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Assessment Of Grid Electric Powered Transformation Into Solar Powered Pumping Water Supply Projects

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Abstract

Solar powered water supply system can enhance the quality of water supply as its availability can be made round the clock. When the water service quality increases to the society, then there could be better health, development, safety and livelihoods of children and their families. The present studyaims to analyze the opportunity and challenges of selected Electric Connected Pumping Water Supply Projects into Solar Powered in Gandaki Province, Nepal. It is a case study of Gandaki Province of Nepal. Six water supply schemes viz; Dunaikhola, Syangja, Pragatinagar, Nawalparashi, Bhadgaun, Tanahu and Budhikhola were selected for economic feasibility of conversion of electric power operated to solar power operated.Primary data collection was done through Interviews, field observations and questionnaires method followed by extensive literature and secondary data such as documents such as publication report, auditing report, records and data of national and international context.The profitability index was computed to ascertain feasibility of conversion of the existing projectsto solar powered. As the solar irradiation values of all project site lies within range of national average, hence all selected projects are found technically feasible.

Keywords: Profitability Index, Technical Power, Solar Irradiation, Life cycle cost, cost estimate, Life Cycle cost

Introduction

Pumping Water Supply Projects (WSP) face technical as well as economic challenges during its whole project cycle due to its technical complexity (electro-mechanical components), accessibility of electricity point, as well as more recurrent cost (consumable and non-consumable items) consumed during operation and maintenance. The pumping Water Supply Projects run either through electric power, diesel generator, and solar power. Pumping project run through electric power consumes high electricity cost and run through the diesel generator consumes high fuel cost. Consumers are not able to afford such costs and they are always seeking zero energy cost.

In order to run the project in a sustainable and affordable manner, the operation cost should be as minimum as possible. The existing drinking water supply sources drying up day by day as a result pumping project demand is increasing enormously in this dry area. The running pumping projects also seeking zero energy cost option to run the project in a sustainable manner. The conversion of electric power to solar power demand by water users and sanitation committee is increasing in recent years. The study is focused on computing performance indicators like functionality index in service delivery, feasibility study of power conversion by computing profitability index. The comparative analysis, as well as the opportunity and challenges of solar power conversion, were focused on during the study.
In recent years the government has allocated a limited budget to address such operational cost issues for conversion of electric power pumping WSP to solar power. In order to assess the opportunity and challenges of solar powered WSP over electrically connected pumping WSP access through different aspects, it is of prime importance to undertake this research. The study helps to explore and analyze the present conditions of the selected electric connected pumping WSPs, present management practices as well as challenges faced by projects in the context of management, technical and economical aspect. The study will be helpful to make investment decision of government side or donor side working in water , Sanitation and hygiene(WASH) sector of Nepal. The feasibility study and assessing opportunity and challenges of conversion of electric connected WSPs to solar powered WSPs will be helpful for making planning decision. It will be helpful for Water Supply and Sanitation Users Committee (WSUC) for improving the management aspects. It will be useful for decision maker to choose the best option of power in pumping WSP. It will be helpful to suggest WASH related policy, plan, and program in order to meet the demand of water supply services to unreached part of Gandaki Province.

Description of study area and availability of solar power

There are many electric power pumping projects undergoing operation stages after being handed over to the community in Gandaki Province. The Government of Nepal is aware that pumping WSPs were facing problems to pay the electricity cost incurred during the operation and maintenance period. To address the issues, it's high time to conduct such a study in order to help the decision-makers prioritize the pumping project conversion based on opportunity and challenges. In order to assess the present status of the selected projects, the feasibility study of conversion to solar-powered and to assess the opportunity and challenges during power conversion into solar-powered pumping projects for the following four projects list in the Table 1 are taken as a research study area.

