1.4 Action plan for geothermal power technology

1.4.1 About geothermal-to-electric power technology

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

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

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

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

1.4.2 Targets for Geothermal transfer and diffusion

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

1.4.3 Barriers to diffusion of geothermal technology

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

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

Table 9: Non financial barriers for geothermal

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

1.4.4 Proposed action plans for geothermal technology

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

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

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

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

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

			assessment and exploration					

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

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

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

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