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A Comprehensive Study of Micro Hydro Plant and its Potential: A Case Study

Studi Komprehensif Pembangkit Mikro Hidro dan Potensinya: Studi Kasus

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Abstrak

Jaringan jaringan listrik nasional yang ada tidak dapat diandalkan dalam menyediakan listrik ke daerah perbukitan pedesaan karena struktur geografis Nepal yang sulit. Oleh karena itu, permintaan pembangkit listrik mikrohidro meningkat di wilayah Nepal ini. MHP menghasilkan hingga 100kW dan membantu mendistribusikan listrik ke masyarakat terpencil. Tujuan utama dari penelitian ini adalah untuk mempelajari kelayakan teknis dan ekonomi dari pembangkit listrik tenaga air mikro di Gairibari Jharna, Kalika Municipality-08, Chitwan, Nepal. Proyek ini merupakan jenis penelitian penjelasan yang didasarkan pada data primer yang dikumpulkan melalui kuesioner dan survei lapangan. Selanjutnya, setelah analisis data yang dikumpulkan dari 41 dari 87 rumah tangga, menunjukkan interpretasi positif. Melalui penelitian kualitatif dan kuantitatif, permintaan daya rata-rata untuk setiap rumah tangga ditemukan sebesar 513.29 W yang menghasilkan rata-rata permintaan energi sebesar 1.9 kWh per hari. Sementara itu, perhitungan teknis menunjukkan head tersedia menjadi 98m, debit yang dihasilkan menjadi 0.24221m^3/s dan desain akhir mencerminkan daya yang dihasilkan menjadi 12 kW. Melalui analisis detail biaya, anggaran untuk proyek ini adalah NepaleseNRs 36,84,730 ($28,102.7) . Setelah analisis ekonomi biaya, periode pengembalian dihitung menjadi 15.37 tahun.

Kata Kunci: estimasi biaya, analisis data, debit dan headmeasurement, pembangkit listrik mikrohidro

Abstract

The existing national grid network is unreliable in providing power tothe rural hilly areas due to difficultto geographical structure of Nepal. Therefore, the demand ofMicro-hydro power plants are increasing in these areas of Nepal. MHPs produces up to 100kW and helps to distribute power to isolated communities. The main objective of this research is to study the technical and economic feasibility of micro hydropower in Gairibari Jharna, Kalika Municipality-08, Chitwan, Nepal.This project is an explanatory type research whichis based on the primary data collected through questionnaires and field survey.Furthermore, upon the analysis of data collected from 41 out of 87 households, it showed positive interpretations.Through the qualitative and quantitative research, average power demand for each household was found to be 513.29 W leading to anaverage energy demandof 1.9 kWhr per day. Meanwhile, technical calculations showed the head available to be98m, discharge produced to be 0.24221m^3/s and the ultimate design reflected the generated power to be 12 KW. Through the detail analysis of cost, budget for this projectwas NepaleseNRs 36,84,730 ($ 28,102.7) . After economic analysis of cost the payback period is calculated to be 15.37 years.

***Keywords**: cost estimation, dataanalysis, discharge and headmeasurement, micro hydro power plant*

1 INTRODUCTION

1.1 Background

Micro hydro Power Plants are defined as having a generating capacity range from 5KW to 100KW.[1]. Micro hydro helps to replace solar power system as in winter, solar energy is minimum whereas the availability of small water resources can be utilized to generate power through micro hydropower system.[2]. The need of micro hydropower is increasing in many countries for power distribution to rural areas, to support isolated industries and to provide illumination at night.Such hydropower is one of the most cost-effective solutions to the existing problem of lack of electricity in rural areas of Nepal.Nepal is a mountainous land-locked country with more than 6000 rivers, and small rivers and rivulets having total length more than 45,000 km.hydropower is the major source of electricity in Nepal as Nepal has estimated theoretical potential 83000 MW capacity and techno economically feasible 45610 MW potential.[3]. Nepal possesses in-country capacity of developing medium-sized hydropower potential of 50 MW [4].Such hydropower is one of the most cost-effective solutions to the existing problem of lack of electricity in rural areas of Nepal.Mostly micro hydropower helps to provide alternative economic to the national grid.Micro hydropower plants operating in isolation mode are serving many remote settlements of Nepal. There is also huge potential of establishment of other forms of standalone power plants in various rural regions in Nepal.. Various sources can be utilized to generate electricity like biomass, solar and other forms[5].They have been electrifying the rural communities for more than two decades which was only limited to lighting purpose[4]**.**

