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Micro – Hydropower Plant in Nepal

Daunekhola Micro – Hydropower Plant

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Executive Summary

In this paper, we analyzed the cost-benefit ratio of Daunekhola Micro – Hydropower Plant and we found that this plant does not pay monetarily but does pay when included the surplus.

Nepal has a huge hydro-power potential of 83,000 MW, out of which 43,000 MW is considered to be economically feasible in the present condition. The present hydro-power capacity is about 635.5 MW which is less than 1.5% of economically feasible capacity. Only 40% of the population has access to electricity. Hydro-power meets only about 1% of the energy needs of the country. Fuel wood (68%), agricultural wastes (15%), animal dung (8%) and imported fossil fuel (8%) meet the bulk of the energy needs. Hydro-power is the major source of electricity (86% of the present capacity, the rest comes from thermal generation).

Considering the precarious political and economic situation of Nepal and taking into account various available natural resources in the country, only those commercial energy sources which are economically, environmentally and socially/politically justifiable should be sought after and promoted. There is a high potential for the utilization of hydropower in Nepal and considering that the rural communities are isolated and scattered, micro-hydro (MH) systems serve as a viable alternative as an energy source. The promotion of MH system is expected to positively impact social welfare through improvements in health and education. In terms of economic welfare, energy from MH system is expected to be beneficial for both producers and consumers in rural economies via the opportunities to create links between them and the national economy. However, the establishment of these MH systems requires considerable resources, so, it is necessary to evaluate the systems' economic desirability to gather its net welfare effect on the rural population.

This report presents a background on the present situation of hydropower and energy scenario of rural Nepal. This is followed by introduction of micro-hydro power and its role in rural development of Nepal. The final portion and the primary objective of this report consist of economic analysis of Daunekhola Micro-hydropower system. In this regard, relevant data concerning Daunekhola Micro-hydropower systems have been collected.

The economic analysis of Daunekhola Micro Hydropower Systems using those data shows that MH systems can be an effective means of increasing the economic welfare of people in the rural areas, even though they may be in a weak financial situation. However, bearing in mind the need to ensure the long-term sustainability of these MH systems in delivering services, the financial viability of a system therefore becomes a crucial consideration.

1. Introduction

1.1 Nepal's situation

Nepal is rich in hydro-resources with access to one of the highest per capital hydropower potentials in the world. In fact, the perennial nature of Nepali rivers and the steep gradient of the country's topography provide ideal conditions for the development of some of the world's largest hydroelectric projects in Nepal. Current estimates are that the theoretical hydropower potential is approximately 83000 MW; however, the economically feasible potential has been evaluated at approximately 43000 MW, of which only 635.5 MW i.e. less than 1.5% of economic potential is installed[1]. Although bestowed with tremendous hydropower resources, only about 40% of Nepal's population has access to electricity. Due to high shortage of electricity, Out of the 24 hours, Nepalese were forced to live without electricity maximum for 18 hours a day in 2009 (dry season)[2]. In 2007, the Nepal Electricity Authority (NEA) was unable to meet the total energy demand of 23% during the day and 41% at night. At present, the evening electricity demand in Nepal is 720 MW, of which the NEA is able to provide a paltry 360 MW. The excess demand is met by India, which exports 60 MW to Nepal[3]. Moreover, in the entire scenario of energy use of the country, the electricity is a tiny fraction; only 1% energy need is fulfilled by electricity. The bulk of the energy need is dominated by fuel wood (68%), agricultural waste (15%), animal dung (8%) and imported fossil fuel (8%)[4].

1.2. Micro-Hydro Power

Hydropower plant of less than 100 kW capacities is generally categorized as micro-hydro (Nepal Electricity Authority, 2007). This technology falls into one of three categories: Peltric, Non-Peltric, or Improved Ghattas. Peltric sets are small, vertically-mounted units with impulse-type turbines and induction-type generators, and usually produce less than 5 kW. Non-Peltric sets use Pelton or cross-flow turbines and typically produce more than 5 kW. Improved Ghattas use a traditional water wheel but instead of wood, the wheel is steel. This difference offers