Table 1 List of pumping projects for study

Name of WSP	Dunaikhola WSP, Syangja	Pragatinagar WSP, Nawalparashi	Bhadgaun WSP, Tanahun	Budhikhola WSP, Kaski
Support organization	RWSSP	DWSSM	DWSSM	WSSDO, Kaski
Location	Kaligandaki	Devchuli	Vyas-01,12,13,	Pokhara -18,

	Gauplika ward no:1,2,3, Syangja	Municipality 7,9,10-15, Nawalpur	Tanahun	Sarangkot
Number of households	223	1000	1055	380
Population	1050	5000	5275	1890
Project type (technology)	Surface water lifting system (3 stage)	Ground water lifting bore hole to elevated reservoir (single stage)	Sub Surface water pumping (single stage)	Surface water lifting system (2 stage)
WSUC Members	11	13	17	13
WUSC head	Chairperson	Chairperson	Chairperson	Chairperson
Status	Operated by WSUC	Operated by WSUC	Operated by WUSC	Operated by WUSC

Description of study area and availability of solar power

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There are various pumping options to deliver water, among them widely adopted option in Nepal are solar powered water pumping system & electric powered water pumping system. Solar powered water pumping system is one of the viable alternative deployed in many hilly settlements for providing water supply where electric facility is not available. Electric expansion to rural area is also capital intensive. Those factors encourage the government to go most reliable and cost-effective alternatives. In this rural area although, Solar powered water pumping system have generally required high investment cost, there is no other alternatives for comparisons. If the hilly settlements having facility of electric then the reliable and cost effective options become a choice of community. In some cases dual system also demands by the community. Solar powered water pumping system relies on sunshine hours. Solar power is the conversion of energy from sunlight into electricity, either directly using photovoltaic (PV), indirectly using concentrated solar power, or a combination. Concentrated solar power systems use lenses or mirrors and solar tracking systems to focus a large area of sunlight into a small beam. Photovoltaic cells convert light into an electric current using the photovoltaic effect.

Solar energy is the radiant energy produced by the sun in the form of light and heat. Solar PV systems are gaining popularity in some parts of Nepal. This is because the majority of the population lies in rural areas has limited access of electrical energy, the cost of diesel generator is

high, biogas plant are not feasible in cold high altitude and small hydro turbine require specific topographical condition which are not possible in many places Nepal has enormous and low-cost solar energy resources. The solar potential in Nepal is 50,000 terawatt-hours per year. Photovoltaic technology is a method of exploiting electrical power from photons (bunch of light particles) in the form of solar radiation. Insolation is the total energy received from the sun in a day in a unit surface area on the earth. The unit of insolation is Kilowatt-hour per sq. meter. per day. For Nepal, on an average Nepal has 6.8 hours of sunshine per day with the intensity of the yearly average insolation (irradiation) can be taken around 4.5 to 5.5 KWh/m2 /day (AEPC, 2003). All the demand of the drinking water to be lifted within sunshine hours. Usually, in the context of Nepal, design assumption is taken as 6-8 hrs. Solar powered water pumping system is not reliable during cloudy and hazy days. To meet the demand of those days the service reservoir capacity should be designed for the storage of 2-3 days. The battery storage option is available but the cost of installation is not affordable in our context. During the winter season the battery is subjected to high risk of damage due to cold weather.
The EWPS runs through electric energy supply through electricity. Electric supply is available for 24 hours in no load shedding period. The designed pumping hours should be taken as normally 16 hours, which helps to reduce the size of the pump and accessories. The service reservoir can be designed for comply 40-60% of daily demand. Hence, it helps to reduce the cost of the reservoir component while choosing electric powered water pumping system rather than solar powered water pumping system.

1.6 Scope of study

The study focuses in present management practices of selected four WSPs of Gandaki Province and also aims to know how about the project has potential for implementation or not. Opportunity and challenges of conversion of electric connected selected pumping WSP to solar power WSPs was measured by present status of the WSP, as well as economical, technical and management aspects.

The research has been done in pumping project run through electric powered. Pumping projects have been operated in Gandaki Province, The mentioned pumping project has been chosen because project resembles numerous pumping projects operated by electric powered managed through WUSC. During calculation of life cycle cost (LCC) of the selected WSPs only cost of conversion of electric powered into solar power has been taken as capital expenditure (CAPEX).

METHODOLOGY

In this study, the qualitative and quantitative approaches through questionnaires were used for collecting the information by the interviews, questionnaires, to WUSC and users of the selected WSPs. The ex-post facto research approach was applied for the research using the qualitative and quantitative approaches of research. A case study of selected projects was conducted.

Data collection

The study is based on the primary as well as secondary data, which was collected to find out the opportunity assessment of solar-powered in comparison to electric connected pumping WSP of Gandaki Province. For the collection of primary data, the following methods are used:

a) Interviews -The data from the interview to the WUSC, pumping operator regarding the condition of the project, and the current management practices were collected.

b) Field Observations –The field observation of the project was done to identify the current physical condition of the project, note the co-ordinate of WSP from GPS, documentation practices of WUSC.

c) Questionnaires- A different set of open and closed questions was prepared for the WUSC chairman, Management Head, Pump operator, and WUSC member regarding the management, the financial aspect of WSP.