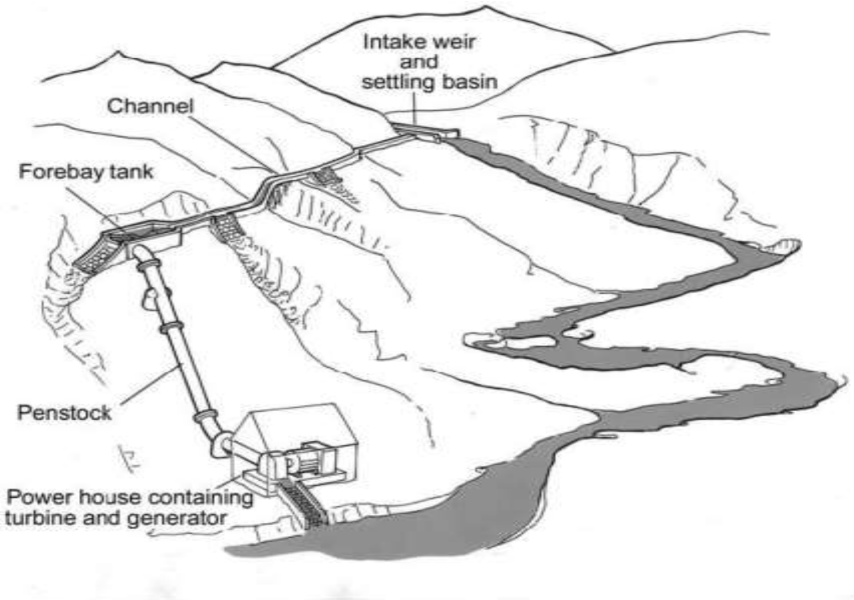

Figure 1*:*Layout of Micro Hydro Power

Figure shows the general components of micro hydro power. Water flow will be diverted in intake weir and it will flow into channel that transport water to forebay tank before going to penstock pipe. Waste will be filtered and stopped from being drawn to the turbine with the help of penstock pipe. Turbine will transfer mechanical energy to generator generates electrical energy.[6]The cost of installation ofmicro hydropower systems in Nepal depends on the location of any sites.Several factors can effect the installation cost including civil works required at the intake and for the canal, the length and type of penstock, the complexity of the turbine design, the distance to the distribution area, and the number of connected households. [7]

Location:The Feasibility Study of Micro Hydropower Project area is located in Ward No.6 of Kalika Municipality, Chitwan Nepal. The proposed project is located between the Longitude 84˚34' 05.6" N and Latitude 27˚44' 05.1" N.The reason behind selecting this site is because of easily accessible.

In rural areas like Gairibari, most of the people belong to poor background. People are mostly uneducated and must rely on farming for their living. In spite of having the facility of electricity, people cannot connect it because of high price rate. The tariff rate is high for them to afford. Local people feel difficulty with billing system as they have to travel long distance only to pay the bill. Some houses are found even without electric connection and houses with electric connection have barely meter box .There is even practice of power theft methods which is illegal tapping of bare wire for electric supply. Some houses that are willing to connect the electricity in house are compelled to live in dark.Thus, Installation of Micro Hydropower in that area is like boon for them. This is the best solution for their problem that can be more beneficial to uplift life standard of the people of Gairibari. In short, the major reasons for undertaking this project are;

a. Local people are not aware about the possibilities of hydro power in Gairibari.
b. The citizens of Gairibari could not afford solar panel as the alternative source of electricity.
c. High electricity rate is not affordable for the local people of Gairibari.

1.2 Objectives

To study the technical and economic feasibility of micro hydropower in Gairibari Jharna, Kalika Municipality.This also creates the concept about the possibility of design of micro hydro power plant in Gairibari.

