'Improving water use for dry season agriculture by marginal and tenant farmers in the Eastern Gangetic Plains (DSI4MTF)' project funded by ***Australian Centre for International Agricultural Research (ACIAR)***

Is Solar Pumping Technology a Viable Solution for Irrigation System in Terai Plain of Nepal?

Kathmandu, Nepal

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ABSTRACT

This study presents the comparative analysis/picture of solar water pump, diesel pump and grid operated electric pump. Based on Life Cycle Cost (LCC) assessment under specific assumptions/conditions, cost effectiveness of these pumps were calculated and is presented in this report. Findings of this study can be generalized in the context of Nepal's Terai region.

It can be concluded from the comparison of these technologies that if solar pumps are run at less than 45% CUF (Capacity Utilization Factor), they become expensive than diesel pump. In general, solar pumps need to be operated at least 700 hrs per year to compete with diesel pump. Grid operated electric pumps is found to be more cost-effective technology amongst the type of pumps compared. However, if solar pumps can be operated at 90% CUF, solar pumps become cost effective than electric pump.

Low utilization factor of solar pumps has been observed in almost all sites. CUF was very low where farmers are still adopting traditional crops. Frequency of irrigation for traditional crops is less compared to vegetables. CUF was found high where people using water for fish farming. Solar pumps were rarely used during monsoon season where pumps were used mainly for irrigation purpose.

High upfront cost of solar powered system seemed a hindering factor to popularize the system. Mostly rich farmers were found installing solar pumps. With better access to financing and technology, solar pumps might become the pumping technology for choice for many smallholder farmers in the future.

LIST OF ABBREVIATIONS

ACIAR	:	Australian Centre for International Agricultural Research
AEPC	:	Alternative Energy Promotion Centre
AC	:	Alternating Current
CREF	:	Central Renewable Energy Fund
CUF	:	Capacity Utilization Factor
B/C	:	Benefit-Cost
DC	:	Direct Current
DoI	:	Department of Irrigation
GDP	:	Gross Domestic Product
GoN	:	Government of Nepal
GW	:	Ground Water
Ha	:	Hectare
HH	:	Household
Hr	:	Hour
IRR	:	Internal Rate of Return
kg	:	Kilogram
KII	:	Key Informant Interview
kW	:	Kilo Watt
kWh	:	Kilo Watt Hour
LCC	:	Life-Cycle Cost
lpd	:	Litres per Day
lps	:	Litres per Second
MIT	:	Micro-Irrigation Technologies
MPPT	:	Maximum Power Point Tracking
m	:	Meter
m2	:	Square Meter
m3	:	Cubic Meter

NITP	:	Non-Conventional Irrigation Technology Project
NPR	:	Nepali Rupees
PAYG	:	Pay As You Go
PPA	:	Power Purchase Agreement
PV	:	PhotoVoltaic
PVP	:	PhotoVoltaic Pumping
PVPS	:	PhotoVoltaic Pumping System
RE	:	Renewable Energy
R&M	:	Repair and Maintenance
Rs	:	Nepali Rupees
TDH	:	Total Dynamic Head
UWC	:	Unit Water Cost
VAT	:	Value Added Tax
VFD	:	Variable Frequency Drive
Wp	:	Watt Peak
yr	:	Year

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1. INTRODUCTION

1.1 Background

Nepal is an agriculturally dependent country with its 66% of population directly or indirectly involved, and this sector contributes to about 33% to national GDP[1]. The average land holding per family across Nepal is less than 0.8 Ha[2]. Agricultural production in Nepal is largely dependent on rains and is adversely affected by the non-availability of water in summers. In the dry season, from November to March, many farmers leave their land barren due to lack of access to water for irrigation[3].

Out of total 14.718 million Ha area of the country, around 2.641 million Ha area is cultivable land. Due to country's specific topography, only 1.766 million Ha area is irrigable. Around 78% (1.392 million Ha) of the irrigable land has irrigation facility with less than one-third of this area has year-round irrigation facility[4].

Majority of farmers are engaged in subsistence farming due to low land holding capacity, fragmented plots, lack of access to irrigation facilities and heavily dependent on monsoon rainfall, etc.

Since agriculture is the backbone of Nepal's economy, it is essential to transform subsistence farming into commercial farming with the provision of irrigation facility. The productivity of irrigated land is approximately three times greater than that of rain-fed land[5]. b Having realized the importance of year-round irrigation to improve the agricultural productivity and production, Government of Nepal (GoN) has introduced favorable policy and mechanism for the promotion of renewable energy in irrigation sector. Solar water pumping technology is one of the emerging technologies to reach to farmers who do not have access to grid electricity and are willing to shift from fossil fuel-based technology to clean energy technology.

In addition to government-initiated program, there are several of non-government organization who are also promoting solar pumping irrigation system with different business model. However, there are several challenges to scale-up the solar pumping technology particularly in rural areas whereby the upfront cost of the system being one of the key challenges. In addition to this technical, managerial, after-sale services, etc. are the other challenges. Currently, solar pumping projects are subsidy driven or funded by grants and few projects have also mobilized loan to match with grant. This study was conducted to assess the effectiveness of the technology and business model comparing with conventional pumping systems, as well as

[1] http://article.sapub.org/10.5923.j.ije.20120202.03.html

2 https://www.researchgate.net/publication/228534387

[3] https://www.researchgate.net/publication/284098829

[4] http://moad.gov.np/public/uploads/1142453195-STATISTIC%20AGRICULTURE%20BOOK_2016.pdf

[5] https://core.ac.uk/download/pdf/82116240.pdf

identifying the barriers which are becoming bottlenecks for shifting solar pumping system from subsidy driven to demand driven with commercially viable.

1.2 Solar Water Pumping Technology

Solar Photovoltaic (PV) Water Pumping Systems are technically proven, mature and cost effective in long run as compared to diesel water pumps[6]. The technology is similar to any other conventional water pumping system except that the power source is solar energy. The PV panels are connected to a motor (DC or AC) which converts electrical energy supplied by the PV panel into mechanical energy which is converted into hydraulic energy by the pump. The solar pumping system generally consists of solar panels on a mounting structure, controller (MPPT system), motor-pump set, storage tank etc. The water tank acts as storage and generally battery is not used for storage of PV generated electricity. Water is more cheaply and effectively stored in a tank rather than storing electro-chemical energy with batteries. However, for specific reliable requirements batteries also can be used.

In general, the performance of solar water pumping system depends on the following parameters:

- Solar radiation availability at the location and size of Solar PV system
- Total Dynamic Head (TDH): Sum of suction head (height from suction point till pump), discharge head (height from pump to storage inlet) and frictional losses
- Flow rate of water

Figure-1 gives a quick overview of the components of Solar Pumping System.

[6]http://www.winrock.org.np/uploads/story/file/Success%20story%20Credit%20Finance_final_20170516054127.pdf

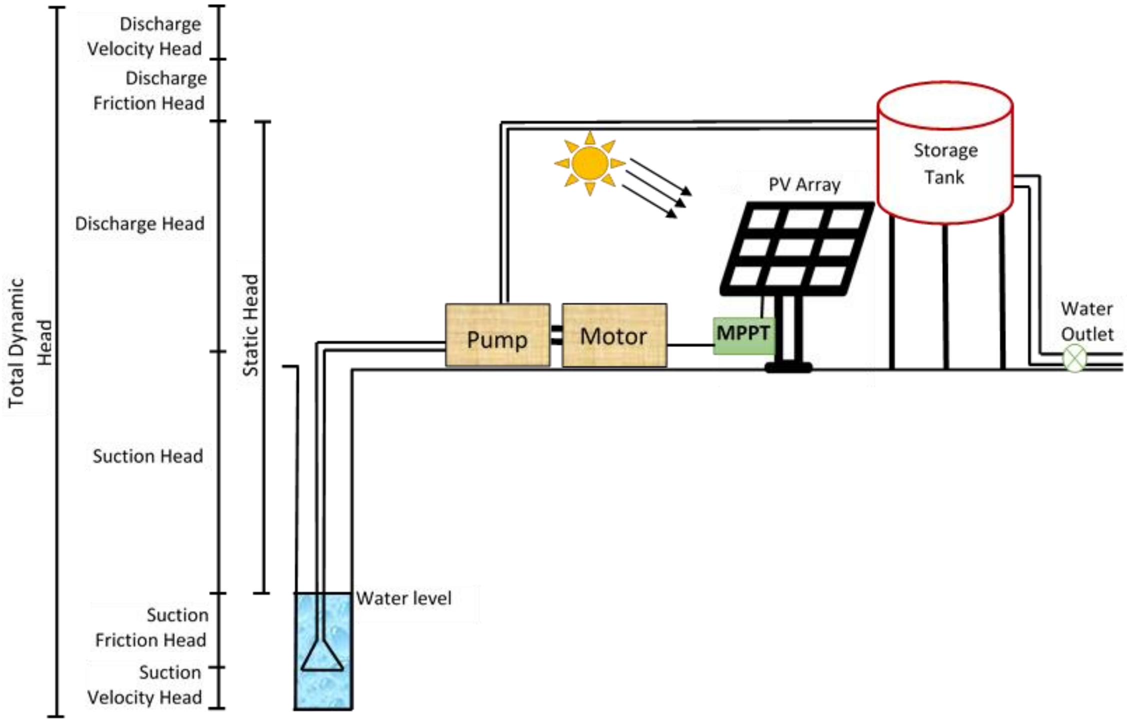

Figure 1: Typical Solar Pumping System Layout

1.3 Rationale for the Study

Water pumping sector in Nepal is still dominated by diesel water pumps followed by electric water pumps[7]. However, the market for solar pump in Nepal is increasing rapidly due to gradual declining in costs and continuous advancement on technology. With an average solar radiation of 4.4 kWh/m2 to 5.5 kWh/m^2 Nepal has a high potential for generating solar power[8]. GoN has formulated the favorable policy and mechanism, subsidy and credit financing to accelerate the deployment of renewable energy technologies including solar pumping technology. Non-government organization and private sectors also lined up with government strategy and are implementing solar water pumping for irrigation by introducing different business model. Despite the claimed benefits of solar pumping technology over conventional type of pumping, solar pumping sector market is surviving as a result of grant or subsidy. With the increase in share of solar pumping technology in the market, various challenges have been observed in the long-term sustainability of the solar pumping technology. Very little study has been carried out to assess the socioeconomic viability of switching from diesel and electric pumps to solar pumps for irrigation purpose, and the sustainability of the technology in long run. This study was designed to evaluate cost effectiveness of solar pumping technology over conventional types of pumping system, and understand the perception of users on different business model.

[7] http://www.wecs.gov.np/uploaded/vision-2050.pdf

[8] http://documents.worldbank.org/curated/en/585921519658176633/pdf/123705-ESM-P150328-PUBLIC-NepalSolarMappingCountrySolarResourceReportMarch.pdf

1.4 Objective

The purpose of this study is to conduct the detailed assessment of solar pumping systems in different aspects as mentioned below and compare with diesel and electric water pumping system to help decision makers to make decisions on their investment for water pumping facilities.

- Compare solar to diesel/electric pumps for small scale irrigation system for marginal farmers at selected sites in Saptari.
- Compare performance of community based solar pumping systems in Saptari, based on:.
  - Technical performance of pumping System
  - Financial performance of pumping System
  - Economic impact on farmers due to access to pumped water, use of micro-irrigation technologies (MIT) for irrigation and changes in cropping pattern.
  - Perceptions and satisfaction level of pump owners/users in relation to financial, technical, supply-demand, and after-sale services provided by service providers.

Specific Objectives

- To assess the solar system size in response to water need/demand;
- To evaluate whether the equipment and installation works are meeting the minimum standards;
- To verify the actual pumped flow with designed flow;
- To understand the supply and demand management in different types of pumps;
- To calculate the cost per unit of water for different pumps using Life Cycle Cost (LCC) for different capacity utilization factor;
- To understand the funding model and financial aspect of the project management;
- To access the satisfaction and perception of pump owner on their pumping technology and their investment decision in relation to financial, technical, supply-demand, after-sale services provided by service providers;
- To collect the information on water usage for various purposes;
- To assess the economic benefits from agriculture sector due to the provision of year-round irrigation using solar pump.

2. METHODOLOGY

A strong and well-structured methodology forms a tangible base for the study. We used three research approaches, including: i) a detailed review of the existing literature on solar pumps technology, ii) semi-structured interviews of different stakeholders involved in the solar pump sector, and iii) field visits to multiple solar pumps installed at Saptari, Nepal. Both qualitative and quantitative information were attained to study the effectiveness and efficiency of different type of pumps in Saptari district.

