 with a focus on R&D and solar manufacturing. In 1980 they launched the national Solar Photovoltaic Energy Demonstration Programme. The key components of which were [16]:

- A solar programme run by the Ministry for Non-Conventional Energy Sources (MNES, now the Ministry of New and Renewable Energy, MNRE)
- Nodal agencies were set up as state-level implementing bodies of MNES, with district offices under them
- These district offices collected orders for three months; these were then aggregated by the nodal agency who put out a tender to the manufacturers that met Government specifications; the district office would then supply the systems at a subsidized rate to the households[16]

Results

- This system of government procurement and tendering did not create the right incentives for high-quality products
- Manufacturers had an incentive to secure tenders through reduction in capacity and quality components as tenders were secured on the basis of lowest cost
- The programme had neither the resources nor the incentives to carry out effective after-sales service
- System performance reports were poor; failure rates were in the range of 33-100 per cent for solar street lighting and 25-94 per cent for solar home systems
- Rates of diffusion were low – 36000 solar home systems were distributed over a period of 15 years and only 0.08 per cent of the unelectrified population were reached [16]

Lessons

Whilst this case study is quite old, there remain a few key lessons that can be learnt:

- Maintenance and follow-up essential
- Standards should be set to protect consumers
- Private sector, along with regulations can be effective in diffusing technology into rural areas

Case Study: Tanzania

Relevance to Rwanda

- Similar levels of access to electricity in rural areas
- Demand for national grid electricity growing faster than supply
- The expansion of the grid to rural villages with small populations is not economically feasible given the cost of transmission and distribution and the limited purchasing power of rural people
- Policy to promote the use of personal solar home systems for rural off-grid electrification [17]

What was implemented?

- The five-year UNDP/MEM Mwanza Solar PV Project, which targeted the Mwanza Region. The project's focus was on building up the technical and marketing capacity of new and existing solar companies through training and awareness raising campaigns
- A second solar project, the Sida/MEM Solar PV Project, started a year after the Mwanza PV Project. The project is similar in design to the Mwanza Project, but larger, targeting sixteen out of twenty regions countrywide. The project components include [17]:

  (1) Business development services for solar companies (technical and marketing training for solar retailers, technicians and vocational school instructors)

  (2) Marketing and awareness raising

  (3) Network building amongst solar industry stakeholders

  (4) Policy and institutional support for the implementation of national quality control standards

Results

- Increase in national solar technology awareness
- A 15-fold increase in the size of the Tanzanian solar market from 100 kW in 2005 to over 1.5 MW in 2009
- Two retailers supported by the projects have transformed into two of the country's major importers/wholesalers
- There are currently nearly a dozen Tanzanian solar importers/wholesalers and over 200 retailers in the regions and districts around the country
- There are a greater number of trained rural solar electricians.
- However the market penetration of solar systems still remains small due to:
    - High up-front costs
    - Excessive margins
    - Lack of credit
    - Inconsistent quality[17]

Next Steps

A new solar project, the Clusters Solar PV Project, aims to:

- Provide standardized high-quality solar systems, bulk purchases to reduce cost, credit financing and subsidies
- The project focuses on private sector involvement
- The model involves market and partner analysis and identification, marketing and awareness-raising, establishing project management and Steering Committees, procurement (which includes drafting business plans), capacity building training for managers, technicians and quality control agents and microfinance
- Under this model, Tanzania's Rural Energy Agency provides a small 20% subsidy for systems procured. Farmers pay for 80% of the systems that they receive, split as 20% down payment and 60% on credit (over three years)
- In 2010 this project provided solar systems to over 1,000 homes

- Capacity building and training provided by the project enables the number of solar systems provided to multiply yearly for several years to come [17]

Lessons

- Ownership and maintenance of systems needed
- Capacity building is key
- Microfinance
- Subsidies can be useful in reducing upfront costs
- Awareness raising potential
- Standards setting needed
- Bulk purchasing can reduce costs

6.7 Micro and pico Hydro

Case Study: Gisuma, Rwanda

Gisuma plant - 12 kW

Benefited: forty-five households, one school, one health centre, one bank branch and the Sector offices.

According to local authorities, the benefits of the plant go beyond this:

- A significant hike in renting and purchase of houses, land plots and commercial premises has been experienced
- Opening hours for businesses like bars and salons have been extended
- Increase in number of local businesses[18]

Lessons

- Small-scale hydropower stations can make large impacts to local communities without grid connection

Case Study: Nepal

Relevance to Rwanda

- Low rural electrification
- Large hydro potential

What was implemented?

A Mini-Hydropower Project as part of a strategy to promote balanced regional growth by providing electricity to inaccessible hill areas. Another aim of the project was to reduce consumption of imported fuel and increase availability of electricity for agricultural processes, such as irrigation, and small industries [19].

Original Project:

- 8 small hydropower generating plants and related transmission and distribution facilities
- Service connections and house wiring
- Canal and pipe irrigation
- A central maintenance workshop in Kathmandu
- Training for plant operators and linesmen[19]

Alterations:

- Reduction of number of projects from eight to six
- Project completed six years later than target[19]

Lessons

- To ensure technical sustainability of the project, training programs in the service and maintenance of small hydro projects should be implemented
- Project design problems stemmed from insufficient data for topography, geology, and hydrology of the areas – good data and planning important

- Project produced a lower economic benefit than expected - negative internal rates of return means that the projects are operationally unsustainable without government subsidies
- Productive uses of energy are important to establish [19]

6.8 Rural Electrification Management

Case Study: Urambo Electric Consumers Co-operative Society

The Urambo township has a population of 20 000 people. Of which, 10% of households access electricity produced by a three 85 kW generator set that is run by an electricity cooperative. This setup began in 1992 with the transfer of the equipment to an informal electricity committee that collected electricity fees and a government engineer in charge of the operations of the generator. Unfortunately this system failed because of unclear obligations and responsibilities for the long-term sustainability of the system[20].

In 1993, the electricity consumers formed the Urambo Electric Consumers Co-operative Society (UECCO). Three influential individuals from Urambo were taken on as trustees with the task to support the co-operative in legal matters. The equipment was formally transferred to cooperative ownership. Regular operation under co-operative management started in June 1994.

Lessons

- Ownership by co-operative needed
- Strong local leadership and committee required
- Formalised legal structure necessary
- Training of staff in technical and management essential[20]

6.9 Regional Energy Sector Integration

Energy Sector Management Assistance Program (ESMAP) Study

The World Bank Energy Sector Management Assistance Program is a technical assistance trust fund which aims to help its clients to increase institutional capacity in order to achieve a sustainable energy system. It has recently produced a report in which it analysed the literature and case studies surrounding regional integration of energy sectors. The report looked at 12 case studies which covered a variety of different forms of regional energy integration including transmission and trade between varying numbers of countries and bilateral generation agreements[21]. The case studies assessed are listed below:

Regional Markets

• Central American Electrical Interconnection System (SIEPAC)
• Greater Mekong Sub-region (GMS)
• Gulf Coast Countries (GCC)
• Nile Basin Initiative (NBI)
• Pennsylvania-New Jersey and Maryland Interconnection (PJM)
• South East Europe (SEE)
• Southern Africa Power Pool (SAPP)
• Union for the Coordination of the Transmissions of Electricity/ European Network of Transmission System Operators for Electricity(UCTE / ENTSO-E)

Cross-Border Projects

• Argentina-Brazil (Garabi Project)
• CahoraBassa
• Manantali

• Nam Theun 2 (NT2)

In general it was found that all of the case studies had successful and problematic features. A number of lessons were taken from the case studies and these are outlined below:

Optimisation of Investment

Optimising generation and transmission investment on a regional basis can offer cost reductions when compared to the national level. However there are a number of issues that prevent these benefits being realised. Often, countries understandably follow national priorities such as domestic energy supply security. Recognising these issues is necessary for achieving a the optimisation of the regional scheme and explicit mechanisms to share benefits, such as allocating shares in cross-border projects, could help to overcome them [21].

Region Institutions

In order for regional integration schemes it is usually necessary to establish a regional institution. There are two predominant types of institution used: Special purpose vehicles (SPVs), which is a corporate structure that executes and operates a specific regional project, and regional bodies, groups that work with governments, regulators and utilities on an on-going basis, for example, power pools and their secretariats. The strongest of the institutions set up tend to be those that develop from local initiatives. The potential to build upon existing arrangements should therefore be explored [21].

Technical and Regulatory Harmonisation

Although it was found that harmonisation is not a precondition for regional integration, it is important where there is a desire to attract the private sector into investing as this will increase the degree of certainty and reliability of the investments. Harmonising technical standards can also help to avoid imposing excessive costs on neighbouring systems. In addition, the higher the level of integration that is proposed the more useful and required harmonisation becomes [21].

Energy Sector Reform

Again, different levels of power sector reform among different integrated countries can be sustained with planning, however, the more integrated the system becomes the more similar national power markets should be [21].

Carbon Emissions Savings

One of the aims of the energy integration scheme is often said to be to lower carbon emissions. However, this has not always been the result, carbon savings have largely been modest with the majority being made from increasing imports of hydropower. Some schemes have applied for CDM funding for the integration projects but none have yet been successful [21].

Renewables

Regional integration, through increasing the shared reserves of energy and diversifying the generation, can mitigate the impact of often intermittent sources of renewable energy, thus reducing the challenges involved in ensuring the systems reliability. Other barriers to renewable energy need to be removed alongside the integration as, with the exception of hydropower, renewable energy has not notably increased in the case studies [21].

7. Analysis of Options

The vision of the energy sector, in line with the 2020 goals and the EDPRS, is to increase electricity access and generation in order to effectively contribute to economic growth and reduce poverty. The aim is to provide reliable, efficient, cost-efficient and environmentally sound energy on a sustainable basis [2].

There are several win-win options in the energy sector for achieving these goals whilst remaining low-carbon and climate resilient. The 2008-2012 energy strategy and the 2012-2017 electricity master plan laid out by MININFRA utilises these win-wins effectively. The policy choices made reflect the compatibility of development and economic growth with climate resilience and low carbon energy. For example:

- The decision to make use of domestic resources
- The use of renewables
- The diversification of electricity generation

It is important that these plans are adhered to; long-term thinking is essential. It would be easy at this point to get locked into a high-carbon electricity generation pathway in the pursuit of quickly increasing generation capacity. This would mean that an increase in Rwanda's emissions would occur at a time when there are likely to be increases in economic opportunities for carbon credits and markets[22]. In addition, an increased dependence on imported diesel-generators and fuel would leave Rwanda increasingly vulnerable to oil price shocks and dependent on a commodity with a steadily growing price.

7.1 Social Security

The national grid in Rwanda is already reasonably extensive, in 2010 it was estimated that the national grid covered around 57% of the country's population within a boundary of 4 km along the MV line[23]. Figure 2 shows the extent of the national grid in 2010, areas further than 4 km away from the grid are highlighted in red. The Electricity Roll Out Programme has ambitious targets of increasing the number of household connection by 350,000 by the end of 2012 plus all health and administrative centres and at least 505 schools[2].

