THE 'CHINA-GHANA SOUTH-SOUTH COOPERATION ON RENEWABLE ENERGY TECHNOLOGY TRANSFER' PROJECT

Mini Hydro Component

CSIR-Water Research Institute

Oak Plaza Hotel, 13-01-2017

Project Team

Name	Position	Activities to engage in:
Dr. Joseph A. Ampofo	Director/Microbiologist/Coordinator	Overall Management/Signing of documents and Co-ordinator
Dr. Emmanuel Obeng Bekoe	Hydrologist/Principal Con sultant/Team Leader	Water Resources Engineer/ Team Leader
Dr. Ruby Asmah	Environmental Chemist/Aquatic expect/Consultant	Environmental Water Quality Assessment
Mr. Mark Akrong	Microbiologist/Consultant	Water quality – Microbiological samples collection, analysis & reporting
Dr. K. Kankam-Yeboah	Water Resources Engineer/Senior Consultant	Surface Water Resources and meteorological data collection and analysis
Koforidua Polytechnic Expert	Collaborator	To assist with SHP ctieria selection and others
Mr. Osafo Kissi	Mechanical Engineer	To establish the mechanical suitability's of proposed project materials
ESIA and ESMP Specialist	External Consultant	To undertake the Environmental and Social Impact Assessment and Plan Studies
Safety Assessment Specialist	External Consultant	To undertake Safety assessment of selected SHP sites
Policy and Legal assessment of SHP	External Consultant	To undertake Policy and legal implications of SHP sites

Presentation Format

- Objective of the Assignment
- Criteria for shortlisting projects/ Site Selection
- Shortlisted projects and their characteristics
- Financials – Investment, Operation and Revenue
- Cost Benefit Analysis
- Business Models - Options

Objective of the Assignment

To develop criteria for selecting mini-hydro sites and conduct pre-feasibility studies for selected locations. However, the objectives are in 3 phases:

- Phase I: Develop criteria for selecting mini hydro site
- Phase II: Laise with the UNDP, Energy Commission and Ministry of Power to select a site for potential piloting of a mini hydro scheme in Ghana,
- Phase III: Conduct pre feasibility studies for the selected site

Geographical and Hydrological Conditions Criteria (1 of 7)

- **Geographical Conditions of the Site**

  Head (m):

  Access conditions:

  Location of power source from where power is needed:

- **Hydrological Conditions**

  Meteorological Data:

  Flow: (l/s or m^3/s)

Development Benefits Criteria (2 of 7)

- **Development Benefits**

  Job creation:

  Economic development:

  Capacity building:

  Use of local materials:

  Contribution to GDP:

  Positive effect on balance of trade:

  Skills development:

Market Potential Criteria (3 of 7)

- **Market Potential**

  Level of initial capital outlay:

  Affordability:

  Investment sustainability:

  Low maintenance:

  Commercial availability:

  Replicability:

Mini Hydro Technologies (4 of 7)

- **Mini Hydro Technologies**
  - Run-of-the-river power plants/river power plants
  - Storage power plants
  - Pumped storage power plants
  - Plants for exploiting marine energy

Turbines Criteria (5 of 7)

- **Turbine Choices**

  Francis turbine:

  Cross flow turbines

  Kaplan and bulb turbines:

  Pelton turbine:

  Hydrodynamic screws:

Scalability: can this technology be scaled up, if need be?

Technology maturity: How resilient is the technology?

Acceptability/Adaptability: How easy would this be accepted in the locality and adaptation?

Capital cost : Cost should be affordable to country and community

Skill requirements: Does the skills for mini hydro power development exist?

Sustainability of Mini Hydro Project Criteria (6 of 7)

F**easibility study needed** to establish the technical and management aspects of the proposed mini hydro project system for sustainability. **D**epends largely on finding a profitable end-use

- **Operation and Maintenance :** Who/what organization should be responsible for the operation and maintenance
- **ESIA and Management Plan (ESIAMP):** Establish these
- **Water resources assessment:**
  - Minimum flows etc
  - Water resources demand projections for hydropower, irrigation/domestic/industrial within the catchments under the influence of climate change and variability
  - Estimate potential impacts of water resources development and abstraction within the river catchments
  - Estimate groundwater recharge/estimates
  - Establish appropriate levels of groundwater abstraction to aid water balance computation
  - Model climate change and variability impacts on river flows and their impact on hydropower generation to aid acquire design flow.
  - Study land use patterns to aid in ESIA preparation

Sustainability Criteria Cont'd (7 of 7)

- **Investigation of Environmental Parameters to Ascertain the Water Quality for Environmental Assessment purposes:**
- **Tariff regime**: Is there one?
- **Policy and legal assessment of the mini/small hydro project:** Do they exist?
- **Capital cost:** Feasible project, there is the need to undertake financial analysis which involves the estimated total cost and the internal rate of return (IRR) for the project
- **Community acceptability to the project: R**eadiness of the people to accept and utilize the project
- **Grid Connection Cost**: If on grid need to establish grid connection cost
- **Space requirement:** Does the space meant for the project free from encroachment and interference by any community?
- **Expected lifespan:** Will the project have succeeded in its objective before extinction?
- **Safety assessment:** How safe will the operation of this project be to workers and community?

