100. MINI- HYDROPOWER PLANT

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I. SUMMARY

This profile envisages the establishment of a Mini-hydro power plant with a capacity of 500 KW per annum.

The present demand for the proposed power is estimated at 375 kW. The demand is expected to reach at 500 kW by the year 2010.

The power plant will create employment opportunities for 17 persons.

The total investment requirement is estimated at Birr 6.45 million, out of which Birr 5.44 million is required for plant and machinery.

The project is financially viable with an internal rate of return (IRR) of 17% and a net present value (NPV) of Birr 1.99 million, discounted at 8.5 %.

II. PROJECT DESCRIPTION

Mini-hydropower plant utilizes relatively small water falls to convert energy of water falls (proportional to the head of the water fall) into electrical energy. Mini hydropower plants produce electrical power in the order of 100-1000 kilo-Watt that can be utilized to supply electricity to the rural population located far away from the inter connected system (ICS) of the electricity corporation (Ethiopian Electric Power Corporation - (EEPCO).

The plants are simple in construction and easy for maintenance. Project implementation normally takes shorter period and low investment cost. China, India, Indonesia, Pakistan, Peru, Nepal and Papua New Guinea are developing countries that have benefited a lot from harnessing the energy of water falls of rivers. The experience of these countries indicates that the undertaking features are the unusually low cost of US 350 to 500 per kW, including distribution. This low cost is attributable, primarily, to three factors:

a) non-conventional use of readily available materials,
b) designs suited to local conditions, and
c) community involvement in the initiation, implementation, management, operation and maintenance of the hydro power schemes.

III. MARKET STUDY AND PLANT CAPACITY

A. MARKET STUDY

1. Past Power Supply and Present Demand

Benishangul-Gumuz is one of the least electrified regions in Ethiopia. Electric supply is limited to few urban centers. The population size of electrified towns is shown in Table 3.1.

Table 3.1
POPULATION SIZE OF ELECTRIFIED TOWNS

Town	Population	Type of Electricity Supply
Assosa	1880	Generator
D.Zeit	3028	Generator
Mandura	N.A	Hydro-power
Almu	2540	Hydro-power
Tongo	2340	Generator
Bulen	4071	Generator
Menge	232	Generator
Kurmuk	403	Generator
Bambasi	6600	Generator
Dangur	5204	Hydro-power
Pawe	8915	Hydro-power
Total	**52133**	

***Source**: Resource Potential Assessment of Benishangul Gumuz Region, IPS, 2003.*

The regional capital, Assosa town has a generator with capacity of 700 kW. Dangur is connected with 15 kV line and Almu with 66/63 kV substations. Mankush, Dibate, Sherkole, Bambasi, Oda, Komesha, Yaso, Koncho, Kamashi, Agalo Meti and Belo Gignatory are towns that are looking for electrification in the future. Both diesel and mini-hydro are options for these towns.

In Benishangul-Gumuz, there are sufficient number of rivers that could generate mini-hydropower for rural as well as urban electrification. At present a 500 kW mini-hydro power plant could satisfy the demand for electricity of each non-electrified town mentioned above.

2. Projected Power Demand

Adequate and efficient supply of energy is a prerequisite for development in general, and industrialization in particular. As population increases, the demand for electricity is also bound to increase inorder to fulfill multifaceted needs. These include household demand for lighting, for powering various electronic appliances and for street lighting. In addition to households, various other sectors (offices, hotels, restaurants etc) will require increased supply of electricity as their number and operations expand. With the help of mini-hydro power development, there is also possibility for rural electrification. Therefore, many units of mini-hydro power plants would be required to satisfy the increasing demand.

Hence, the 500 kilowatt mini-hydro power plant could start operation with 75% capacity and move to 85% and 100% capacity utilization in subsequent years. The demand projection executed in this manner is shown in Table 3.2.

Table 3.2
PEOJECTED DEMAND FOR ELECTRICITY

Year	Projected Demand (Kilowatt)
2005	375
2006	425
2007	500
2008	500
2009	500
2010	500
2011	500
2012	500
2013	500
2014	500
2015	500
2016	500
2017	500
2018	500

3. Pricing and Distribution

The pricing of electricity generated by the power plants under Ethiopian Electric Power Corporation (EEPCO) varies according to different categories of users. There are also different tariff categories and blocks within each user category. The domestic tariff category includes dwelling houses, government schools, health institutions etc. The general category includes government offices, private offices, international organization and most business sectors. Industries are included in the third, fourth and fifth categories.

The current energy tariff or price of electricity for different categories of users and blocks ranges from 0.273 Birr/kWh to 0.6087 Birr/kWh. However, the flat rate of 0.6087 Birr/kWh is recommended as the lowest price for the envisaged plant could charge.