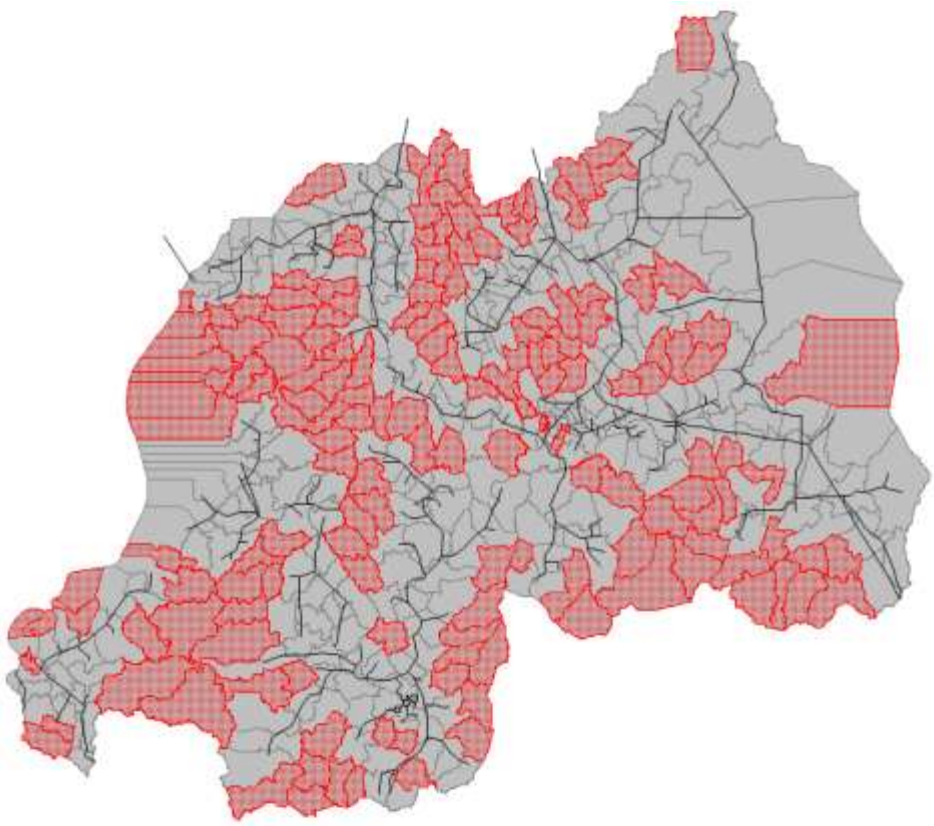
However, despite the density of the national grid in Rwanda, only around 35% of the population within a distance of 4 km from it have the purchasing power to pay the necessary fees for their consumption[23]. Numerous studies have shown that expanding the grid to rural areas does not necessarily mean that the poor will have access to electricity. A study conducted in 2001 that evaluated the findings of studies conducted on a series of major electrification programmes found that there was 'no general conclusion that the poor benefit' from these schemes [24].The reasons for this are largely cost-based; it is not proximity to the power line but cost that contributes the main factor excluding poor people from grid connection [25]. In general the positive effects from electrification on household income are lower than expected, except in cases where programs were accompanied by specific programs for promoting productive uses of electricity [26]. In solution to this problem, simply lowering tariffs is not effective as it leads to financially unsustainable systems. In order for electrification programs to reach the poor, 'life-line tariffs' for households using only very small amounts of electricity, for example less than 50 kWh/month, are key for increasing access[25]. This could be funded by the Universal Access Fund proposed in the National Energy Policy and National Energy Strategy. In addition, special credit markets should be developed to allow poor households to borrow money for the connection charge[26].

As the majority of the country's population lives in small and scattered rural settlements, combined with the hilly terrain, extending the national grid is expensive. From international experience it can be seen that grid extension projects in areas without any form of pre-electrification are mostly financially unviable[23]. Off-grid electrification can prepare consumers to learn to use and pay for the electricity they consume before the national grid is extended to them. Both off- and on-grid electrification can be seen as complementary features of an electrification program and off-grid electrification should be a strong feature of rural electrification.

Off-grid electrification can be seen as pre-electrification in that it provides electricity to communities before they can be reached by the grid. During this time productive uses of electricity can be created. This is essential in ensuring the financial sustainability of an electrification project as it is this productive use of energy that will make up the base load and generate income. One example of a productive use of electricity is the introduction of a village mill as a load centre. The load centres can then be expanded to nearby houses to provide them with lighting.

In addition to off-grid, small-scale generation can be expanded from a single house or mini-grid to be connected to the main grid. This technique of decentralising the energy sources generates energy where it is used and is known as distributed power generation (or variations of this).This form of grid architecture, with multiple smaller-scale generation facilities as opposed to a centralised system with a few large power stations, has become popular and widely used [15]. There are numerous advantages to this form of grid over the centralised architecture. Widespread use of distributed power can providean alternate and cost-saving system architecture for the generation and delivery of heat and electricity. In the context of rural Rwanda, decentralized power generationcould reduce distribution line losses as energy is produced where it is used and therefore does not require transmission to elsewhere. Using distributed power generation structure can improve voltage profiles and supply reactive power locally. It can thus benefit both the users, through higher quality power, and the suppliers, through lower losses [15].

***Figure 2**: Existing grid in 2010 and its economic reach (Source: Fichtner, 2010[23])*



There are already a few examples of off-grid electricity projects in Rwanda. Unfortunately, there have been a number of issues with them, particularly with solar PV projects. The reasons for this are usually inadequate investment or poor maintenance which results in a large number of broken or underperforming installations[23].

There are a number of actions that can increase the success rates of electrification projects. Firstly, it is important that rural electrification projects and programs are developed at a local level. The beneficiaries of a project need to be actively involved[27]. This can be achieved through two key ways: through conducting consumer education and participation programs such as workshops and by requiring through policy that all projects for rural electrification include a local value added component. Consumer education and acceptance of any program is essential. Secondly, thorough research into the consumer energy needs and willingness to pay should be conducted. Cost-benefit analysis should be conducted on the different technology options available for each location[27]. From international examples it is found that the best rural electrification programs are those that are tailored to the needs of the consumer and that have managed to develop a strong sense of ownership of the project in the consumer[23].With further private sector involvement the diffusion of small scale technologies could be increased. Two key factors are essential, aside from finance:

- Local capacity development
- Maintenance of any systems or programmes installed needs to take place. Maintenance strategies could be a useful way of ensuring this occurs. Different strategies may be needed dependent upon whether the technology is on or off-grid and who implemented it, i.e. government, private sector, system users.

In terms of encouraging development and increasing the number of productive uses of electricity in rural areas there are several factors that have been identified as necessary, these are [26]:

1. Access to a reliable electric service
2. Access to a local market for goods and services
3. Availability of electric equipment
4. Access to financial resources
5. Qualified human resources
6. Coordination and promotion

In implementing rural electrification schemes the GoR should strive to ensure that all six factors are present.

Off-grid power generation options within Rwanda include pico hydro, hydro mechanical mills with battery chargers, micro-hydro, solar PV systems, solar lanterns biogas digesters and small diesel engines. Hydropower, solar PV and biogas are discussed in detail below. The three options for small-scale power generation discussed below represent an area of great potential. Table 9 shows a comparison of the three technologies. In addition, Annex 1 shows price comparisons of the technologies with others.

7.1.1 Micro hydropower

There are many benefits to using hydro power electricity. Micro hydro can provide electricity for lighting and communication as well as delivering enough capacity to supply mini-grids and can thus be used for various forms of productive end-uses including small industrial applications. Micro and pico hydro can be utilised to increase rural electrification rates. Micro hydro can also provide additional capacity for the national grid [28].

Micro and pico hydro are usually run-of-the-river designs and as such are environmentally benign as they do not alter the river flow. They are cheap to operate and maintain and often have a long lifetime. Promoting the micro and pico manufacturing and installation industry in local areas will also ensure that the systems are sustainable [28].

A Hydro Atlas of the hydro potential of Rwanda was produced in 2007[29]. This identified 333 sites. Table 6 shows the range of classes of generation potential as well as the frequency of each class occurring that the study produced. Several key lessons can be drawn from the study. Firstly, total theoretical hydropower potential for Rwanda, excluding border sites is estimated to be around 82.6 MW. Of this total, 61.2 MW is present at sites that have already been equipped with hydropower stations – although not always operational – or are in the process of being equipped. The remaining unexploited potential is therefore 21.4 MW. Although these sites are technically exploitable, this does not mean that they will also be economically sustainable. In addition, some of the sites may also be mutually exclusive, a fact that is noted in the Hydro atlas. Therefore it is likely that the remaining potential for micro hydropower is in fact below this figure [29].

***Table 6**: Hydropower potential estimation – internal sites*

Class	Frequency (#/class)	% Frequency (%/class)	Potential (kW/class)	% Potential (% potential/class)
Zero	50	15.3%	0	0.0%
0- 5 kW	59	18.0%	146	0.2%
5 – 25 kW	89	27.2%	1168	1.4%
25 – 50 kW	32	9.8%	1169	1.4%
50 – 100 kW	38	11.6%	2801	3.4%
100 – 250 kW	31	9.5%	4769	5.8%
250 – 500 kW	10	3.1%	3572	4.3%
500 – 750 kW	1	0.3%	685	0.8%
750 – 1000 kW	6	1.8%	5381	6.5%
1000+ kW	11	3.4%	62904	76.2%
Total	327	100.0%	82595	100.0%

The remaining unexploited potential, as identified in the Hydro Atlas 2007[29], is presented in table 7. As can be seen from the table, 15 sites (with potentials of 250 kW plus) make up 61.5% of the total remaining potential. A large number of sites, almost 50 %, are in the range of 5 and 100 kW. These sites could represent opportunities for local level development in the short-term [29].

***Table 7**: Total unexploited hydropower potential for Rwanda*

Class	Frequency (#/class)	% Frequency (%/class)	Potential (kW/class)	% Potential (% potential/class)
Zero	49	17.0%	0	0.0%
0 – 5 kW	58	20.1%	142	0.7%
5 – 25 kW	83	28.8%	1062	5.0%
25 – 50 kW	27	9.4%	977	4.6%
50 – 100 kW	30	10.4%	2174	10.2%
100 – 250 kW	26	9.0%	3977	18.2%
250 – 500 kW	6	2.1%	2165	10.2%
500 – 750 kW	1	0.3%	685	3.2%
750 – 1000 kW	5	1.7%	4381	20.6%
1000+ kW	3	1.0%	5853	27.5%
Total	287	100%	21416	100.0%

Financing

To promote micro hydro three issues need to be addressed: financing must be available to overcome the high initial investment costs of implementing a micro hydro plant; steps need to be taken to ensure that there is demand for the electricity produced; and incentives need to be in place to promote proper management of the dam and construction of a mini-grid [28].

Direct subsidies should focus on the initial barrier – the high initial investment costs – rather than operational costs [28]. PSP Hydro, managed by GTZ, currently offers grant financing of up to 25 percent of the costs of dam construction, and a pending GEF programme will supplement this grant to a maximum of 50 percent. Eligible dams cannot exceed 3 MW. It is important that in combination with grant financing, access to affordable lines of credit is in place. Bank loans for micro-hydro plants in Rwanda are difficult to secure and carry a minimum interest rate of 16 percent. The GoR could buy down the risk to commercial banks by providing partial risk guarantees, in which it would commit to cover a portion of the bank's losses in the event that the borrower defaults. This strategy worked well in Sri Lanka where the World Bank underwrote the loans provided to micro hydro developers by local banks [28]. Alternatively, the GoR could establish a revolving loan fund for renewable energy development, potentially as a component of FONERWA. For example, in Peru, a revolving loan fund was established in the 1990s by the NGO Practical Action and the InterAmerican Development Bank. It had an initial capitalization of US$520 thousand and provided loans ranging from US$10-50 thousand with a repayment period of up to 5 years and an annual interest rate of 8 percent (at the time, the commercial rate was at least 12 percent). As loans are paid back, the fund continually relends them for construction of new micro hydro dams.