Criteria Selection

- Mainly three types:
  - Technical
  - Economic and Social
  - Technology

Proposed Criteria for project

- **Technical**
  - The site must have a stream with a minimum head (H) = 2m
  - The water way length (L) to head (H) ratio L/H <25 for it to qualify as mini hydro project
  - The flows must be able to sustain the scheme such that firm flow Q_F lies between 0.8-2.0m^3/s ($0.8m^3/s < Q_F < 2.0m^3/s$) for 100$km^2$ area (DOE, 2009c).
  - The site must be easily accessible

Economic and Social

- Overall cost, operation and maintenance cost must be acceptable to implementers.
- Environmental and Social Impact Assessment (ESIA) report and a management plan should be established for the chosen site.
- Permission documents e.g. project permit from required ministries to establish mini hydro project must be acquired.
- Tariff regime for payment of energy generated cost must be economic and acceptable to all parties, i.e. government and users of the power.
- Grid connection cost must be economical if it should be on grid.
- The SHP project must bring about social benefits to the people and accompanying challenges should be mitigated.
- Potential risk to the projects must be noted and planned for in ESIA document
- Project should establish good compensation packages through ESIA reports for displaced persons should there be the need to resettle people.
- Community must accept the project.
- An SHP Policy and Legal backing document must be in existent.

Technology

- Type of Technology should be technically feasible and robust e.g. type of turbines etc.
- Design and construction of project has to be well planned, accepted and executed
- Operation and maintenance must be well planned for good sustainability

This criteria has been set the way it is because the identified schemes in Ghana namely the Kokuma falls, Randall falls, Fuller falls, Boumfoum falls, Wurudu falls, Wli falls, Tsatsadu falls, Barekese water works and Kwanyaku water works have technical characteristics which qualify as mini hydro projects according to Togobu and Amankwa, (2006).

Site Selected-Tsatsadu

- Minimum Technical Conditions met
  - Accessibility good
  - Head of water fall good
  - Flows are good for about 7 months
  - Turbine Available (Head; 32-100m)
  - Significant reduction of cost because of Turbine availability

Relevant Regulatory Conditions Available (To be updated)

- Environmental Impact Statement (Final) (Envi-Logica, 2007) –Being Reviewed for this project
- Environmental Protection Act 1994 (Act 490)
- Environmental Assessment Regulations, 1999 (Li 1652)
- The Local Government Act, 1993 Act 462
- Energy Commission Act, 1997 (Act 541)
- Water Resources Commission Act, 1996, Act 522
- National Museum Decree, 1969 (NLCD 387)
- Lands (Statutory Wayleaves) Regulations, 1964 (LI 334)
- Lands (Statutory Wayleaves) (Ammendmen Regulations, 1964 (LI 346)
- Lands (Statutory Wayleaves) Act, 1963 (Act 186)
- Electricity Company of Ghana Safety Policy, 1995
- ECG’s Environmental Management Plan, 1999
- Fire Precaution (Premises) Regulations, 2003, LI 1729
- Factories, Offices and Shops Act, 1970, Act 328

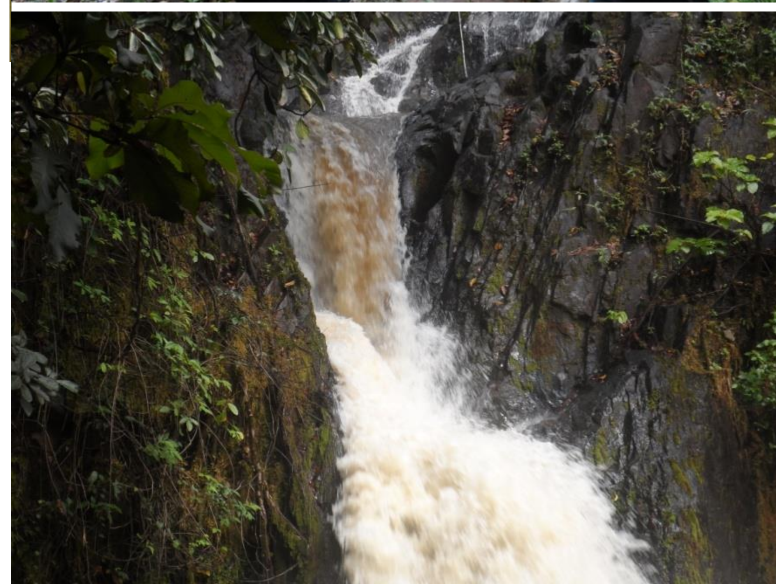
Characteristics of Selected Site Cont'd

- Located about 200km from Accra in the Alavanyo Abehenease in the Hohoe District of the Volta Region
- Hosted in a 80 acre Catholic pilgrimage house "Foyer de Charite" for religious activities.
- Its catchment area is approximately $40km^2$
- Estimated design flows of 500l/s suitable for 320kW plant (grid connected); can generate annual energy of about 1.2GWh, suitable for grid connection (Togobo and Amankwa, 2006).
- The nearby village Alavanyo-Abehenease which is a few hundreds of meters from the proposed location for the power house is connected to the ECG grid