[1] Prajwal Khadka, et al (2011) http://nrec.mn/data/uploads/Nom%20setguul%20xicheel/Water/badrakh%20china/Nepal.pdf
[2] Nowpublic Crowd Powered Medhia http://www.nowpublic.com/world/nepal-hit-18-hour-power-cuts
[3] Shradha Upadhayay (2009) pp. 1.
[4] Independent Power Producer's Association http://www.ippan.org.np/HPinNepal.html

significant increases in productivity[5]. Plants in 1–100 kW range generally supply power through a mini-grid to a rural community. Such plants mostly produce alternating current (AC) and as such the supply is not much different from the supply of electricity from the national grid. There are currently 1,956 micro-hydro schemes in Nepal, of which 810 are Peltric, and 347 are Non-Peltric. The installation of these systems are installed and overseen by local entrepreneurs, Non-Governmental Organizations (NGOs), local manufacturers, International Non-Governmental Organizations (INGOs) and the United Nations Development Program-Global Environment Facility (UNDP-GEF). The Nepalese government has taken a number of initiatives that they hope will foster the development of these projects. A license is not required to install a micro-hydro project as long as it produces 1000 kW or less. In addition, the government established the Alternative Energy Promotion Center (AEPC) to promote renewable energy within the country. In addition, to help foster the development of micro-hydro projects, Nepal joined the United Nations Development Program-Rural Energy Development Program (UNDP-REDP). This relationship has encouraged INGOs to support these installations through providing capital subsidies and building greater capacity. Nepal administers its subsidy program through the national Agricultural Development Bank (ADB)[6]. The power is mainly being use to grind grain, hull rice, and expel oil from oilseeds, as well as generating electricity in the hills of Nepal. Moreover, this power project has encouraged micro-enterprises, which would not have been possible in the absence of electrification. This is being hailed as a major achievement since only six per cent of the rural population has access to electricity through the national grid.

[5] Shradha Upadhayay (2009) pp. 3.

[6] Alternative Energy Promotion Center, *Micro-hydro data of Nepal (AEPC 2005)*, Kathmandu, Nepal

2. Main text

2.1. Area & Project

2.1. 1. Daunekhola Micro Hydropower Project (DMH Project)

DMH project is located at Pinthali village of Kavre District in Nepal. The capacity of the project is 12KW. This project uses water from the nearby river Daunekhola. The cost of constructing the plant is summarized on Table 1. The construction cost is $36,138 which comprises of the financial cost, subsidy and grant. The subsidy is provided by the government for the establishment of the DHM project. The interest rate is pegged at 6% per annum. While the grant is from Rural Energy Development Program (REDP) is the major source of financing for the MH system.

Table 1. Construction costs (US$)

Financial cost	Subsidy	Grant
22,792	3,064	10,282

There are 116 households in the community they will use the energy that generated by the project. Energy generated from the plant will be mainly used for lighting purposes. All the households in the village are linked to the electricity source and agriculture is the main source of livelihood of the people of Pinthali[7]. For the use of electricity, subscribers pay tariffs on a flat rate, which is $0.06 per KWh[8]. In terms of industrial use, there is a huller and an oil expeller that use electrical energy generated by the DHM project.

Table 2 on the other hand, shows the annual operating cost (also called as the variable cost) which comprises the salary of people managing the plant as well as the maintenance cost for the plant amounting to $1,238 annually. The rate for the operating and maintenance cost is $0.064/kWh.

[7] *Sanjay Prasad Gorkhali* (2005)

[8] http://www.nea.org.np

Table 2. Annual Operating and Maintenance Cost (US$)

Operating cost	Maintenance Cost	Total
554	684	1,238(S0.064/kwh)

Annual revenue is shown on Table 3. The total revenue of the plant annually is $1,157 generated from the usage of the plant by both the households and the industry. Annual electricity consumption from the household and from the industry is 11,716.7 kWh and 7,566.7 kWh respectively. The tariff rate is $0.06 per kWh.

Table 3. Annual Revenue (US$)

	From household	From industry	Total	Revenue-Cost
Revenue	703	454	1,157	-81
(price)	0.06kwh			
(consumption)	11716.7	7566.7	19283.4	

Before the plant was constructed, all the households in the village heavily depended on kerosene for their lighting purposes thus the cost of their lighting is equal to the cost of their usage of kerosene. But with the micro hydropower plant in place, there is a huge decline in the consumption of kerosene thereby giving household additional savings amounting to $3,408 as shown on the table below.

Table 4. Change in Kerosene Consumption

	Without	With	Savings
Annual expenditure (US$)	3,945	537	3,408
Price [9] (US$)	0.95 / liter		
Annual consumption(l)	4,152.6	565.3	3,587.4
Annual consumption(kl)	4.153	0.565	3.587

[9] http://www.nea.org.np Kerosene is Rs. 68.50 per liter and Rs1 = US$0.145 (August 8, 2011)

2.1.2. Our Assumptions

We assume that micro – hydropower plant has some secondary market, such as the kerosene market, the battery market, the candle market, “Time saving”, fire hazard reduction, and has the various spread effects such as education, health benefits and so on. Since the project is located in a very small village so that there are data constrains and including the benefits in the not distorted & price-unchanged markets lead to the double counting. Hence, we only treat the kerosene market as the secondary market because this market has an externality, which is carbon dioxide (CO2), and we assume that the price of kerosene has not changed even with the existence of the plant that is $0.95 per liter.

