Cost and Revenue Structures for Micro-Hydro Projects in Nepal

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Cost Structure of Micro Hydropower Plant

The cost of the MHP is site specific and varies greatly depending on the remoteness of the site and physical features of its major components, namely, civil works (including waterways), generating equipment (turbine, generator, control, protection) and electrical transmission/distribution lines. While the cost of generating equipment in the powerhouse is almost a linear function of its kW size, the cost of civil works further depend upon the gradient of the waterway (intake to powerhouse). Similarly, the cost of electrical line further depends upon the energy density of the load centers. Therefore, unit cost of MHP installations can vary widely from scheme to scheme. Moreover, low cost solutions are often sought for survey/design and construction but such actions might reduce the reliability and increase the O&M cost on the long run.

The share of initial civil works component cost may vary from a mere 20% for a relatively high gradient waterway profile and low cost construction to 60% for a relatively low gradient and expensive construction. Similar would be the situation with generating equipment and electrical lines. Therefore, the percentage share of one component on the total initial investment cost would depend upon its own as well as other component's construction feature. Table 2.1 below illustrates the cost and percentage situations.

Table 2.1: Component construction costs of some representative MHPs

		Present Value (10%) Unit cost, $				
Project		Civil	Gen. Equip.	El. Lines	MHP Total	Transport (included)
Gaura Rice Mill, Baglung	2041 (19 kWe)	379 (29.6%)	578 (45.2%)	322 (25.2%)	1279 (100%)	166 (13%)
Barpak MHP	2048 (46.5 kWe)	308 (20%)	247 16.2%)	493 (32.2%)	1530 (100%)	185 (12.1%)
Pemba Gelu, Solukhumbu	2051 (12 kwe)	630 (30.6%)	574 (27.9%)	540 (26.3%)	2057 (100%)	314 (15.3%)
Radhalaxmi, Ilam	2041 (7.5 (kWe)	435 (24.7%)	574 (32.6%)	788 (44.8%)	1759 (100%)	164 (9.3%)
Ghandruk MHP	2048 (50 kWe)				2180	
Bhujung MHP	2055 (80 kWe)	1170 (56.6%)	380 (18.4%)	517 (25%)	2067 (100%)	190 (9.2%)
Sikles MHP	2041 (120 kWe)				2350	

The initial investment cost of both stand-alone and add-on micro hydro plants are in general competitive in comparison to the cost of small and medium scale hydropower which is about US$ 2,000/kW and above.

Small and medium scale hydropower, either grid connected or isolated, are generally constructed with higher level of reliability as it would effect a larger supply area, equipment need to be imported, etc. As a result, the initial investment cost tends to rise, despite the scale effect. On the other hand, percentage of local cost coverage on the total cost tends to reduce as the size goes up.

In case of micro-hydropower, there is reason to be satisfied with compromise on the quality of construction. On one hand the load centers are often not economically very active to justify for very high reliability. On the other hand, there is need to include local resources as far as possible to bring up the manufacturing, construction and management capability.

The MHPs which are being studied/constructed with support from REDP, feature unit cost range of RS 87,000 (US$ 1279) to RS 121,000 (US$ 1779) per kW. The REDP projects which would be community owned and managed would receive about 45% grant finance through REDP, 16% from HMG/N subsidy and some 10% from VDC/DDC fund indicating a total subsidy of about 70% or so.

The present value of ACAP/KMTNC implemented MHPs also receive about 70% subsidy on the initial investment cost. Remaining local equity is often further relaxed through VDC funds. The per unit construction cost of ACAP/KMTNC implemented projects like Ghandruk (50 kWe) and Sikles (120 kWe) are given in the table 2.1 above.

Total subsidy (PV) as compared to the total investment cost for the four privately owned MHPs (see table 2.1 above) ranges from 19.8% (Barpak) to 27% (Pemba Gelu Sherpa).

Cost per Connected Customer

The MHP investment cost per connected household (cost of power system infrastructure, village distribution system) is estimated to be in the range of US$ 325 (refer Table 2.2 below). As can be seen this cost is a function of average peak watt subscription per connected household and the cost of the plant itself. In average the cost of internal wiring and customer connection charge (which has to be borne by the customers) alone may account roughly 22 percent of the total investment cost per connected household.

While the cost of investment per kW connected households in the cheapest micro hydro project may be lower than the cost in typical new rural distribution projects of NEA, this cost advantage is however attributed to low quality of supply, reflected in the voltage fluctuations, and longer duration of outage.