Characteristics of Selected Site Cont'd

Tsatsadu Falls
(Alavanyo - Volta Region)

- Located about 200km from Accra.
- Catchment Area: 40 km^2
- Head: 43m falls + 37m rapids
- Designed Flow 500 l/s suitable for 320 kW plant (grid connected)
- Annual Energy Generation: 1.2GWh
- Suitable for grid connection (4km).
- Does not require dam construction
- Used for religious activities



Courtesy WRI, 2016

Flow Measurements Tsatsadu

Month	Station Name: Tsatsado	Coordinate			Area (m²)	Velocity (m/s)	Discharge	
		Lat.	Long.	Alt.			m^3/s	m^3/day
November, 2016	Up Stream	07.13669° N	00.39006° E	247m	1.95	0.33	0.650	56,127.62
November, 2016	Down Stream	07.13323° N	00.38940° E	201m	1.17	0.84	0.984	85,017.60
January, 2017	Up Stream	07.13669° N	00.39006° E	247m	0.08	1.32	0.100	8,640.00
January, 2017	Down Stream	07.13323° N	00.38940° E	201m	0.54	0.37	0.20	17,280.00

	Suspended Solids Concentration on Tsatsado Water Falls			
Date	**Stations**	**concentration (mg/l) (Cs)**	***Discharge (m^3/s)(Qw)***	**Sediment Discharge(Qs) (tonnes/day)**
23/11/16	Up-stream	1666.3596	0.650	94
23/11/16	Down Stream	45.0813	0.984	4

Project Turbine

- Inspected on 27 - 9 September 2016
- Visited the VRA Tema to Inspect Turbine:
- The Turbine is a Chinese DLLD Micro Turbine with a power range of 30-150 KW. The head ranged from 32-100m. The manufacturing date was September, 2005.
- Physically found in a good state

Outstanding

Pre feasibility Study

- Financials – Investment, Operation and Revenue
- Cost Benefit Analysis

Yet to be Undertaken

- Some Business Models (Mini Hydro)

	Brazil (6 Cases)	Cambodia (6 Cases)	China (6 Cases)
Organizational Form	Dominant: Centralized utilities Alternative: Coops, NGOs, small entrepreneurs	Dominant: Small entrepreneurs Alternative: Government and international donor projects	Dominant: Local governmental and private, some hybrid/dual Alternative: Decentralized private tech dealers, centralized governmental
Technology Choice	Dominant: Diesel Alternative: Biomass, PV	Dominant: Diesel Alternative: Biomass, PV, small hydro	Dominant: Small hydropower Alternative: Small thermal, PV, wind
Target Customer Base	Dominant: Households Alternative: Varied	Dominant: Village electrification Alternative: Households	Dominant: Village and higher electrification Alternative: Individual systems
Financial Structure	Dominant: Subsidized connections and low income consumers Alternative: Market prices with cost recovery	Dominant: Market prices Alternative: Highly subsidized	Dominant: Cost-plus regulated prices Alternative: Subsidized, cash markets

(Making Small Work: Business Models for Electrifying the World Working Paper #63, Hisham Zerriffi (2007)

Appendix D: Scores on Individual Business Model Cases in China

		SHP-Early	SHP-Recent
Business Model Parameters	Organization	Central-Local Government Hybrid	Local-Central Government Hybrid + Private
	Target Customers	Primarily Productive	Productive plus households
	Technology	Small Hydro Power mini-grids	Small Hydro Power mini-grids
	Financial: Capital	Central Gov. subsidies/loans plus labor equity	Mix of funds
	Financial: O&M	Supposed to be cost-recovering tariff	Supposed to be cost-recovering tariff
Control Variables	Capital Cost Subsidies	High	Medium
	Operating Cost Subsidies	None	None
	Density of Customers	High	High
	Remoteness of Customers	High	High
	Policy Regime	Favorable	Favorable
	Regulatory Regime	Favorable	Favorable
Outcomes	Access	High	High
	Sufficiency	High	High
	Quality	Medium	High
	Sustainability	High	High
	Replicability	High	High
Notes on Institutional Factors	Policy Measures	Numerous favorable policies	Numerous favorable policies 1998 policy decision for centralized take-over of grids Rural grid renovation policy to improve quality
	Regulatory Measures	Favorable Regulations	Favorable Regulations
	Other	Relationship with local government	Change in State-Local relations

Note: SHP – Small Hydro Power

Independent Variable Variation for the Different Models in Each Country

Thank you