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Under 35 years of age - First Place

Future Development of Mini & Micro Hydro in Sri Lanka : A Macro Level Study

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Abstract: As a developing country, Sri Lanka needs energy for its future industrial development. The main energy source was large hydropower schemes and thermal power plants. However all the potential large hydropower schemes are developed or being developed and thermal generation is restricted because the fuel has to be imported. But the Ceylon Electricity Board is exploring possibilities of enhancing the grid capacity by introducing thermal power plants.

However, there is a potential of mini hydro power plants to fulfill the energy requirement of the national grid. This report emphasizes the investment opportunities in mini hydropower projects in Sri Lanka, being a profitable source of investment.

The annual electricity demand for year 2000 was 5370 GWh with a peak demand of 1276MW. The annual growth rate for energy is estimated at 8%. It is expected that by 2008, the annual energy demand will be 10195 GWh with a peak demand of 2309 MW. Apart from the mega solutions to fill the gap, a short term solution is to bridge up with mini hydro power plants. With this idea the Ceylon Electricity Board has invited the private sector investors to develop mini hydropower so that the CEB can buy the electricity, which will be produced, by private investors.

Sri Lanka, is a tropical country experiencing an annual rainfall of 5m in the wet zone. This blends with the country's unique geography resulting in a potential mini hydropower development capacity of 200 MW. 23 MW has been developed so far and 150 MW will be developed by prospective developers.

With the favourable fiscal policies and the financing assistance an annual addition of 20MW of mini hydro can be expected. This means that with in seven years the total installed capacity of small hydro will be as high as 163 MW. (The installed capacity of the Victoria hydro power plant, which is the largest hydro power plant, is 270 MW)

Apart from these, mini hydro will result in clean, renewable and environmentally friendly sources of energy.

This paper illustrates the basic parameters, costs, centers of a mini hydropower projects (with different cases), and the revenue with the investment appraisal parameters such as NPV and IRR. Further, the author hopes to investigate the economic benefits of mini hydropower projects, the problems faced by the developers and possible solutions for these problems.

The potential of micro hydro development, as an independent source for energy will also be considered in this paper as an off grid solution to the power crisis of this country. The technology of the hydropower projects will also discussed.

The ultimate objective of this paper will be to enhance mini and micro hydro capacity in Sri Lanka and by fulfilling the above, develop our own technology in the industry due to the rapid expansion of the sector.

1. Present Power Scenario of the Country

The annual electricity demand for year 2000 was 5370 GWh a peak demand of 1276 MW.

The annual growth rate for energy is estimated at 8% It is expected that by 2008, the annual energy demand will be 10195 GWh with a peak demand of 2309 MW.

To meet the peak demand for 2000 - 2008 an additional capacity of 1033 MW will be required.

Unfortunately, the addition of generation capacity was not successful. CEB has failed to commission the Upper Kotmale Hydro Power

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Project (123MW), Trincomalee Coal Power Plant Phase I (150 MW), Phase II (150 MW), Phase III (300 MW) Phase IV (330MW) due to environmental and security reasons.

Even at the end of 2001, the Upper Kotmale Hydro Power Project is in the design stage. The expectation of power generation from Upper Kotmale will be 2005 at the earliest. Expectation of power plant to be relocated for security and environmental reasons is still in the pre feasibility stage. Even the location for this is not finalized yet.

If there is no drastic decision from the government there will be a shortage of supply of 820 MW, resulting in a 35% shortage of the capacity. This deficit is crucial and the end result will be power cuts during the peak hours.

Period	Hydro Addition (MW)	Thermal Addition (MW)	Thermal Retirement (MW)	Balance (MW)
1994 - 1999	70	256	0	70
2000 - 2005	123	720	135	708
2006 - 2008	49	388	32	405

Apart from the mega solutions to fill the gap, a short term solution is to bridge up with mini hydro power plants. With this idea the Ceylon Electricity Board has invited the private sector investors to develop mini hydro power so that CEB can buy the electricity which will be produced by private investors.