Whichever financing scheme the GoR pursues, in order to secure a loan or grant, a hydro developer should first be able to demonstrate that there will be demand for the energy produced. To be financially viable, micro dams must operate with a high load factor – i.e. a large proportion of the energy produced must be consumed. When a micro hydro dam is located near to the central grid, a high load factor can be guaranteed through a power purchasing agreement (PPA) or a well-designed feed-in tariff, which are discussed in detail in the section 6.4.1. Profitable operation in non-electrified areas is more difficult, as mini-grids often do not consume enough electricity throughout the day to provide a high enough load factor. Consideration should be given to productive end-uses of the energy from the outset. For example, a hydro plant could be developed in tandem with an "anchor consumer" such as a mill, school, or tea plantation that will make up the bulk of the load factor. Night-time uses for electricity should also be considered, such as battery charging stations. Once the load factor is guaranteed, it is then possible to consider construction of a mini-grid [28].

Whether privately owned and operated or not, it is generally desirable that mini-grids operate in a commercial manner. Subsidized tariff rates are often an unnecessary and endless sink of public funds. To extend electricity services to low-income households that cannot afford commercial tariff rates, an operator could instead charge higher rates to more affluent households in order to cross-subsidize lower "lifeline" rates for less affluent [28].

For a commercial operator, there is often little incentive to construct and manage a mini-grid in areas where energy consumption is very low. In Rwanda, there are a number of micro hydro plants built with public funds from the government and donors that are not fulfilling their purpose of providing electricity to low-income rural households. To improve the performance of these hydro plants, the GoR should consider performance-based grants rather than direct tariff subsidies. For example, DFID is currently implementing a pilot project with six micro hydro plants in which it will pay upfront grants to the operator for each new household connected and a monthly payment for ongoing connections contingent on successful management. The GoR should implement similar performance based grants to new and existing micro hydro plants with similar management issues.

Capacity

Issues that have been identified relating to current micro-hydro plants are largely related to maintenance and financial management. Local capacity needs to be developed in order to ensure functionality of the installed hydropower station. Lack of local capacity for maintenance is often a cause of a poorly operating station. There are several ways in which this can be done [28]:

- Establish international or regional knowledge networks and ensure that foreign experts train local technicians.
- Strengthen technical schools and science institutes to build up local capacity.

- Project-driven approaches - involve local engineers in the planning and implementation of project and at the same time build up their skills.
- Including the local governments in the energy infrastructure planning process

In addition, restoration of currently installed hydropower stations should take place to ensure all are working at full capacity.

7.1.2 Solar PV

Solar energy is a viable option for Rwanda; average solar radiation is 4 – 6 kWh per square metre per day. At present the GoR plans to install solar PV in over 600 institutions. There is currently one solar PV plant connected to the grid – the 250 kW Kigali Solaire project. Given the potential, more could be made of the solar PV electricity generation opportunities. Small household PV systems are a relatively inexpensive way of giving households at least minimal electricity access. The 2004 Energy Policy only mentions solar energy as a "potential" source of energy for off-grid areas [30]. This is unfortunate, because although solar will not play a significant role in the GoR's efforts to produce 1000 MW by 2017, it could play an important role in achieving the GoR's goal of increasing access to electricity in rural areas. As previously mentioned, the GoR plans to have 50 percent of the population connected to the grid by 2017[2], bringing off-grid electricity to rural areas could lessen the immediate demand for grid connection and also reduce the pressure on national generation projects.

The Belgium Technical Cooperation (BTC) produced a study on the problems encountered with solar PV in rural areas. These can largely be summarised in four points. First, there are no standards regarding PV systems. This will need to be addressed in order to protect consumers. Secondly, there are a large variety of systems in use as the result of donations from overseas which unfortunately are incompatible with each other and, third linked to this there is little coordination between donor agencies. Last, there are a number of systems out of operation due to a lack of maintenance and technical capacity to operate and maintain the systems.

The GoR's support for the solar industry has been largely limited to public procurement for rural institutions: schools, hospitals, government offices, etc. Likewise, the GEF Sustainable Energy Development Project focuses on institutional procurement mechanisms. While such procurement schemes are a great tool to provide electricity to important rural facilities, they are not the types of subsidies necessary to kick-start a private solar industry. In fact, they may have a dampening effect.

When designing policies to promote private industry, policy-makers must consider the position of those in the private sector[16]; it is the entrepreneur's willingness to take on risk that is going to drive the industry. Public procurement schemes serve to remove that risk. Private companies can safely import products to meet their buyers' needs and will have very little incentive to venture into private markets.

There are three main bottlenecks to the private solar industry:

1. A lack of solar entrepreneurs that not only sell solar products, but also provide after-sales-service.
2. Low purchasing power of consumers.

The first barrier, the lack of solar entrepreneurs and technicians requires a number of interventions: an incentive to encourage private companies to both take on risk and provide after-sales-service for systems sold, lines of credit to allow them to do so. The policy that has been most effective in other countries to kick start the solar industry is a grant-per-unit-sold to the company that invoices the sale. The company can choose how much of the subsidy to pass on to the consumer, and how much to keep for itself. The appropriate level seems to be about 20 percent of the products cost – so for a US$500 system, US$100 [16].

Crucially, this subsidy should be made contingent on two factors: that the solar panels adhere to quality assurance standards, and that the invoice specifies the inclusion of a buy back guarantee. After a number of complaints over poor quality products, MININFRA established a task force to create basic standards for solar PV equipment and installation. The task force should draw from already established international standards, such as those provided by the Lighting Africa Initiative. They will be instrumental in enhancing customer awareness and boosting confidence in new lighting products and services, and making the grant contingent on them will be an important step in cutting out low quality products that threaten to spoil the market [16].

Solar panels require regular maintenance to function properly. Creating the proper incentives to ensure after-sales-service will a vital component of any successful solar strategy [16]. Often following installation there is little follow-up, which can lead to very low numbers of systems functioning. This has often occurred when SHSs are installed by a donor agency and there is no funding reserved for maintenance. If the SHSs are provided and installed by a private company which is receiving a grant-per-unit-sold, the GoR might consider withholding a portion of this grant for a specified number of years and only releasing it on the provision that the installation is functioning properly. However, this system might prove overly cumbersome. If so, at the very least, grants should be contingent on invoices including a buy-back guarantee [16].

The final barrier, the low purchasing power of the consumers, is a challenge. Price subsidies are an effective tool to promote a product when it is not cost-competitive with its alternative. However, in rural areas in Rwanda, solar products are cost-competitive as shown by table 8.

***Table 8**: Monthly amortized costs of solar and kerosene/battery charging[16]*

Solar Home System		Kerosene and Batteries	
Equipment	Monthly Cost ($)	Equipment	Monthly Cost ($)
50 watt SHS: **8 hrs of area lighting** **6hrs of task lighting** **60 Wh for radio/TV**	8.25	2 wick lanterns 1 mantle lantern 1 battery	9.25
100 watt SHS: **12 hrs of area lighting** **14hrs of task lighting** **150 Wh for other loads**	13.75	3 wick lanterns 2 mantle lanterns 2 batteries	19.25

The barrier is not overall cost, but the ability of the consumer to afford the initial investment costs. Whether a SHS costs US$500 or US$400 it will not make a difference to a low-income consumer. When the barrier to industry is the purchasing power of the consumer, the appropriate policy is consumer finance.

Securing a stream of consumer finance for SHSs will be difficult as Rwanda's microfinance industry is relatively nascent. However, there are a number of financial institutions operating in rural areas. The government could incentivize these institutions to extend loans for SHSs by providing partial guarantees, in which it would assume the risk of a certain percentage of clients defaulting, or by providing a grant-per-unit-financed. For example, a grant-per-unit-financed scheme for SHSs in Bangladesh began with a grant of US$20 per system, and gradually reduced the rate to US$7 per system [16]. The GoR may also have to extend or secure lines of credit to the financial institution so that it has sufficient liquidity to deal with increased demand.

If a stream of consumer finance cannot be secured, rather than subsidize the product price, the GoR could instead target smaller systems. Splitting products into smaller, more affordable units is a common method of overcoming low purchasing power. One example is a company in India that sells small packets of shampoo to target low-income markets [16]. Over the years, solar panels have also been split into progressively smaller, more affordable units. Solar LED lanterns represent the smallest unit possible – a single tiny panel, with a single light costing US$15-50. The solar LED lantern industry is still relatively small in Rwanda. DFID is currently launching a pilot project aimed at kick starting it. Over three years it will provide a grant-per-unit-sold, beginning at US$8 and declining to US$4, with a cap of

25,000 per year. The GoR should follow the development of this pilot project closely, and if necessary supplement or carry on the grant programme.

7.1.3 Biogas Digesters

Biogas digesters can offer a stable supply of energy at low cost. They can be used to supplement other sources of energy, including hydropower, which is susceptible to changing flow levels. Within biogas digesters, human and animal waste and plant residues can be broken down through a process of anaerobic decomposition to produce methane. The methane can then be combusted to produce electricity or heat for cooking. The by-product of the process is slurry that can be used as organic compost.

The GoR is currently implementing a National Domestic Biogas Programme (NDBP), funded by the Netherlands Development Organization (SNV), which is focused on using the methane gas for cooking. However, MININFRA is also interested in industrial biogas, possibly to feed into the national grid.

NDBP aims to install at least 15,000 biogas digesters in rural households owning 2-3 cows by the end of 2011. While the product is not applicable for the poorest households, the Government's one-cow-per-family programme may facilitate more widespread adoption. SNV is also exploring whether NDBP can generate carbon credits, and is in talks with HIVOS as a potential buyer through voluntary markets, which could provide a sustainable source of finance for operations.

NDBP offers an attractive mix of subsidies and financing. Each biogas digester costs approximately RWF 800,000. RWF 200,000 must be paid upfront by the consumer; RWF 300,000 is provided as a direct subsidy by SNV, and RWF 300,000 is provided as consumer finance by Bank Populaire. The proper financing elements are in place; however the programme has been slow to take off. It may be necessary to offer a greater portion of the cost as consumer finance, as RWF 200,000 is still a very high upfront cost for most rural households. Also, it might be more effective to offer the grant portion to the businesses implementing and maintaining the biogas digesters, rather than the consumers, as performance-based grants incentivizing entrepreneurs to take on risk, scale-up operations, and market their products. With increased competition, a large portion of the subsidy would presumably be passed on to the customer either way. Finally, it may be necessary to invest in marketing and demonstration to promote consumer awareness of biogas digesters.

Table 9: Comparison of three small-scale technologies: Micro/Pico hydro, Solar PV and Biogas digesters

Option	Capital Cost	Operating Cost	Potential Funding Source	Conditions required for promotion	Time to Delivery	Ease of Use	Development Benefit	Climate Benefit	
								Mitigation	**Adaptation**
1. Micro/Pico Hydro	~US$1000 – 6000 per kWh	low	Private sector, CDM, donor agencies, GoR	Simplify legal and regulatory framework	Short to medium: 5-10 years	Established technology within Rwanda	Increases supply, Employment,	Low carbon	
2. Solar PV	USD 4.3 million for 0.38 MWe Av. Cost of US$15.000 – 22.5000 per KWc Purchase price of 20cUS$/KWh by users	Low, annual overheads approx 1% of the total costs of equip. installed, made up of:	Private sector, CDM, donor agencies, GoR	Specify adequate feed in tariffs, Waiver of import duties on equipment, Setting of standards	1-5 years	Simple to use	Enables productive night-time activities, saves kerosene fuel costs, health benefits. Can reach rural areas without need for grid extension	Low carbon	Diversifies electricity source
3. Waste to energy – Biogas digesters	National Domestic Biogas Programme funded by Dutch Gov	Low	Subsidies to households to acquire digesters needed		1-5 years	Simple to use, Reasonably widespread applicability	Lower fuel bills / time collecting fuel	Reduced forestry resource use	Diversifies electricity source

7.2 National Security

Table 12 (page 32) compares the four technologies discussed in this section.