Secondary data were collected from the literature study (ADB, 2006; Chandel et al., 2015; Chapagain, 2019; DPR, 2015; Kabade et al.,2013) of national and international articles (about the adaptation of the management practices in WSPs in developing countries. The present status of the selected WSPs, the possibility of conversion of electric-powered to solar-powered has been measured. The PV GIS software is used to find the value of solar irradiation. The feasibility of electric-connected pumping WSPs conversion to solar-powered have been assessed through financial reports, which was documented and published by WUSC and compared with the value of solar irradiation with national average. Opportunity and challenges of solar powered water pumping project have been measured through evidence documents related to financial, technical and management aspects. The data analysis has been collected from both primary and secondary sources and have been summarized, classified, tabulated and categorized in several categories. All data from individual projects have been analyzed separately of all four projects. Computer software such as MS office tools, MS Excels and PV GIS software for solar irradiation selected water supply project site value was used for the derivations of the data. And the logically interpreted outcomes were presented in tables, charts, graphs.

Profitability index

This index helps to find out the project has potential for implementation or not. The financial feasibility of the project depends upon the profitability index. The investment decision will be made by computing the profitability index. If this index is more than 1, the project is suitable for investment. In this research, the profitability index was calculated for the schemes considered.

Results and Discussion

The profitability index for all four schemes in terms of electric powered as well as solar powered is calculated and presented in the Table 2. It is found from the analysis that all four schemes are having profitability index based on solar power is greater than corresponding electric power. This clearly indicates that these schemes are eligible to convert as solar powered schemes.

Table 2. Profitability Index of WSPs using different power

Projects	Dunaikhola WSP,Syangja	Pargatinagar WSP,Nawalparashi	Bhadgaun WSP,Tanahu	Budhikhola WSP,Kaski

Profitability index using electric power	0.61	1.33	1.60	0.74
Profitability index using solar power	1.63	1.68	1.74	1.53

To in order investigate further the feasibility of converting existing system to solar powered, the various technical parameters were collected through questionnaire and field survey. The collected technical parameters are tabled (Table 3, 4 and 5) for further study. The hourly solar irradiation is obtained by inputting the GPS data PVGIS software. The yearly values calculated over the time period covered by the chosen solar irradiation database from PVGIS. The co-ordinates are collected through GPS during field survey. While comparing national average value, all the projects under study are technically feasible because the solar irradiation value of all project is lies within the range of national average of 4.5 to 5 Kwh/m^2/day. All the projects under study are economically viable and socially acceptable.

table 3 Different technical parameter of WSPs

Projects	Dunaikhola WSP, Syangja	Pargatinagar WSP, Nawalparashi	Bhadgaun WSP, Tanahu	Budhikhola WSP,Kaski
Discharge , LPS	1.2	15	9	2
Pumping Head (m)	581	120	250	523
Solar Pump module	SQF 1.2-3	SP46-18	SP30-28	SP5A-52
Cost of intervention, NRs.	13,42,258	1,26,39,796	1,10,71,146	36,22,204
No of pumping stage	3	1	1	2
Pump availability	Yes	Yes	Yes	Yes
Land availability	Yes	Yes	Yes	Yes
Land facing other than north	Yes	Yes	Yes	Yes
No of cloudy and hazy days in a year	10	20	90	10

Table 4 Co-ordinate of the selected project measured using GPS

S.N.	Name of Project	Latitude (N)			Total	Longitude (E)			Total
		Degree	Minute	Second	Degree	Degree	Minute	Second	Degree
1	Dunaikhola WSP	27	57	6	27.95	83	29	40.31	83.49
2	Pragatinagar WSP	27	40	43.13	27.68	84	11	24.91	84.19