2. Potential Mini Hydro Capacity

According to statistics of the Ceylon Electricity Board, there are 24 MW of Mini hydro power plants connected to the grid as at the end of 2001 and a further 20-25 MW under construction. Besides the plants connected to the grid today, LOIs has been issued by the CEB for approximately 220 MW. Applications for LOIs for another 60 MW of mini hydro power plants are being evaluated by the CEB. According to the authors evaluation the total mini hydro potential of Sri Lanka exceeds 500 MW with the potential low head irrigation schemes.

3. Basic Parameters of Mini Hydro Power Project

3.1 Rainfall

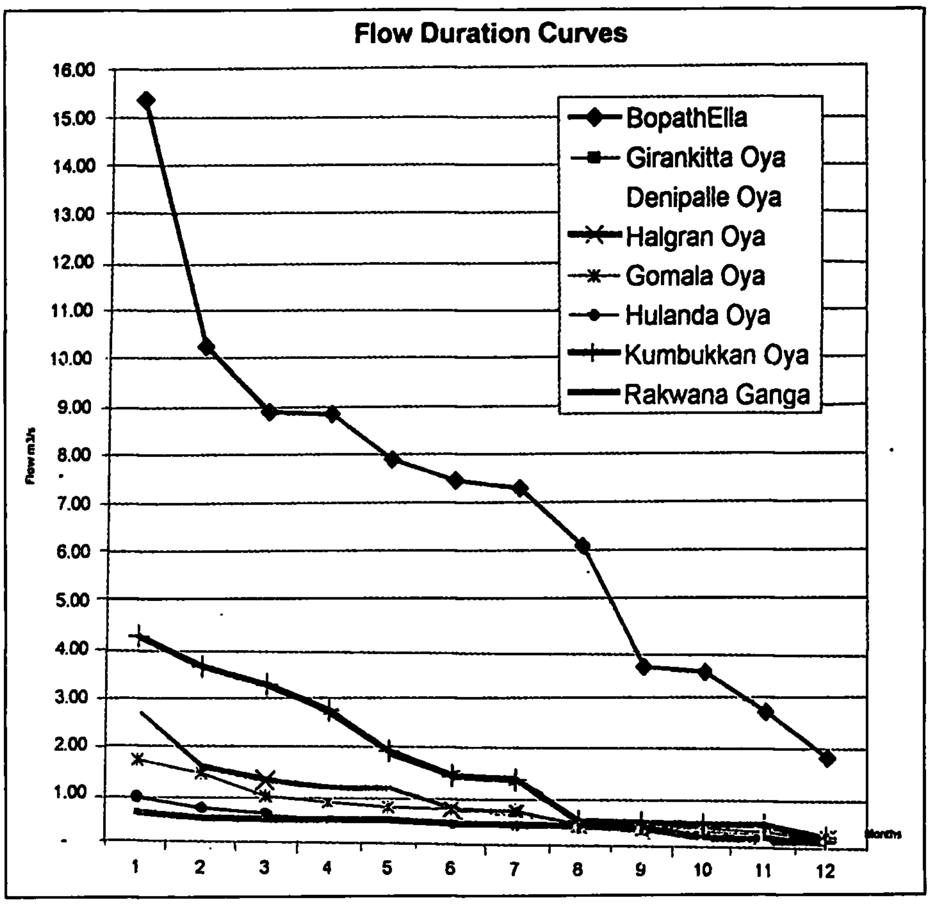
Basically, all mini hydro power projects are run off river type and rainfall in the selected area is the most critical parameter. The highest annual average rainfall is recorded at Maliboda averaging 5300 mm per annum and Heel Oya follows. As described earlier, the wet zone of the country will receive an annual average rainfall of 5000mm. However, the author has studied the annual average rainfall in mini hydro catchment areas which are tabulated below.

Based on the rainfall, catchments and the runoff coefficient the duration curve can be generated. This is a main tool for the selection of design flow. The following graph illustrates the flow duration curve of different sites.

Station	Annual average rainfall in mm
Keragala	3,999
Kitulgala	4,629
St. Leonards	2,025
Deniyaya	3,894
Madolsima	2,325
Kurundu Oya Falls	2,596
Rakwana	3,371
Stallenberg	3,071
Balangoda	2,063
Mahawalatenna	1,800
Maliboda	5,300

This massive difference is based on the size of the catchments. For example, Bopath Ella has 70km of catchments with 4000 mm average annual rainfall with a peak flow of 15.36 m/s and Rakwana Ganga with 5 km^2 of Catchment and 3376 mm of annual average rainfall. With the flow duration curve the first approximation of design flow can be carried out and this can be verified with power and production of the plant. Basically, the design flow is 3 months accidences flow. For example, Bopath ella falls obtains 9 m3/s flow for three months. If the design flow is 9 m3/s, the plant will run 4 months in full capacity, 3 months above 75% of capacity, 3 months above 40% capacity and two months above 20% capacity.