2.1 Literature Review

Team was engaged in an intensive literature review of the related project documents, previous studies and reports to

- Identify the policy and strategic measures to promote solar pumping system in Nepal;
- Scope, application and cost effectiveness of solar pumping technology;
- Identify the barriers hindering solar pumping market, sustainability of the system and explore the potential measures to address such issues.

Following this in-depth review, the team developed a well-structured methodology.

2.2 Sampling

2.2.1 Sample Area Selection

This comparative study was carried out using a multi-stage sampling method. For the first stage of sampling, Saptari district was chosen.

According to the constitution of the federal republic of Nepal, Saptari district lies in province number 2. Spatially it is located between 26°25’ and 26°47’ north latitude, and between 86°28’ to 87°07’ east longitude with altitude range of 61 m to 610 m. The district lies in Terai region covering an area of 1,363 km^2. Out of total 83,240 Ha of arable farm land in the district, only 25,000 Ha has access to irrigation facility[9].

It is one of the districts where different solar pumping technologies and business models have been introduced. In addition, involvement of various organizations and stakeholders for the installation of various pumps lured us to choose Saptari as our sample district. This research was focused on Saptari district but to get a wider knowledge of the scenario, the neighbouring districts were also surveyed to collect the information about pump suppliers, service providers, etc.

The second phase of sampling was conducted within Saptari district. First of all, an inventory of installed pumps in municipalities and rural municipalities of Saptari district was prepared

[9] *District climate and Energy Plaan (Saptari)*

through secondary data. Focusing on wide geographical coverage within Saptari district, sample area was selected as shown in *Figure-2*.

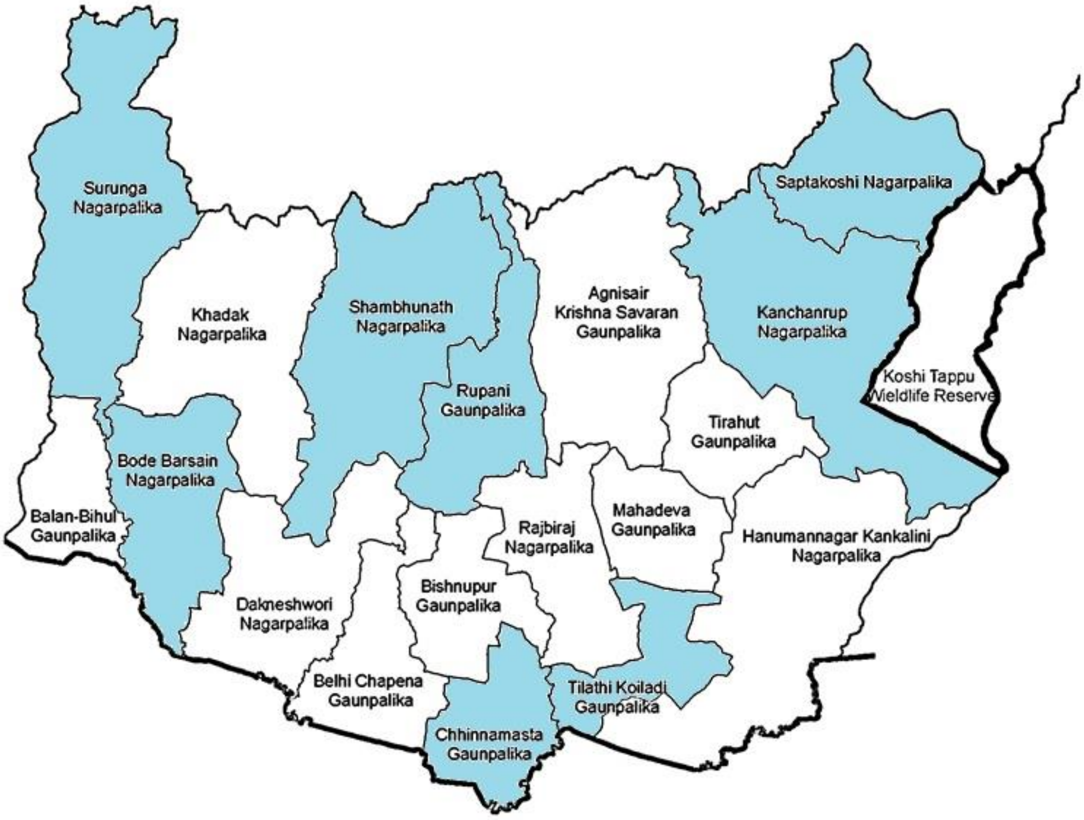

Figure 2 : Study area in Saptari District

Source: LGCDP, GoN

2.2.2 Sample Size Selection

Once the sample area was selected, the sample size was determined based on the number of solar pumps installed in the selected area. From literature review and secondary data, we identified that Saptari district alone consists of 73 installed solar pumps including sunflower pumps. *Figure-3* depicts the characteristics included: size of system, date of installation, beneficiary HHs number, grid situation, solar vendor, implementing organization, funding agency and major application of water (Irrigation, Livestock, Fishery, and Drinking) for sampling and selection of solar pumps

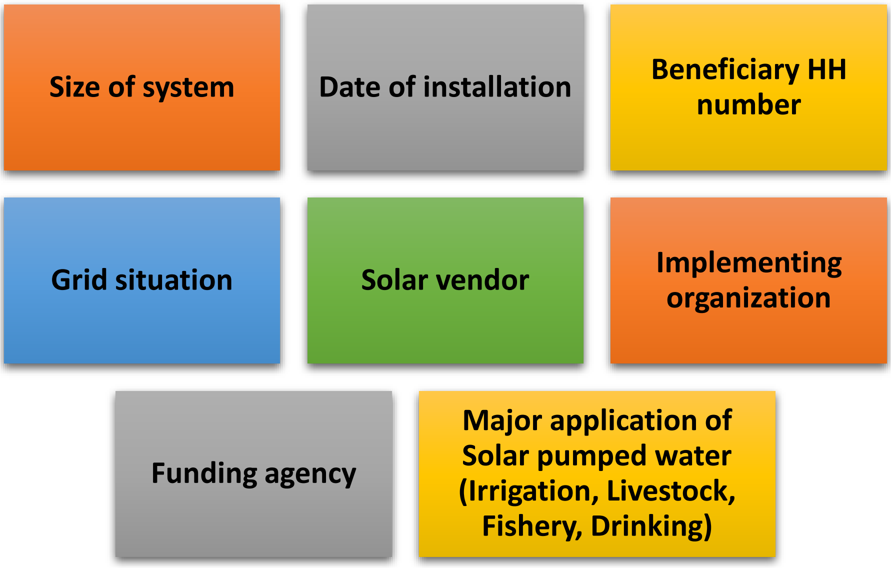

Figure 3 : Characteristics for Sample Selection

for this study. Therefore, based on the information and characteristics, we initially sampled 20 solar pumps to conduct the study. While considering these characteristics, overlaps were observed and based on the unique characters, avoiding repetition and with an attempt to select as much variety as possible, selection was done.

However, some of the secondary information received were inconsistent and not reliable resulting in sample size change. We slightly deviated from the initial plan of considering 20 samples to 14 samples by considering the characteristics and considering the geographical proximity between the samples collected as well as not compromising on the purpose of the research. The general information of these 14 sites selected for the study are presented in *Annex-1*.

In addition to Solar/Sunflower pump owners, we also interviewed few diesel pump and electric pump owners, installers, and repair and maintenance (R&M) service providers of all the pumps (*Please refer to Annex-2)*.

2.3 Tools Development

Observation checklist was developed to attain quantitative data on the studied pumps. The aim of collecting this information was to compare the performance and efficiency between these pumps.

Alongside quantitative data, qualitative data was retrieved through Key Informant Interview (KII). KII Guidelines were developed to collect qualitative data to: Identify and compare various pumping technologies and business models; Compare performance of solar pump with other conventional pumping systems; Compare different irrigation techniques; Identify perceptions and satisfaction level of pump owners/users in relation to financial, technical, supply-demand, and after-sale services provided by service providers.

Table-1 shows the type of tools used, along with the characteristic of the participants who were interviewed during this study.

Table 1: Tools for Data Collection

Tools		Participants	Remarks
Quantitative	Observation Checklist	- Solar Pumps - Diesel Pumps - Electric Pumps - Sunflower Pumps	Checklist was used to compare between different Solar pumping systems
Qualitative	Key Informant Interview (KII) Guidelines	- Solar/Sunflower Pump Owners and Operators - Solar/Sunflower Pump Installers and R&M service providers - Diesel/Electric Pump Owners - Diesel/Electric Pump Suppliers and R&M service providers	

2.4 Data Collection and Analysis

2.4.1 Field Visit

We undertook field visits to multiple solar pump installed in Saptari district. We conducted field visits to:

- Observe the working of solar pumps under different contexts;
- Enrich and validate our findings from literature review regarding financial and business model, application of water;
- Capture the perception and experience of solar pump users and benefits received by the users
- Interview other relevant stakeholders to understand the scope of solar and conventional pumping system

Following the tools development, a 9-day long field visit was planned. While checklist was focused on collecting technology related data, KII guidelines attempted to collect qualitative data based on interaction and in-depth discussions. Overall, this visit was focused on: Identifying solar system size in response to water need/demand; Equipment and Installation works meeting their minimum standards; Pump flow; Supply and Demand management of different pumps; Funding model and Financial aspect of different projects; Satisfaction and Perception of pump owner on their pumping technology and their investment decision in relation to financial, technical, supply-demand, repair-maintenance services provided from service providers; Information on water usage.

Quantitative information was collected together to compare between the technological findings. Alongside, qualitative information received from KIIs was translated before structuring and grouping, to identify recurrent themes and patterns in data.

a) Flow Measurement Method

To measure the pumps' performance in terms of pumping rate, flow rate was calculated using plastic tank and stop watch. The measured data were validated with the flow measured by pump installer in the past. In many sites, pump owner has maintained the record of pump operation period. This duration of pump operation and the total meter readings in the pump helped to calculate the average water pumping rate of the pump.

2.4.2 Stakeholder Interviews

We conducted semi-structured interviews to key stakeholders comprising solar pump users (13), solar pump suppliers (3), solar pump promotors (4), diesel and electric pump suppliers (4), pump repair and maintenance service centres (2), diesel and electric pump users (10). The interviews focused on:

- Capturing the views, experience and concerns of the pump owners/users regarding the use of diesel and electric pumps, and factors for motivating them to adopt solar pumping system;
- Identifying the determinants for promotion and sustainability of solar pumping system, and impact of solar pumping in agriculture sector;
- Identifying the possible intervention measures to maximize the use of solar pumping system and alleviate the barriers which pose threat to sustainability of the system;
- Evaluating the effectiveness of different business model.

2.4.3 Data Processing and Analysis

a) Data Processing

Data obtained from primary and secondary sources were organized with proper coding in digital format for further analysis. Data were thoroughly checked for errors and consistency. Data were classified based on the specific characteristic of data.

b) Data Analysis

Life Cycle Costing (LCC) approach was used to compare different pumping systems offering the same service/output. This approach allows systems to be compared on an equal basis by reducing all future costs, which occur at different intervals of the systems life, to one value. Per unit water cost (UWC) was calculated for different pumping technologies considering the life-cycle cost over 20 years of period taking into account:

- Initial upfront cost;
- Operating costs;
- Repair & maintenance cost;
- Replacement costs

The UWC reflects the cost of water and therefore provides a measure for the cost at which water at a particular installation needs to be sold at in order to recover the all-inclusive costs for providing the water supply service.

Capacity of solar pump is usually expressed in daily flow rate whereas diesel and electric pump systems are based on hourly flow rate. To compare the solar pump with diesel and electric pump, daily flow rate has been considered at a particular head. Daily flow rate of solar pump has been considered as the maximum daily water demand and UWC for diesel and electric pump has been calculated to meet the same demand.

3. FINDINGS AND DISCUSSIONS

3.1 Overview of Solar Pumping Technology Development in Nepal

Nepal is endowed with good solar energy potential with an average of more than 300 sunny days per year and average solar radiation of 4.4 $kWh/m^2/day$ to 5.5 $kWh/m^2/day$[10]. There has been significant progress in terms of solar home lighting system whereas solar pumping sector is gradually growing.