7.2.1 Large-ScaleHydropower – Domestic and Regional

Rwanda has substantial hydropower potential and this should be utilised. Hydropower on a larger scale produces cheaper electricity than hydro projects of a smaller scale (see table 10). Large-scale hydropower has in the past had fairly negative connotations; in particular the negative environmental effects and the displacement of people often involved in the projects[31]. However, it is widely recognised that large-scale hydropower can bring large development and economic benefits if correctly implemented. A substantial number of reviews of large-scale hydropower projects have been conducted, from which a number of lessons and guidelines have been established for their implementation, outlined in section 5.1.3.

***Table 10**: Cost comparison of electricity generation costs[32]*

Technology	Power range	Generation Costs (US cents/kWh)
Large hydro	> 10 MW	3-4
Small hydro	1MW – 10 MW	4-7
Mini hydro	100 kW – 1 MW	5-10
Micro hydro	1kW – 100 kW	7-20
Pico hydro	100W – 1kW	20-40
Wind	3kW – 100 kW	15-25
Solar Home System	20W – 100W	40-60

Large-scale hydropower has often been criticised due to the treatment of people who are displaced in order to construct them and the negative environmental effects that can occur. The people affected are often the poorest and most vulnerable. Of the guidelines drawn up by the WCD (section 5.1.3) a key success factor is good communication – this must be used to ensure public acceptance of the project before it takes place. In addition, those that are negatively affected by the project should be given adequate compensation so that they too gain benefits from the construction.

One of the key challenges in the large-scale hydro power generation projects planned by the GoR is that a number of them involve shared resources; Rusizi III and IV will be shared with the DRC and Burundi, Rusumo falls with Tanzania. In addition, the Rusumo Falls plant will be based on a river in the Nile basin, this resource is used by a number of countries downstream. Effective communication and management will be necessary to successfully implement and run these hydropower stations. Studies on potential water and energy resource sharing agreements should be investigated so that all countries can benefit from energy and clean water. Rwanda could benefit from imported energy in exchange for maintaining a clean water resource.

7.2.2 Geothermal

Geothermal energy offers a renewable low-carbon source of electricity. It is unaffected by climate and weather changes, its main advantage is that it is available 24 hours per day, 365 days a year and are only shut down for maintenance. Power generation systems typically have capacity factors of 95%. It is therefore extremely useful for increasing the climate resilience of the energy sector and diversifying the generation. Geothermal is also a relevant technology for developing countries: among the top 15 countries in electricity generation from geothermal, 10 are developing nations[6].

Geothermal power is commonly divided into two categories; electricity production and direct application. Conventional electric power production is commonly limited to fluid temperatures above 150°C, but considerably lower temperatures can be used in direct application [33]. In Kenya, the less productive wells that have been drilled are being utilised for direct uses such as greenhouse heating. The geothermal technology is well known and well developed and the risk lies in initially confirming the resource size by drilling. Most of the geothermal plants when installed have very low maintenance costs and high availability[1].

Geothermal exploration and development in Rwanda is still at a very early stage and substantial investments are required to accelerate geothermal development [34]. Surface reconnaissance studies have been carried out in the western region (Gisenyi, Karisimbi and Kinigi). However, further detailed surface studies and exploration drilling needs to be carried out in order to confirm the resource potential. At present, estimates of the resource are around 700 MWe[34]. Experience from other countries show that good studies of the resource are essential for bringing down costs and ensuring that initial drilling targets the most productive areas. This is essential for stimulating confidence in the resource and attracting private investment.

The GoR is understandably giving high priority to geothermal development. Following the confirmation of the resource, it is important that a competitive bidding process is set up for private companies that wish to develop the resource.

There are several actions and policies that can be implemented to minimise risks; a well-defined risk strategy is important to develop.

Capacity

At present, Rwanda needs to develop technical capacity in geothermal power, this is critical for the sustainable development of geothermal resources[35]. This can be gained through developing relevant University courses and overseas training, both at universities and in industrial placements. The UNU-GTP, KenGen and the Geothermal Development Company are investigating the possibility of setting up a permanent regional short-course in geothermal energy. Before national capacity is developed, experts from abroad will need to be brought in. It is important that these experts develop the national capacity whilst implementing projects.

Although other countries in the Eastern Africa region may also have geothermal potential, various barriers, such as the high initial costs and institutional and regulatory barriers, have prevented its exploitation. Within the region, only Kenya and Ethiopia have developed their resources. In order to overcome these barriers, a number of organisations have developed support programmes [36]. One example is an African Rift Geothermal Facility (ARGeo) that has been established. This project is funded by the Global Environment Facility (GEF) and was initiated by six countries – Ethiopia, Eritrea, Djibouti, Kenya, Uganda and Tanzania. It is to be implemented by the United Nations Environment Programme (UNEP) and the World Bank[35]. The ARGeo project was officially approved by GEF in May 2010 and will run for the next 5 years.

Although Rwanda is not part of this project, ARGeo has stimulated a separate facility proposed by KfW, designed to mitigate risk in geothermal development. This facility will be available to Ethiopia, Kenya, Rwanda, Tanzania and Uganda[35].

Regional projects such as these highlight the potential for Rwanda to become a leader in this technology in the region in the future. The technical capacity and experience of pioneer countries in this technology, such as Rwanda, can serve as an example upon which other regional projects can be based. In the long-term, a regional network of geothermal agencies can deliver capacity building activities, information and databases, as well as best practice in policies and regulatory frameworks. The unified geological setting of the rift and similar challenges related to data collection and interpretation means that lessons learnt and skills gained in Rwanda during geothermal resource development will be applicable to other countries in the region [35]. In this respect, development of technical capacity now will enable Rwanda to become a regional knowledge hub in the long-term.

At present, technical capacity in the region varies between countries. Kenya has made considerable investments in its human resources and as such is strong in geophysics and environmental issues. Ethiopia has a knowledge base strong in geochemistry. Rwanda can make use of this expertise and also move to fill in the knowledge gaps.

7.2.3. Methane

Lake Kivu is estimated to contain 250 billion cubic metres of carbon dioxide and 55 billion cubic metres of methane gas. For electricity production, the quantity of methane that is available is believed to be sufficient to power 700 MW of electricity generation (350 MW for Rwanda) over a period of 55 years [2]. Electricity generation from this source represents a relatively low-carbon, domestic source of electricity. Exploiting this resource will diversify electricity generation and, as it is unlikely to be significantly impacted by climate change, will increase Rwanda's climate resilience. At present there are four projects on-going at Lake Kivu [2]:

1. ContourGlobal Gas-to-power project:

This projects concerns construction of 100MW methane power plant in two phases by an American company, ContourGlobal,

First phase: 25 MW (2012),

Second phase: 75 MW (2013)

2. Methane Pilot Project by the Rwanda Investment Group (RIG) (50 MW)
3. Gas-to-Power Project:

Kibuye Power pilot (KP1) project (3.5 MW), Israel Africa Energy Ltd (50 MW)

Phase 1 (at least 5 Mw) by end 2012,

Phase 2 (25 Mw) by 2013,

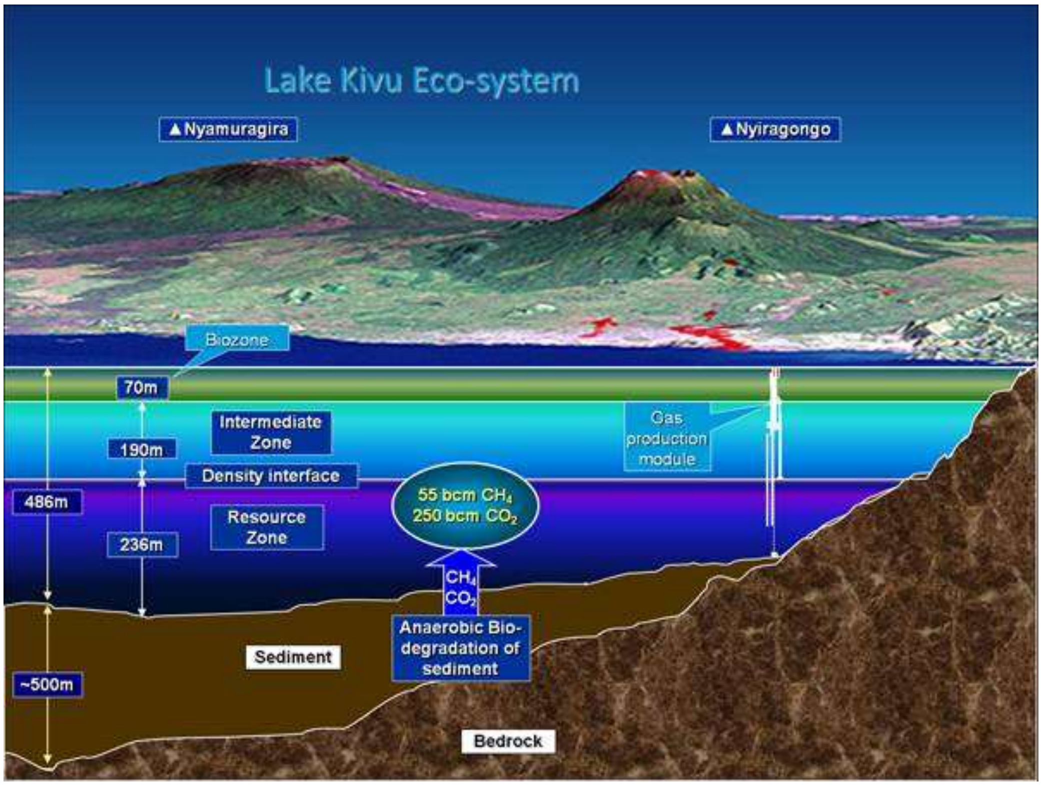
Phase 3 (20 Mw) by 2015

The KP1 project has since 2008 delivered only 1.2 MW to the grid; out of a capacity design of 4.5 MW.

4. Joint Project between Rwanda and DRC:

A joint 200 MW project between Rwanda and DRC with a 100 MW share for Rwanda

***Figure 3**: The layers and resource zones in Lake Kivu*



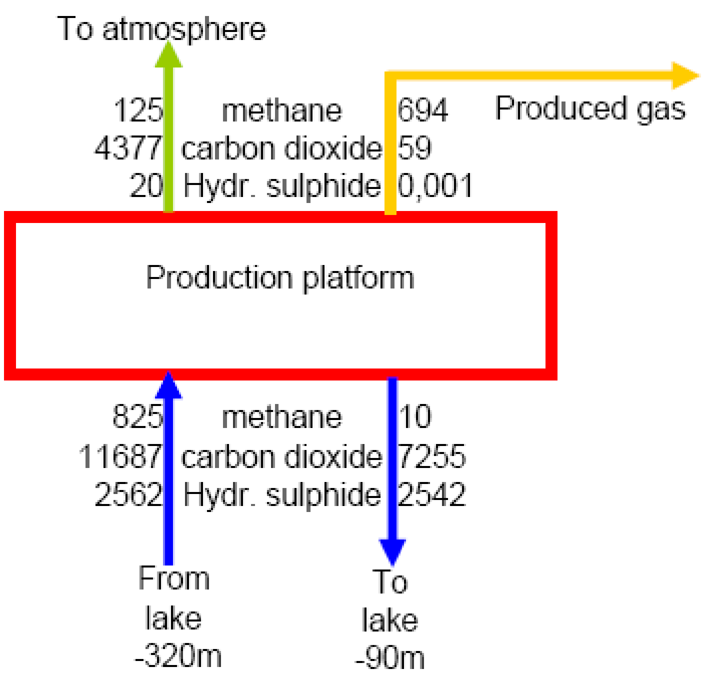
The GoR developed a set of management prescription for Lake Kivu Development in 2009 [10], to which it is essential that all companies operating there adhere in order to ensure the safety of the operations. These form the basis for the GoR's legislation for licensing and development of the lake. The gases in the lake present a safety hazard to those living nearby. Methane must be removed from the lake to reduce the risk of dangerous, uncontrolled gas outbursts. At least in the short to medium term, the total rate of methane extraction from all operations should be greater than the rate of estimated natural increase, which is approximately equivalent to 100 to 150 MW of power generation [10]. However, risk lies in increasing the size of extraction as this has never been done before. In doing this, it is very important that the overall density gradient of the lake is not weakened, and therefore that the overall stability of the lake is not reduced [10]. The main density gradient, at approximately 260 m (figure 3) must remain strong enough to prevent the movement of dissolved methane upwards from this region.