However, many hydro power projects consist of small catchments below 20 km2. In this regard, it is a must to find out a relatively flat flow duration curve, or rainfall is evenly distributed throughout the year to run the plant throughout the year. The following flow duration curve illustrates the ideal situation for a small catchment mini hydro power site.



When developing a mini hydro power project the hydrology of the stream is the most important parameter because the total project viability depends on the hydrology of the stream. It is a must to obtain the services of a qualified hydrologist.

Since many of these streams are not gauged by the Irrigation Department, the only option is to depend on the rainfall, (which is a reliable source) from the meteorological department. However, the author's experience reveals that measuring the flow of the stream, even for a short period of six months, will facilitate a better picture of the stream flow. Usually the time lag between approvals and the commencement of construction can be used for measuring of the flow by temporary V notch, or a weir across the river can easily be carried out. The author also proposes the existing mini hydro developers to gauge their streams and maintain the flow records, thus enhancing the accuracy of the potential of prospective developers.

3.2 Head

The Head of a mini hydro project is the elevation difference between the forbay and the powerhouse location. This is the potential energy of water, which will be converted to kinetic energy and electrical energy by the turbine and electrical energy by the generator. The Head classifies the type of turbine. High head sites are above 100 m and Pelton Turbine can be used.

The Pelton turbine provides excellent efficiency even in very low discharges than Turgo. Medium head sites are below 100m to 10 m with lower discharges. Low head sites, which are below 10 m, Kaplan & Bulb turbines, can be used. Still these sites are not very much attractive with the developers.

3.3 Grid

The distance to the grid is also a major parameter since a mini hydro power plant is connected to the grid . Usually, the plants will be connected to the closest 33 kVA line by a step up transformer. However, this line to the grid has to be constructed under the supervision and guidance of the CEB

The 33 kVA line has to be checked by the CEB before issuing the LOI. This will provide the exact connecting point to the grid as well as the line, which is going to be connected, will have the necessary capacity of transmitting the generated power.

3.4 Access

Access to the project is critical since some of the projects are well away from the main access and access has to be constructed up to the project in order to transport the construction material as well as electromechanical equipment. This is a costly affair.

4. Costs of a Mini Hydro Power Project

4.1 Cost Centers

Preliminary expenses including studies and approvals, lands, civil construction, electromechanical equipment expenses, Penstock supply and laying, and financial charges, project management charges, taxes and the contingencies are the cost centers of a mini hydro power project.

4.2 Preliminary expenses

This includes the cost of approvals such as CEB LOI, Central Environmental Clearance, Local Government & Divisional secretary approval, all necessary clearances including lands, and the cost of the land. These exercises are time consuming and time is money. Further, an excellent study has to be carried out because the total investment depends on the study. Hydrological, Geological, environmental factors have to be carefully considered as well as the civil designs and electromechanical designs. The author has experienced many mini hydropower sites, which are in operation, have to be altered because of the design problems. Some of the plants have to be stopped during the rains because the desilting & forebay tanks together with thrash racks are not properly designed. It is always recommended to pay more attention at the design stage for a good design rather than stopping the plant during operation when all the obligations, especially financial, are being spent.

4.3 Civil Construction

This includes construction costs of weir, intake, forebay & desilting tank, canal if necessary, penstock path with the anchors, powerhouse and the access road. Many of the hydropower sites are unique, since the dimensions of all the structures vary.

4.4 Electro mechanical Equipment

This is the cost of the turbine, generator, controls, switchyard & transformer with all the necessary accessories. This contributes the major cost component of a mini hydropower project, which is further illustrated in the latter part of this paper. The origin of the equipment will also make a big impact on the project, (with West European products) as well as the quality, efficiency, reliability and maintenance. Most West European equipment is fully automated, highly efficient, and sophisticated. Most West European equipment will also make a big impact on the project cost. There is a massive cost difference between Chinese or Indian products with West European Products as well as the quality, efficiency, reliability and maintenance. Most West European equipment is fully automated highly efficient, sophisticated and reliable and therefore more expensive than its rivals in the rest of the world.