The current EEPCO's estimate for connection fee of 780 Birr per customer is very high for rural population accordingly the cost of connection is assumed to be Birr 300 only. Assuming that the envisaged mini-hydropower plant will serve 5,000 house holds the project will generate Birr 1.5 million from connection fees.

B. POWER GENERATION CAPACITY AND GENERATION PROGRAMME

1. Power Generation Capacity

As shown in the market study, demand projection of electricity in the year 2005 is 375 kW, and this figure would grow to 500 kW by the year 2007 and thenafter. A mini-hydropower plant of 500 kW is, therefore, the capacity of the envisaged plant.

According to the Resource Potential Assessment Study Conducted by IPS for the region, sites suitable for mini-hydro power development are available at different locations. The level of power generated depends on the quantity of water available at the upper stream, the head of the waterfall, and the sustainability of water flow over the dry seasons of the year. It would, therefore, be possible to generate from very low and to several kilowatts. The intention of this project is to utilize the generated power in areas not far from the powerhouse.

If standard voltage of 240V is to be transmitted, then it is rarely transmitted more than a couple of kilometers. If power is transmitted farther, a transformer would be used to increase the voltage. In this study, a generator of 240/415 V a-c is anticipated and power will be transmitted to longer distances with the help of step-up transformers.

Inorder to determine the capacity (or output power) of a mini-hydropower plant, it would be necessary to specify, further, the net head and flow of waterfall. This would inturn determine the turbine specifications and the sizing of penstock pipes. The net head and flow are usually specified by the site developer. Based on this, the equipment supplier can state the actual value of the output power of the turbo-generator. The plant will operate 10 hours a day, and for 365 days a year.

2. Generation Programme

Generation of electrical power can be effected fully once commissioning work is complete. However, distribution of power to commercial and residential areas can take time. It is believed that preliminary preparations will be carried out with regard to electrification of towns and villages together with erection and commissioning. The envisaged plant will start operation at 75% of its full capacity (i.e, 500 kW), in the first year and increase to 85% and 100% capacity utilization in the second & third year, respectively.

IV. RAW MATERIALS AND INPUTS

A. CONSUMBELS

The consumbels required for the smooth running of the power plant are lubricating oil and grease. Annual expenditure of Birr 15,000 is estimated to cover for thire expenditure.

B. UTILITIES

Inputs like electricity and water can be accounted for the envisaged plant since the envisaged plant uses these utilities for various reasons. A total of Birr 15 to 20 thousand can be considered as annual consumption.

V. TECHNOLOGY AND ENGINEERING

A. TECHNOLOGY

1. Description Process

In the context of mini-hydropower plant generation, transmission, and distribution of electrical energy can be carried out with the help of water intake structure, penstock, turbine, powerhouse (generator), transformer and transmission and distribution systems.

Required quantity of water is diverted and allowed to pass into the penstock. At the end of the penstock, the water with high kinetic energy runs the turbine at a specified speed, which inturn rotates the turbo-generator at a speed designed to generate the required electric power. The electric voltage generated is stepped-up by a transformer, from where it is transmitted and distributed to end-users. Various switching, protective and control devices are involved from the point of generation to consumption.

2. Source of Technology

The technology of electric power generation from waterfalls is well developed and applied in many developing countries like Pakistan, China, India, and Nepal. The different components of the hydropower plant, namely: the intake dam, the penstock, the powerhouse, the turbine and governor, the turbo-generator, the transformer substation and switch gear, the protection and transmission are all highly developed, and can be designed, manufactured, constructed, installed and easily maintained.

The technology of mini-hydropower plant can be obtained from the following countries where it is well developed and applied such as India, China, Nepal, and Pakistan. Address of the machinery supplier is given below.

ASEA BROWN BOVERI PVT.LTD
2nd Floor, Jason Trade Centre
39-A-1, Block 6, P.E.C.HS.
Shahrah - e - Faisal … 4548162
Karachi - 75400 ….. 4537594, Pakistan.
Fax …. 4548163

B. ENGINEERING

1. Machinery and equipment

Machinery and equipment required for the mini-hydropower plant is shown in Table 5.1 below.