2 LITERATURE REVIEW

Among all the alternative sources of energy, micro hydro is one of the most widely used. Micro Hydro has created tremendous opportunities for technical. Micro Hydro technology has been providing energy to the people living in 55 all hill and mountain districts. Out of all districts across the country, who are in off grid remote areas. Reliable source claim that approximately 3300 community-owned and community-operated MHPs installed in Nepal.[8]

2.1 Micro Hydro Power in Past

A decade ago, when much of the country's rural population lived off the grid, Nepali villages boasted their own renewable energy sourcesmicro hydro. Evolution of hydro power development in Nepal begins with traditional *Ghatta*and Mills. Reliable source claim that around 3000 Micro Hydro plants of capacity of up to 100 kW to electricity to generate have been installed.

2.2 Micro Hydro Power in Present

With the active participation from the private sector and through the technical and financial assistance of AEPC and other national/international financing agencies, around 3,300 MHPs have been installed in the country in hilly and mountains locations.Currently, 40 plants are operating.Locals had built a 12 kW plant on the Rumdi River in Manebhanjyang Rural Municipality-5 a decade ago which is still in operation.The 13 MW Sikles Hydropower Project, located in Madi in Kaski district in western Nepal, has started trial production[9].Districts of Baglung and Gulmi, located in Gandaki Pradesh and Province No. 5 respectively, were identified as a region with a high density of MHPs. These districts have reasonable road access and a high density of MHPs. [10]

2.3 Micro Hydro Power in Future

Availability of abundant water resources and geographical feature provides a best opportunity for hydro power production in Nepal. Out of the total hydro power generation capacity of 83,000 MW in the country about 42,000 MW of power generation is financially and technically feasible. Not only in Manebhanjyang, many micro hydro plants built in the eastern hills will become useless sooner or later, according to locals [11].

3 MATERIALS AND METHODS

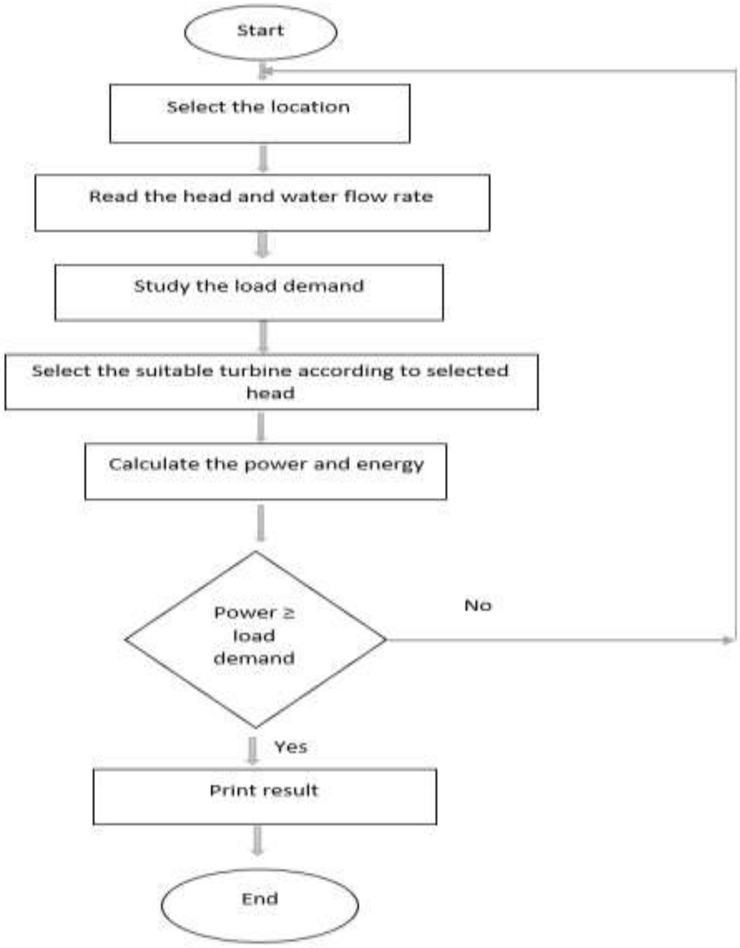

Figure 2:Flow Chart of Micro Hydro Power Project

1. Selection of suitable location

Suitablelocation selection is very important. The places near like Jalbire and Saktikhor are also have potential of having micro hydro but these places are not easily accessible. The transportation facilities are very poor in comparison to Gairibari. The resources cannot be obtained easily.