The history of solar pumping system in Nepal began in 1993 with a 4 kW system installed in Sundari-ghat. In few years' time bigger solar pumping systems were installed in Bode a 40 kW system in 1995, Bhulke Siraha a 60 kW system (30 m3/day) in 1996 and Phulberiya, Siraha in 1998[11].

At the beginning of this century the GoN introduced subsidies promoting renewable energy and the policy includes incentives for rural villages to exploit their optimum solar exposure with solar powered water pumps. Subsidy policy opened new avenues for the deployment of solar pumping technology in Nepal.

3.2 Policy and Institutional Setup

Alternative Energy Promotion Centre (AEPC) is the government focal institution for promotion and implementation of renewable energy based technologies in Nepal. AEPC was established in 1996 which helped in wider and extensive promotion of renewable energy technologies in Nepal. Subsidy Policy, 2009 introduced subsidy in solar pumping system for drinking and micro-irrigation. A dedicated unit for Photovoltaic Pumping System (PVPS) was established under Solar Energy Component since 2009. The institution has supported for the implementation of over 300 pumping systems for drinking and 200 system for irrigation in rural Nepal[12]. Renewable Energy Subsidy Policy-2016 introduced the provision of solar pumping system for irrigation.

According to Subsidy Policy-2016, maximum subsidy provision is up to 60% of the total costs but not exceeding $ 15,000 per system for PV pumping system for drinking water managed by community or private company. Similarly, maximum subsidy amount of up to 60% of the total costs but not exceeding $ 20,000 per system will be provided for PV pumping system for irrigation of agricultural land managed by community or private company[13].

Department of Irrigation (DOI) established Non-Conventional Irrigation Technology Project (NITP) in 2060 B.S. to promote other than conventional irrigation technology and techniques

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[10] http://documents.worldbank.org/curated/en/585921519658176633/pdf/123705-ESM-P150328-PUBLIC-NepalSolarMappingCountrySolarResourceReportMarch.pdf

[11] *www.icimod.org/resource/17216*

[12] https://d2oc0ihd6a5bt.cloudfront.net/wp-content/uploads/sites/837/2018/06/Ram-Prasad-Dhital-Solar-Pumping-Experience-in-Nepal.pdf

[13] http://www.aepc.gov.np/uploads/docs/2018-06-19_RE%20Subsidy%20Policy,%202073%20(English).pdf

which also includes lifting water using renewable energy (Solar pumps, Electric pumps, Barsha Pumps etc). NITP provides up to 90% subsidy for solar pumping system which are implemented for irrigation purposes[14].

GoN further introduced the provision of exemption of VAT and custom duty in RE equipment/materials including solar pump and modules though Financial Act, 2014.

In addition to government programs, non-government organizations are also promoting solar pumping technology by mobilizing grant and credits. However, subsidy or grant are provided mainly for purchasing the capital equipment. Introducing subsidy or revolving fund for operation and maintenance could be even more beneficial.

3.3 Performance and Technical Features of Solar Pumps

Deployment of solar pumps for irrigation is gradually advancing in Saptari district. Governments, development agencies and private sectors are exploring and implementing solutions to improve access to, and sustainability of, irrigation services. We observed the solar pumping system with variations in size, type of pump, application, financial model etc.

It has been found that deployment of solar pumping technology in Saptari district started since 2014. This district has been found suitable for solar pumping technology since the average ground table lies in the range of 5m-15m and most part of the district receive the average solar radiation of 4.5 kWh/m2/day[15].

3.3.1 System Sizing

In general the system size is determined based on the need/demand of water, solar irradiance and dynamic head. Whereas, water requirement in agriculture depends on crop type, crop stage, soil type, irrigation methods, climatic factors such as temperature, humidity, sunshine, wind speed, etc.[16]. The water requirement parameters were not found considered while determining the size of solar pumping technology at site. Our interviews with solar pump suppliers revealed that the likelihood of future decline in ground water (GW) levels was not factored in while designing solar pumps, even though most of the interviewees/respondent regarded it as a challenge for sustained use of solar pumps over their technical life. We noticed that determination of system size was guided by the business model of the promotor as well as the availability of the size in the market. Off-the-shelf model were promoted rather than tailoring the size based on design parameters. One of the reasons for this could be to test the technical performance as well as to test the acceptance of business model.

Size of solar pumping were found in the range of 80 Wp (Watt peak) to 2400 Wp, with 1200 Wp system as the most commonly used with 1.5 HP submersible AC pump. Size of single PV

[14] http://doi.gov.np/nitp/about-us/

[15] https://maps.nrel.gov/gst-nepal/?aL=diAr-R%255Bv%255D%3Dt&bL=clight&cE=0&lR=0&mC=26.870630960767105%2C86.47064208984375&zL=9

[16] http://www.fao.org/docrep/u3160e/u3160e04.htm

module was in the range of 80 Wp to 300 Wp. *Figure-4* provides the number of pumping units and their installed solar capacity.

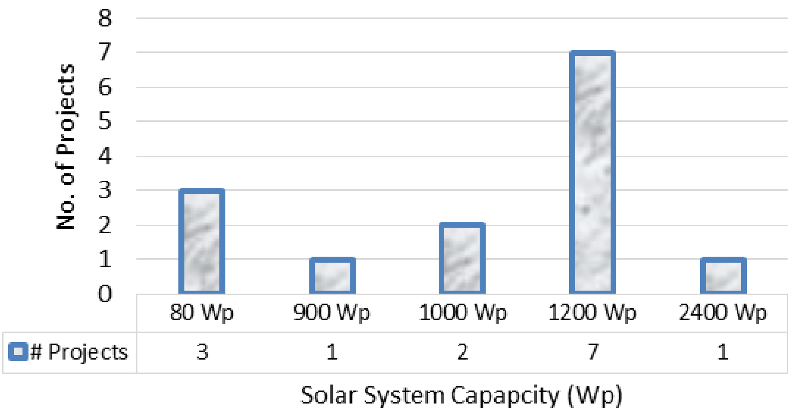

Figure 4: Solar System Capacity for Pumping Units

3.3.2 Type of Pumps

Different types of pumps were found to be used for different application under different financing model. Relatively smaller size of pumps including sunflower pump are operated using DC motor. The source of water in the surveyed area was groundwater for all solar pumping units. More than 50% of the surveyed pumps were surface mounted. Solar pumping units other than Sunflower pump are named as "Solar Pump". Details about the types of pumps used are presented in *figure-5*.

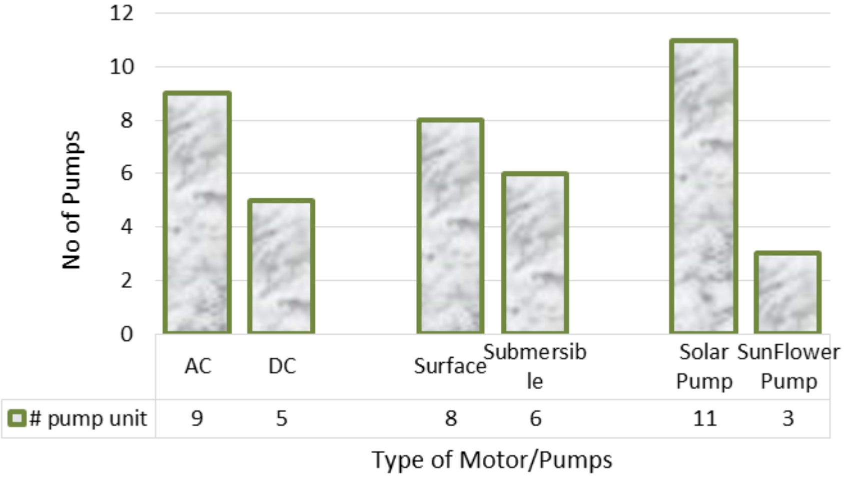

Figure 5: Type of Motor/Pumps

3.3.3 Mounting Structure

Automatic or manual tracking system can be installed in solar pumping units to maximize power production and increase the daily discharge. The use of tracking arrays to increase the daily output of the PVP is a popular option. Tracking arrays can be passive or active, single or double axis, all of which determines the increase of the daily energy harnessed. Solar panel with passive solar tracking system can increase the efficiency by 23%[17]. However, there was no data to evaluate the effectiveness of rotating structure compared to static frame for the study area as solar trackers are slightly more expensive than their stationary counterparts, due to the more complex technology and moving parts necessary for their operation.

Manual tracking system was provided in one of the sampled plants where the PV modules were

Figure 6: Solar Panel on Adjustable Mounting Structure at Shambhunath Municipality-2, Bhaluwahi, Saptari

mounted in adjustable frame structure and the system could be rotated in dual axis. Solar pump owner mentioned that they adjust the system manually on seasonal basis.

3.3.4 Storage Facility

Storage can be done either by constructing elevated storage water tank and collect the water to use when there is demand, or storing the energy generated by PV modules in the battery and use to run the pump when there is demand of water. The first is apparently more feasible and less maintenance-demanding as compared to battery storage systems. None of the solar pumping system had the provision of battery in our sampled sites. Storage tanks were provided only in two sites where the water was pumped for the purpose of drinking and sanitation.

3.3.5 Application of Water

Solar pumps amongst the surveyed units were found to be used for the following purposes:

[17] http://dergipark.gov.tr/download/article-file/256992

* Drinking & Sanitation in Institutions
* Irrigation
* Hatchery and fish farming

Out of 14 pumping sites visited, 10 units were for irrigation purpose. Similarly, 2 units were used for fish farming and the other 2 units were used to supply water in institutions (Madrassa and Temple) for drinking and sanitation purpose.

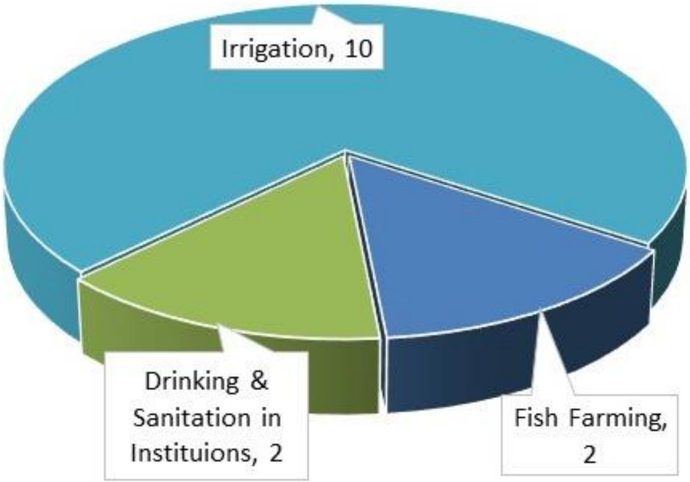

Figure 7: Application of Solar Pumped Water

Figure 9: Solar Pumping System (900 Wp) at Fish Pond (Rupani Rural Municipality-1, Saptari)

Figure 9: Bodebarsaien Municipality-5, Saptari (1200 Wp) installed last year


Figure 10: SunFlower Pump used by Tenant Farmers (Kanakpatti, Shambhunath-2)

i. **Irrigation Methods**

It was observed that flood irrigation methods was used where farmers were still engaged in producing traditional cereal crops and furrow irrigation method was adopted to irrigate vegetable crops. Around 50% farmers were found producing traditional crops using solar powered water pump.

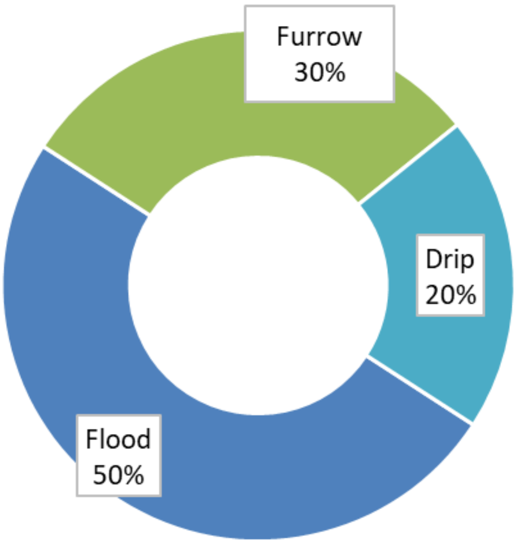

Figure 11: Methods of Irrigation

ii. Crop Types

The study showed around 30% farmers of the total surveyed solar pump units were still practicing traditional crops throughout the year. The reason behind this as stated by the surveyed farmers is the requirement of more labour force for vegetable production. Insufficient labour force was mainly due to temporary migration of youth members of the family to cities and abroad for better opportunities and hence the continuation of traditional crops is still persisting among these farmers in the study area.