Table 2.2: Investment cost per customer

Project		Customer Numbers now	Peak Watt per customer	Cost per customer ($)	Subsidy per customer ($)
Gaura Rice Mill, Baglung	2041 (19 kWe)	224	80	108	27
Barpak MHP	2048 (46.5 kWe)	604	60	118	23
Pemba Gelu, Solukhumbu	2051 (12 kwe)	40	147	617	166
Radhalaxi, Ilam	2041 (7.5 (kWe)	40	200	330	77
Ghandruk MHP	2048 (50 kWe)	250	200	436	305
Bhujung MHP	2055 (80 kWe)	400	175	413	289
Sikles MHP	2041 (120 kWe)	525	190	537	376

Annual Operation and Maintenance Cost

Annual operating costs (repair and maintenance, labor, salaries, depreciation and interest charge on loan) are also found to diverge widely from plant to plant. The determining factors are site selection, quality of construction and skill/training of the operating/managing staffs.

Studies have shown that many plants have been unable to generate sufficient revenue even to make a minimum operating surplus, forget about creating depreciation fund. Plants are designed to meet certain load growth in the future. Unlike diesel power station, hydropower plant capacity once built may not be easily extendible. Therefore in the initial years the revenue would naturally tend to be lower by virtue of peak-power sales. Accordingly, a plant's financial performance could be considered satisfactory if it manages to make operating surplus in the initial years of operation.

Apart from the staff and maintenance cost-components, which can be narrowed down to a certain percentage of initial investment, there is the interest on loan cost-component, which increases with owner's inability or unwillingness to self-finance part of the project cost. Therefore financial cash flow situation does only indicate the plants financial sustainability in terms of keeping the plant running.

While estimating O & M costs, long term cost situations must be considered. Certain expenses like major repair/maintenance of machinery, replacement of poles would not be encountered every year. Table 2.3 below shows O & M and total operating cost share as a percentage of initial investment and percentage of revenue. The costs are representative of privately owned MHPs (first four) and NEA leased out plants. The MHP cost data are a result of 4 to 14 years of operating experience while the SHP cost data are based on their yearly budget.

Table 2.3: Operating costs

Project		O & M cost		Total cost	
		% of investment	% of revenue	% of investment	% of revenue
Gaura Rice Mill, Baglung	2041 (19 kWe)	10.11	60	16.97	106
Barpak MHP	2048 (46.5 kWe)	7.02	33	20.85	99
Pemba Gelu, Solukhumbu	2051 (12 kwe)	7.84	62	21.88	173
Radhalaxi, Ilam	2041 (7.5 (kWe)	13.94	45	24.97	81
Jomsom SHP	2040 (240 kWe)	6	42.5	7.1	49.5
Khandbari SHP	2046 (250 kWe)	4.9	44	8	73
Bajhang SHP	2046 (200 kWe)	2	69	4	80
Darchula SHP	2049 (300 kWe)	N/a	50	N/a	85

It has been recognized that the MHP plant operating staffs lack sufficient training, thus resulting in longer downtime which in turn reduces the potential revenue. NEA managed plants are reported to be better than 95% time reliable. The gross estimate from interviews with the owners of the representative MHPs presented here indicate that their reliability are not bad, too. Reliability, in terms of supply days, of milling part seemed to have varied from 90% in case of Baglung to 98% in case of Ilam. Similalry, the electricity supply part seems to vary from about 90% in case of Ilam to 98% in case of Bahlung. The figures are very crude and should be on the higher side, as the data reflects all historical operating days and entrepreneurs possibly only reported major downtime that they remember.

Generation/Sales And Load Factor

It is not easy to find out sales/generation in kWh for micro-hydro plants since there is mostly no metering system. Add on electrification has directly driven milling machinery, hence it would be close to impossible to measure kWh supplied/consumed. Most domestic electricity consumers and even some non-domestic consumers are un-metered and are charged on a flat tariff basis. This is for the reason of simplicity, transparency, controlling peaking demand and costs. However, as most financial and economic indicators and parameters are best expressed and measured in terms of kWh, attempt has been made to grossly ascertain even the historical running hours of the milling machinery. A certain usage/capacity factor on the part of the milling machinery has been used to arrive at approximate kWh delivered to the machinery.

The Table 2.4 below shows kWh generated (cumulative and compounded) for some representative MHPs till the end of B.S. 2054. Also given are kWh sold per annum (typical of 2052/53) for some of the privatized SHPs. Therefore the figures take into account system technical losses. The load-factor indicated in the table is the ratio of total kWh generated to nominal plant capacity and are the latest figures for the MHPs.

Table 2.4: Supply/consumption and load factor

Project		KWh		Load factor, %
		Cumulative and compunded		
		Total	Non-domest.	
Gaura Rice Mill, Baglung	2041 (19 kWe)	1217504	450000	29.1
Barpak MHP	2048 (46.5 kWe)	596068	450500	31.1
Pemba Gelu, Solukhumbu	2051 (12 kwe)	104704	19830	20.6
Radhalaxi, Ilam	2041 (7.5 (kWe)	854678	199000	31.8
		Typical of 2052/53		
Jomsom SHP	2040 (240 kWe)	1951519	160899	44
Khandbari SHP	2046 (250 kWe)	2042400	156180	35
Bajhang SHP	2046 (200 kWe)	810403	64565	18
Darchula SHP	2049 (300 kWe)	1305255	95116	17.1

It should be noted here that, with properly trained staffs and sufficiently quick repair services, the downtime of the plants should be possible to improve by some 10%. This would be reflected into the kWh generated, revenue and the plant load factor.