2.2. Cost benefit analysis

2.2.1. The model

This paper aims to calculate the cost – benefit ratio of having the Daunekhola micro – hydropower plant in place for the Pinthali village. Thus, we use the formula below.

$$\text{Ratio} = \frac{\sum_{i=1}^{\infty}\frac{\text{The first ary market' SS}_i}{(1+\delta)^i} + \sum_{i=1}^{\infty}\frac{\text{The second ary market' SS}_i}{(1+\delta)^i}}{\text{Construction costs}}$$

First we calculate for the net present value of the social surplus for the primary and secondary market. For the primary market, the net present value of social surplus is equal to the sum between the total Consumer Surplus and the difference of expenditure and the operating cost. While for the secondary market, the net present value of social surplus is equal to the benefit from the reduction of CO2.

Table 5. Benefits and cost

Benefits	Cost
Consumer surplus (the first market)···(a)	Construction cost···(d)
Revenue from the plant (the first market)···(b) Benefits of external cost reduction (the second market)···(c)	Running cost (the first market) (=Operating cost + Maintenance Cost) ···(e)

$\varDelta$(The social surplus in the first market) = (a) + (b) －(e) =(f)
$\varDelta$(The social surplus in the second market) = (c)
Cost – benefit ration = NPV of {(f) + (c)} / (d)
(Appendix D)

2.2.2. Demand and Supply Estimation (Construction the demand and supply curve)

We assume that the demand curve is linear and then infer the curve using the price elasticity of electricity for simplicity. However we couldn't find the elasticity for Nepal, thus we consider using the elasticity of other countries. Based from a research paper, the price elasticity of electricity in Indonesia is -0.57[10] and Pakistan is -0.33. These figures are higher than the elasticity in developed countries, for example, the UK (which is -0.19), the US Texas (which is -0.08) and Japan (which is about -0.1)[10]. In this case compared to developed countries, one might think that developing countries lack electricity making that their demand for electricity will be huge and the absolute price elasticity will be very small; but this perception is wrong. This is because developing countries have low disposable income that they cannot afford to pay high electricity price, so if the electricity price is high, people in such countries will be inclined to use other energy resource such as kerosene. Hence the absolute price elasticity is not so small. We suppose that the price elasticity of electricity in Nepal is -0.4. Due to uncertainty of our assumption we will calculate for the sensitivity analysis on Discussion 2.3.

We set the demand curve as

$$q^h = \alpha_0 + \alpha_1 p^h,$$

And the elasticity

$$\varepsilon = \frac{\varDelta q^h / q^h}{\varDelta p^h / p^h} = \frac{\varDelta q^h}{\varDelta p^h}\frac{p^h}{q^h} = \alpha_1 \times \frac{p^h}{q^h} \ \therefore\ \alpha_1 = \varepsilon\,\frac{q^h}{p^h}$$

From the data on the household, the consumption or quantity is equal to 11,716.7 kwh with a price of electricity equal to \$0.06 per kWh. Thus we have,

$$\alpha_1 = -0.4 \times \frac{11{,}716.7\text{kWh}}{\$0.06} = -78{,}111.1,\ \ \alpha_0 = q - \alpha_1 p = 16{,}403.3$$

$$\therefore q^h = 16{,}403.3 - 78{,}111.1 p^h$$

10 *Yuko Hoshino*(2009) pp4

The reverse demand curve is

$$p^h = \frac{1}{\alpha_1} q^h - \frac{\alpha_0}{\alpha_1} = -0.000013q^h + 0.21$$

Similarly, the industry's reverse demand curve is

$$p^i = -0.000020q^i + 0.21$$

The consumption or quantity is equal to 7,566.7 kWh and with same price of electricity with the household equal to $0.06.

The supply curve for both household and industry is the same and is horizontal since the rate of the operating cost is $0.064 per kwh. Both the demand and the supply curve of the two sectors of the community are shown below on Chart 1.

