Technology Fact Sheet for Mitigation
B. Small Hydropower Technology [i]

1. Introduction	
1.1. Historical	- All over the World, hydropower sector is playing a great role in economic development since the last decades of the 20th century - In Rwanda, hydropower development started mainly with harnessing water from Lakes Bulera and Ruhondo but also the River Sebeya - Before 1980's local production of hydropower was very small
1.2. Location of Resources	- Rich Hydrography covered by the upper Nile and Congo river basins with many streams - High lands in Northern, Western and Southern Provinces for hydropower development - Reforestation is welcomed for stability of water resources - Rainfall is enough along the two main wet seasons - A Rwanda hydropower atlas has been recently established and about 333 potential sites for small hydro development have been characterized and recommended for exploitation
1.3. Variability of Resources	- It is important to highlight that, by now and then, rainfall resources for recharging the aquifers towards the baseline flow are affected by the ENSO phenomenon - Eastern Province is characterized by a

	specific geology resulting in poor potentialities for micro hydropower
2. Main Characteristics	
2.1. Conditions	- Usual no need of water storage - Reservoir in case of need of storage of water (use of dams and spillways) to avoid seasonal impact - Enough head and water levels - Option of in-stream turbine for pico-hydro - Control of river flow by crested weirs - Permissible head, turbine and generator
2.2. Characteristics	- Efficiency of converting hydraulic energy into electric power is high, about 60% - Use of Manning equation for designing small hydroelectric power systems drivers by water flowing through closed conduits (steel or PVC or concrete penstocks) - For capacity less than 600 kW, installed transformers can be very small - Hydraulic turbines (efficiency: 80%), Generators: 90% and Transformers: 90% - Option of in-stream turbine is appropriate for low lands like in Western Province of Rwanda - Design: Kaplan or Francis Turbine; self excited induction for picohydropower - Amount of electric power is proportional to the head drop and the

	water flow discharged on turbine - Pico-hydro: lifespan is about 15 years - Micro-hydro: lifespan is about 30 years - The capacity factor i.e. operational time duration per day: about 30% - Power capacity: less than 50 kW for a pico-hydro system and less than 1 000 kW for a micro-hydro plant - Electric output is linked to seasonal variations of water flow
3. Applicability and Potentialities in Rwanda	
3.1. Applicability	- Illustrative example: For a head drop of 2 m, any stream flow of 0.3 m^3/s can generate an electric power of 3 kW; such a stream cross-section is 25 cm x 30 cm if v = 2 m/s - Pico-hydropower systems (for lowest capacity i.e. less than 10 kW) are yet to be introduced - Also in-stream turbine alternative is not used in Rwanda, but it is quite applicable and recommended especially for Akanyaru, Nyabarongo and Akagera rivers in low lands in Eastern areas - Remark: Micro-hydropower systems are popular in Rwanda and got a great acceptability by all kinds of stakeholders
3.2. Potentialities	- Important water resources and sites presenting head drops in Northern, Western and Southern Provinces - During the year, apart from the underground base flow towards the

	rivers and streams, rainfall trends are stable in the two main rain seasons
3.3. Limitations	- Eastern Province: Not proper for Micro-hydropower - Seasonal variations affected for instance the hydro sector in 2000-2003 during the drought linked to El Nino/La Niña events - Hydrological risk is thus to be considered for a proper design and sustainability of the project
4. Status of the Technology in Rwanda	
4.1. Local Production	- Domestic hydropower productions: 44 MW in year 2006, with supply to industrial sector (40%) and to services (20%) - These above 44 MW represent 56% of the total electric production (against 44% by oil-fired thermal power plants) - Rate of access to electricity services to population: 6% in year 2006 - Tariff: 22 US cents/kWh
4.2. Shared Power Plants	- Hydropower resources in Rwanda are shared with neighbouring countries - Thus, Rusizi river power plants and coming Rusumo project are among examples of share
4.3. Projects	- Pico and Micro-hydropower sectors are expected to generate above 20 MW of electric capacity against for instance 27.5 MW by the Nyabarongo Hydropower Project
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	- Progressive replacement of diesel engine power generators and of wood fuels(at some extent) will result in a significant decrease in GHG emissions - The total annual CO_2 emissions by energy sector in Rwanda in year 2002 (MIINITERE, 2005) was 6 948 gig grams (4% by petroleum, 11% by charcoal and 85% by wood fuel) - Only 43 kg/MWh are emitted by a hydro plant; thus the rate of

	contribution to reduction of GHG emissions is very high(94%),compared to the use of oil in thermal power plants(emission factor : about 750 kg/MWh)
6.2. Low Carbon Credits	- Promotion of pico/micro hydropower sector will contribute in reducing CO_2 and CH_4 emissions as far as the projections predicted that electricity will be also used for cooking and of course for industrial purposes; therefore wood fuel and charcoal will be partially replaced - Given the importance of sequestration of carbon emissions by the forests, any reduction in use of wood fuel and charcoal results in increase of carbon credits opportunity
7. Financing Requirements and Costs	
7.1. Private Sector Involvement	- Development, as wider scale, of pico/micro hydropower systems will require more involvement of private sector in close partnership with among others the districts - In fact, off grid scenario is widely applicable in different areas of Rwanda and potential of pico-hydro is high
7.2. Capital Cost	- Probable capital cost of pico/micro hydro systems in year 2015 (Ref.: ESMAP, 2007) is 1 470 USD/kW, 2 550 USD/kW and 2 450 USD/kW respectively for the capacity of 300 W, 1 kW and 100 kW; these, against 1 560

	USD/kW, 2 680 USD/kW and 2 600 USD/kW in year 2005 - Comparison to a mini hydroelectric power system of 5 MW: cost of 2 370 USD/kW in year 2005 and 2 250 USD/kW in year 2015
7.3. Generating Costs	- Probable generating costs for a 100 kW power plant is, in year 2015, about 11 US cents/kWh (with 13% for O & M costs and 87% for levelized capital cost) in coming year 2015 [Ref.: ESMAP, 2007] - Compared to a 5 MW mini hydropower (7 US cents), the generation cost is higher for the pico/micro hydro
7.4. GHG Emissions	- Externalities are not considered, the pico/micro hydro is a friendly environmental
7.5. Capability Building	- There is a great need in enhancing the capacity building for further skilled staff and technicians for design, operation and maintenance once the technology is widely deployed in Rwanda

[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/**