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# Performance Evaluation of 18kW Solar Photovoltaic Baidi MicroGrid at Baidi, Tanahun, Nepal

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**Abstract**

In Nepal, only 34% of the rural population have access to electricity and 9% of them completely relies on off-grid technologies like micro hydro and solar photo voltaic, it is important to assess performance characteristics of this project in order to see its suitability in Nepalese context. This study carries out performance evaluation of 18 kW Baidi Micro Grid (BMG) implemented by Alternative Energy Promotion Center (AEPC) in Dubung village, Rising Gaupalika, Tanahun district, Nepal. The grid is built and has been operational under Baidi Micro Grid Pvt. Ltd, a Special Purpose Vehicle (SPV) established under "Pro-Poor Public Private Partnership (5P)" concept supported by UNESCAP/IFAD. Dubung and Mauribas community with 115 households and Saral Urja Nepal Pvt Ltd jointly owns the SPV strengthening not only technical, managerial and financial support but also the community participation and engagement in all decision making process.

Annual energy generation, performance ratio, capacity utilization factor during the year 2016/2017 AD were 13,601 kWh, 36.98%, 17.49% respectively. In two years of its operation, the average annual income of 55 sampled houses increased from NPR 18,167 to NPR 364,550. This led to the betterment of livelihood of the people leading to increase in their energy demand from 13,601 kWh to approximately 64,992 kWh per year. Improvement in performance of power plant and enrichment in capacity utilization factor is very crucial to overcome the future demand.

**Keywords**

Demand – Supply – Micro-grid–Solar Photo-voltaic–Income

## 1. Introduction

Baidi Micro-Grid (BMG) is a solar photovoltiac 18kW pilot project under Pro-Poor Public-Private Partnership (5P) Concept. It is located 83 km far from the Byas municipality with latitude 27°51'54" N, longitude 83°15'3.6" E in Dubung village, Rising gaupalika (former Baidi VDC) of Tanahu District, Nepal [1]. It is special purpose vehicle (SPV) with ownership of community and Saral Urja Nepal (SUN) a private energy company. Alternative Energy Promotion Centre (AEPC) with United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP) have recently started 5P business model in Nepal. It is a flagship business model promoted and was practiced from Cinta Mekar, Indonesia. Using this model a community hydro power plant is operational since 2004 [2].

Energy projects like Kagbeni wind power has been shutdown due to the lack of proper operation and maintenance. Here there been certain equity of private energy company then such project would have received regular service and would sustain [3]. In order to get technical supports even after installation of power system private companies are included in the ownership structure of 5P projects. The ownership of 5P projects would be both the community and the private company with equity injection in terms of land, money or labor. The responsibilities would be to control tariff, instrument managements operation and maintenance.

A five member committee was formed to register Baidi Micro-Grid where 3 of them were from SUN and 2 of them were from the community [4]. Its structure is demonstrated in the figure 1. Baidi micro grid consists of 72 solar panel 250W each, 3 inverters of 7kVA capacity, 3 charge controllers, 72 batteries of 2V and 800Ah each, 3km insulated wire from power house to community, a smart meter and a desktop computer.

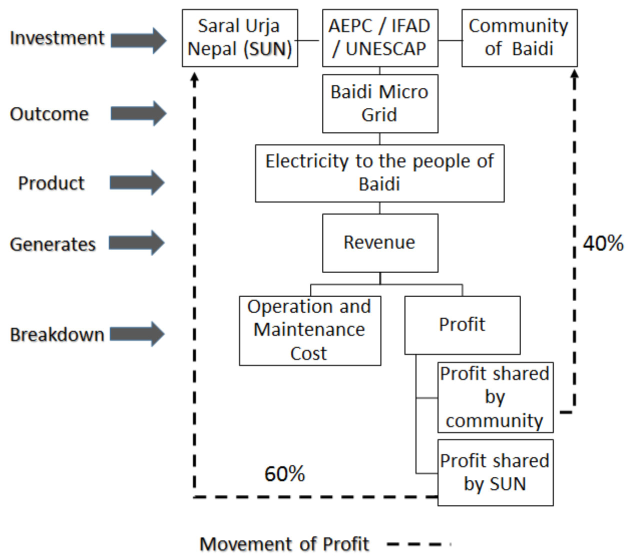


**Figure 1:** Structure of BMG

## 2. Methodology

This study is based on both primary and secondary data. Primary data are collected through the power plant itself and developed questionnaire. The methodology was followed displayed in figure 2