2.2.3. Social benefits and Social costs of the Primary Market

Using the estimated demand and the supply data, we were able to derive the social benefits, social cost and social surplus for both the household and the industry with the implementation of the Daunekhola Micro – hydropower plant. Table 6 shows the summary of the benefits (Appendix A to C). The social surplus includes tax revenues however in the case of Nepal there is no tax levied on electricity. Government expenditure, in terms of subsidy and grant are considered as cost.

Chart 1. Demand and Supply Curve of Pinthali Village
Refer to Appendix D

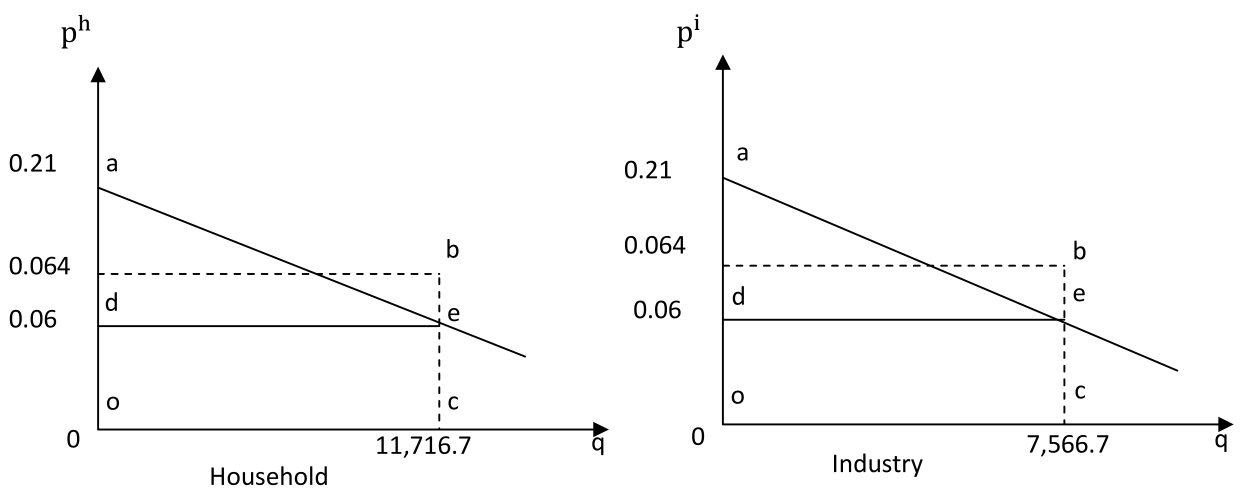

Table 6. Summary of Social Benefits, Costs and Surplus in the first market

	Household	Industry	Total
Social Benefits (SB) -aoce	$ 1,581.8	$ 1,021.5	$ 2,603.3
Social Costs (SC)-docb	$ 752.2	$ 485.8	$ 1,238.0
Social Surplus(SS) = SB-SC	$ 829.5	$ 535.7	$ 1,365.3

The net present value of primary market's social surplus is $22,754.2 (Appendix E)

2.2.4. The secondary market

The electricity decreased the consumption of the kerosene, which reduce carbon and reduction of carbon generates the benefits. In Nepal the reduction of 1ton of carbon (C) is estimated to be in the range of $5 to $10. So, we set three case scenarios below as shown in Table 7.

Using the middle case scenario the net present value of the reduction of carbon emission is $305 (Appendix G). This is the SS in the second benefits.

Table 7. Carbon Reduction Scenarios

	Low	Middle	High
Price	1tC = $5	1tC = $7.5	1tC = $10
Reduction of C		2.436 tC	
Total	$ 12.2	$ 18.3	$ 24.4

2.2.5. Cost-Benefit Ratio

With the calculated net present value of both the Social Surplus of the primary and secondary market, the total benefits amounts to $23,059.2. Thus, the ratio of the benefit against the cost is 1.01 (Appendix H). This indicates that it is better adopt and construct the micro hydropower plant in the Pinthali village as its benefits exceed its costs.

2.3. Sensitivity Analysis

Because of lack of available data particularly on the price elasticity of electricity and cost of reduction of carbon emission in Nepal, Table 8 shows the different scenarios under different price elasticity of electricity in Nepal of -0.5, -0.4 and -0.3 as well as the cost of reducing one (1) ton of carbon emission. The scenarios are categorized into the following "Worst Case", "Middle Case" (we have already calculated) and "Best Case".