However, the remaining 70% of the studied farmers reported that they can adopt 3 crop cycles after the installation of solar pump whereby they previously used to produce only one crop per year. They produce vegetables in two seasons and rice in monsoon period.

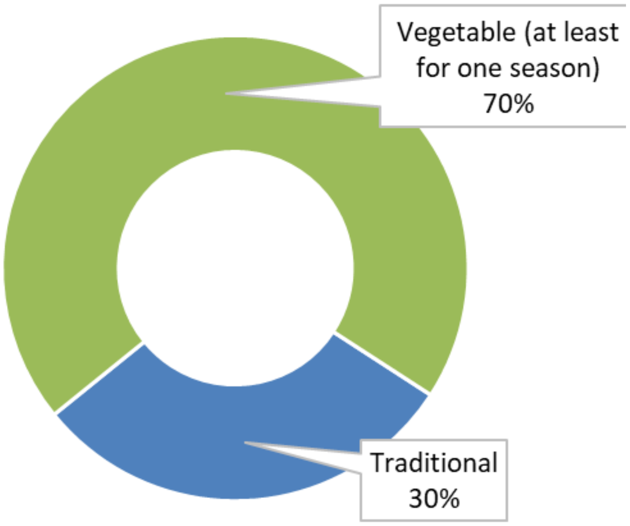

Figure 12: Type of Crops Produced by Solar Pump Users

To maximize the benefits of solar pump, it is necessary to facilitate community to adopt cash crops by replacing traditional crops, optimize cropping patterns to maximize the use of the solar pump, and promote micro-irrigation technology such as drip, micro-sprinkler, etc. to optimize the water use.

3.3.6 Functional Status and Performance

Out of 14 pumping units, two pumps (including one sunflower pump) of them were found to be not functioning since last six months. The reason behind this were mainly technical issues. They tried to contact the service providers but did not receive the response from them.

Technical faults in the solar array and power supply system were not reported and seemed to be rare. However, problems in the submersible pump and plumbing were reported as more common. However, such faults were almost always remedied within a short span of reporting time where the pumps are still under warranty provision. But in case of other projects where warranty period was over, pump users had to wait for long time to get services.

Figure 13: Solar Water Pumping System at ChhinnaMasta Temple, Saptari *(not in Function since last six months)*

Capacity utilization Factor (CUF) is the ratio of the actual output from a solar plant over the year to the maximum possible output from it for a year under ideal conditions. Average value of CUF was calculated by classifying the pumps into three different categories based on their application, which is presented in *figure-14.*

58% CUF was found in case of solar pumps used for fish farming followed by 50% for domestic purpose. Solar pumps used for irrigation purpose only are utilized around 37% of its capacity. It was found that solar pumps were rarely used during monsoon period as farmers mainly cultivate rice during this season. Even farmers who are engaged in vegetable production in other seasons are also cultivating rice during the monsoon season. For rice plantation around five times irrigation is required according to the surveyed farmers of which one time irrigation were recorded using solar pump and rest of the irrigation demand was met by monsoon water. This could be the reason for low CUF value in solar pumps for irrigation and hence recommended to explore other possible areas to utilize energy available from solar PV during the monsoon period in order to reduce the payback period for the overall system cost.

Relatively, as stated above solar pumps installed for fish farming were found having higher utilization factor even though they are kept idle during off-season, i.e. around 4 months in a year. In principle, solar pumps used for drinking and sanitation purpose should have higher utilization factor but was calculated to be only 50%. But these pumps were installed in institutions a Temple and Madrassa whereby the water demand varies since the number of users vary.

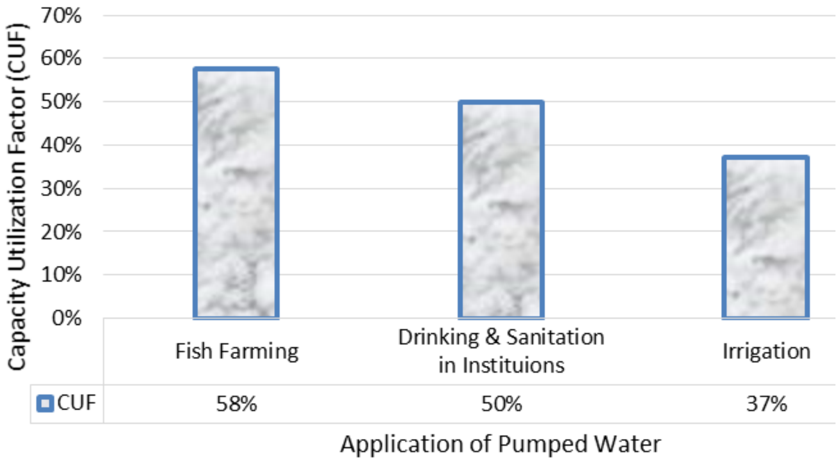

Figure 14: Capacity Utilization Factor (CUF) of Solar Pumps

ICIMOD had installed three units of solar powered irrigation pumps in August 2014 and recorded total number of cumulative operating hours of those three pumps for a period of 15 months. ICIMOD study shows the average operating hours of each pump in 15 months period was 525 hours[18], i.e. 420 hours per year. If we consider 4.5 hours/day as conservative value of effective sunshine hour, the total number of available hours for pump operation in a year is around 1600 hours. This implies the CUF of these monitored solar pumps is only around 26% which is very low.

Study team was able to visit only three units of Sunflower pump and one of them was not functioning for a long time. Other two pumps were located nearby the same places used by tenant farmers in group ownership. ACIAR project was supporting them to produce vegetable using solar pumped water in an effective and efficient way. CUF of those pumps was calculated as 70%. Further study is essential to compare the performance of Sunflower pump with other pumps in terms of CUF.

3.3.7 Safety and Protection

Safety issues are common in solar systems, but proactively putting preventive measures in place can help to mitigate the injuries during project installation and operation.

Solar pumping systems include several components that induce/conduct electricity: the PV solar array, an inverter/controller, breaker, motor and other essential system parts. When any of these components are "live" with electricity generated by the sun's energy, they can lead to injuries associated with electric shock and arc-flash. Even low-light conditions can create sufficient voltage to cause injury.

Fencing around the solar pumping unit is most essential to avoid such risks. It is also important to ensure that control boxes are sealed properly and systems are properly grounded.

[18] ICIMOD-Sustainable financial solutions for the adoption of solar powered irrigation pumps in Nepal's Terai

Figure 15: Solar pump installed in open area without fence, Surunga Municipality-7, Saptari

Though no theft issues have been reported until now from all studied sites, it is recommended to have proper fencing to avoid any theft or vandalize issues in the future. Most of the solar pumps are either installed inside the building premises or fenced using barbed wire. A few of the solar plants are installed in open field with easy access to people and animals.

Figure 16: Broken Earthing Wire

In addition, devising innovative insurance products could help to manage the risks due to extreme events. Measures such as fencing, security fasteners, alarms and system monitoring tools could be used to secure property against the risks of theft. As per the information received from the system supplier/installer, anti-theft bolts are used at some of the sites to fasten the PV modules in the mounting structures.

To protect the system from lightning strike, installation of lightning arrester with proper earthing/grounding is essential. We did not observe lightning arresters in any of the surveyed sites. At some sites, earthing wire was damaged/broken. An awareness activity to solar pump users is recommended to avoid any incidents/accidents in the future.

3.3.8 Repair and Maintenance Services

Access to timely and economic repair and maintenance service is critical to farmers' confidence and public acceptance of PVP technology as a reliable solution for irrigation in the long run. During interviews as well as field visits, we found that farmers having defunct system due to lack of repair and maintenance, perceived the technology as unfit for irrigation and thus had an adverse effect on the scale-up of the technology. Most of systems are still getting free services from pump supplier since they are in warranty period. Evaluation of/Research on after-sale services and technical performance during post warranty period will provide critical insight to the technical sustainability of PVP systems.

After Sale Service

- Most of the studied solar plants are still in warranty period. Warranty period was found to be in the range of 1 to 3 years. Technical suppliers who installed technology are responsible to provide the technical services at free of cost during warranty period. It is essential to carry out further study to assess the technical performance during the post warranty period over the time span of project life.
- Experiences shows that there are many operation and maintenance related issues in most of the solar pumping projects due to lack of technical human resources in the local market, which could eventually lead into shut down of these solar plants. Hence, it is important to establish an effective supply chain network at local market to improve the technical sustainability of the project in post warranty period.
- Some of the solar pump users/owners expressed their dissatisfaction regarding after-sale service from the solar companies. If the services from solar pumps are intermittent resulting to longer period of the system staying defunct and having to wait to bring them back into operation, the users might lose the trust on the technology and thus can shift back again to conventional fossil fuel based pumping technology. In such scenario it would be difficult to promote solar pumping technology in those areas where farmers have bitter experiences with solar pumping.

3.4 Financial Analysis

To assess the financial viability of solar pumping system, UWC for different pumping technologies has been calculated and compared. Similarly, payback period for solar pump at different CUF has been calculated for different water prices. LCC was calculated over a 20 year period for each type of pumping system taking into account:

- Initial upfront cost;
- Operating costs (diesel/or electricity cost, inspections of pumping systems);
- Repair-maintenance costs; and
- Replacement costs.

Due to lack of field data, it was difficult to estimate the lifetime and thus the annual operation, repair-maintenance, and periodic replacement cost of these systems over the project lifetime. Assumptions are made to represent long-term recurring cost of operation, maintenance and replacement even though the schemes had only been in operation for a few years. The assumptions made in the technology comparison calculations are informed guesses, but include a large margin of error.

3.4.1 Cost Effectiveness of Different Pumping Technologies

The unit water cost (UWC) has been calculated for each type of pump. UWC reflects the cost of water and therefore provides a measure for the cost at which water at a particular installation needs to be sold at in order to recover all-inclusive costs for providing the water supply service. The UWC is calculated from the life cycle cost based on the assumption that the capital investment for the implementation of the water supply system is a Bank loan.

To compare the cost effectiveness of different pumping technologies, most commonly used solar pumping unit (1200 WP, 1.5 Hp Pump, 5m lift height) was considered for the analysis. LCC was calculated over a 20 year period taking into account initial upfront cost, operating costs, maintenance costs, and replacement costs. LCC costs were calculated for different CUFs. UWC was calculated considering different CUFs. Similarly, UWC for diesel powered pump and grid operated electric pump was calculated to deliver the same volume of water over 20 year time span.