The reasons behind the selecting the Gairibari are easily accessible, raw materials availability, favorable climates, availability of suitable lands.

2. Read the Head and Flow Rate

The gross head is the vertical distance between the water surface level at the intake and at the tailrace for the turbines [12].We followed the Google earthfor head measurement with the help of coordinates of that site. The coordinates of respective site were 27˚45'4" NL and 84˚34'15" EL.Similarly, for the discharge measurement we applied the bucket method. This is simple and easy method. The whole flow to be measured is diverted into a bucket or barrel and the time it takes for the container to fill is recorded. The volume of the container is known and the flow rate is obtained simply by dividing this volume by the filling time[2].

$$\text{Flow Rate}(x) = \frac{\text{volume of bucket(m3)}}{\text{Average time (sec)}}$$

3. Study of Load Demand

Load demands are need to be studied properly so as to give proper data. The main purpose of this project is to meet the load demand. The load demand is studied through the quantitative research. The total number of connected loads is to be collected. By using this data we can calculate the average load demand for each household.

$$\text{Average load demand}, x = \frac{\text{Actual power consumed(W)}}{\text{Number of households}}$$

4. Selection of Turbine According to the Head

Criteria of selecting the turbine are head, specific speed , flow rate, rotational speed, efficiency of turbine[13].For this project, the suitable turbine is Pelton turbine because Pelton turbine is cost effective and highly effiecient.

5. Calculation of Power and Energy

Total power produced can be calculated from the formula[14].

Power $=9.81 \times Q \times h \times \eta$ kW

where,

Q = Discharge of water (m^3)

H =water head (m)

Ƞ = Total efficiency of plant

4 RESULTS AND DISCUSSION:

4.1 Socio-Economic Impacts

While carrying out the survey, the people of Gairibari were questioned and various data were collected about them. Some of them are mentioned below;

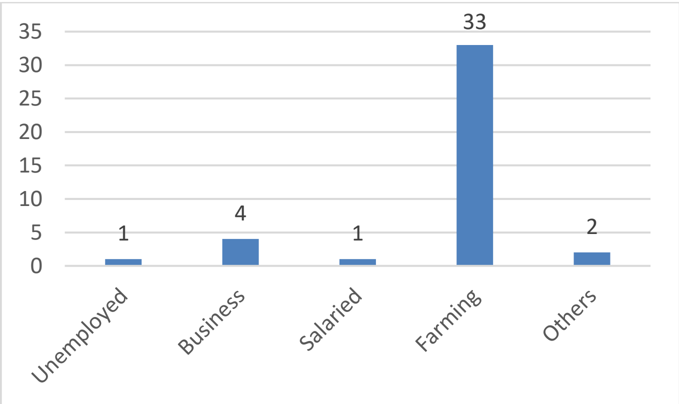

Figure 3:Bar GraphShowing The Occupation of Respondents

The bar graphs show the information of the occupation of the chief earner of the house. Most of them are involved in farming. 33 out of 41 respondents depend upon the farming for living. Less number of chief earnersis businessman. Some are still unemployed.

