Technology Fact Sheet for Mitigation

F. Geothermal Power Technology [i]

1. Introduction	
1.1. Historical	- By the year 1870: discovery of the role of radiogenic heat generated by long-lived radioactive isotopes of Uranium, Thorium and Potassium - In 1942, installed capacity of worldwide geothermal -electricity reached 127 MW against 9 028 MW in year 2003
1.2. Location of Resources	- With reference to hydrothermal manifestations on ground surface mainly along the lake Kivu, it is considered that main reservoirs of underground hot water are expected in parts of Rwanda belonging to the Rift Valley Branch (Kivu, Tanganyika)
1.3. Variability of Resources	- In Rubavu District, near the breweries of BRALIRWA for instance, and in Rusizi District mainly in Bugarama low lands, hydrothermal manifestations [hot springs of about 70° C) prove that geothermal resources in Rwanda are a promising option
2. Brief Description	
2.1. Conditions	- Geothermal exploitation follows a substantial investigation and exploration before concluding on the type of technology - 2 types: Engineering Geothermal System (Hot Dry Rocks) or Naturally

	Hydrothermal Resources (Wet Rock Technology) - We hereby present only the option called Binary Hydrothermal Electric Power System
2.2. Characteristics	- Binary Hydrothermal Electric Power Technology is based on 2 fluids (Geothermal steam and brine), hydrocarbon working fluid) - Working Fluid: Kalina water-ammonia mixture; butane; n-pentane - Capacity range: 200 kW to 20 MW (Remark: a flash hydrothermal technology can generate up to 50 MW) - Temperature required for the geothermal water brine is about 120 °C to 170 °C for 200 kW up to 20 MW - Flow of fluids: mode of a closed-loop in order to minimize GHG emissions - Modern drilling can reach a depth of 10 km underground - Average geothermal gradient: 3 °C/100 m - Conventional steam turbines require about 150 °C - Binary plants are elaborated for commercial purposes in small modular units (small mobile plants) which can be, hence, assembled for higher capacity up to about 110 MW - For instance in Ethiopia, the installed geothermal-electric power was 8.5 MW in year 2003 against 45 for

	Kenya; up to now, leading countries are mainly USA (2 800 MW), Philippines (1 905 MW), Italy (862 MW), etc. - In case of geothermal resources reaching a temperature of 180 °C and a pressure equals to 8 atmospheres or more, the steam can be directly passed through the turbine; then condensed and re-injected in deep layers of ground for recharging the source - Such avoidance of use of heat exchanger and hydrocarbon working fluid makes the geothermal technology more cleaner without emission of GHG; in fact for lower temperatures and pressures, steam is still containing brine, thus: need of an exchanger
3. Applicability and Potentialities in Rwanda	
3.1. Applicability	- Wet rock-based binary geothermal electric power technology is applicable in Rwanda, due to key parameters (hot springs, volcanoes area) and preliminary investigations (capacity potentially up to 340 MW)
3.2. Potentialities	- Wider geological exploration covering the overall scenarios of geothermal options (binary direct transmission to turbine, non use of heat exchanger, mapped temperatures, flash in expansion vessel, hot dry rock, wet rock technology
3.3. Limitations	- Drilling can be expensive in case of

	deeper wells for both extraction and re-injection
4. Status of the Technology in Rwanda	
4.1. Local Production	- Geo thermo electric power technology is not yet introduced in Rwanda - Only preliminary technical studies have been conducted and resulted in an estimated potential capacity of up to 320 MW (REMA, 2009)
4.2. Shared Power Plants	- N/A
4.3. Projects	- Rwanda is greatly committed in exploration of geothermal resources and in planning for an electrical production of about 300 MW from such a resource
5. Benefits to Development	
5.1. Social	- Especially, rural population will be more committed to join the Umudugudu policy and settlements - Facilities like charging phones, internet and TV access are thus becoming more popular
5.2. Economic	- Promotion of exploitation of local natural resources for electric power generation - Reduction of exodus from rural to urban areas - Small scale business and factories are more promoted and increased towards a better GDP and incomes - Increases rate of access to electricity services and thus to good growth of economy

	- Creation of jobs
5.3. Environmental	- Decrease of use of wood and charcoal fuels, of petroleum for lighting - Increase of promotion of electric vehicles through wider available battery stations
6. Climate Change Mitigation Benefits	
6.1. Reduction GHG Emissions	- Geothermal technology systems emit very small amount of GHG, just due to use of hydrocarbon working fluids for use of heat exchanger - Thus with its GHG emission factor of about 197kg/MWh, replacing oil thermal power plants by geothermal plants can result in a reduction rate of 74%.
6.2. Low Carbon Credits	- Geothermal, being a non-carbon resource, will hence contribute in carbon market
6.3. Specific Sectors of Health	- Air and water quality are conserved due to use of such a clean source of electricity - Pollution is limited or avoided
7. Financing Requirements and Costs	
7.1. Private Sector Involvement	- Promotion of small plants and modular units of geo thermoelectric power systems (up to 200 kW or even 1 MW) is possible in Rwanda - For such a small scale of production, moderate private business companies can participate under the partnership with EWSA among others
7.2. Capital Cost	- For a 200 kW binary unit, cost was

	7220 USD/kW in 2005 and projected to about a probable value of 6 410 USD/kW (ESMAP, 2007) - In case of a binary 20 MW plant, cost was 4 100 USD/kW in 2005 and expected to about 3 730 USD/kW in 2015 (ESMAP, 2007) against 2 510 USD/kW and 2 290 USD/kW respectively in 2005 and 2015 for a flash 50 MW plant - Installed capital cost is influenced by an optimal design of an atmospheric exhaust plant instead of a condensing plant (UNESCO, 2003)
7.3. Generating Costs	- A binary 200 kW unit: O & M costs were 3 US cents/kWh (19% of total average levelized cost) in 2005 - For a binary 20 MW power plant: O & M costs were 1.7 UC cents/kWh (28%) for the flash geo thermoelectric 50 MW - Regarding the projection for the total average levelized cost (energy generation cost) in year 2025, expectations are 14.2 US cents/kWh, 6.3 US cents/kWh and 4 US cents/kWh respectively for a binary 200 kW, a binary 20 MW and a flash 50 MW (ESMAP, 2007)
7.4. Environmental	- Environmental impacts associated with the geo thermoelectric power production are very small for the matter of GHG emissions - But small amount of CO_2 and H_2S

	gases are emitted and thus a closed cycle is more recommended instead emission towards atmophere - In fact, geothermal plant can emit up to 0.4 gigagrams of CO_2 per kWh against 1.1 by a coal-fired plant, and 0.45 by a natural gas-fired plant (Fridleifsson[ii], 2001)
7.5. Capability Building	- Given that the expected introduction of such a new technology and deployment in Rwanda will require specific studies, exploration, installation and skills for operation and maintenance, the cost for training and capacity building has to be considered in financial and economic analysis

[i] **This fact sheet has been extracted from TNA Report – Technology Needs Assessment and Technology Action Plans For Climate Change Mitigation– Rwanda. You can access the complete report from the TNA project website http://tech-action.org/**