3	Bhadgaun WSP	27	58	13.18	27.97	84	16	58.6	84.28
4	Budhikhola WSP	28	14	37.06	28.24	83	55	55.75	83.93

Table 5 Monthly solar irradiation value at different selected project

S.N.	Month	Unit of Solar irradiation H(I)	Water Supply Projects			
			Dunaikhola WSP	Pragatinagar WSP	Bhadgaun WSP	Budhikhola WSP
			H(I)	H(I)	H(I)	H(I)
1	Jan	kwh/m2/month	165.1	137.1	166.1	172.3
2	Feb	kwh/m2/month	158.7	148.5	173	159.9
3	Mar	kwh/m2/month	189.1	192.9	209.2	185.1
4	Apr	kwh/m2/month	183	185.3	197.3	184.6
5	May	kwh/m2/month	170.2	178.9	188.2	174.9
6	Jun	kwh/m2/month	147.2	148.5	159.4	150.4
7	Jul	kwh/m2/month	129.8	132.8	136.9	133.4
8	Aug	kwh/m2/month	137.9	137.8	142.4	142.3
9	Sep	kwh/m2/month	158.9	151.2	166.5	159.3
10	Oct	kwh/m2/month	187.5	171.7	194.6	185.9
11	Nov	kwh/m2/month	165.4	158.1	182	177
12	Dec	kwh/m2/month	162.6	159.1	169.4	176.3
Yearly	H(I)	KWh/m2/year	1955.4	1901.9	2085	2001.4
Daily	H(I)	kwh/m2/day	5.4	5.2	5.7	5.5
National average H(I)		kwh/m2/day	4.5 to 5.5	4.5 to 5.5	4.5 to 5.5	4.5 to 5.5

The cost estimate helps to determine the probable cost of the conversion of electric power pumping projects into solar powered ones. The field appraisal was also carried out during this study. Table 6 shows the cost estimate for conversation into solar powered. Total cost of intervention of the project ranging from NRs.12,10,343 to NRs.1,18,80,084 which is very low as compared to the cost of a new project of this capacity. Quality assurance of old constructed structures might be one of the challenges.

Table 6 Salient feature with cost estimate for conversion in to solar power

Projects	Dunaikhola WSP, Syangja	Pargatinagar WSP, Nawalparashi	Bhadgaun WSP,Tanahu	Budhikhola WSP, Kaski

Discharge, LPS	1.2	15	9	2
Pumping Head (m)	581	120	250	523
Solar Pump module	SQF 1.2-3	SP46-18	SP30-28	SP5A-52
No of Solar PV module	7	216	180	36
Cost of Solar PV module NRs.	1,95,615	60,36,120	50,30,100	10,06,020
Cost of Pump in NRs.	2,90,000	15,60,000	15,15,000	8,00,000
Cost of Invertor in NRs.	1,00,000	11,90,000	11,90,000	5,90,000
Cost of frame and foundation in NRs.	47,342	14,60,834	12,17,362	2,43,472
Cost of grounding surge, protection and lightening arrestor in NRs.	1,33,962	1,33,962	1,33,962	1,33,962
Cost of Panel board in NRs.	67,563	2,44,628	2,34,536	1,22,526
Cost of removal of existing pump in NRs.	13,310	13,283	13,310	13,310
Cost of installation in NRs.	1,10,839	1,85,150	1,14,576	1,09,844
Cost of cable in NRs.	1,13,000	2,24,000	2,24,000	65,800
Cost of transportation and commissioning in NRs.	1,46,000	7,73,000	6,65,000	2,33,000
Cost of insurance in NRs.	6,021	59,104	51,622	16,602
Total cost without VAT in NRs.	12,10,343	1,18,80,084	1,03,76,158	33,21,227

Data Source: DPR report of DWSSM, 2020

Two types of water pumping systems such as solar powered pumping and electrical power pumping for water supply were taken into consideration for estimating and comparing the cost of water production. Average life of pumping WSP price per unit electricity, discharge rate of pumping system and other relevant parameters were taken into consideration to estimate the unit production cost in NRs./m3.