I) Cost Per Unit Water for Solar Powered Pump

Cost per unit water has been calculated considering LCC at different capacity utilization factor. Following assumption were made while determining the cost:

- *All costs mentioned are in NPR*
- *Cost for storage tank, distribution system are not included in the costing*
- *Routine and Periodic Maintenance cost are adjusted based on the number of operating hours per year. NPR 3,000 per year for routine maintenance and NPR 15,000 in every 4th year for periodic maintenance cost have been considered for maximum number of operating hours (optimum level)*
- *90% has been considered as maximum CUF considering 10% outage for R & M Services*
- *Maintenance cost for 3 years is covered under warranty provision*

Parameters for Cost Analysis

System Capacity	:	Solar Array-1200 Wp; Pump-1.5 HP
Lift Height	:	5m
Average Daily Flow Capacity	:	61,560 litres
Average Daily Solar Radiation	:	4.5 kWh/m2/day
Time Span	:	20 years
Discount Rate	:	10%

Table 2: Cost per Unit Water for Solar Powered Pump

Capacity Utilization Factor (CUF)	**10%**	**25%**	**50%**	**70%**	**90%**
Annual volume of Water to be Pumped by Diesel Pump (m3)	***2,247***	***5,617***	***11,235***	***15,729***	***20,222***
Initial Investment (NPR)	406,450	406,450	406,450	406,450	406,450
Solar Pumping Technology	*380,000*	*380,000*	*380,000*	*380,000*	*380,000*
Tube well Development (4" dia,60 ft depth)	*26,450*	*26,450*	*26,450*	*26,450*	*26,450*
O &M Cost (NPR)					
Annual Routine Maintenance (with 5% annual increment)	*1,500*	*1,500*	*2,000*	*2,500*	*3,000*
Periodic Maintenance (in every 4th year)	*10,000*	*10,000*	*15,000*	*15,000*	*15,000*
Replacement Cost (NPR)					
Pump/Motor Replacement Cost (in every 7th year)	*28,476*	*28,476*	*28,476*	*28,476*	*28,476*
Controller (VFD) (In every 10th year)	*80,000*	*80,000*	*80,000*	*80,000*	*80,000*
Cost Per Unit Water (NPR/m3) *(Considering 5% increment in every 5th year)*	**24.40**	**9.80**	**5.00**	**3.60**	**2.83**

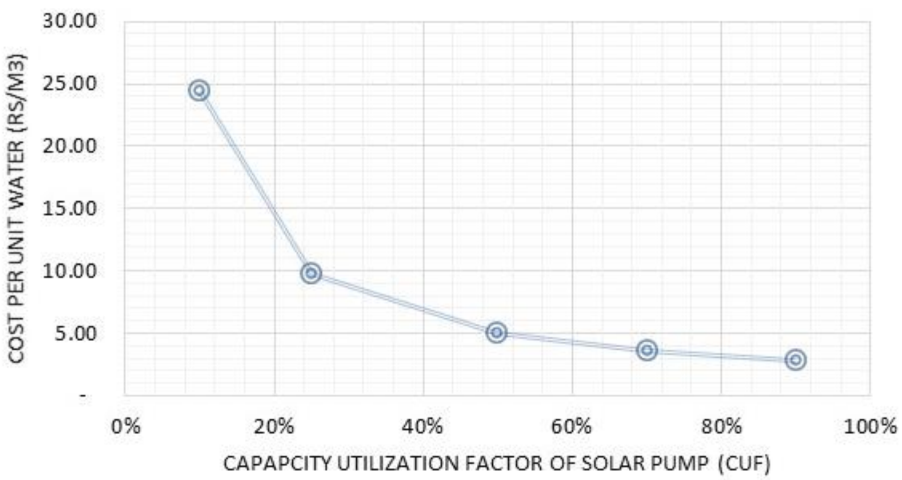

Figure 17: Cost Per unit Water for Solar Pump at Different CUF

II) Cost Per Unit Water for Diesel Powered Pump

5 HP diesel pump set has been considered for cost analysis since this size of diesel pump set was found to be the most common one to irrigate the agricultural land in this area.

The cost per unit water for diesel pump has been calculated for different scenarios however with the same volume of water pumped by solar pump at different CUFs.

Other assumptions to calculate the UWC for diesel pumps are as follows:

- *All costs mentioned are in NPR*
- *Cost for storage tank, distribution system are not included in the costing*
- *Lift Height*: 5m
- *Flow Rate for 5m lift*: 12 lps
- *Time Span: 20 years*
- *Discount Rate: 10%*
- *Repair and Maintenance cost are adjusted based on the number of operating hours per year (with 5% annual increment)*
- *Specific Fuel Consumption (Litre/kWh): 0.3*
- *Specific Oil Consumption (Litre/kWh): 0.0046*
- *Price of Diesel: NPR 92/litre (with 5% annual increment)*
- *Price of Oil: NPR 600/Litre*

Table 3: Cost per Unit Water for Diesel Pump

Solar Pump CUF	*10%*	*25%*	*50%*	*70%*	*90%*
Annual volume of Water to be Pumped by Diesel Pump (m3)	***2,247***	***5,617***	***11,235***	***15,729***	***20,222***
Initial Investment (NPR)	**68,450**	**68,450**	**68,450**	**68,450**	**68,450**
Diesel Pump Set	*42,000*	*42,000*	*42,000*	*42,000*	*42,000*
Tube well Development (4" dia,60 ft depth)	*26,450*	*26,450*	*26,450*	*26,450*	*26,450*
Annual Operation Cost (NPR) (a+b)	***5,930***	***14,824***	***29,648***	***41,507***	***53,366***
Number of Hours to be operated per year	*52*	*130*	*260*	*364*	*468*
Total kWh equivalent per year (Assuming Diesel pump set is operated in full capacity)	*195*	*488*	*975*	*1,365*	*1,755*
a. Annual Cost of Fuel	***5,392***	***13,480***	***26,960***	***37,743***	***48,527***
b. Annual Cost of Oil	***538***	***1,344***	***2,688***	***3,763***	***4,839***
Annual Maintenance Cost (NPR) (a+b+c)	***3,020***	***6,040***	***9,060***	***15,100***	***18,120***
No. of routine servicing per year (servicing after every 80 hours of operation)	*1*	*2*	*3*	*5*	*6*
Service charge per time	*1,000*	*1,000*	*1,000*	*1,000*	*1,000*

a. Annual Cost for Routine Servicing	***1,000***	***2,000***	***3,000***	***5,000***	***6,000***
Cost for Spare Parts in each servicing	*1,020*	*1,020*	*1,020*	*1,020*	*1,020*
b. Annual Cost for Spare Parts	***1,020***	***2,040***	***3,060***	***5,100***	***6,120***
c. Other Cost (NPR 1000 per service period)	***1,000***	***2,000***	***3,000***	***5,000***	***6,000***
***Replacement Cost** (after 5,000 hours of operation)*	-	-	*42,000*	*42,000*	*42,000*
Cost Per Unit Water (NPR/m3) *(Considering 5% increment in every 5th year)*	**8.80**	**6.39**	**5.51**	**5.48**	**5.26**

III) Cost Per Unit Water for Grid Electric Pump

1.5 HP electric pump has been considered for cost analysis as this is the most common electric pump size used in the surveyed area.

The cost per unit water for electric pump has been calculated in different scenarios with the same volume of water pumped by solar pump at different CUFs.

Other assumption considered are as follows:

- *All costs mentioned are in NPR*
- *Cost for storage tank, distribution system are not included in the costing*
- *Lift Height*: 5m
- *Flow Rate for 5m lift*: 12 lps
- *Time Span: 20 years*
- *Discount Rate: 10%*
- *Repair and Maintenance cost are adjusted based on the number of operating hours per year (with 5% annual increment).*
- *Price of Electricity: NPR 10/kWh*
- *Access to grid electricity*

Table 4: Cost per Unit Water for Grid Electric Pump

Solar Pump CUF	*10%*	*25%*	*50%*	*70%*	*90%*
Annual volume of Water to be Pumped by Electric Pump (m3)	***2,247***	***5,617***	***11,235***	***15,729***	***20,222***
Initial Investment (NPR)	**57,926**	**57,926**	**57,926**	**57,926**	**57,926**
Electric Pump Set	*28,476*	*28,476*	*28,476*	*28,476*	*28,476*
Wiring, Switches and installation	*3,000*	*3,000*	*3,000*	*3,000*	*3,000*
Tube well Development (4" dia,60 ft depth)	*26,450*	*26,450*	*26,450*	*26,450*	*26,450*
Annual Operation Cost (NPR)	***1,560***	***3,900***	***7,800***	***10,920***	***14,040***
Total kWh	*156*	*390*	*780*	*1,092*	*1,404*

Annual Cost for Electricity	***1,560***	***3,900***	***7,800***	***10,920***	***14,040***
Annual Maintenance Cost (NPR)	***2,887***	***6,468***	***11,435***	***17,209***	***21,483***
No. of routine servicing per year (in every 200 hours of operation)	*1*	*2*	*3*	*5*	*6*
Service charge per time	*1,500*	*1,500*	*1,500*	*1,500*	*1,500*
Annual Cost for Routine Servicing	***1,500***	***3,000***	***4,500***	***7,500***	***9,000***
Annual Cost for Spare Parts and other accessories[19]	***1,387***	***3,468***	***6,935***	***9,709***	***12,483***
Replacement Cost *(after 5,000 hours of operation)*	-	***28,476*** ***(1x28,476)***	***56,952*** ***(2x28,476)***	***85,428*** ***(3x28,476)***	***85,428*** ***(3x28,476)***
Cost Per Unit Water (Rs/m3) *(Considering 5% increment in every 5th year)*	***5.58***	***3.81***	***3.14***	***3.06***	***2.90***

Figure-18 and *table-5* show the cost per unit water for three different technologies in different scenario. If solar pump is operated utilizing only 10% of its capacity, the per unit water cost is NPR 24.4, and the cost is reduced to NPR 2.83 if it operated at 90% CUF. The reason behind this is that the high upfront cost of solar pump and minimal operation and maintenance cost. But on the other hand, operation cost increase with increase operation hours in diesel and electric pump. The cost is reduced rapidly with increase in operating hours in solar pump whereas the curves are almost flat in diesel and electric pump. The graph shows that when solar pump is operated at more than 45% CUF, solar pumps become cost effective option compared to diesel pump. If solar pump is operated at more than 90% CUF, solar pump becomes cost effective solution than electric pump.

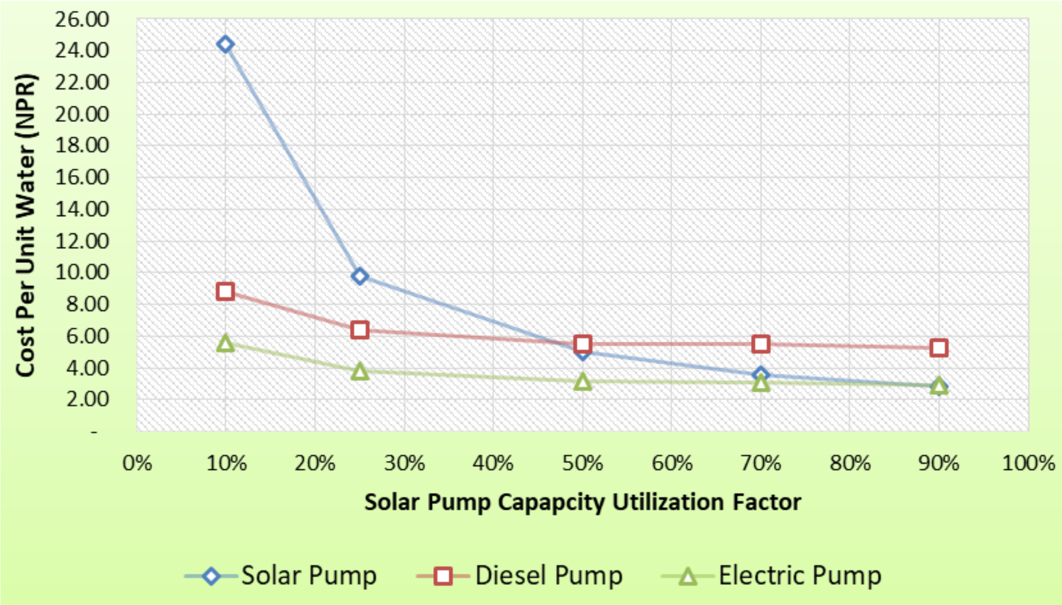

Figure 18: Cost per Unit Water in Different Pumping Technologies

[19] NPR 1000 per 100 hrs operation

Table 5: Cost per Unit Water in Different Pumping Technologies

Solar Pump CUF	Water Volume (m3/day)	Cost Per Unit Water (Rs/m3)		
		Solar Pump	Diesel Pump	Electric Pump
90%	55.40	2.83	5.26	2.90
70%	43.09	3.60	5.48	3.06
50%	30.78	5.00	5.51	3.14
25%	15.39	9.80	6.39	3.81
10%	6.16	24.40	8.80	5.58

3.4.2 Payback Period for Solar Pump

Payback period refers to the period of time required to recoup the funds expended in an investment, or to reach the break-even point.

The payback period is one of the selection criteria, or deciding factor when we need to decide from multiple options. This will help the investor to make decision on their investment plan.

Solar pumps are found cost effective solution if they are operated for longer period of time. The payback period of solar pump is calculated at different scenarios using sensitivity analysis of solar pump at 70% and 90% CUF and comparing with diesel pumps. The results are presented in *table-6*.

Table 6: Payback Period (yrs) for Solar Pump at Different Unit Price of Water

Price of Water (NPR/unit) ►		5.51	7.92	10
Solar Pump (CUF) ▼	Average Daily Water (m3/day)	*Minimum price of water for diesel pump if it is operated equivalent to 50% CUF Solar pump.*	*Prevailing rate of water from diesel pump set*	*Community's Desire to pay for water*
90%	55	4.79	3.08	2.37
70%	43	6.97	4.18	3.14
50%	31	>20 yrs	6.90	4.76
25%	15	-	>20 yrs	18.66
10%	6	-	-	>20 yrs

Assumption

1. Increase in price of water by 5% in every 5th year

2. Annual O & M cost increases by 5% per annum

3. Discount rate=10%

Payback period for Solar Pumping system has been calculated for three types of tariff rates and different values of CUFs. Following conclusions can be drawn from *table-5*.