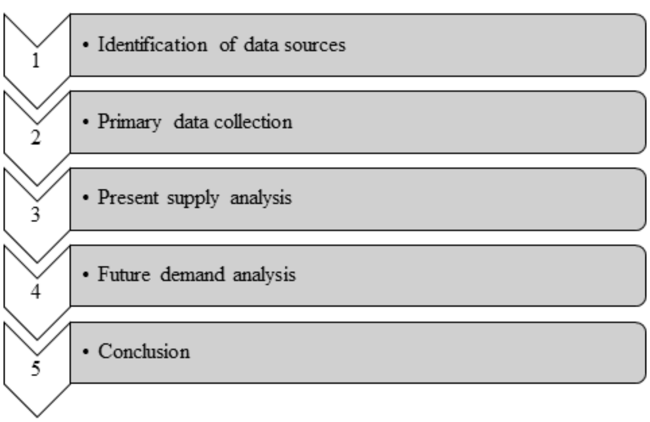


**Figure 2:** Research Methodology

### 2.1 Data Sources

Feasibility survey report from UNESCAP and AEPC is the major source of secondary data. Anticipated electronic use, anticipated benefits and reported annual income were observed. In the basis of secondary data primary data are collected from the BMG.

### 2.2 Data Collection

A visit was scheduled to Baidi Micro-grid with a check list and daily stored energy, daily consumed energy, peak load, generated peak power, battery voltage and lowest battery voltage were obtained from the powerhouse.

From the initial observation 150 house hold were ready to get electrified with the micro grid. Later 119 joined the micro grid but due to migration number of consumer has come to 115. The micro grid has offered three packages namely light package "A", television package "B" and commercial package "C" according to the consumer's demand but special package has been introduced to those who are very poor and are selected by the community itself and are known as below poverty line. Among 115 houses within 10% confidence interval and 95% confidence level a sample of 55 houses has been selected as sample size as demonstrated in figure 3.

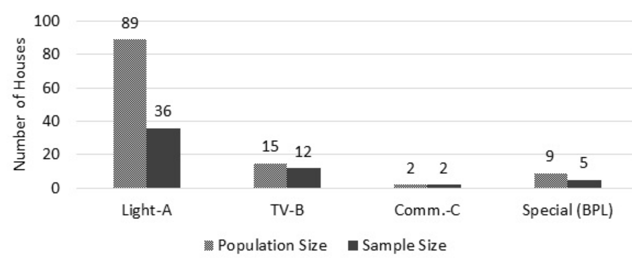


**Figure 3:** Population and Sample Size

A questionnaire was made and demand analysis was performed. Various parameters like performance ratio, capacity factor, and carbon dioxide emission would be discussed and could be computed in order to evaluate performance.

### 2.3 Present supply analysis

In order to analysis performance of power plant monthly energy generation and monthly insolation are necessary.

#### 2.3.1 Monthly energy generation

The total daily energy generated by the PV system is given by equation 1.

$$E_{AC,d} = \sum_{n=1}^{24} E_{AC,t} \tag{1}$$

The monthly energy generated by the PV system is given by equation 2.

$$E_{AC,m} = \sum_{n=1}^{N} E_{AC,d} \quad (2)$$

This monthly energy generation is used to calculate performance ratio and capacity utilization factor of the power plant.

#### 2.3.2 Performance ratio

The Performance Ratio (PR) is used to measure the quality of a solar photovoltaic and is also known as quality factor that is independent of location [5]. The relation of PR as given in equation 3.

$$PR = \frac{E[kWh]}{GE[\frac{kWh}{m^2}] \times A_{plant}[m^2] \times \eta_{module} \times (1 - P_{tpv})} \quad (3)$$

where,
E is monthly generated energy that is obtained from equation 2. GE is irradiation energy on module plane. It is obtained from various secondary sources of data from Boxwell [6]. A is area of installed modules. One module has length of 1.640 m and width 0.992 m with total. There are 72 pannels that makes the total area of 117.14 $m^2$. $\eta$ is module efficiency with the value of 14.75%. $P_{tpv}$ is thermal loss factor of -0.0779.

#### 2.3.3 Capacity utilization factor

Capacity utilization factor (CUF) is another ratio that is defined as a ratio of total energy generation of a power plant to the maximum energy generation possible during the operation time [5]. It is calculated by the expression as expressed in the equation 4.

$$CUF = \frac{E[kWh]}{P[W] \times T[hr]} \quad (4)$$

where,
E is monthly generated energy that is obtained from equation 2. P is installed capacity and T is net operating time.

### 2.4 Future demand analysis

Demand of frequently usable equipment's like bulb, radio, television, mobile chargers and other electrical equipment were collected by the use of questionnaire and interview at Dubung and Mauribas village and was used to forecast future demand.

## 3. Results and Discussion

Analysis on supply side, demand side, socioeconomic, past, present & future scenario and carbon dioxide emission were carried out during the research.

### 3.1 Present supply analysis

Monthly energy generation data from July 2016 to June 2017 were recorded and summed in monthly basis. An average of 1,133.45 kWh was generated with an annual sum of 13,601.41 kWh. Monthly energy generation data is plotted in figure 4.