The key objectives of the Management Prescriptions are[10]:

- Public safety and well-being of the lake community
- Environmental safety for the lake and surrounding area
- Socio-economic benefit, through efficient extraction and sustainability of the resource
- Commercial viability for the developer of the gas production plant.

At present a small amount of the CO2 and methane that is extracted from the lake is released into the atmosphere. If the technology could be developed that prevented these leakages then this means of generation would be viable for carbon credits. Figure 4 shows the transfers of gases that take place in the application of the technology used by Contour Global. About 84 % of the methane extracted ends up in the produced gas, 15 % is vented to the atmosphere, and 1 % is returned to the upper part of the lake (below the biozone). A difficulty in utilising new technology for methane extraction lies in the fact that the methane is a shared resource. A large part of Rwanda's share in this resource has now been contracted out.

Figure 4: The end destinations of the three gases involved in methane extraction from Lake Kivu [9].



7.2.4 Peat

There are both benefits and drawbacks to utilising Rwanda's peat resources for electricity production. In terms of the low carbon aspect of this report, peat does not fare well with high emissions levels. Table 11 shows the CO2 emissions from peat compared to other sources of energy. Given the focus of this report of low-carbon growth, peat is therefore not an ideal choice. From a carbon perspective alone other forms of generation, including diesel-generated power would therefore be preferable. However, it is not realistic to view electricity generation in only these terms; for Rwanda development is a key issue. The use of imported diesel-powered plants and fuel would generate lower CO2 emissions per KWh; however, they do not compare well in terms of cost being much more expensive.

***Table 11**: Comparison of fuel by emission factor (Source: IPCC[37])*

Fuel	Emission Factor
Peat	106 g CO_2/MJ
Coal	95 g CO_2/MJ
Diesel Oil	74 g CO_2/MJ
Natural Gas	56 g CO_2/MJ

The exploitation of peat resource does bring other benefits; after mining the peat the land is much better for farming. During the mining process the water movement through the soil is improved which benefits potential future farmers. In addition, the peat used for electricity generation is unsuitable for using as fertilizer except after being burnt when the ash can be used. It is quite dangerous if this ash is generated by burning the peat in the bog and when produced in this way, can burn for many years. Studies should be conducted into the effects of burning peat for energy combined with diesel on the chemical composition on the resulting ash.

Peat could be used to generate electricity to cover the intermediate load whilst the base load generation could be produced using renewable energy such as geothermal[38]. If this was the case, the peat power plant would be ramped up and down during the day and potentially turned off several times a year. This role is currently being played by diesel generators which are vastly more expensive[38]. Peat could also be used to increase electricity generation if there are delays in geothermal, methane or large-scale hydro projects. However, if peat is used to generate electricity it should be considered as a short-term measure to increase supply and should be phased out as soon as possible due to the negative impact that its use has on the environment and the fact that it is not an endless resource.

7.3 The National and Regional Electricity Transmission Network

At present electricity is transmitted along around 386.6 km of high voltage power lines (110 KV and 70KV) and 4900 km of medium and low voltage lines (30 kV, 15 kV and 6.6 kV and low-voltage of 380 volt three-phase and 220 volt single-phase). There are plans to increase the grid extent by 2100 km (700 km of HV and 1400 of MV) by 2017[3].

There is considerable energy potential in the East Africa Region and there is potential for regional cooperation. The East African Community (EAC) Secretariat produced an East African Power Master Plan in 2003 [39]. This covered three countries – Kenya, Tanzania and Uganda – and produced a 25 year plan aiming to develop power generation and transmission project with a regional perspective enabling the most competitive and advantageous projects to be utilised. This study is now being expanded to include Rwanda and Burundi in the EAC as well as five other countries. The opportunities highlighted by this study should be investigated. There could be potential for using imported energy for meeting peak load demand without having to deploy peak load generation technologies such as diesel generation or peat. In addition, the connection could mean that Rwanda can benefit from exporting electricity thus generating income.

There are several regional interconnection transmission projects to link Rwanda with Uganda, Burundi, DRC and Tanzania. In addition, there are plans to strengthen transmission links within Rwanda to make the most of these connections. An assessment of the requirements of these connections highlighted that due to the high expected load in Rwanda and within the region the operation of the new lines would have to be on the 220 kV level. There are studies that proposing the potential for 400 kV linkages[40].

7.3.1 Smart Grids

Both decentralized and national grids can benefit from aspects of smart grid technologies [41]. The Smart Grid concept incorporates the entire electricity supply chain and is characterised by the use of technologies to intelligently integrate the generation, transmission and consumption of electricity [42]. One definition of a Smart Grid from the Electric Power Research Institute is 'a modernisation of the electricity delivery system so it monitors, protects and automatically optimises the operation of its interconnected elements' [43].

In Rwanda there may be opportunities to 'leapfrog' the traditional power system and avoid old technology 'lock-in'. As the economic lifetime of electrical power equipment can be longer than 50 years developing a Smart Grid in Rwanda now could prevent a development of a dependence on technology that will be out-dated in the medium term [41]. Studies should be done on the feasibility of Smart Grids in Rwanda.

7.4 Other Opportunities

7.4.1 Energy Efficiency

Energy efficiency is a key way of reducing demand and its value cannot be stressed enough. If possible it should be analysed for its impact on load growth assumptions. The biggest opportunities for efficiency are at the end use, e.g. lighting, and will be covered in the Built Environment Working Paper. However, in the production and distribution there is room for improvements that will make the system more efficient. According to information provided by RECO-RWASCO, loss of energy in 2005 due to the transport and distribution of electricity including commercial loss is estimated at 20% [2]. A potential way of increasing the efficiency could be through increased use of distributed power generation, which can reduce losses through electricity transportation.

The use of combined heat and power (CHP) involves the generation of both heat and power in the same plant, maximising the use of energy produced. In conventional power production large quantities of heat that are produced as a bi-product are wasted. CHP can enable total energy conversion efficiencies of 90% [44].

7.4.2 Other Technologies

There are many other potential sources of electricity which have not been explored here in detail due to their present unfeasibility.

- Nuclear power: this technology is relatively high cost in comparison to alternatives at present
- Wind: A wind map of Rwanda has been produced from five locations; this revealed that Rwanda's wind potential is low with low capacity factors at all sites measured [45].

Other technologies that have also not be explored in detail due to current lack of data on potential feasibility but which may have potential following further investigation include:

- Biomass: This technology is low carbon as the carbon dioxide that it produces was previously combusted by the plants involved [46]. One issue is that biomass fuels are lower in energy and density than fossil fuels meaning that large quantities must be grown for combustion. Biomass energy is therefore most suited to small-scale local generation facilities or CHP [47]
- Concentrated solar: requires direct sunlight, more technically complex as the panels must move to face the sun. Potential for combining with biomass electricity generation at night. Storage of electricity generated in large-scale concentrated solar plants is an issue. Lighting is one of the key requirements for electricity use; however solar plants do not generate electricity when it is required. Solar could be used by industry during the day displacing diesel generated electricity until the evening.

7.4.3 Importing Gas

Natural gas has a much lower emission factor than peat, oil and coal (table 11). It is also relatively abundant and low cost due to the technical developments in shale gas extraction. Further studies should be conducted in order to find the full costs of importing gas and potential gas pipeline construction.

Table 12: Comparison of large-scale electricity generation technologies

Option	Capital Cost	Operating Cost	Potential Funding Sources	Conditions required for promotion	Time to Delivery	Ease of Use	Development Benefit	Climate Benefit	
								Mitigation	**Adaptation**
1. Geothermal	$935 million USD for 310 MWe	1% of capital	Private Sector	Legal and contractual framework for private sector exploration	2 years (once decision for location is made, takes 2 years to complete power plant), long term	Once built, minimal maintenance required. However, low levels of technical capacity in Rwanda.	Increased electricity supply, Can bring jobs to local community during construction, Reduces cost of electricity	Renewable energy.	Not sensitive to climate change. Reduces dependency upon hydro power.
2. Hydro	€260 million (Rusizi III) $875 million for 291.9 MWe	low	Private Sector, IPP	Need for communication and awareness raising at all levels	Medium – long	Political issues over managing regional shared resources	Increased electricity supply. Employment Social impact Reduces cost of electricity	Renewable energy. No carbon emissions.	Water storage
3. Methane	$905 million USD for 299.1 MWe		Private Sector, IPP	Safety prescriptions need to be adhered to	Medium term – 10 years	New technology, limited technical capacity	Increased electricity supply. Employment, Social impact, Reduces cost of electricity	Renewable energy. Low carbon.	Not climate sensitive. Again reduces dependency upon hydro.
4. Peat	$300 million USD for 100MWe	Electricity generated at a cost of around Euro 6 cent/kWh	Private Sector	Adequate feed-in tariffs needed	1-5 years	Easy to use and run	Increased electricity supply. Employment Reduces cost of electricity	High emissions	Diversifies electricity supply

7.5Implementation

The four main barriers to implementation – finance, capacity, legal and institutional frameworks and data – each need to be addressed as all four are needed for successful implementation. They are interlinked: for example, private finance can be put off by a poor legal and institutional infrastructure.

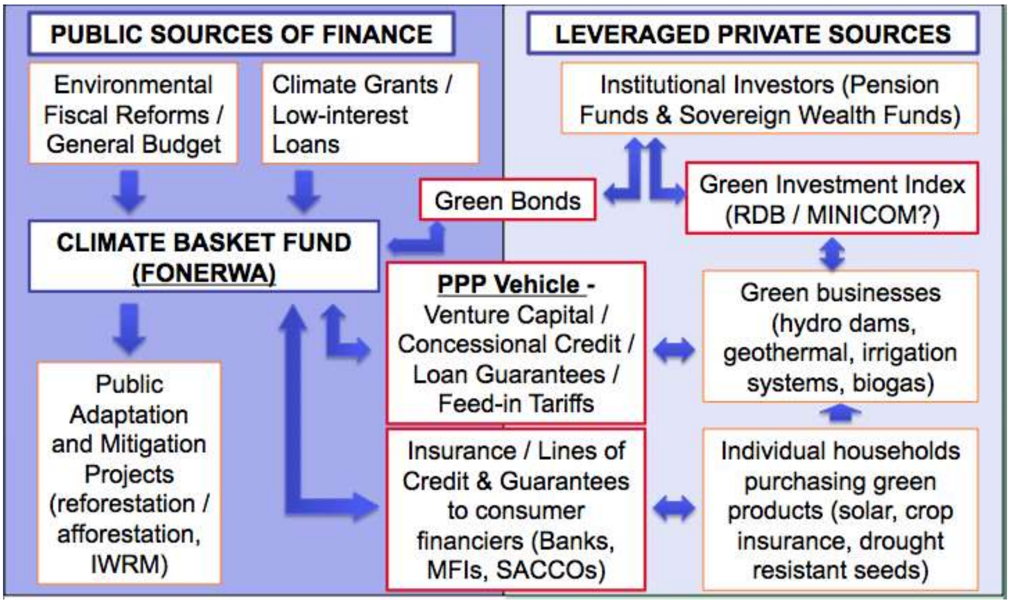
7.5.1 Finance for Renewable Energy

A substantial portion of the finance for renewable energy should come from private sources: investors in mega projects such as geothermal, methane, and large hydro; small and medium enterprises (SMEs) that construct micro-hydro dams and mini-grids; and individual households and businesses that purchase private energy units such as solar panels and biogas digesters. However, public sources of financing can be used to incentivize this private investment. As illustrated in Figure 5, grants, concessional lines of credit, loan guarantees, public venture capital, equity capital, and mezzanine finance can be used to leverage private capital for low carbon projects. Annex 2 provides a list of public financing mechanisms and the investment barriers that they address.