If a diesel pump is operated to supply water equivalent to water volume pumped by solar pump at 50% CUF, cost per unit water to be pumped is NPR 5.51. If we consider this price as a tariff rate, the payback period for solar system will be 6.97 years, if the solar system is operated at 70% CUF. If solar pump is operated at less than 50% CUF, solar pump entrepreneur will not be able to recover his/her investment in entire project life.

Currently farmers are paying NPR 7.92 per unit water to diesel pump owner where farmers are buying water for irrigation from diesel pump set. If we consider this price as a tariff rate per unit water, payback period for solar pumping system is 4.18 years, if solar pump is operated at 70% CUF.

Farmers mentioned that they are happy to pay up to NPR 10 per unit water if they get water on demand. If we consider this price of water as tariff rate, payback period for solar pumping system will be 3.14 years, if solar pump is operated at 70% CUF.

3.5 Economic Performance

The evidence based impacts of solar pumping interventions on cropping patterns, yields, irrigation methods and cost savings over time is limited. Almost all solar pumping units were installed in last 3 years under piloting and testing the technology and business model. It is too early to define the benefits received by the farmers from solar pumping system and needs to be matured enough to see how farmers will reap the full benefits of solar pumping system during its life time. However, we were able to observe and record some of the tangible benefits received by the farmers in the field and interviewed some farmers to understand the impact of solar pump from their point of view.

Cropping intensity in Terai region of Nepal is around 186 %[20] and main reason for leaving the land fallow during dry season is due to lack of water for irrigation. The study shows that the cropping intensity has increased by 52% when the agricultural plot received year-round irrigation facility. The crop yield has increased by more than 50%[21].

Solar pumping system integrated with micro-irrigation helps to conserve water, increase crop yields, and lower expenditure on fertilizer and other farming inputs. Overall, the increase in productivity leads to a rise in farmers' net incomes[22].

In our study, we found that 50% of the farmers, who were dependent mainly on rain fed irrigation and produced only single crop (rice) in a year, have increased their crop intensity from 100% to 300% after solar pump installation. It has been claimed by farmers that the crop productivity has increased by around 15% after solar pump installation. However, there was no quantitative data available to validate this information.

According to the farmers, the use of diesel pumping set has reduced drastically. 10 out of 12, 83% farmers reported that they use diesel pump set around 2 times in a year: i) when they need large flow of water during paddy plantation, ii) to irrigate wheat field/vegetable field during winter.

[20] http://cbs.gov.np/image/data/2017/Statistical%20Year%20Book%202015.pdf

[21] http://www.worldbank.org/en/results/2014/04/11/nepal-irrigation-and-water-resource-management

[22] https://www.worldwidejournals.com/global-journal-for-research-analysis-GJRA/file.php?val=August_2015_1441258483__18.pdf

Awareness has increased farmers on the benefits of solar pumps if it is used for cash crop production. Sailendra Jha, engineer at Water Supply and Sanitation office and owner of 1200 Wp solar pumping capacity, says *'farming cereal crops would be expensive using solar pumps and would be difficult to recover the investment'.*

Study findings also showed people who used to produce traditional crops are shifting towards vegetable production.

One of the farmer has been able to demonstrate a model of *water-as-a-service* model where he sells pumped water to farmers. This model can be an incentive to maximize the benefit of solar pumping system by operating the pump at higher value of CUF. Detailed analysis about this model is presented in section 3.6.

3.6 Financial and Business Model

High initial capital cost has been perceived as one of the barriers to wider adoption and reach of solar pumping technology by farmers. Average capital cost for solar pumping system was found as NPR 307 per Wp. GoN and non-government organizations are introducing different financial and business models to overcome this barrier. We have identified three types of financial model implemented in Saptari district.

- Subsidy/Grant Model
- Grant cum Loan Model
- Rent-to-Own Model

Solar pumping systems in Nepal are mainly subsidy or grant driven. Around 50% of the sampled solar plants in Saptari district were implemented through 100% grant. Remaining 50% were having mix financing model: 60% subsidy and 40% equity investment. Most of the organizations have used this financial model to implement their program.

ICIMOD and SunFarmer Nepal introduced two other following financial models:

- Grant cum Loan Model
- Rent-to-Own Model

In Grant cum Loan Model, 60% upfront cost of the solar pumping system was covered by grant, 20% upfront cost from farmer as an equity and project provided loan for 20% of the upfront cost @ 5% interest for 3 years period of time.

In Rent-to-Own model, project invested 100% of the upfront cost and installed the technology for farmers. Farmer is entitled for 60% of the investment as subsidy and 40% as loan. There will be no upfront cost required for farmer to purchase the technology. Interest rate for loan is @ 5% and loan recovery period is 3 years. Farmer will own the pump after 100% loan repayment.

Farmers pay off the loan in instalment basis through the designated cooperative within the Power Purchase Agreement (PPA) period (generally three years). In addition to financing, farmers receive technical and financial assessments to ensure that the system is properly installed and guarantees free repair and maintenance, to ensure system performance within the PPA period. It has been found that loan repayment rate is 100%.

The Government of Nepal, through AEPC, has been promoting solar pumps for irrigation since 2016. The subsidy policy approved by the GoN is 60% of the project cost, but not exceeding more than NPR 2,000,000 for individual projects. Subsidy can be accessed by individual farmers, group of farmers, private company etc. fulfilling required terms and conditions outlined by subsidy delivery mechanism. AEPC has also established an entity CREF (Central Renewable Energy Fund) which provides credit at subsidized rate[23].

Current pump users from sampled plants are relatively affluent farmers with more land, better access to irrigation and have alternatives (diesel or electric pump) for irrigation. Average land holding of the farmers who purchased the technology in mix financing model (grant and loan) is in the range of 3 to 4 bigha (2.03 to 2.7 Ha). Different study reveals that only affluent farmers are able to purchase the technology as the subsidy and delivery mechanism are not found very supportive to smallholders. Hence, favorable environment to access finance is required for solar pumps to be a choice of pumping technology for many smallholder farmers in the future.

Without investment from private sector into this business, solar pumping sector cannot be shifted from subsidy/grant driven to commercially driven. But, there are still many challenges to attract the private sector into this business. The biggest concern for private sector is thier investment security, followed by the return on its investment compared to other alternative investment opportunities. Furthermore, as the target client are smallholder farmers living below the poverty line, the perceived risk of payment default is higher, which could make the investors wary. There needs to be more incentives to attract private developers into this business in addition to subsidy. Provision of low interest rate on loan; collateral free debt finance; exemption on taxes and import duties on equipment needed for RE projects are some such incentives that could help attract private sectors and accelerate the market of solar pumping systems..

3.6.1 Case Study: "Water-as-a-Service" Business Model

In this type of business model, investor invests the upfront cost for installation of pumping technology and infrastructures, and supply the water to customers at fair price. Customers will pay for water services in Pay-As-You-Go (PAYG) model. The advantage of this model to smallholder farmers is to receive the water services without investing on technology.

We observed this model in Surunga Municipality-2, Saptari. Jiten Prasad Yadav, a commercial farmer and owner of a 2.4 kWp solar pumping system, was providing water for irrigation to nearby four households to irrigate their vegetable field @ NPR 100 per 2 kattha per one time irrigation.

He installed a solar pumping technology in his field with the financial support from ICIMOD and technical support from SunFarmer Nepal in August 2015. He built ae tube well (4" dia, 60

[23]http://www.aepc.gov.np/files/20160606165013_RE%20Subsidy%20Policy%202016%20(2073%20BS)_Unofficial%20Translation_English.pdf

ft depth) and contributed additional cash of NPR 7,000 to construct the foundation for solar frame structure. Cost for complete solar pumping system to was provided as grant.

He owns 1.75 bigha (1.19 Ha) agricultural land, however only 15 kattha (0.75 bigha, 0.51 Ha) of this land is irrigated using solar pump. The remaining land of 20 kattha (1 bigha, 0.68 Ha) is located far from the solar pump site and thus has other provision of irrigation facility. Jiten mentioned producing vegetables in 15 kattha of land using solar pumped water. He sells water to other 4 households who also produces vegetables. Other households in that area are using rented diesel pump set to irrigate their land. Cost analysis for both cases are calculated and cashflow analysis has been done for solar pumping system comparing with diesel pumping set.

As per thumb rule, the amount of water required to irrigate 1 Ha of land per time irrigation is 1000 m3 [24]. Using this thumb rule, the amount of water required to irrigate 2 kattha land and cost per unit water is calculate and presented in *Table-7*.

Table 7: Cost per unit water for solar pump

Solar Pumping System	
Cost of Water to irrigate 2 kathha of Land per time (NPR)	100.00
Amount of Water required to irrigate 2 Kattha land (m3)	66.73
Cost per Unit Water (Rs/m3)	1.50

Farmers whose fields are located at a distance from solar pumping system are not able to access the solar pumped water. Therefore, they were found to be using diesel pump on rent to irrigate their land. Considering the rental charge of diesel pump and operating cost, the cost per unit water is calculated in *Table-8*.

Table 8: Cost per unit water for diesel pump

Diesel Pumping System	
Rental Charge for 5 HP Diesel Pump Set (Rs/hr)	250.00
Diesel Consumption (Litres/hr)	1.00
Total Cost of Diesel (Rs)	92.00
Total Cost per hour (Rs)	342.00
Total volume of water pumped (m3/hr)	43.20
Area of Land irrigated (Kattha)	1.29
Cost per Unit Water (Rs/m3)	7.92

Comparing *tables-7 and 8* clearly reflect water service from rented diesel pump is expensive i.e. 5 times more than that of solar pump. It is known that the set tariff structure for water from solar pump is too low and it cannot recover its investment in its project life. As per table 2, minimum fee structure to recover the investment should be at least NPR 5 per unit water, if the system is operated at 50% CUF.

[24] http://www.cawater-info.net/bk/4-2-1-1-3-3_e.htm

Table-9 presents the financial analysis of solar pumping unit (1200 WP, 1.5 HP Pump) if water is sold @ NPR 7.92 per unit water. It has been assumed that the solar pump will be operated at 70% CUF.

Table 9: Cash flow Analysis for Solar Pump comparing with Diesel Pump

Yearly Flow Rate:	:	20,222 m3
Cost per Unit Water *(Diesel Pump)*:	:	NPR 7.92
Discount rate	:	10%
Payback Period	:	4 years
B/C Ratio	:	2.2
IRR	:	29%

3.7 Satisfaction and Perception

Users' perceptions and experiences on solar, diesel and electric pump sets were gathered through interviews. Issues that were raised for solar pump were: high capital cost, lack of spare parts and maintenance center at local market, long response time from service providers, limited working hours, less discharge and unable to supply variations in water demand, chances of PV module damage/or stolen etc. The perceived benefits were: no fuel cost, automatic in operation system, no pollution, no need to transport pump set which makes life of women and children easy.

The weight of even small diesel pump (5 HP) is heavy, around 60-70 kg and is difficult for women and children to take to field and bring it back to home every time. Big solar plants are fixed at site with fencing and anti- theft bolt, and smaller solar pump set (sunflower pump) are portable and very light, as well as easy to transport.