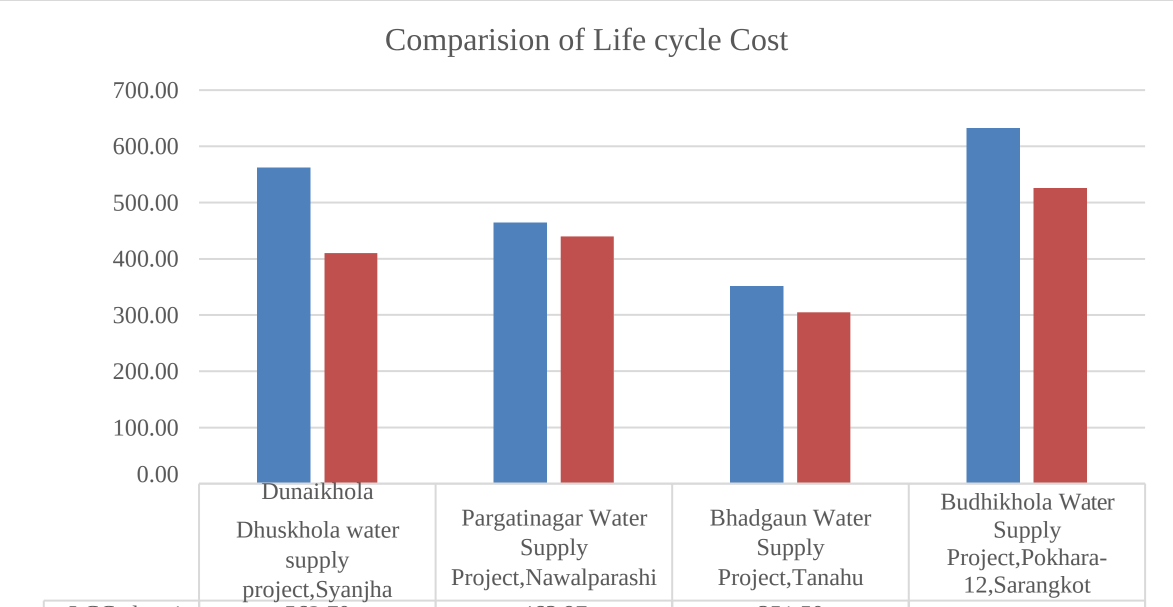
Table 7 Comparison of Unit production cost using different power

Projects	Dunaikhola WSP,Syangja	Pargatinagar WSP,Nawalparashi	Bhadgaun WSP,Tanahu	Budhikhola WSP,Kaski
Unit production cost	10.647	3.65	4.71	13.58

NRs./m3 using electric power				
Unit production cost NRs./m3 by using solar power	4.29	2.86	3.06	8.10
Cost saving in NRs./m3 of solar power compares with electric power	6.357	0.79	1.65	5.48
Percentage of saving	59.70	21.64	35.03	40.35

The stage increase required more power hence during conversion there was a high percentage of saving of unit production NRs./m3 were found in Dunaikhola WSP,Syangja and Budhikhola WSP,Kaski. The unit production cost obtained in solar power pumping is attached as Appendix 3, Feasibility of conversion to solar power pumping. Life cycle cost was found to decrease from 20.68% to 5.25% in these projects while converting electric power to solar power. The life cycle cost obtained in different power are attached as Appendix.2 and Appendix.3 respectively.

Figure 4.1 Comparis on o flife cycle costusing different power



	Dunaikhola Dhuskhola water supply project,Syanjha	Pargatinagar Water Supply Project,Nawalparashi	Bhadgaun Water Supply Project,Tanahu	Budhikhola Water Supply Project,Pokhara-12,Sarangkot
LCC electric	562.70	463.97	351.50	632.07
LCC solar	410.30	439.62	304.72	526.10

The selected all projects were found running through electric power but faces technical as well as economical problems. The energy cost issues will be addressed by the conversion of WSPs into solar power. Solar power pumping is a cost-effective application in all locations of developing countries if it is technically viable. The economy and reliability of solar power made it an excellent choice for water pumping. Even though solar power water pumping has zero energy cost in the operation period but some challenges are associated with solar power water pumping, especially in operation and maintenance. Opportunities and challenges using solar power are presented in tabular form. Table 8 gives the opportiniuty and challenges of using solar power for WSP.

Table 8 Opportunity and challenges using solar power

Opportunity	Challenges
Availability of financing by government budget allocation	Dependency syndrome while any failure occurs.
Already constructed water supply projects and its pipeline networks	Quality assurance of constructed structure
Power storage option is also installed	Skills for repair/spare parts not available in many places.
Falling of Solar module prices improve the economic competitiveness	Vandalism and theft (panels etc.)
Potential for job creation in the renewable energy sectors (producers, supplier sand services)	Possible over consumption of water (Unit production rate –low)
Reduction of per unit cost of water production in NRs./m3	Cloudy and hazy day's increases due to climate change.
Independent for electricity consumption prices.	