Tariff Structure

Tariff setting and management plays an important role in the improvement of the plant's technical and financial performance. Milling tariff for MHPs have always been a certain percentage of the amount of the agro-processing. For most domestic users, electricity tariff is based on the amount of peak-power purchased. This system is easy to handle for administrative reason, but does not reflect consumer's equity toward the investment cost of the infrastructure and discourages use of off-peak power for further revenue generation. Considering the amount of time a domestic lighting-only consumer actually need to switch on his lamps in the evening/night time, the equivalent tariff in kWh for a now commonly used rate of RS 1 per watt per month appears high. In Barpak MHP, domestic high level customers are exception to this general rule. They are charged a combination of base as well as metered tariff. The base charge is relatively high to discourage use of high wattage appliances. Whereas, NEA owned utilities (including the now leased-out SHP plants) have very low base charge. This encourages consumer to switch to high wattage appliances. In view of lack of sufficient off-peak hour load for isolated MHPs, this would result in a highly peaking load curve and thus a poor load factor.

The flat tariff applied in most MHPs range from a mere RS 0.25 per watt per month to RS 2 per watt per month. Considering typical usage hours of 4 to 5 hours per day for bulbs, a RS 0.50 to RS 1 per watt per month would compare with NEA tariff for low level domestic consumers. Whereas, considering the typical operating costs of a MHP (Table 2.3 above), a flat tariff of less than RS 1 per watt per month might not even result in a operating surplus, unless there are sufficient day-time end uses contributing to the revenue. Gaura Rice mill, Baglung, is a case example where the annuatised revenue almost covers all of his operating expenses despite of a relatively low electricity tariff rate. Please refer Table 2.5 for the average tariff rates for some representative sites. Flat tariff is recommendable for add-on electrification plants, where the electricity is anyway available in the evening hours.

It stand-alone MHPs like Barpak, add-on MHP like Radhalaxmi MHP, Ilam, it is interesting to note that the average domestic tariff rate is higher than the non-domestic tariff. While in the case of Barpak, it is understandable that the owner has encouraged use of off-peak load power, in the case of Radhalaxmi, the domestic tariff rate is high because he sells energy for take-away battery charging at a very high tariff rate. Whereas, the tariff rate for the SHPs are typical of NEA system. Similalry, in case of Ghandruk, the low level non-cooking domestic consumers are paying high tariff rate, whereas, cooking consumers and lodges are enjoying highly relaxed rate about RS 2.5 per kWh). This is just opposite to the paying capacity of consumer level. Should tariff be revised in Ghandruk, with cooking consumers charged on a combination of flat (relatively lower than non-cooking) and metered tariff (NEA standard or even lower), it would immensely add to the revenue generation.

Tariff management plays an important role in making MHPs financially attractive. Compound tariff (base and metered) should be carefully calculated and introduced to encourage higher level consumers to use more kWh and eventually contribute more to the revenue. At the same time attempt should be made to avoid peaking and poor load factor by maintaining the capacity demand tariff sufficiently high. Salleri Electricity Utilization project (SCECO) is one good example to refer to for tariff management. There the peak power demand per consumer is one of the highest for isolated rural grid system (360 watts per consumer), and yet the load factor is 33%.

Table 2.5 Tariff structures in terms of kWh of some representative sites

Project		Tariff, RS/kWh		
		Domestic	Non-domestic	Average
Gaura Rice Mill, Baglung	2041 (19 kWe)	2.43	2.54	2.5
Barpak MHP	2048 (46.5 kWe)	6.59	4.55	5.72
Pemba Gelu, Solukhumbu	2051 (12 kwe)	4.61	7.21	6.6
Radhalaxi, Ilam	2041 (7.5 (kWe)	4.21	2.82	3.14
Jomsom SHP	2040 (240 kWe)	3.96	5.49	4.54
Khandbari SHP	2046 (250 kWe)	4.43	5.84	3.74
Bajhang SHP	2046 (200 kWe)	4.05	6.9	4.59
Darchula SHP	2049 (300 kWe)	3.73	5.27	4.2
Ghandruk MHP	2048 (50 kWe)	6	2.5	4.4

Financial and Economic Performance

Internal rate return of return has been calculated for the four privately owned representative sites. The investment costs, operating costs and revenues are a result of visiting each of the sites and interviewing the plant owner for collection of all historical data related to initial and intermittent capital investments for upgrading, operating and maintaining the plant, revenues from milling, electricity for lighting and battery charging, sizes and approximate operating hours of the milling machinery over the years, downtime, electricity and battery charging tariff, etc. It is well known that there is no proper book-keeping system in most of the MHPs. Therefore it was difficult to get accurate cost, revenue and downtime data. However, the selection of the representative MHP schemes were made carefully. Only those which were likely to have kept records of all financial transactions and important events were selected. Of the four sites, the data related to the Harichour, Baglung and Barpak, Gorkha should be more accurate. The data from Khamche, Solukhumbu and Radhalaxmi, Ilam may not be as accurate, it should not be far from reality.