Sailendra Jha and Murari Karki, Owners of Solar Pump Systems, says, *'The main constraint of the solar pump is the insufficient discharge during paddy plantation as well as during consecutive cloudy days in winter when we need water for wheat'.*

Karim Sheikh, who installed solar pump around 3 years back, says '*Solar companies are located in main cities and takes long time to response. Technician's fee and cost of equipment for replacement are high compared to diesel pumping system. In case of diesel pumping system, service providers comes to the site immediately in one phone call and spare parts are easily available in the local market'.*

Balaram Yadav, owns a solar pump for fish farming, says ' *Diesel and electric pump sets are available in the various range of capacity in the local market. It gives the flexibility to farmers to match the size of pump with their water requirement. Market of solar pumping system can grow if they are also available off-the-shelf in different range of capacity in local market. I am expanding fish farming from 6 bigha to 10 bigha and planning to install two more solar pumps of the same size (1 HP). I have seen the benefits of solar pump especially for fish farming'.*

4. CONCLUSION AND RECOMMENDATION

4.1 Conclusion

- Fossil fuel based pumping technologies are still an attractive options to those farmers who are producing traditional crops and utilization of the pumping equipment is for short period. Effective supply chain network, easy access to repairing services, low capital cost etc. are also making fossil fuel based pumping technologies as the first choice of farmers.
- It seems that farmers adopted solar pumping system as a supplementary to conventional pumps. Fully granted or subsidized price of the system somehow motivated farmers to install the technology. Diesel/electric pumps are not completely replaced by solar pumps. However, the use of diesel/electric pump has been greatly reduced and tangible benefits can be seen.
- High upfront cost of solar powered system seems hindering to popularize and flourish the system among the smallholder farmers. Subsidy and delivery mechanism are not found very supportive to smallholders. With better access to finance, technology and services, solar pumps might become the first choice for smallholders in the future.
- Low utilization factor of solar pumps are found to be one of the challenges. Cost per unit water becomes cheaper when the CUF of solar pump increases. In general, Solar pumps needs to be operated at least 700 hrs per year to compete with diesel pump. Grid operated electric pump is found to be more cost effective technology over the other two diesel and solar pumps. However, if solar pumps are operated at 90% CUF, solar pumps come out to be cost effective than grid electric pump.
- Considering the rental charge of diesel pump set and operation cost, the cost per unit water was found as NPR 7.92/m3. Payback period of Solar Pumping system will be 4 years when cost per unit water price is set as same to rented diesel pump set, and the solar pump is operated at 70% CUF.

4.2 Recommendation

- Due to lack of field data to estimate the life time and annual cost of solar pumping projects, assumptions were made based on literature review, equipment catalogues and interview with users/experts. Hence, it is recommended to conduct further future studies to assess the performance of the system with the time span as well as annual cost for maintenance.
- Facilitate and encourage community to adopt cash crops by replacing traditional crops, Optimize cropping patterns to maximize the use of the pump. Promote micro-irrigation technology to optimize the water use by using drip, micro-sprinkler etc.
- Establishment and improvement of supply chain system through support to the private sectors to establish distribution outlets and repairing services. The local financing sector

needs to be engaged in order to offer loans specifically suited for smallholder farmers' investments in solar pumping irrigation equipment.

- Most of the solar pumping plants installed for irrigation purpose remain idle for four months during monsoon season. Payback period of the pumping unit can be reduced if we could utilize the energy that can be generated during monsoon period. Further study is required to assess the followings:
    - Is it possible to sign the PPA between farmers and electricity utility company to sell the surplus energy to grid where plants are located nearby grid line?
    - Is it cost effective for small size solar plants (1 kWp-3 kWp) to install grid-tied inverter and other required accessories to sell the electricity into grid?
- There is no policy or strategy for the provision of subsidy/grant for operation and maintenance. Priority has been given for financing the capital cost in the beginning and operation-maintenance aspect is somehow overlooked. Introducing revolving fund for repair-maintenance could be useful for long term technical sustainability of the project.
- While determining the unit water cost for electric pump set, gird line was assumed to be available nearby pump site. Sometimes the grid line is found to be far from the field/pump site, and the cost of extending the wire from grid line becomes high. It is advised for further study to calculate the unit water cost for electric pump set for considering different segment of transmission line. This will help decision makers to make prompt decision on either to go for solar pump or electric pump based on the transmission line cost.

5. ANNEXES

Annex-1: General Information on Surveyed Solar Pump Sites

Annex-2: List of Stakeholders Interviewed

Annex-1

General Information on Surveyed Solar Pumping Sites

Project ID#1

1. General				
Address:	:	Rupani Rural Municipality-1, Saptari		
Name of Project Owner	:	Balaram Yadav		
Type of Ownership	:	Private		
Beneficiary Households	:	1 HH		
Date of Installation:	:	2017 FEB		
2. Technical				
Capacity of Solar PV	:	900 Wp		
Pump Size and Type	:	1 HP	DC Motor	Surface Mounted
Lift Height (Static)	:	12 feet		
Measured Discharge	:	4 litres/sec		
Date of Measurement	:	2/Feb/2018		
Water Storage Facility and Size	:	Fish ponds serve the purpose for water storage		
3. Financial				
Financial Model	:	Subsidy/Grant		
Total Solar Pumping System Cost	:	NPR 200,000		
Grant	*:*	*NPR 120,000*		
Equity	*:*	*NPR 80,0000*		
Loan	*:*	*0*	*Loan Repayment Period=*	*Interest Rate=*
4. Socio-Economic				
Total Land Holding	:	10 Bigha		
Application of Water	:	Fish Pond		
Irrigated Land using Solar Pump	:	Fish pond covers 6 bigha of land. *Solar pump complements with diesel and electric pump to meet the water demand.*		
Type of Crops Produced	:	N/A		
Cropping Intensity	:	N/A		
Methods of Irrigation	:	N/A		
Alternative solutions for Water Supply	:	Diesel Pump and Electric Pump. *(Solar Pump is brought is operation whenever there is water need during sunshine hours, solar pump is brought in operation. Other pumps are run to meet additional water demand.)*		

Project ID#2

1. General				
Address:	:	Surunga Municipality-7, Basanpatti, Saptari		
Name of Project Owner	:	Bandhu Lal Chaudhary *(One of the project Owner)*		
Type of Ownership	:	Community		
Beneficiary Households	:	5 HHs		
Date of Installation:	:	2015 AUG		
2. Technical				
Capacity of Solar PV	:	1200 Wp		
Pump Size and Type	:	1 HP	AC Motor	Surface Mounted
Lift Height (Static)	:	11 feet		
Measured Discharge	:	4.44 litres/sec		
Date of Measurement	:	4/Feb/2018		
Water Storage Facility and Size	:	No water storage facility		
3. Financial				
Financial Model	:	Subsidy/Grant		
Total Solar Pumping System Cost	:	NPR 380,000		
Grant	*:*	*NPR 380,000*		
Equity	*:*	*0*		
Loan	*:*	*0*	*Loan Repayment Period=*	*Interest Rate=*
4. Socio-Economic				
Total Land Holding	:	Average Land holding of each Farmer=3 bigha		
Application of Water	:	Irrigation		
Irrigated Land using Solar Pump	:	10 kattha *(2 kattha per farmer)*		
Type of Crops Produced	:	Rice and Wheat		
Cropping Intensity	:	200%		
Methods of Irrigation	:	Flood		
Alternative solutions for Water Supply	:	Diesel Pump *(Each farmer owns diesel pump)*		

Project ID#3

1. General				
Address:	:	Shambhunath Municipality-2, Bhaluwahi, Saptari		
Name of Project Owner	:	Amrica Devi Yadav		
Type of Ownership	:	Community		
Beneficiary Households	:	7 HHs *(initially 7 households were associated but now only one HH is managing and using the pump)*		
Date of Installation:	:	2015 AUG		
2. Technical				
Capacity of Solar PV	:	1200 Wp		
Pump Size and Type	:	1 HP	AC Motor	Surface Mounted
Lift Height (Static)	:	22 feet		
Measured Discharge	:	3 litres/sec		
Date of Measurement	:	2/Feb/2018		
Water Storage Facility and Size	:	No Water Storage Facility		
3. Financial				
Financial Model	:	Subsidy/Grant		
Total Solar Pumping System Cost	:	NPR 380,000		
Grant	*:*	*NPR 380,000*		
Equity	*:*	*0*		
Loan	*:*	*0*	*Loan Repayment Period=*	*Interest Rate=*
4. Socio-Economic				
Total Land Holding	:	Average Land holding of each Farmer=2.5 bigha		
Application of Water	:	Irrigation		
Irrigated Land using Solar Pump	:	25 kattha		
Type of Crops Produced	:	Vegetables: 2 seasons, Rice- 1 season		
Cropping Intensity	:	300%		
Methods of Irrigation	:	Furrow		
Alternative solutions for Water Supply	:	Diesel Pump		

Project ID#4

1. General				
Address:	:	Chhinnamasta Rural Municipality-3, Chhinnamasta Temple		
Name of Project Owner	:	Chhinamasta Temple		
Type of Ownership	:	Public		
Beneficiary Households	:	One Temple		
Date of Installation:	:	2016 JUNE		
2. Technical				
Capacity of Solar PV	:	1200 Wp		
Pump Size and Type	:	1 HP	AC Motor	Submersible
Lift Height (Static)	:	35 feet		
Measured Discharge	:	1.0 litres/sec		
Date of Measurement	:	31/Jan/2018		
Water Storage Facility and Size	:	2*1000 litres overhead tank (stainless steel)		
3. Financial				
Financial Model	:	Subsidy/Grant		
Total Solar Pumping System Cost	:	NPR 250,000		
Grant	*:*	*NPR 250,000*		
Equity	*:*	*0*		
Loan	*:*	*0*	*Loan Repayment Period=*	*Interest Rate=*
4. Socio-Economic				
Total Land Holding	:	N/A		
Application of Water	:	Drinking and Sanitation		
Irrigated Land using Solar Pump	:	N/A		
Type of Crops Produced	:	N/A		
Cropping Intensity	:	N/A		
Methods of Irrigation	:	N/A		
Alternative solutions for Water Supply	:	Electric Pump		

Project ID#5

1. General				
Address:	:	Surunga Municipality-2, Saptari		
Name of Project Owner	:	Jiten Prasad Yadav		
Type of Ownership	:	Private		
Beneficiary Households	:	5 HHs (including pump owner)		
Date of Installation:	:	2015 AUG		
2. Technical				
Capacity of Solar PV	:	2400 Wp		
Pump Size and Type	:	3 HP	AC Motor	Surface Mounted
Lift Height (Static)	:	20 feet		
Measured Discharge	:	6.67 litres/sec		
Date of Measurement	:	4/Feb/2018		
Water Storage Facility and Size	:	No Water Storage Facility		
3. Financial				
Financial Model	:	Subsidy/Grant		
Total Solar Pumping System Cost	:	NPR 707,000		
Grant	*:*	*NPR 700,000*		
Equity	*:*	*NPR 7,000*		
Loan	*:*	*0*	*Loan Repayment Period=*	*Interest Rate=*
4. Socio-Economic				
Total Land Holding	:	1.75 Bigha (land holding by pump owner)		
Application of Water	:	Irrigation		
Irrigated Land using Solar Pump	:	55 kattha (Total land irrigated by 5 HHs)		
Type of Crops Produced	:	Vegetables- 2 seasons, Rice: 1 season		
Cropping Intensity	:	300%		
Methods of Irrigation	:	Furrow		
Alternative solutions for Water Supply	:	Diesel Pump		

Project ID#6

1. General				
Address:	:	Shambhunath Municipality-12, Jitpur, Saptari		
Name of Project Owner	:	Naresh Chawdhury		
Type of Ownership	:	Private		
Beneficiary Households	:	1 HH		
Date of Installation:	:	2017 FEB		
2. Technical				
Capacity of Solar PV	:	1200 Wp		
Pump Size and Type	:	1.5 HP	AC Motor	Submersible
Lift Height (Static)	:	25 feet		
Measured Discharge	:	2.5 litres/sec		
Date of Measurement	:	3/Feb/2018		
Water Storage Facility and Size	:	Fish pond serves the purpose for water storage		
3. Financial				
Financial Model	:	Rent to Own		
Total Solar Pumping System Cost	:	NPR 380,000		
Grant	*:*	*NPR 228,000*		
Equity	*:*	*0*		
Loan	*:*	*NPR 152,000*	*Loan Repayment Period=3 years*	*Interest Rate=5%*
4. Socio-Economic				
Total Land Holding	:	2.75 Bigha (fish pond)		
Application of Water	:	Fish Pond		
Irrigated Land using Solar Pump	:	Fish pond covers 2.5 bigha of land. *Solar pump complements with diesel and electric pump to meet the water demand.*		
Type of Crops Produced	:	N/A		
Cropping Intensity	:	N/A		
Methods of Irrigation	:	N/A		
Alternative solutions for Water Supply	:	Diesel Pump and Electric Pump. *(Solar Pump is brought is operation whenever there is water need during sunshine hours, solar pump is brought in operation. Other pumps are run to meet additional water demand.)*		


Project ID#7

1. General				
Address:	:	Bodebarsaien Municipality-5, Saptari		
Name of Project Owner	:	Om Prakash Rajak		
Type of Ownership	:	Private		
Beneficiary Households	:	1 HH		
Date of Installation:	:	2017 FEB		
2. Technical				
Capacity of Solar PV	:	1000 Wp		
Pump Size and Type	:	1.0 HP	DC Motor	Surface Mounted
Lift Height (Static)	:	22 feet		
Measured Discharge	:	2.0 litres/sec		
Date of Measurement	:	3/Feb/2018		
Water Storage Facility and Size	:	No Water Storage Facility		
3. Financial				
Financial Model	:	Subsidy/Grant		
Total Solar Pumping System Cost	:	NPR 200,000		
Grant	*:*	*NPR 120,000*		
Equity	*:*	*NPR 80,000*		
Loan	*:*	*0*	*Loan Repayment Period=*	*Interest Rate=*
4. Socio-Economic				
Total Land Holding	:	2.0 Bigha		
Application of Water	:	Irrigation		
Irrigated Land using Solar Pump	:	8 kattha		
Type of Crops Produced	:	Vegetables: 2 seasons, Rice: 1 season		
Cropping Intensity	:	300%		
Methods of Irrigation	:	Flood		
Alternative solutions for Water Supply	:	Diesel Pump and Electric Pump.		