Public Finance

Public financing could come from a variety of sources including the general budget or Rwanda's future environmental fund, FONERWA. FONERWA, in turn, could be capitalized by bilateral development partners as well as fiscal sources. To enable non-grant financing mechanisms to be utilized, a portion of FONERWA should be managed as a venture capital/revolving loan fund by the National Bank of Rwanda (BNR) or by MINECOFIN. Such a fund could operate as a public enterprise and be instrumental in leveraging private capital towards renewable energy as illustrated in Figure 6.

Figure 5. *Using Public Funds to Leverage Private Sources of Finance*



Multilateral Grants

Concessional loans or grants for renewable energy could also be sought from a wide-range of multilateral development funds. A sample of relevant funds includes the Public-Private Infrastructure Advisory Facility, the GEF, the ClimDev-Africa Special Fund, the Global Energy Efficiency and Renewable Energy Fund, KfW Development & Climate Finance, the International Climate Initiative (Germany), the Hatoyama Initiative (Japan), and the Climate Finance Innovation Facility. Each has its own mandate, institutional requirements, and application and monitoring procedures which are outlined on the website www.climatefinanceoptions.org.

Clean Development Mechanism

Alternatively, the government could establish carbon projects for renewable energy technologies. Projects that reduce the amount of greenhouse gas emissions produced can monetize those emissions and sell them over the Clean Development Mechanism (CDM) or voluntary carbon markets. Carbon markets are discussed in depth in the Finance Sector Working Paper.

The first step to estimating the potential for a CDM project to reduce emissions is to calculate baseline, or the amount of emissions that would have been produced in the absence of that project. The method used to calculate the baseline varies according to the scenario. A list of approved methodologies can be found at http://cdm.unfccc.int/.

To make baseline calculations easier, Rwanda's Designated National Authority has provided the emission factor of the electricity grid: for each MWh produced by the central grid, 0.7 tCO_2 are emitted. As seen in Figure 6, this emission factor is relatively high compared to other countries in the region, and is the result of the high proportion of electricity produced by burning fossil fuels. Combined with the high cost of importing these fossil fuels, Rwanda's high electricity grid emissions factor should increase the viability of renewable energy CDM projects.

Figure 6. *Electricity Grid Emission Factors of Select African Countries (Source: Blodgett, 2009[48])*

Country	Grid emission factor (tCO2/MWh)
Ethiopia	0.006
Swaziland	0.17
Ghana	0.41-0.58
Kenya	0.43
Egypt	0.49-0.51
Uganda	0.58
Cote d'Ivoire	0.59
Rwanda	0.70
South Africa	0.95-1.25
China (average)	0.93

As seen in Box 2, there is a particularly high potential for Rwanda to access carbon finance for the development of hydroelectric dams, both through standalone CDM projects and pCDM. There is also standalone CDM for geothermal, and programmatic CDM potential for biogas digesters, solar home systems, and solar lanterns. More research is required to determine whether there is potential for generating carbon revenues through the electricity produced with Lake Kivu methane. It would likely need to be demonstrated that a more expensive and less carbon intensive technology was chosen over cheaper carbon-intensive alternative.

Box 2. Calculating the CDM baseline calculation for hydro electric dams

The methodology used to calculate the baseline will depend on the size of the dam, and whether it is connected to the central grid or not. Methodology AMS.I.D is used for small-scale hydro dams (or any other renewable energy source) that will feed into the central electricity grid, thus offsetting more carbon intensive sources of electricity. Small-scale hydro dams that supply a mini-grid with total capacity not exceeding 15MW would use AMS.I.F, and standalone off-the-grid hydro dams would use methodology AMS.I.A. The latter methodology will be discussed in the section on solar PV. Large-scale dams fall under ACM0002. In each, dams are only eligible in the following conditions:

1. The dam is implemented in an existing reservoir with no change in the volume of the reservoir;
2. The dam is implemented in an existing reservoir, where the volume of reservoir is increased and the power density is greater than 4W/m2;
3. The dam results in new reservoirs and the power density of the power density is greater than 4W/m2.

To illustrate, let us consider a 100 kW dam that will feed-in to the electricity grid. The baseline calculation for methodology AMS.I.D is as follows:

$$BE_y = EG_{BL,y} * EF_{CO_2,grid,y}$$

Variable	Definition	Value
BE_y	Baseline emissions in year ‘y’ (tCO2)	490.56 tCO2/year

$EG_{BL,y}$	Quantity of net electricity supplied to the grid as a result of the implementation of the CDM project activity in year y (MWh)	700.8 MWh/year
$EF_{CO2|,grid,y}$	CO2 emission factor of the grid in year y (tCO2/MWh)	0.7tCO2/MW

A 100 kW hydro dam operating at a realistic 80 percent efficiency for 8760 hours per year will produce 700.8 MWh per year, resulting in a carbon offset of 490.56 tonnes each year. Valued at US$15 per tonne, this represents a potential subsidy of $7358.40 per year minus transaction costs. For mini-grid systems using methodology AMS.I.F the baseline equation is exactly the same as above, except that the emissions factor is a default value for a modern diesel generating unit, which will result in an even higher offset.

The cost of developing a hydro dam is site specific. Although size-cost is generally not a linear relationship, the cost generally ranges from US$1200 to US$6000 per kW. Using this price range, a 100 kW hydro dam would cost between $120,000 to $600,000 to build. Carbon finance could be generated for either seven years and renewed twice, or ten years and renewed once. Twenty years of carbon finance at $7358.40 per year would amount to $147,168 minus transaction costs. Of the population connected to the grid in Rwanda, the average electricity consumption per person is 720kWh/person. A 100 kW dam, producing 700,800 kWh per year, could thus serve almost one thousand people.

An important decision that the GoR must address is how it should support CDM initiatives. Should it initiate projects and programmes on its own, perhaps with MININFRA or RECO operating as the implementing entity, or should it instead support private companies and NGOs to develop CDM projects? There is significant risk in developing a CDM project – if carbons credits are sold that are found to be "erroneously included" there could be financial liabilities. However, the GoR has advantages over other organizations in that it can more easily achieve the scale necessary to access markets, and it has the financial capacity to pay the upfront costs. Another type of organization that could potentially achieve the necessary scale and funds to fulfil these requirements are microfinance institutions. Box 3 discusses some of the potential synergies between microfinance institutions and CDM programmes for small-scale technologies.

The appropriate action for the government to take will vary from project to project, and will depend largely on how involved the GoR is with implementation. For those potential projects that the government will not implement on its own, it should ensure that adequate technical assistance and public financing is in place to allow the implementing entities to overcome the initial investment barriers.

Box 3. Potential synergies between Microfinance Institutions and Programmatic CDM

Microfinance Institutions (MFIs) have a number of attributes that make them logical vehicles through which pCDM could be implemented. The two are similar in structure and concept. To overcome the high transaction costs associated with delivering small products and services, both MFIs and pCDM aim to achieve economies of scale by delivering high volumes of micro-products and services. MFIs are often embedded in small rural communities, which are the primary market for decentralized renewable energy. Estimates of the number of global microfinance customers are in the hundreds of millions, making MFIs in aggregate the world's largest network with a direct relationship with the poor. Loan officers are generally educated and meet with their members on a weekly or bi-weekly basis, providing a valuable platform for the 'piggybacking' of products and dissemination of information. Finally, successful MFIs are characterized by strong management, which is an exception rather than the norm among organizations in the areas that they operate [49]. Below are potential synergies we identified between MFIs and pCDM projects:

1. MFI networks can be used to broker small-scale energy technologies to low-income populations en masse. At centre meetings loan officers can inform borrowers about the health and environmental pitfalls of traditional fuels, and the advantages of renewable energy.

2. MFIs can provide consumer finance for purchases of technology allowing clients to overcome high initial investment costs, and pay for products in small instalments over a prolonged period.

3. MFIs generally have a system in place for monitoring borrower's loan utilization, which could be leveraged to include monitoring of carbon offsets.

4. MFIs are well positioned to organize and finance community-level carbon offset projects, such as reforestation/afforestation and large biomass plants or run-of-the-river hydroelectric dams that can provide electricity to multiple households.

5. MFI employees' experience delivering large volumes of microfinancial services would translate well to managing and implementing pCDM projects.

The largest financial institution operating in rural areas of Rwanda is the Union des BanquesPopulaires du Rwanda (UBPR), a cooperative and credit union network with commercial bank status. Traditional microfinance institutions are relatively small, but included Urwego Opportunity Bank (UOB), Centre Financier Aux Entrepreneurs (CFE), COOPEDU-Kigali, Duterimbere, Rwanda Microfinance Limited, and Union Des CoopecsUmutanguha. More research will need to be done to determine the capacity and interest of these MFIs in becoming involved in carbon projects.

Feed-in Tariff

Feed-in tariffs have proven to be the most successful policy mechanism to promote private investment in renewable energy such as micro and pico hydro, solar home systems, and wind power. Feed-in tariffs provide a secure investment environment for independent power producers (IPPs) by guaranteeing long-term procurement of the energy at a fixed-rate for typically 15 to 20 years. According to Deutsche Bank feed-in tariffs are responsible for 75% of global solar photovoltaic power deployment and almost half of global wind deployment. They are championed by twelve American states, China, Germany and Spain – first, second, third and fifth in renewable energy world rankings (India ranks fourth[50]).

It is important that Rwanda not only implement a feed-in tariff to incentivize private production of electricity, but also a law stating that once the grid is expanded to include an area with private electricity producers, the utility will either purchase the technology outright, or it will begin procuring the electricity via the feed-in tariff. IPPs will be hesitant to invest in a renewable energy unit if they feel there is a chance that the electricity grid will expand to their region. This law will remove the danger facing IPPs that grid extension could undermine their business.

A recent tariff study, commissioned by RURA (Economic Consulting Associates 2010), explored the potential for Rwanda to implement a feed-in tariff. The study proposed that the tariff could be set at the rate equivalent to the costs avoided by the utility by purchasing the electricity from IPPs rather than other sources. It proposed the tariff be set at FRW 69 ($0.115) per kWh for individual electricity producers selling exclusively to RECO, and FRW 49 ($0.0817) per kWh for electricity producers selling only their surplus, taking into account that those selling their surplus will likely be providing electricity to the grid predominantly during off-peak hours. However, the avoided costs will likely be much higher than these rates. As stated in the study, the current rate of electricity is FRW 112 ($0.187) per kWh before taxes, which was predicted would decrease to FRW 89 per kWh ($0.149) in 2011-2012. The reason given for the reduction from FRW 89 to FRW 69 is that many IPPs will be selling to the grid from a region that is a net exporter of electricity, and thus the utility will also need to pay for transmission costs. While this may be so, the estimates rely on an ambitious assumption that electricity prices will fall 20.5 percent.