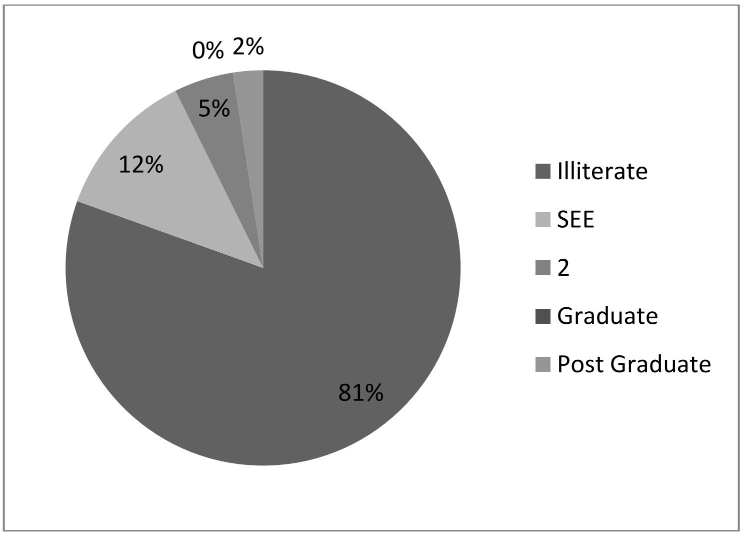

Figure 4: Education of The Respondents

The pie charts show the education of the respondents.in 1st pie chart, out of total respondents in our survey, more than 80% were illiterate. Whereas 12% are higher secondary graduate. However, only 2% are post graduate.

Above data illustrates that the majority of the people are illiterate and depend upon farming. This shows that most of the people are from poor background. Currently most of them are out of electrification facility. Exploration of further potential sites and proper utilization of the existing sites will create opportunity to bring them under electrification. Besides improving their standard of life it will enable them to start small-scale industries in those remote areas . Therefore, there will be opportunities for jobs and self-employment. It would also encourage the people to start home-based industry through availability of three-phase power themselves[15].

Table 1: Likert Scale Summary Showing Responses about the Statements

Statement	Strongly agree	Agree	Neutral	Disagree	Strongly Disagree
Reduces the electric bill	59%	24%	7%	0%	10%
Solves the electric problem	44%	37%	7%	0%	12%
Provides the job opportunity	41%	49%	5%	0%	5%
Creates problem in irrigation	7%	54%	5%	5%	29%
Utilizes the local resources	41%	39%	5%	5%	10%
Encourages the sustainable development	37%	51%	10%	0%	2%

While carrying out the survey, the people of Gairibari were asked about their opinions about the installation of micro hydro in their areas through the different statements. In response 59 % of them strongly agreed with the statement of reducing the electric bill amount. They believed that this project is beneficial for them and will help to save some amount. Likewise, 24% of them agreed with it whereas 10 % showed their strong disagreement with the statement. However, 7% didn’t show any response. Furthermore, responses collected about the different statements are shown in above Likert scale.

4.2 Analysis of Load Survey.

Table 2: Total Connected Load in Households of Gairibari.

Items	No(f)	Watt(x)	f ×x
Bulb	141	20	2820
Fan	51	75	3825
TV	14	100	1400
Refrigerator	10	500	5000
Radio	10	50	500
Electric Iron	5	1500	7500
Total			**=21045 Watt**

Through the load survey of Gairibari, the total household's survey is 41 and connected loads are bulb, Fan, TV, Refrigerator, Radio, Electric iron. The total load demand is 21,045 Watt whereas average load demand is 513.2927 Watt.