Table 8. Summary of Sensitivity Analysis

	Low(Worst)	Middle(Normal)	High(Best)
Financial Cost	22,792		
the price elasticity of electricity	-0.5	-0.4	-0.3
$\sum_{i=1}^{\infty} \frac{\text{The second market's } SS_i}{(1+\delta)^i}$	17,933.3	22,755.0	30,788.3
$\sum_{i=1}^{\infty} \frac{\text{The second market's } SS_i}{(1+\delta)^i}$ / Construction costs	0.79	1.00	1.35
1 ton carbon price	\$5/tC	\$7.5/tC	\$10/tC
Benefit from reducing co2	12.2	18.3	24.4
$\sum_{i=1}^{\infty} \frac{\text{The second market's } SS_i}{(1+\delta)^i}$	203.3	305.0	406.7
$\sum_{i=1}^{\infty} \frac{SS_i}{(1+\delta)^i} + \sum_{i=1}^{\infty} \frac{\text{The second market's } SS_i}{(1+\delta)^i}$	18,136.6	23,060.0	31,195.0
Cost-Benefit ratio(R)	0.80	1.01	1.37

3. Conclusion

Micro – hydropower plants serve as a move to greener environment. They use the power of running – water in generating electricity. They are introduced and used in developing countries to reduce carbon emissions and other greenhouse gases. Moreover, they are the source of electrification in rural areas in countries like Nepal. Their presence develops and improves the socio – economic aspects of every household in rural areas. With electricity in place people start to engage in different economic activities such as business and industries emerge. And, villagers start owning essential household appliances.

However, in the case of the Daunekhola micro – hydropower plant, the benefits of having a hydropower plant is hard to recognize because the community cannot sustain the maintenance of the plant. Given that the annual revenues both from residential and industrial usage cannot cover the annual total running cost. And since the demand for the electricity is highly inelastic, increasing the price or tariff on kilowatt per hour would only burden the villagers by making them pay a higher tariff as well as making their agricultural products expensive. Thus, the best way is for the government to give subsidies and grant in order to help the community meets the operational and maintenance cost of the plant.

Furthermore, other industrial use such as micro – enterprises and small cottage industries should also be promoted aside from the existing use on huller and oil expeller and of household lighting purpose only. In support to this, the government through the help of non-governmental organizations (NGOs) should conduct livelihood seminars and trainings in order for the community to venture to small cottage industries or businesses. This is to take advantage of having electricity during the day that would promote and enhance economic activities and thereby generate additional revenues for each household and community as a whole. With this, the community will be self – sufficient and need not to depend on government subsidies in the future.

Though this paper attempts to have a comprehensive analysis on the cost and benefits of the Daunekhola micro – hydropower plant but due to lack of necessary data, most our calculations are based on assumptions. Thereby we are restrained of producing accurate estimates. But rest assured that assumptions used were based on current and reliable information from other studies conducted by international organizations. Furthermore, future study on other secondary markets aside from kerosene should also be undertaken.

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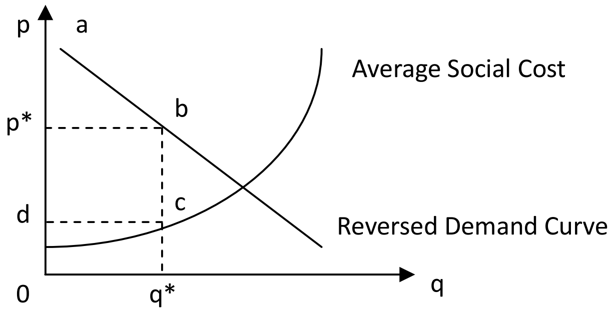
6. Appendix

A. Social Benefit (SB) = Consumer Surplus(CS) + total expenditure
B. Social Cost (SC) = private cost (+ external cost)
C. Social Surplus (SS) = SB－SC
D. Illustration of SB, SC and SS



CS = abq*
Total expenditure = P*bcd
SB = abq*o
SC = oq*cd
SS = SB-SC = abcd

PS(Producer's surplus) = p*bcd
SS = CS + PS = abcd

E. Net Present Value of Primary Market's Social Surplus

$$\sum_{i=1}^{\infty} \frac{SS_i}{(1+\delta)^i} = \frac{1,365.3}{0.06} = 22,754.2$$

F. Molecular weight

co2 emission rate	2.49 tco2 / kl
carbon / co2 (Molecular mass)	c = 12/ 44×co2
carbon	2.436 tC

G. Net Present Value of Secondary Market's Social Surplus or the Reduction of Carbon Emission

$$\sum_{i=1}^{\infty} \frac{\text{The second market's } SS_i}{(1+\delta)^i} = \frac{18.3}{0.06} = 305$$

H. Cost – Benefit Ratio

$$R = \frac{22,754.2+305}{22,792} = 1.01$$