In order to ensure transparency in the pricing, the feed-in tariff should be determined by an independent body, and set at least as high as the current avoided costs of the utility. This price can be changed as electricity prices change, but to ensure a secure investment environment, changes should be grandfathered in so to speak, and investors should be guaranteed a stable price over a fixed term.

Taking into account the environmental benefits of renewable energy, the government might also consider setting the rate higher than that of carbon intensive energy. Doing so would create long-term costs, and it is important to consider who will be responsible to bare them. There are five separate possibilities:

1) **Regulatory tariff model (eg. Germany)** – The government could mandate that the utility (RECO) purchase the power at a rate set higher than the utilities avoided costs. The higher costs would then be passed on to consumers via higher electricity prices. This model is advantageous in developed countries, because the higher prices promote demand management. However, in Rwanda where electricity prices are already high and increased energy consumption is vital to economic growth, this model will likely not be Rwanda's first choice.
2) **Subsidized tariff model (eg. Spain)** – The government could subsidize the marginal increase in cost from the national budget. The costs would then be passed on to the taxpayer. Again, this model would likely not be Rwanda's first choice. As occurred in Spain, in which the government reneged on its feed-in tariff commitments, the costs could create a large burden on the national budget. Furthermore, with so much of the population living without electricity, it would be inequitable to pass the costs on to the taxpayer.
3) **Tax-exemption model** – By making renewable electricity tax exempt, the government could increase the avoided costs for RECO, enabling it to offer a higher rate to IPPs. Note that a tax-exemption is a form of subsidy from the taxpayer to the IPP, thus this model is a watered-down variation of the "Spanish-model."

4) **FONERWA Model** – The new environment fund could be used to pay the marginal cost of the feed-in tariff. This would be the simplest method and perhaps the most appropriate if FONERWA is primarily capitalized by donors.
5) **CDM Model** – An innovative alternative might be possible through a CDM Programme of Activities. In this case the higher price of the feed-in tariff for renewable electricity would be paid by those purchasing the carbon credits in Annex 1 developed countries. Using the emissions factor and baseline calculation discussed in Box 2, such a programme could add an extra US$0.0105 (FRW 6.29) per kWh minus transaction costs to the feed-in tariff rate. The advantage of such a CDM programme would be the reduced monitoring costs, because the energy fed in to the grid would guarantee that the technology is working.

7.5.2 Capacity

Capacity needs to be developed in Rwanda at a variety of levels in order to properly plan and implement energy strategies. Local capacities need to be developed as well as those within the relevant Ministries. Local technical and managerial capacity is essential for the sustainability of energy projects. Within the planning of electricity generation projects legal and financial capacity is also required.

Capacity can be developed through a variety of means:

- University training in Rwanda
- University training abroad
- Industrial placements abroad
- 'On-project' training – skills can be passed on from experts to local people; policies should be put in place to ensure that this happens.

Within MININFRA, at present the short-term nature of staff contracts in relation to both project length and training courses does not provide incentives for training and capacity building. This should be addressed.

In the long term, if Rwanda invests enough in developing domestic technical capacity, there is an opportunity to become a regional hub of expertise in renewable energies. There will be a high demand in the region for the technical skills that Rwanda will develop due to the similarities of the energy resources in the region. In addition there is potential for forming an 'African Energy Research Alliance' that would bring together key research organisation across the region allowing energy research to be aligned regionally. In addition, initiatives that bring together industry, the research community and the Government may be one future opportunity.

7.5.3 Institutional and Legal Frameworks

At present, MININFRA focuses upon both policy-making and implementation. Implementation is soon to be the responsibility of EWSA. This should allow MININFRA to focus upon policy-making and long-term planning. RURA, the regulator of the energy sector, plays a large role in providing licenses and permits for investments in the energy sector. Streamlining of these organisations would make the sector work more efficiently and encourage investors. Further studies should be conducted into how they can be made more efficient.

Master plans for each technology sub-sector should be developed to give a clear indication of intention to the private sector.

7.5.4 Data Gathering

Good quality data on a variety of areas is needed for effective planning. Data on the energy sector system as it is now is needed in order to assess how the sector is progressing towards its aims. Sound data is also necessary for mitigation and climate finance. In order to ensure an effective energy sector, it is recommended that the GoR collect data on the following:

- Energy resources, i.e. Hydro Atlas
- Efficiency of the system
- Projects implemented should be monitored for effectiveness/functionality
- Use of energy within Rwanda
- Use of electricity specifically
- Growth of the private sector in various technologies, including levels of investment
- Courses available for capacity development
- Research underway within research institutions
- Quality and safety standards
- Emissions from the sector
- Investment in technology research

Further studies should be conducted in order to identify other areas in which more data would be beneficial.

8. Strategic Framework

Overall, the strategies that the GoR has put in place are good in terms of a low carbon and climate resilience perspective. The majority of the large-scale generation options are low carbon and these should be priorities, particularly geothermal. Key priorities in terms of future national grid electricity generation include:

- Develop geothermal generation capacity as soon as possible
- Increase volume of hydropower electricity generation whilst decreasing its share of the generation mix to reduce the vulnerability to hydrological risks
- Increase the share of methane gas to power in the generation mix
- Reduce and phase out diesel generation of power. A strategy and timeline to phase out diesel-powered generation would be advisable
- Utilise the peat resource to make up the supply if delays occur in the development of other resources such as geothermal, methane and hydro
- Develop regional connections so that electricity can be both exported and imported where required

In terms of rural electrification and increasing access to electricity, utilisation of off-grid potential should be increased. This should be seen as pre-electrification and complimentary to the grid expansion plans. One way of increasing off-grid projects could be to encourage the private sector and rural micro-finance investment in small-scale renewable energy projects. Smart grid technology feasibility should be investigated and energy efficiency potential should be utilised.

In all electricity projects implemented it is clear from experience globally and within Rwanda that ensuring maintenance and sustainability is essential.

In the medium and long term, new technologies are likely to become feasible and research should be done to investigate potential new technologies for Rwanda.

In the short term, collecting more data on different energy resource potential in Rwanda is vital. This will enable the resources to be prioritised more effectively. In addition, capacity – technical, financial and legal - needs to be developed, within the relevant Ministries and across Rwanda. This will enable more effective implementation and planning and allow the Ministries to get the best deal possible when dealing with the private sector. In the long term, capacity should continue to be built. Rwanda has the potential to become a leader in the region and could develop itself as a 'knowledge hub'. Links between the research institutes in Rwanda, the Government and industry should be studied so that the best ways of linking the three to enable effective, relevant research and communication of this research are identified.

Assessments should also be conducted to identify ways in which the relevant Ministries and implementing organisations could be made more efficient and streamlined.

Given the range of low-carbon technologies being utilised in Rwanda it will be possible to access carbon finance, capacity for applying for this should be developed to maximise this opportunity.

Table 13 outlines the various policy options and actions related to each option and focus area that could potentially be implemented along with the timeframes involved and how they can be monitored. This table is elaborated on in Annex 3.

Key: Short term - 1-5 years
Medium term – 5-10 years
Long term – 10 years +

Table 13: Potential Policies and Actions for Each Focus Area

Focus Areas WHY	Policies WHAT	Actions WHAT	Timescale WHEN	Stakeholders WHO	Measurables HOW	Sources of Finance
Develop small scale generation	Encourage Private Sector Maintenance strategy Product standards Plan productive end uses	Grant-per-unit sold Removal of VAT and import tax Rural micro finance	1-5 years 1-5 years 1-5 years 1-5 years	MININFRA, EWSA, RURA, MINECOFIN, Private Sector	Uptake of solar in rural areas, No. of solar businesses, % working after X years, Load factors	Private Sector, Microfinance, Donors, Climate Finance
Ensure Renewables Development	Least Cost, Renewable Energy Development Plan Fossil fuel phase out timeline and strategy Peat phase out timeline and strategy	Local benefits Stakeholder engagement Private sector Efficiency	On-going Medium term Long term	MININFRA, EWSA, RURA, MINECOFIN, Private Sector	% renewables, % access, MW capacity, Cost, Feedback , Investment, Efficiencies	CDM, Climate finance, Private Sector, GoR
Capacity Building	Strategy for Local and within Ministries	Technical Schools University	On-going	MININFRA, EWSA, RURA, Private Sector	No. of courses, students	

	Knowledge hub for Renewables	courses Training abroad Regional knowledge networks Knowledge transfer Linkages: academe, Gov. and industries in region	Medium to Long term	KIST, IRST, NUR, MININFRA, EWSA		
Finance	Renewables feed-in-tariff Tax exemptions Develop CDM capabilities Encourage micro finance investment in renewables	Risk Guarantees Grant-per-unit sold	1-5 years	MINECOFIN, RURA, MININFRA, EWSA, RDB	% renewables No. of MFIs	GoR, Donor Agencies, Bilateral funding
Institutional, Regulatory and Legal Frameworks	Strategy for Private Sector Involvement Strategy for ensuring efficiency	Training on negotiations Regulations assessment RURA	On-going 1-5 years Short to	MININFRA, RURA, EWSA	Efficiency rates, investment from private sector	GoR, Donor Agencies, Bilateral funding

	Streamlining assessments Staff empowerment	EWSA MININFRA Training Long term contracts	medium term On-going			
Data Gathering	Resource maps Energy usage Efficiency	 Households Industry Storage needs	1-5 years and on-going	MININFRA, RURA, EWSA, local private sector, academia	Production of maps, data sets	GoR, Donor agencies

Resources

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Annex 1: *Status of Renewable Energy Technologies, Characteristics and Costs[51]*

Technology	Typical Characteristics	Typical Energy Costs (U.S. cents/kilowatt-hour unless indicated otherwise)
Power Generation		
Large hydro	*Plant size*: 10 megawatts (MW)–18,000 MW	3–5
Small hydro	*Plant size*: 1–10 MW	5–12
On-shore wind	*Turbine size*: 1.5–3.5 MW *Blade diameter*: 60–100 meters	5–9
Off shore wind	*Turbine size*: 1.5–5 MW *Blade diameter*: 70–125 meters	10–14
Biomass power	*Plant size*: 1–20 MW	5–12
Geothermal power	*Plant size*: 1–100 MW; *Types*: binary, single- and double-flash, natural steam	4–7
Solar PV (module)	*Cell type and efficiency*: crystalline 12–18%; thin film 7–10%	—–
Rooftop solar PV	*Peak capacity*: 2–5 kilowatts-peak	20–50
Utility-scale solar PV	*Peak capacity*: 200 kW to 100 MW	15–30
Concentrating solar thermal power (CSP)	*Plant size*: 50–500 MW (trough), 10–20 MW (tower); *Types*: trough, tower, dish	14–18 (trough)
Hot Water/Heating/Cooling		
Biomass heat	*Plant size*: 1–20 MW	1–6
Solar hot water/heating	*Size*: 2–5 m2 (household); 20–200 m2 (medium/multi-family); 0.5–2 MWth (large/district heating); *Types*: evacuated tube, flat–plate	2–20 (household) 1–15 (medium) 1–8 (large)
Geothermal heating/cooling	*Plant capacity*: 1–10 MW; *Types*: heat pumps, direct use, chillers	0.5–2
Biofuels		
Ethanol	*Feedstocks*: sugar cane, sugar beets, corn, cassava, sorghum, wheat (and cellulose in the future)	30–50 cents/liter (sugar) 60–80 cents/liter (corn) (gasoline equivalent)
Biodiesel	*Feedstocks*: soy, rapeseed, mustard seed, palm, jatropha, and waste vegetable oils	40–80 cents/liter (diesel equivalent)
Rural Energy		
Mini-hydro	*Plant capacity*: 100–1,000 kilowatts (kW)	5–12
Micro-hydro	*Plant capacity*: 1–100 kW	7–30
Pico-hydro	*Plant capacity*: 0.1–1 kW	20–40
Biogas digester	*Digester size*: 6–8 cubic meters	n/a
Biomass gasifier	*Size*: 20–5,000 kW	8–12
Small wind turbine	*Turbine size*: 3–100 kW	15–25
Household wind turbine	*Turbine size*: 0.1–3 kW	15–35
Village-scale mini-grid	*System size*: 10–1,000 kW	25–100
Solar home system	*System size*: 20–100 watts	40–60