It appears that the Barpak and Gorkhe MHPs would have performed satisfactorily on the long run even without the subsidy. While the other two has not been able to a good business even with subsidy on electrical components. While the investment cost does seem to have a bearing in the case of poor performance of Khamche, the real reason is the management part. He has a high amount of accumulated bad debts, which might be irrecoverable now. He does not have milling services and the only other end-use of electricity is his local paper making factory. He is doing good business with his paper factory and actually covering the financial deficit of the MHP from the factory. The approximate tariff his factory is paying is already on the higher side (RS 7.21) and in effect his factory is paying RS 3 per kWh extra on top of that tariff and covering the tariff deficit (see economic cost of production, Table 2.6) for sustaining the plant.

Gaura Rice Mill has relatively good load factor. But due to low tariff, both for lighting and milling, he is not able to make as much profit as he should. The load factor has actually decreased over the years since its peak at the time of adding generator to his mill. There is stiff competition for milling with nearby conveniently located diesel mills. And the competition will get stiffer in the days ahead. On top of that he has not been able to raise the tariff much due to consumer objection. He has already revised it twice from RS 0.25 to 0.50 per watt now - still low. The owner however is trying to maximize the use of electricity by using it for charging take away batteries for far off houses. But there is a limitation on this too, because most settlements around Harichour already have electricity supply from their own MHPs.

Table 2.6 Some key financial and economic indicators, 15 yrs., 10%

Project		B/C ratio	Eco. Cost of production	Subsidy needed as % of An. cost	IRR, % w/o subsidy	IRR, % with subsidy
Gaura Rice Mill, Baglung	2041 (19) kWe)	0.86	3.01	14.33	1.71	8.2
Barpak MHP	2048 (46.5) kWe)	1.15	5.17	-15.24	12.15	15.29
Pemba Gelu, Solukhumbu	2051 (12) kwe)	0.7	10.07	29.72	-2.15	1.58
Radhalaxi, Ilam	2041 (7.5) (kWe)	1.22	2.61	-22.13	23.69	35.04

The financial viability of micro hydro project depends on how well the load factor can be increased through augmenting productive demand for power during the day. In case of smaller schemes this is best done by integrating the plant with direct-driven milling services wherever possible. In case of larger plant promotion of productive end uses and better management needs to apply. Training of operating staffs and timely after sales services are of paramount importance for improving the supply reliability and improve sales. MHPs are mostly in remote areas where national grids can not reach in the near future. The representative sites presented here are only a few days walking from road point and the entrepreneurs are relatively trained to act efficiently. However, those sites, which are much farther and have low level management staffs suffer heavily for simple repair and maintenance problems. Just to site examples, there cases where MHPs in the remote parts of Gorkha, Mustang and the Far West have remained shut down for months due lack of poor management and lack of repair services.

Providing financial support alone is not a viable solution to make such projects economically sustainable. How to blend productive end uses of electricity must be an integral part of rural electrification programs from the very beginning. Also, the future performance of a MHP is connected to its initial stage when the survey/design is being done. Over designing and under designing are sometimes done to suit the user's and the surveyors immediate interest. The surveyors who go to the site for the first time and return to make a project document with design and costs are probably the best persons to train in aspects of "long term sustainability of MHP" and grounds for it. Equally important is to prepare the management team and provide infrastructure to attend to minor repair and replacement problems for which the cost of inviting technician from Kathmandu is out of proportion. While subsidies are important to improve financial return and encourage investors. Equally important is to use subsidies for developing environment targeted at better technical performance of MHPs and compounding technical performance with means to attain even better financial performance.

- Power cost per kWh is very sensitive to the utilization of installation capacity.
- Investor in rural electrification apparently assume that load factor increases over time
- Power systems in rural areas tend to be unnecessarily expensive when they are over designed. Manufacturers have no incentive to reduce the cost due to fixed percent subsidy.
- Cost reduction may have been possible by paying careful attention to design and standard of supply.

In general there exist no standard tariff determination guideline for use in MHPs. Converting power cost into effective tariff is however far form simple. While higher power price may often be necessary and justified in term of efficiency ground but the crucial question is whether a sufficient number of consumers would be willing and able to pay more.