Maximum Demand =21045 Watt

Average Demand per Household =21045/41 Watt
= 513.2927 Watt

Let us consider demand factor 0.5

Actual load for an average household of Gairibari =513.2927 ×0.5
= 256.5 Watt

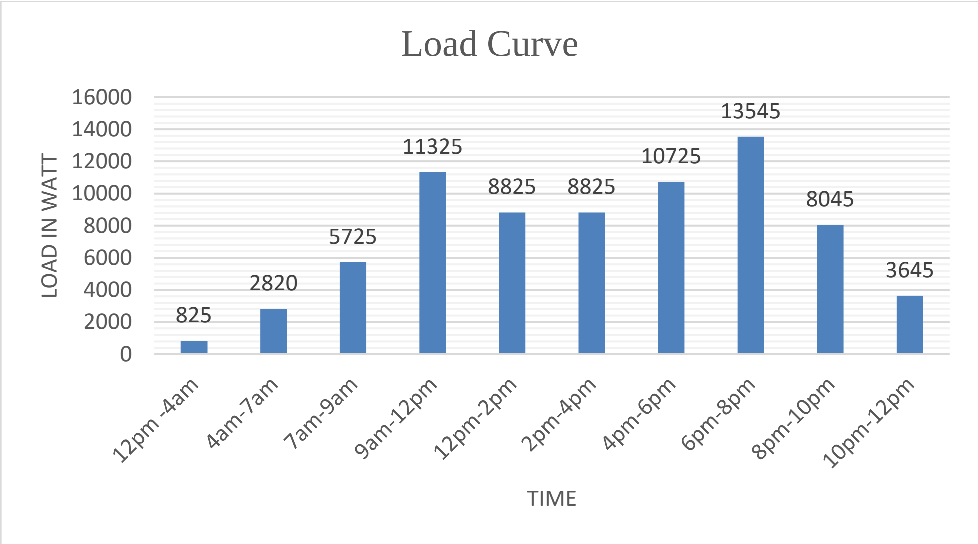

Figure 5: Load Curve

Energy Demand per day
=13545×2+10725×2+8025×2+11325×2+8825×4+3645×2+5725×2+2820×3+825×4
=155825Whr

Average Energy Demand per day = 155825/41
= 3800.61Whr

Load Factor = 0.5

Actual Energy Demand per day = 3800.61× 0.5
=1900.3Whr
= 1.9kWhr

4.3 Analysis of the Power Generation and Energy Production

To obtain the power generation potential we followed the bucket method of flow rate measurement. This is simple and easy method. The whole flow to be measured is diverted into a bucket or barrel and the time it takes for the container to fill is recorded. The volume of the container is known and the flow rate is obtained simply by dividing this volume by the filling time. A bucket of 30 liter was taken and followed the process. The time taken to fill the bucket was recorded as;

Table 3: Flow Rate Measurement using Bucket Method.

Sample No.	Time taken (in Seconds)
1	1.2
2	1.21
3	1.07
4	1.47
5	1.01
6	1.21
7	1.3
8	1.32

9	1.31
10	1.35
Total	=12.44 sec
Average	=12.44/10 =1.244sec

Average time taken to fill the bucket =1.244sec
Volume of bucket = 30 liter
1000 liter =1 m^3
30 liter=30/1000 m^3

Then, Discharge (Q) $= \frac{\text{Volume of bucket}}{\text{Time taken to fill the bucket}}$

$= \frac{30}{1000 \times 1.244}$

$=0.024116 m^3/s$

Power generated = Q ×g×h×η kW
= 0.024116×9.81×98×0.95×0.9×0.8×0.85×0.96×0.9
=12 kW

Power generated from hydropower= 12 kW

From the above calculation the discharge of water flow is obtained to be 0.024116 m^3/s Total power potential of Gairibari is 12 kW.

It is economical to run the plant for 20 Hrs. During uneven fluctuation of load Ballast Load is operated.

Energy Generated =12×20
=240 kWhr

Diameter of penstock

Length of penstock = 130m
Head (H) = 98m
Δh = 0.35m
Q =0.024112 m^3/s
H =H+Δh×H
= 98+98×0.35
= 132.3 m