CONCLUSION AND RECOMMENDATION

1. All selected electric-connected projects are found technically feasible, economically viable for conversion of electric powered to solar powered. The solar irradiation value of all project lies within the national average hence all are technically feasible. The profitability index of all four projects is more than 1, which shows the project has potential for implementation.
2. The financial analysis proved that the solar power pumping system was more cost-effective and suitable to use than the electric power pumping system. Also, a profitability index was carried out and showed that the PV system is a good option to be recommended highly compared with the electric power use option.

3. The cost of intervention funded by the Government, falling of solar module prices are the opportunity and dependency syndrome of WUSC, quality of existing infrastructures, vandalism, and theft of solar panels are the major challenges.

5.2 Recommendations

The following recommendations are made based on the conclusions:
1. the conversion of selected electric power WSPs to solar power will help to reduce the energy costs to enhance the financial sustainability of all projects.
2. The WUSC should be built up by conducting relevant training to cope with solar power technology and made fully functional for the improvement of water service level.

3. The government should revise the water supply policy for uses of solar power instead of electricity while designing of pumping project if technically feasible.

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APPENDICES

A. Technical feasibility

Head, m	Discharge, LPS	Required Solar pump & specification	Cost of solar pump, in NRs.	No. of Stage of Pumping
581	1.2	SQF1.2-3	1342258	3
Pump required & its availability				Yes
Land area required and its availability				Ha
Solar Radiation				Ok
Alignment inclined other than north				OK

A. Financial feasibility

Design Population	Design Year	CAPEX	OPEX (for operating ratio)	LCC
1050	15	4026774	2435386.396	410.30
Sum of net cash flow computed in to present value in NRs.				**2519355.578**
Profitability index		**1.63**	feasible for conversion	
1	Revenue from tariff collection NRs.			592200
2	Operation and maintenance cost for Manpower salary			228600
3	Others cost			22860
Operating Ratio				**0.42**
Unit Production cost				**4.29**

A. Technical feasibility

Head, m	Discharge, LPS	Required Solar pump & specification	Cost of solar pump, in NRs.	No. of Stage of Pumping
120	15	SP46-18	12639796	1
Pump required & its availability				Yes
Land area required and its availability				Ha
Solar Radiation				Ok
Alignment inclined other than north				OK

B. Financial feasibility

Design Population	Design Year	CAPEX	OPEX (for operating ratio)	LCC
5000	15	12639796	20331705.04	439.62
Sum of net cash flow computed in to present value in NRs.				**8533306.46**
Profitability index		**1.68**	feasible for conversion	
1	Revenue from tariff collection NRs.			3450000
2	Operation and maintenance cost for Manpower salary			1080000
3	Others cost			1190089.6
Operating Ratio				**0.66**

Unit Production cost		2.865

A. Technical feasibility

Head, m	Discharge,lps	Required Solar pump & specification	Cost of solar pump, in NRs.	No.of Stage of Pumping
250	9	SP30-28	11071146	1

Pump required & its availability	Yes
Land area required and its availability	Ha
Solar Radiation	3 month cloudy and hazy days
Alignment inclined other than north	OK

B. Financial feasibility

Design Population	Design Year	CAPEX	OPEX (for operating ratio)	LCC
5275	15	11071146	13039716.62	304.72
Sum of net cash flow computed in to present value in NRs.				**19231726**
Profitability index		**2.74**	feasible for conversion	

1	Revenue from tariff collection NRs.	3857143
2	Operation and maintenance cost for Manpower salary	1013173.7
3	Others cost	385714.3
	Operating Ratio	**0.36**
Unit Production Cost		**3.06**

Life Cycle Cost using Solar

Project Name:Budhikhola Water Supply Project,Pokhara-12,Sarangkot

A.Technical feasibility

Head,m	Discharge,lps	Required Solar pump & specification	Cost of solar pump,in NRs.	No.of Stage of Pumping
523	15	SP5A-52	3622204	2

Pump required & its availability	Yes
Land area required and its availability	Ha
Solar Radiation	OK
Alignment inclined other than north	OK

B.Financial feasibility

Design Population	Design Year	CAPEX	OPEX (for operating ratio)	LCC
1890	15	7244408	7670508.335	526.10
Sum of net cash flow computed in to present value in NRs.				**3875496.265**
Profitability index		**1.53**	feasible for conversion	

1	Revenue from tariff collection NRs.	1380000

2	Operation and maintenance cost for Manpower salary	720000
3	Others cost	72000
Operating Ratio		**0.57**
Unit Production cost		8.11