Annex 2. *Public Financing Mechanisms (Taken from Gomez-Echeverri 2010[52])*

PFMs	Description	Financial Barriers Addressed	Financial Market Characteristics	Applicable Market Segment
Credit line for Senior debt	Debt facilities provided to commercial FIs for on-lending, and usually on a full-recourse basis. Typically meets 50-80% of project cost. Can also be offered on limited or non-recourse basis depending on FIs willingness to take project risk.	(i) lack of funds among FIs; (ii) shortage of long-term funds; (iii) high interest rates.	Underdeveloped financial markets where there is lack of liquidity and borrowing costs are high.	(i) large scale and medium scale RE and EE; (ii) wholesale loans for energy access market.
Credit line for subordinated debt	Debt provided to CFIs for on-lending, in combination with senior debt to improve security for senior lender. Typically meets 10-25% of project cost. Can take other legal structures such as convertible debt or preferred shares.	(i) lack of available equity among project sponsors; (ii) restrictive debt-to-equity ratio.	Lack of liquidity in both equity and debt markets.	(i) medium and small scale.
Guarantee	A risk management tool shares in the credit risk of project loans which CFIs make with their own resources. Typically covers 50-80% of outstanding loan.	(i) high credit risks, particularly perceived risks.	Existence of guarantee institutions and experience with credit enhancements.	(i) large-scale and grid-connected RE; (ii) medium scale RE and EE; (iii) energy access market.
Project Loan Facilities	Debt facilities organized by entities other than CFIs and providing financing to clean energy project on a project finance basis. Can be combined with commercial financing or can be provided as credit lines to small CFIs for on-lending.	(i) lack of experience with clean energy project finance; (ii) inability or unwillingness to underwrite loans on a project finance basis; (ii) lack of long term lending capacity.	Strong political environment to enforce contractual obligations and enabling laws for special purpose entity.	(i) medium and small scale RE and EE.
Soft Loan Programme	Provides debt capital at concessional interest rate.	(i) financing gap during project development stage.	Lack of liquidity or interest in the target sector.	(i) medium to small scale EE and RE.

Equity Fund	Equity investment in clean energy companies and/or clean energy projects. Can be targeted at specific market segments, or full range.	(i) lack of long term capital; (ii) restrictive debt-to-equity ratio requirements.	Highly developed capital markets to allow equity investors an exit from investees.	(i) large-scale grid-connected RE; (ii) energy companies
Venture Capital	Equity investment in technology company.	Lack of risk capital for new technology development.	Developed capital markets to allow eventual exits.	Any new technology.
Carbon Finance	Monetization of future cash flows from the advanced sales of CERs which can be used to finance project investment costs or enhance project revenues. Can also be in the form of carbon delivery guarantee to minimize the risk of under-delivery of carbon credits.	(i) lack of early stage project development capital; (ii) lack of cash flow to provide additional security to project lenders; (iii) uncertainty in the delivery of carbon credits.	Developing countries or emerging markets.	(i) large-scale grid-connected RE; (ii) medium-scale RE and EE; (iii) programme of activities such as in energy access market.
Project Development Grants	Grants that are "loaned" without interest or repayment until projects demonstrate financial viability.	(i) lack of sufficient capital during project development stage; (ii) costly development process.	Developing countries or emerging markets.	(i) large-scale grid-connected RE considered high risk with lengthy project preparation cycle.
Loan Softening Programmes	Grants to help CFIs begin lending their own capital to end-users initially on concessional terms.	(i) lack of FIs interest in lending to new sector; (ii) limited knowledge of market demand.	Competitive local lending markets.	(i) medium to small scale EE and RE.
Inducement Prizes	"Ex-Ante Prizes" to stimulate R&D or technology developments. Still needs to be proven in the climate sector.	(i) high and risky technology development costs and spill-over effects.	Sufficient financing availability to deploy winning technologies.	Any technology sector.

Grants for Technical Assistance	Funds aimed at building the capacity of market actors. Technical Assistance programmes include: (i) market research and marketing support; (ii) transaction structuring support and development of new financial products; (iii) staff training and business planning; (iv) establishment of technical standards and engineering due diligence; (v) market aggregation programmes to build deal flow.	(i) lack of investment ready project; (ii) lack of skills and knowledge among market actors.	Developing countries or emerging markets.	(i) all segments in the supply side of the market; (ii) demand side; (iii) FIs.

***Annex 3**: Elaborated Focus areas and policy options and actions*

Focus Area	Policies and Actions	Stakeholders	Timescale	Measurables	Sources of Finance
Social Security	Solar PV: - Encourage private sector in solar PV sector: Grant-per-unit-sold scheme - Maintenance needs to be ensured. For the private sector, can provide grants per unit sold with part of grant given only if installation is fully functional after X number of years. Or buy-back guarantee - Implement product standards - Encourage rural micro finance - Develop the solar lighting kit market	MININFRA, EWSA, MINECOFIN, Private sector	Short term	Uptake of solar pv Percentage working after X number of years	Private sector, microfinance, donor agencies
	Micro/pico hydro: - Financial assistance should be given to overcome the high initial costs - Actions need to be taken in order to ensure the financial sustainability of the installation, consideration should be given to productive end-uses from the outset - Devote resources to building local capacity to build, manage, operate and maintain micro hydro plants: Establish regional knowledge networks and ensure that foreign experts train local	MININFRA, EWSA, MINECOFIN, Private sector	Short to medium term	Number successfully installed, capacity factor over the long term	GoR funding, Private sector, microfinance, donor agencies

	technicians. Strengthen technical schools and science institutes to build up local capacity. Involve local engineers in the planning and implementation of projects Including the local governments in the energy infrastructure planning process - Create a business-like management structure, even if co-operative or other forms of joint ownership are used - Develop maintenance strategy				
	Biogas: - Ensure maintenance of installations - Train local technicians (schemes similar to those related to micro hydro) - Can encourage private sector involvement - Can promote electricity generation from medium and large scale biogas and landfill methane plants through: - Feed-in-tariffs that allow sale of electricity to the grid, - Power Purchase Agreements	MININFRA, EWSA, MINECOFIN, Private sector	Short to medium term	Level of uptake	GoR funding, Private sector, microfinance, donor agencies

National Security	Geothermal: - Develop geothermal resource map - Technical reviews key – extensive data collection benefits geothermal exploration by ensuring most productive wells are drilled and reduces risk of unproductive wells. - Develop a legal and regulatory framework for geothermal development, utilization and management - Need to involve and seek concurrence of all stake-holders - need for local community, local government and local private investor participation - Strategy for compensating/ensuring benefits for displaced people. - Early utilisation of exploration wells important in order to create interest. In addition funds from early usage can be used for further exploration and development - Geothermal drilling will have to be integrated into planning for national grid expansion - Train local staff to be proficient in geothermal exploration. This may include overseas and on-project training - Attract foreign investors through incentives	MININFRA, EWSA, MINECOFIN, Private sector	Short-long term	Production of detailed resource maps, Number of trained staff, Number of courses available in Rwanda,	GoR funding, Private sector, Donor agencies, Carbon finance

	such as tariffs. - Potential for building technical capacity in the long-term that can be used in the region – regional hub of technical knowledge				
	Large-scale Hydro: - Need to take rights of poor and marginalized groups into account in planning, construction and sharing of benefits. - Policy implementation to ensure compensation of displaced people/ensure that they benefit from the move - Gender issues need to properly considered in implementation - Where existing benefits from water are withdrawn, alternative benefits must be provided that are greater than simply compensation for lost rights - Should adhere to WCD guidelines	MININFRA, EWSA, MINECOFIN, Private sector	Medium - Long term	Assessments of projects in comparison to WCD guidelines,	GoR funding, Private sector, Donor agencies, carbon finance
	Methane: - Ensure Management Prescriptions adhered to - Build local capacity - Encourage research into potential for making technology low-carbon - Implement strict monitoring of Lake Kivu as	MININFRA, EWSA, MINECOFIN, Private sector	Medium term	Measurements of lake stability, emissions, technology efficiency, methane level in the Lake	GoR funding, Private sector

Implementation	well as extraction				
	Peat: - Utilisation of peat resource should be for short-term emergency use - Use should be kept to minimum	MININFRA, EWSA, MINECOFIN, Private sector	Short term	Emissions levels	GoR funding, Private sector,
	General - Encourage and create and enabling environment for investing in renewable energy technologies - Provide incentives for investment in this sector including phased subsidies where the sub-sector is non-competitive with more conventional energy sources. - Need to treat all energy supply options equally and to favour what best meets the needs of the consumer in different locations - Increase electricity generation focus on distributed power options	MININFRA, EWSA, MINECOFIN, Private sector	Short - long term		
	Capacity - Capacity building initiatives to enhance observation, research and knowledge management - Technical skills need to be developed for all technology options - Local capacity building needed	MININFRA, EWSA, MINECOFIN, Private sector	Short-long term	University courses, number of overseas placement opportunities utilised,	

	- Energy RD&D planning should be seen as an important instrument to achieve larger economic development and energy security goal - African Energy Research Alliance – bring together key research organisations across region and align individual R&D activities to the needs of the region and the energy strategies - Potential for new initiative that brings together industry, the research community and gov't for the region.			Number of local industries
	Finance - Feed-in-tariffs for renewables - Tax exemption for renewables - Capital cost grants - Non-economic support mechanisms, mainly aiming at facilitating independent power producers (IPPs) to be able to enter the market more easily - Subsidies should focus on lowering initial costs rather than operating costs - Average tariffs for small-scale generation kept in line with local inflation - Cross subsidise households	MININFRA, EWSA, MINECOFIN, Private sector	Short – long term	Amount of CDM of finance accessed, amount of private sector investment

	- Develop CDM capabilities - Encourage micro finance sector			
	Legal and Institutional - Introduce utility efficiency program to reduce technical and economic losses from existing power generation and transmission - RURA streamlining – build capacity - Build MININFRA's policy-making, legal and finance capacities - Quality and safety standards should be enforced to prevent user exploitation - Promote climate change integration in all planning and design of infrastructure - Develop specific master plans for each sub-sector of energy production - Need for Maintenance Strategy: 1. Separate strategies for on and off-grid 2. Strategies according to implementation, i.e. government, private sector, beneficiaries/system users	MININFRA, EWSA, MINECOFIN, Private sector	Short - long term	Master plans for each sub-sector, progress in their implementation
	Data - Set up information systems - As with micro-hydro, produce an atlas of potential generation for each source would be useful for initial planning stages	MININFRA, EWSA, MINECOFIN, Private sector	Short – Long term	Production of resource maps, databases