Therefore,

D $=[[5.2\times\frac{Q3}{H}]^{0.5}]^{1/7}$m
=0.357 m

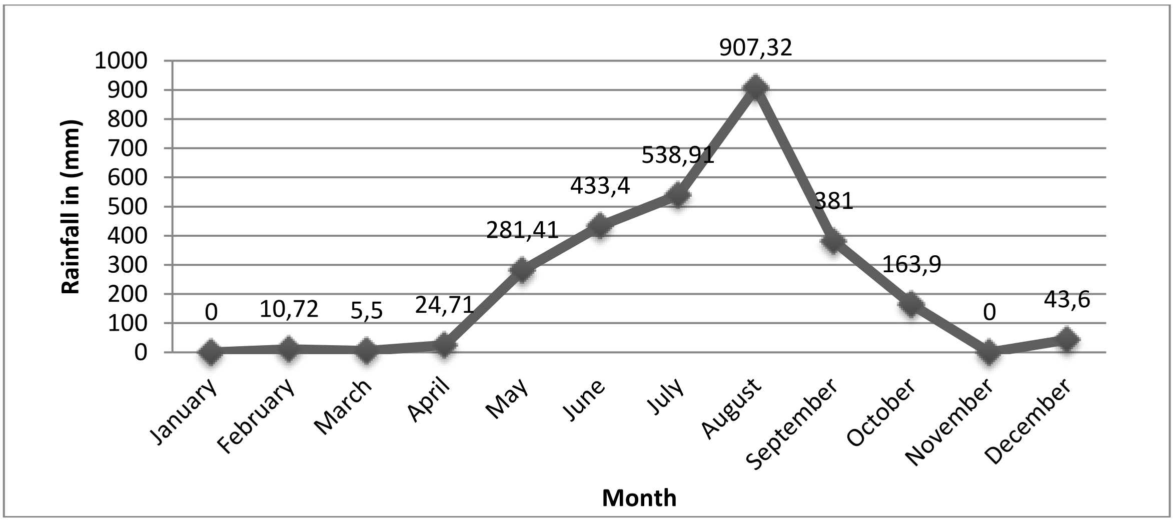

Figure 6: Monthly Rainfall Pattern of Site

Calculation of number of households that can be served

Total household served with energy demand $=\frac{240}{1.9003}$
=126.13
=126

This concludes this project will serve 126 households around Gairibari. However, total households around Gairibari are 87 only.

5 COST ESTIMATION

The total cost estimated amount for design of project is NRs 36,84,731.73. The estimated cost of electrical and sanitary and plumbing is NRs 26,15,043(twenty six lakh fifteen thousand forty three only) whereas estimated cost of civil works is NRs 6,08,947.43 (six lakh eight thousand nine hundred forty seven only)

Table 4: Cost Estimation of the Entire Project

S.No.	Description of Works	No. of Blocks	Total Amount	Remarks
A	Electrical	1	2,940,525.41	
B	Sanitary and Plumbing	1	135,258.89	
	E. Total Budgetary Cost Estimate of Electrical and Sanitary Works (A+B)		3,075,784.30	
C	Total amount of Civil Works	1	529,519.50	
D	Add 15% Contractor Profit		79,427.93	
	F. Total Budgetary Cost Estimate of Civil Works (C+D)		6,08,947.43	
	Total Budget Estimated (E+F)		**36,84,731.73**	

5.1 Economic Analysis

Total Energy produced =12 kW
Total Energy generated in 20 hrs of plant running time =12×20 kWhr
=240 kWhr
Providing electricity in rate of Rs 6 per unit, we get;
Total estimated income in a day =NRs 6.5×240
=NRs 1,560
Annual estimated income = NRs 1,560×365
= NRs 5,69,400
For actual earning we need to reduce the expenses like manpower salary, maintenance cost
Let Annual Operators' Salary =NRs 40,000
Annual Repair and maintenance costs =Rs 50,000
Actual earning =NRs 5,69,400 – 90,000
=NRs4,79,400
Initial Cost for the project =NRs 36, 84,731.73
Let MARR= 10%
Now the discounted payback period can be calculated as the following

Table 5: Calculation of the Payback Period using Discounted Cash flow Method

Period(years)	Net Cash Flow (Rs)	Discounted cash flow at present @10%	Cumulative Cash Flow (Rs)
0	-36,84,731.73	-36,84,731.73	-36,84,731.73
1	4,79,400	4,35,198.35	-32,48,913.55
2	4,79,400	3,96,198.35	-28,52,715.2
3	4,79,400	3,27,436.65	-24,92,534.88
4	4,79,400	2,97,669. 68	-21,65,098.2
5	4,79,400	2,70,608.8	-18,67,428.5
6	4,79,400	2,46,008.02	-15,96,819.75
7	4,79,400	2,23,643.63	-13,50,811.748
8	4,79,400	2,03,312.39	-11,27,168.118
9	4,79,400	1,84,829.45	-9,23,855.73
10	4,79,400	1,68,026.77	-739026.28
11	4,79,400	1,52,751,6	-570999.5

12	4,79,400	1,38,865.1	-418247.9
13	4,79,400	1,26,241.1	-279382.8
14	4,79,400	1,14,764.54	-153141.8
15	4,79,400	1,04,331.4	-38377.26
16	4,79,400	104331.4	65954.13

Here, in the column of cumulative cash flow the sign changes in between 15 and 16. So the payback period occurs in it. After using the interpolation method, we calculated the discounted payback period to be 15.37 years. Hence, the investment of project will be recovered after 15.37 years.