Table 5.1
MACHINERY AND EQUIPMENT REQUIREMENT AND ESTIMATED COST

Sr. No.	Description	Qty. No.	Cost, ['000 Birr]		
			LC	FC	TC
1	Intake structure	set	7	-	7
2	Penstock (size of pipe depending on quantity of water required)	As req.	15	-	15
3	Pelton Turbine and related structure	set	-	350	350
4	Governor	set	-	150	150
5	Turbo - generator with excitation and battery supply	set	-	1500	1500
6	Transformer (s) - step up voltage, complete with switch gear	set	-	1100	1100
7	Overhead transmission line complete with all accessories and step-down substation	-	50	1000	1050
8	Accessories	as req.	-	35	35
9	Wooden Pole	20,000 pcs	1,000	-	1,000
	FOB price		**1620**	**4135**	**5197**
	Freight, Insurance, Bank charges, etc		250	-	250
	CIF		**1,870**	**4,135**	**5,447**

2. Land, Building and civil works

Land requirement for the plant consists of diversion site, intake and power conduit area, spillways, forebay, penstock, powerhouse, and tailrace.

At some locations, the lay of the land and natural formations within the stream may direct sufficient water into the intake without a weir. Simply placing a few stones across the stream bed also could achieve the purpose. A weir is a dam across a river to raise the level of water upstream.

Intake:- An intake permits a controlled flow of water from a river or stream into a conduit which eventually conveys it to the turbine to generate power. The intake serves as a transition area between a stream which can become a raging torrent and a flow of water which must be controlled in both quality and quantity.

Power conduit:- It signifies the component of a hydropower scheme used to convey water to a relatively large distance from the stream to the inlet of the penstock, with minimum loss of head and at minimum cost. It is a canal excavated in soil, because this approach reduces cost. Other options are canals constructed with concrete or impervious materials to reduce seepage of water, or an installation of low pressure pipe (conduit) to convey water from the intake to the beginning of the penstock.

Forebay:- It is a basin located just before the entrance to the penstock. Possible designs range from a simple excavated area or pond to a structure of reinforced concrete. Forebay serves as a storage in order to facilitate the supply of water to the turbine for several hours each day. It can also serve as a settling basin where any waterborne debris which either passed through the intake or swept into the canal can be removed before the water passes onto the turbine.

Penstock:- This is a pipe that conveys water, under pressure to the turbine. It is an essential part of any mini-hydropower plant. A penstock can be installed either above or below ground. PVC pressure pipe can be used as penstocks usually buried underground. For penstocks laid over ground steel pipes frequently required support piers, anchors, or thrust blocks to resist forces which can displace the pipe.

Powerhouse:- The powerhouse protects the turbine, generator, and other electrical and mechanical equipment. It also can include workshop, office and sanitary facilities. If project size and cost are to be minimized, a powerhouse should be sized to house only the turbo-generating equipment.

Tailrace:- This is usually a short, open canal which leads the water from the powerhouse back into a stream. A tailrace is usually very short and located near a stream. Often, it is simply a ditch which is designed to ensure that erosion will not undermine the powerhouse.

Land coverage refers to the intake area, the penstock, power house and tailrace. The size of land, therefore, depends on the topography of plant site. It is, therefore, assumed that a total land area of about 3000 m^2 will be required for the project, of which only 120m^2 area will be used for powerhouse.

According to regulation No. 4/2001 of the BGRS land for infrastructure construction, and other related development could be granted free. Therefore, no cost is assumed for acquiring the land which would be utilized for the mini-hydropower plant.

The foundation of the powerhouse will be strongly constructed inorder to resist the dynamic force created during rotation of the turbine - generator set. The roofing and the walls can be covered by Ega-sheets.

Other civil works are construction activities associated with erection of substations and installation of overhead transmission lines.

For the sake of simplicity, casts related to buildings, and other civil works can be categorized as:-

a) Intake, power conduit, forebay and penstock,
b) Power house, and
c) Substations and overhead transmission lines.

Investment costs associated with these categories are given Table 5.2.

Table 5.2
INVESTMENT COST OF CIVIL WORKS

Sr. No.	Description	Cost ('000 Birr)
1	Intake, power conduit, penstock, etc Refer to machinery & equipment	-
2	Powerhouse (inc. accessories)	250
3	Substations and transmission lines	100
	Total Cost	**350**

3. Proposed Location

The resource potential assessment study identified seven locations. However, depending on priority of development for certain areas, and suitability of location, it is proposed that the hydro power plant needs to be located in an area suitable for the production of 500 kW electric power. Candidates for this project are identified as DP4, DP1, DP5 and DP3 (refer to Resource Potential Assessment, Benshangul-Gumuz, IPS, 2003)

VI. MANPOWER AND TRAINING REQUIREMENT

A. MANPOWER REQUIREMENT

The total manpower required by the envisaged plant is 17 persons. The type of manpower required includes operators for the turbine room, powerhouse, and substation technicians are also required for the workshop and powerhouse. The details of manpower and annual labour cost are shown in Table 6.1.