4.5 Penstocks

The cost of fabrication of the penstock together with installation, transportation etc. contributes towards the cost of the penstocks. Today, many of the developers will import spiral welded mild steel pipes and weld at site. However, fabricating these pipes locally is not a difficult task.

4.6 Other Costs

Many of the hydropower projects are partly financed through long-term loans through financial institutions. When the loan is disbursed during the construction stage the developer has to pay the interest and this cost has to be incorporated in the project cost as an operative cost.

Even though the developers are BOI companies, VAT on imported goods and construction, and duties, if applicable, has to be paid and these costs are classified as taxes. Project Management cost during the implementation period and contingencies are also incorporated as the components of the project costs.

5. Cost of Project

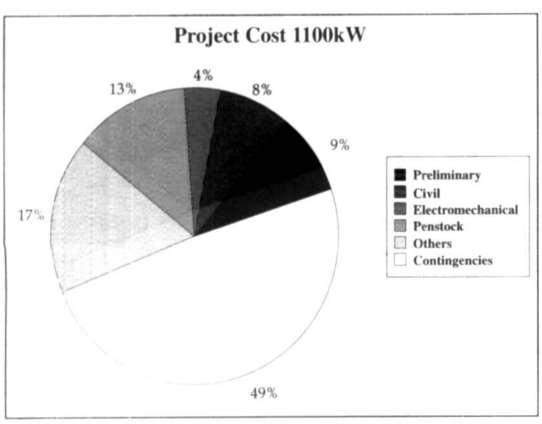
The following table illustrates the project cost for different cases of mini hydro power projects:

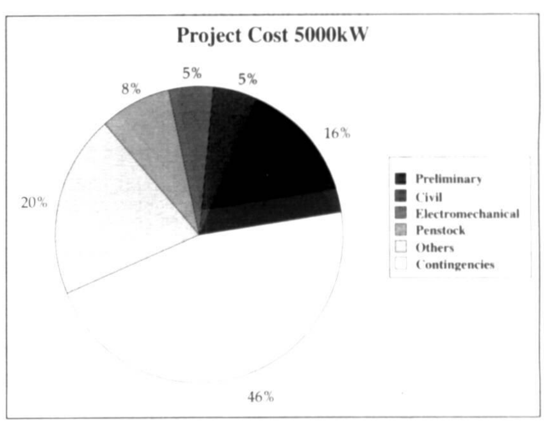
Cost in Rs. Million

Capacity kW	1,100	3,486	1,262	5,022	598
Preliminary	**5.00**	**10.00**	**5.00**	**16.00**	**5.00**
Civil	5.50	23.00	15.00	46.00	5.50
Electromechanical	**31.00**	**105.00**	**43.00**	**135.00**	**31.00**
Penstock	11.00	15.00	11.00	60.00	9.50
Others	8.00	16.00	10.00	24.00	10.00
Sub Total	**60.50**	**169.00**	**84.00**	**281.00**	**61.00**
Contingencies	2.50	6.00	6.00	14.00	4.00
Total	**63.00**	**175.00**	**90.00**	**295.00**	**65.00**

Components to the project cost as a percentage for the same cases is tabulated below.

Capacity kW	1,100	3,486	1,262	5,022	598
Preliminary	**8%**	**6%**	**6%**	**5%**	**8%**
Civil	9%	13%	17%	16%	8%
Electromechanical	**49%**	**60%**	**48%**	**46%**	**48%**
Penstock	17%	9%	12%	20%	15%
Others	13%	9%	11%	8%	15%
Sub Total	**96%**	**97%**	**93%**	**95%**	**94%**
Contingencies	4%	3%	7%	5%	6%
Total	**100%**	**100%**	**100%**	**100%**	**100%**





Project Cost 1100 MW and Project Cost 5000 kW

The above graphs and the table reveal that the major cost component comes from the Electro mechanical equipment. This is nearly 50% of the project cost in four cases. All four sites have one common feature i.e. High head sites using Pelton turbines. The exceptional one is a medium head one using a Francis Turbine. Usually, the cost of Electro mechanical equipment for high head sites is cheaper than medium and low head sites. In general, medium head sites are 1.5 times more expensive than high head sites and low head sites are two times more expensive than high head sites in terms of electro mechanical equipment.