6 CONCLUSION

The power system of Nepal has grown to a much bigger capacity now and is still continuing to grow. The percentage share of private power generation in the power system has been increasing. This project has been recommended as a 12 kW. No development strategy can be implemented without power. On the present context, as electricity has been a major basic need of the common people. Most of the households in Gairibari do not have electricity as they could not afford the rate of Nepal grid electricity. But, Gairibari has limited resources which can be utilized for the generation of power whereas the average power consumption of Gairibari is 513.29 W. Through the research and analysis of collected data the total house to be served as 126 whereas the number of households in that area is 87 only. So the project is feasible. The budget estimation of construction of micro hydro in Gairibari is proposed in this project that is NRs 36, 84,731. During installation, it is highly recommended to involve only experienced parties or technicians. Obviously, the socio- economic status of the village will be improved with implementation of the project.

7 REFERENCES

[1] U. S. N. T. Ros, “A Suistainable Energy Future in Bangladesh: Current Situation and Need for Effective Strategies,” dalam *Suistainable Energy and Environment,* Bangkok, Thailand, 2006.

[2] B. Rimal, G. Bhandari dan P. Subedi, A complete note on Microhydro, Lamachaur: Dept. of Economic and Community Development, 1999.

[3] S. Agrawal dan R. Pandey, “Current Status of Small/ Micro Hydropower in Nepal ; A Case Study of Giringdi SHP,” *Journal of the Institute of Engineering,* vol. 15, pp. 21-27, 2019.

[4] P. N. Chaudhary dan R. Dhital, “Micro & Mini Hydro Based Mini-Grid for Rural Energy Access in Taplejung, Nepal,” IOE Graduate Conference, lalitpur, 2016.

[5] S. R. Bhandari, N. Sapkota, A. Wagle dan A. Shrestha, “Assesment of Biomass Energy and Electrical Potential from Bio-degradable Waste as a Renewable Source of Energy,” dalam *International Conference on Development in Renewable Energy Technology ICDRET'18*, Kathmandu, 2018.

[6] Y. R. Pasalli dan A. B. Rehiara, “Design Planning of Micro-hydro Power Plant in Hink River,” *Procedia Environmental Sciences,* vol. 20, pp. 55-63, december 2014.

[7] Y. B. K. K. N. K. B. B. M. H. Dhakal Rabin, “Feasibility study of distributed wind energy generation in Jumla Nepal,” *International Journal of Renewable Energy Research,* vol. 10, September 2020.

[8] B. Joe, W. Sam dan B. Julian, “Micro-Hydropower in Nepal: Analysing the Project Process to Understand Drivers that Strengthen and Weaken Sustainability,” dalam *15th Conference on Sustainable Development of Energy Water and Environmental Systems*, 2021.

[9] “Sikles Hydro Start Trial Production.Available Online:https://kathmandupost.com/money/2017/11/04/sikles-hydro-starts-trial-production,” *The Kathmandu Post,* 2017.

[10] W. S. J. T. A. K. P. B. G. B. Butchers Joe, “Understanding sustainable operation of micro-hydropower: a field study,” *Energy for Suistainable Development,* pp. 12-21, 2020.

[11] K. Rai Raj, “Micro hydro plants destined for oblivion in rural Nepal,” *The Kathmandu Post,* 2022.

[12] B. A. Nasir, “Design of Micro - Hydro - Electric Power Station,” *International Journal of Engineering and Advanced Technology (IJEAT),* vol. 2, June 2013.

[13] “Factors Affecting Selection of Hydraulic Turbine,” *Available online:https://theconstructor.org/practical-guide/hydraulics-lab/turbines-pumps/factors-affecting-selection-hydraulic-turbine/30826/,* 2020.

[14] A. harvey, *micro hydro design mannual a guide to small-scale water power schems,* united kingdom: intermediate technology publication, 1993.

[15] I. R. Jahidul, S. I. Riasal, H. Rezaul, H. Samiul dan I. Fokhrul, "A Comprehensive Study of Micro-Hydropower Plant and Its Potential in Bangladesh," *International Scholarly Research Notices,* p. 10, 2012.