Project ID#8

1. General				
Address:	:	Tilathi Koiladi Rural Municipality-8, Topa Vilage, Saptari		
Name of Project Owner	:	Shailendra Kumar Jha		
Type of Ownership	:	Private		
Beneficiary Households	:	1 HH		
Date of Installation:	:	2017 FEB		
2. Technical				
Capacity of Solar PV	:	1200 Wp		
Pump Size and Type	:	1.5 HP	AC Motor	Submersible
Lift Height (Static)	:	16 feet		
Measured Discharge	:	3.8 litres/sec		
Date of Measurement	:	3/Feb/2018		
Water Storage Facility	:	No Water Storage Facility		
3. Financial				
Financial Model	:	Grant cum Loan		
Total Solar Pumping System Cost	:	NPR 380,000		
Grant	:	*NPR 266,000*		
Equity	:	*NPR 57,000*		
Loan	:	*NPR 57,000*	*Loan Repayment Period=3 years*	*Interest Rate=5%*
4. Socio-Economic				
Total Land Holding	:	4.0 Bigha		
Application of Water	:	Irrigation		
Irrigated Land using Solar Pump	:	20 kattha		
Type of Crops Produced	:	Vegetables: 1 season+ Rice: 1 season		
Cropping Intensity	:	200%		
Methods of Irrigation	:	Flood		
Alternative solutions for Water Supply	:	Diesel Pump and Electric Pump.		

Project ID#9

1. General				
Address:	:	Surunga Municipality-7, Saptari		
Name of Project Owner	:	Yogendra Shah		
Type of Ownership	:	Private		
Beneficiary Households	:	1 HH		
Date of Installation:	:	2017 JUNE		
2. Technical				
Capacity of Solar PV	:	1200 Wp		
Pump Size and Type	:	1.5 HP	AC Motor	Submersible
Lift Height (Static)	:	42 feet		
Measured Discharge	:	1.5 litres/sec		
Date of Measurement	:	4/Feb/2018		
3. Financial				
Financial Model	:	Subsidy/Grant		
Total Solar Pumping System Cost	:	NPR 380,000		
Grant	*:*	*NPR 228,000*		
Equity	*:*	*NPR 76,000*		
Loan	*:*	*NPR 76,000*	*Loan Repayment Period=3 years*	*Interest Rate=5%*
4. Socio-Economic				
Total Land Holding	:	6.0 Bigha		
Application of Water	:	Irrigation		
Irrigated Land using Solar Pump	:	10 kattha		
Type of Crops Produced	:	Rice, Maize, Wheat		
Cropping Intensity	:	300%		
Methods of Irrigation	:	Flood		
Alternative solutions for Water Supply	:	Diesel Pump, supply from nearby deep tube well which was developed by Indian Government support in 2066 BS.		

Project ID#10

1. General				
Address:	:	Kanchanrup Municipality-1, Saptari		
Name of Project Owner	:	Madrassa (Karim Sheikh-Contact Person)		
Type of Ownership	:	Public		
Beneficiary Households	:	350-400 students		
Date of Installation:	:	2014 NOV		
2. Technical				
Capacity of Solar PV	:	1050 Wp		
Pump Size and Type	:	0.75 HP	AC Motor	Submersible
Lift Height (Static)	:	56 feet		
Measured Discharge	:	0.74 litres/sec		
Date of Measurement	:	2/Feb/2018		
Water Stroage Facility and Size	:	2*1000 litres (Hilltake)		
3. Financial				
Financial Model	:	Subsidy/Grant		
Total Solar Pumping System Cost	:	NPR 481,005		
Grant	*:*	*NPR 481,005*		
Equity	*:*	*0*		
Loan	*:*	*0*	*Loan Repayment Period=*	*Interest Rate=*
4. Socio-Economic				
Total Land Holding	:	N/A		
Application of Water	:	Drinking and Sanitation		
Irrigated Land using Solar Pump	:	N/A		
Type of Crops Produced	:	N/A		
Cropping Intensity	:	N/A		
Methods of Irrigation	:	N/A		
Alternative solutions for Water Supply	:	Electric and Hand Pump.		



Project ID#11

1. General				
Address:	:	Saptakoshi Municipality-4, Saptari		
Name of Project Owner	:	Murari Karki		
Type of Ownership	:	Private		
Beneficiary Households	:	1 HH		
Date of Installation:	:	2017 March		
2. Technical				
Capacity of Solar PV	:	1200 Wp		
Pump Size and Type	:	1.5 HP	AC Motor	Submersible
Lift Height (Static)	:	33 feet		
Measured Discharge	:	1.5 litres/sec		
Date of Measurement	:	2/Feb/2018		
3. Financial				
Financial Model	:	Grant cum Loan		
Total Solar Pumping System Cost	:	NPR 380,000		
Grant	*:*	*NPR 228,000*		
Equity	*:*	*NPR 76,000*		
Loan	*:*	*NPR 76,000*	*Loan Repayment Period=3 years*	*Interest Rate=5%*
4. Socio-Economic				
Total Land Holding	:	2 bigha		
Application of Water	:	Irrigation		
Irrigated Land using Solar Pump	:	20 kattha		
Type of Crops Produced	:	Vegetable: 2 seasons + Rice: 1 season		
Cropping Intensity	:	300%		
Methods of Irrigation	:	Flood		
Alternative solutions for Water Supply	:	Electric pump for domestic water and canal water for irrigation		


Project ID#12

1. General				
Address:	:	Shambhunath Municipality-3, Dangrahi, Saptari		
Name of Project Owner	:	Kulananda Chaudhary		
Type of Ownership	:	Private		
Beneficiary Households	:	1 HH		
Date of Installation:	:	2017 FEB		
2. Technical				
Capacity of Solar PV	:	80 Wp		
Pump Size and Type	:	Sunflower Pump	DC Motor	Piston
Lift Height (Static)	:	20 feet		
Measured Discharge	:	0.25 litres/sec		
Date of Measurement	:	1/Feb/2018		
3. Financial				
Financial Model	:	Subsidy/Grant		
Total Solar Pumping System Cost	:	NPR 60,000		
Grant	*:*	*NPR 36,000*		
Equity	*:*	*NPR 24,000*		
Loan	*:*	*0*	*Loan Repayment Period=*	*Interest Rate=*
4. Socio-Economic				
Total Land Holding	:	0.75 bigha		
Application of Water	:	Irrigation		
Irrigated Land using Solar Pump	:	4 kattha		
Type of Crops Produced	:	Rice and Wheat		
Cropping Intensity	:	200%		
Methods of Irrigation	:	Flood		
Alternative solutions for Water Supply	:	Electric pump and hand pump		

Note: Not working properly. Either due to leakage from piston or low water table

Project ID#13

1. General				
Address:	:	Shambhunnath Municipality-2, Kanakpatti,Saptari		
Name of Project Owner	:	Satya Narayan Chaudhary *(one of the Beneficiaries)*		
Type of Ownership	:	Group		
Beneficiary Households	:	4 HH		
Date of Installation:	:	2017 FEB		
2. Technical				
Capacity of Solar PV	:	80 Wp		
Pump Size and Type	:	Sunflower Pump	DC Motor	Piston
Lift Height (Static)	:	16 feet		
Measured Discharge	:	0.3 litres/sec		
Date of Measurement	:	1/Feb/2018		
3. Financial				
Financial Model	:	Subsidy/Grant		
Total Solar Pumping System Cost	:	NPR 60,000		
Grant	*:*	*NPR 60,000*		
Equity	*:*	*0*		
Loan	*:*	*0*	*Loan Repayment Period=*	*Interest Rate=*
4. Socio-Economic				
Total Land Holding	:	8 Kattha (Lease, 2 kattha/HH)		
Application of Water	:	Irrigation		
Irrigated Land using Solar Pump	:	8 kattha		
Type of Crops Produced	:	Vegetables. Paddy in some plots during monsoon.		
Cropping Intensity	:	300%		
Methods of Irrigation	:	Drip and Furrow for vegetable production		
Alternative solutions for Water Supply	:	No		

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5. General				
Address:	:	Shambhunnath Municipality-2, Kanakpatti,Saptari		
Name of Project Owner	:	Ramakant Chaudhary *(one of the Beneficiaries)*		
Type of Ownership	:	Group		
Beneficiary Households	:	8 HH		
Date of Installation:	:	2017 MAR		
6. Technical				
Capacity of Solar PV	:	80 Wp		
Pump Size and Type	:	Sunflower Pump	DC Motor	Piston
Lift Height (Static)	:	16 feet		
Measured Discharge	:	0.3 litres/sec		
Date of Measurement	:	1/Feb/2018		
7. Financial				
Financial Model	:	Subsidy/Grant		
Total Solar Pumping System Cost	:	NPR 60,000		
Grant	*:*	*NPR 60,000*		
Equity	*:*	*0*		
Loan	*:*	*0*	*Loan Repayment Period=*	*Interest Rate=*
8. Socio-Economic				
Total Land Holding	:	12 Kattha (Lease, 1.5 kattha/HH)		
Application of Water	:	Irrigation		
Irrigated Land using Solar Pump	:	12 kattha		
Type of Crops Produced	:	Vegetables. Paddy in some plots during monsoon.		
Cropping Intensity	:	300%		
Methods of Irrigation	:	Drip and Furrow for vegetable production		
Alternative solutions for Water Supply	:	No		

Annex-2

List of Stakeholders Interviewed

SN	Name	Organization/ Institutions	Address	Remarks
1	Bijaya Khadgi	ICIMOD	Kathmandu, Nepal	Intergovernmental Organization. Working on Research and development on different business model to promote solar pumping technology
2	Resha Piya	Winrock International	Kathmandu, Nepal	INGO, Solar Pumping Promotor
3	Avishek Malla	SunFarmer Nepal	Kathmandu, Nepal	Social Enterprise. Technology+ Business Solution
4	Lava Mani Rajbhandari	Bhanu Tole, Krishan Grill	Biratnagar	Solar Pup Supplier and Installer. Authorized dealer of Sunflower Pump.
5	Asharam Chaudhary	SABAL Nepal	Rajbiraj, Saptari	Working as local partner for ICIMOD and SunFarmer to implement Solar Pumping Projects in Saptari
6	Raj Kishore Ray	iDE Nepal	Kathmandu, Nepal	INGO, SunFlower Pump promotor
7	Narayan Prasad Shah	Jilla Krishak samuha (Distrct Farmers' Group)	Saptari	Established farmers' group and working as a social mobilizer/coordinator to scale-up solar pumping technology.
8	Puskal Giri	Nirmal Trading Concern	Dharan Road, Biratnagar	Pump Supplier (Diesel and Electric)
9	Nava Prabhas Gupta	Ganapati Machinary & Tools	Main Road, Ramesh Chowk, Lahan-1, Siraha	Pump Supplier (Diesel and Electric)
10	Basant Shah	Bhavna and Daulat Trade Center	Lahan-8, Siraha	Pump Supplier (Diesel and Electric)
11	Dev Narayan Sah	Bajrang Machinery Stores	Mills Area, Janakpurdham-1, Dhanusha	Pump Supplier (Diesel and Electric)
12	Satya Dev Chaudhary	Pump Repairing Centre	Lahan Bazaar, Siraha	R&M service provider (Diesel and Electric)
13	Tej Narayan Chaudhary	Janaki Electronics	Traffic Chowk, Shambhunath-2, Saptari	R&M service provider (SunFlower, Diesel and Electric Pump)
14	Bhuwan KC	EcoPrise	Kathmandu, Nepal	Solar Pump Supplier and Insaller