The other important factor to note is the project cost per kW analysis. The results for all the cases are tabulated below;

Capacity kW	1,100	3,486	1,262	5,022	598
project cost per kW (Rs.)	5,216.74	4,121.88	4,002.19	3,661.08	5,229.86

The above table reveals that the project cost per kW will diminish when the capacity is high. This is a very good example for economies of scale. This is a very important point because big projects like the Upper Kotmale project cost per kW is Rs 192,000.00 at US$ 300 Mn project cost, 150 MW @ Rs. 96.00 per US$.

6. Revenue

The Ceylon Electricity Board calculates the tariff on mini hydro based on the avoided cost of production. The tariff is announced every year and the average tariff as at date is Rs 5.675 per unit. With the present tariff the annual revenue of the selected cases is given below.

Cost in Rs. Million

Capacity kW	1,100.00	3,486.00	1,262.00	5,022.00	598.00
Revenue (Rs M)	32.37	81.54	25.66	104.25	17.73

It is obvious that higher the capacity of the project higher the revenue. However, it is attractive to invest in mini hydro as the revenue comes in millions and the developer does not have to invest any working capital again. Even a 200 kW site at 60% plant factor will generate nearly Rs. 6.00 Mn per annum. This implies that investment in hydro will ensure a guaranteed and massive income to the investors.

7. Ratio Analysis

The basic investment appraisal ratios such as simple pay back, IRR & NPV was calculated and the results are listed below; When calculating IRR & NPV the following assumptions were made.

Tariff will be subject to an annual increment of 5%

O & M cost will be 5% of the revenue

Projects will be financed by loan : equity , 60:40 @ 16% , 1.5 years grace and 8 years repayment.

Forecasting is carried out for 15 years.

8. Problems faced by the developers

When obtaining the approvals for hydro several approvals are necessary and those have to be obtained from different authorities. This is time consuming and the main cause of discouraging the investors and developers .

Since there is no policy on mini hydro, different authorities will adopt different methodologies to grant approval. A clear policy and guidelines on approvals will attract and accelerate many developers and investors to the sector.

Insufficient awareness of the projects among the public in project areas will also retard the implementation of projects. Especially when water is used for hydro generation and agricultural purposes insufficient awareness will create problems and lead to the delaying of projects. Unawareness about the returns of the projects will extend to the financial sectors also, resulting in struggles to implement the projects.

Insufficient capacity of the 33 - k VA lines is also a problem to the developers. In some areas the lines are overloaded but still lots of mini hydro potential to be developed will be restricted.

Capacity kW	1,100	3,486	1,262	5,022	598
Project Cost	63.00	175.00	90.00	295.00	65.00
Average Annual Revenue	32.57	81.54	25.66	104.25	17,73
Simple Payback	1.93	2.15	3.51	2.83	3.67
NPV Rs Mn @ 16%	113.88	214.79	73.36	369.62	51.96
IRR %	34%	40%	29%	36%	29%

The above table also reveals the profitability of investing in a mini hydro power project. The IRR for all the projects is nearly 30% which is very attractive with the current commercial rates.

9. Potential Off Grid Micro Hydro Development

The Intermediate Technology Development Group has carried out an island wide survey on off grid micro hydropower projects for rural electrification. This will reduce the high cost of extending the national grid to the uneconomical corners of the country only for lighting purposes. A large number of projects are being carried out under the ESD credit line I and many of these projects were carried out with local technology thus enhancement of knowledge on micro hydro technology is speeded. This will facilitate the extension of off grid micro hydro in the near future. Thus the expensive grid power can be concentrated only to high populated areas and industries. Further, micro hydro will eliminate dependency of the public on the national grid.

10. Conclusion

Investment in the mini hydro sector is a viable and a profitable decision and also helps to provide a clean renewable source of energy without damaging the environment. There are adequate potential mini hydropower projects which are available in the island for development. However, a clear policy on the approvals is a must to attract more developers to the sector.