Table 6.1
MANPOWER REQUIREMENT AND LABOUR COST

Sr. No.	Description	Req. No.	Salary (Birr)	
			Monthly	Annual
1	Plant manager	1	1800	21600
2	Secretary	1	600	7200
3	Clerk	1	400	4800
4	Operators	6	600	43200
5	Technicians	3	600	21600
6	Cashier	1	600	7200
7	General services	3	200	7200
	Sub Total	**17**		**112800**
	Employees benefit (25% BS)			28200
	Total			**141,000**

B. TRAINING REQUIREMENT

Operators and technicians will have to be supplied on-the-job training during implementation of the project. The training programme will be executed for a period of two weeks by EEPC training staff. Training cost is estimated to be Birr 10,000.

VII. FINANCIAL ANALYSIS

The financial analysis of the Mini-Hydro Power Plant project is based on the data presented in the previous chapters and the following assumptions:-

Construction period	1 year
Source of finance	30 % equity
	70 % loan
Tax holidays	6 years
Bank interest	7.5 %
Discounted cashflow	8.5 %
Repair and maintenance	3 % of the total plant and machinery
Accounts receivable	30 days
Raw material, local	30 days
Raw materials, import	90 days
Cash in hand	5 days
Accounts payable	30 days

A. TOTAL INITIAL INVESTMENT COST

The total initial investment cost of the project including working capital is estimated at 5.8 million, of which 71 per cent will be required in foreign currency.

The major breakdown of the total initial investment cost is shown in Table 7.1.

Table 7.1
INITIAL INVESTMENT COST

Sr. No.	Cost Items	Total ('000 BIRR)
1	Land lease value	-
2.	Building and Civil Work	350
3.	Plant Machinery and Equipment	5,447
4.	Office Furniture and Equipment	65
5.	Vehicle	250
6.	Pre-production Expenditure*	326.8
7	Working Capital	8.1
	Total Investment cost	**6,446.7**
	Foreign share	**67.65%**

* *N.B Pre-production expenditure includes interest during construction (Birr 311.6 thousand), training (Birr10 thousand), and (Birr 5 thousand) costs of registration, licensing and formation of the company including legal fees, commissioning expenses, etc.*

B. OPERATING AND MAINTENANCE COST

The annual operating and maintenance cost at full operation capacity of the power plant is estimated at Birr 0.9 million (see Table 7.2). The material and utility cost accounts for 3.7per cent while depreciation and financial costs take 85.3 per cent of the production cost.

Table 7.2
ANNUAL PRODUCTION COST AT FULL CAPACITY ('000 BIRR)

Items	Cost	%
Consumbles	15	1.7
Utilities	17.5	2.0
Maintenance and repair	20.0	2.3
Labour direct	64.0	7.4
Factory overheads *	5.0	0.6
Administration Cost **	6.0	0.7
Total Operating Costs	**127.5**	**14.7**
Depreciation	621	55.5
Cost of Finance	258.8	29.8
Total Production Cost	**1,007.99**	**100**

*Factory overhead cost includes salaries and wages of supervisors, insurance of factory workers, social costs on salaries of direct labour, etc.

*** Administrative cost includes salaries and wages, insurance, social costs, materials and services used by administrative staff etc.*

C. FINANCIAL EVALUATION

1. Profitability

According to the projected income statement, the project will start generating profit in the 2nd year of operation. Important ratios such as profit to total sales, net profit to equity (Return on equity) and net profit plus interest on total investment (return on total investment) show an increasing trend during the lifetime of the project.

The income statement and the other indicators of profitability show that the project is viable.

2. Break-even Analysis

The break-even point of the project including cost of finance when it starts to operates at full capacity (year 3) is estimated by using income statement projection.

$$BE = \frac{\text{Fixed Cost}}{\text{Sales} - \text{Variable cost}} = 57\ \%$$

3. Pay-Back Period

The investment cost and income statement projection are used to project the pay-back period. The project's initial investment will be fully recovered within 5 years.

4. Internal Rate of Return and Net Present Value

Based on the cash flow statement, the calculated IRR of the project is 17% and the net present value at 8.5% discount rate is Birr 1.99 million.

D. ECONOMIC BENEFITS

The project can create employment for 17 persons. In addition to supply of the domestic needs, the project will generate Birr 0.24 million per annum in terms of tax revenue when it starts to operate at full capacity. Moreover, the Regional Government can collect employment, income tax and sales tax revenue. The establishment of such plant will have a power supply increasing effect to the country and thereby speed up the industrial sector development pace in provision of required power for production machinery.