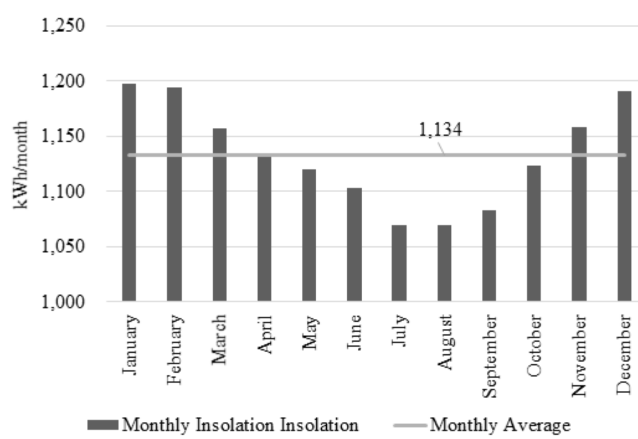


**Figure 4:** Monthly energy generated during July 2016 to June 2017

Monthly energy generation is used to compute the performance ratio (PR) and capacity utilization factor (CUF) of the power plant. Maximum PR of 40.54% was observed in the month of January with an average of 36.98%. The site is prone to high dust and heavy soiling of dust that decreases the performance ratio[7]. Similarly maximum CUF of 18.49% was seen in the month of January with an average of 17.49%. Monthly performance ratio and capacity utilization factor are plotted in figure 5 and figure 6 respectively.

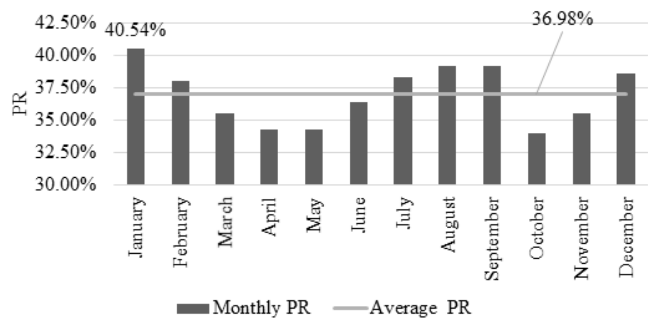


**Figure 5:** Monthly performance ratio of BMG during July 2016 to June 2017

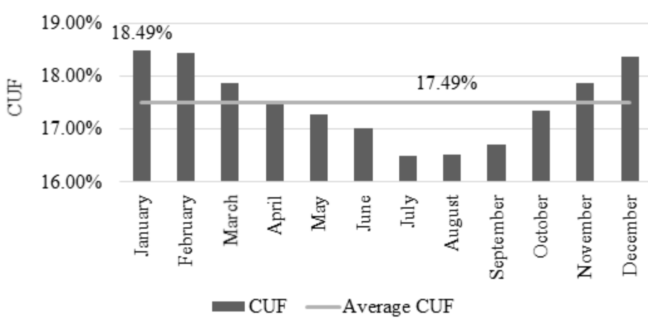


**Figure 6:** Monthly capacity utilization factor of BMG during July 2016 to June 2017

## 3.2 Future demand analysis

In order to analyze the future demand, socioeconomic status of the people living in the villages were carried out. And the detail electricity demand was asked with the sample households.

### 3.2.1 Socio-economic status

From the initial survey report average annual income of household were taken as reference that is plotted in figure 7. The average annual income of house hold was NPR 18,167 with a modal income of NPR 7,017.

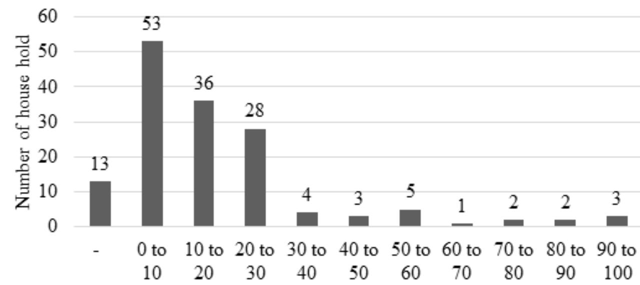


**Figure 7:** Average annual income in 1000 of NPR before the operation of BMG

After the grid connection average annual income and modal average income of sample houses has increased to Rs 364,550 and Rs 237,500 respectively. The micro grid has very significant role in this 20-fold increment in average annual income. The average annual income after the grid connection is plotted in the figure 8.

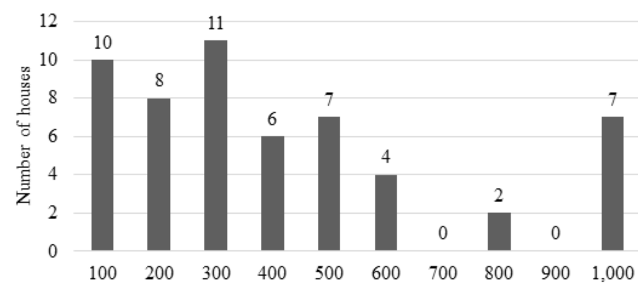


**Figure 8:** Average annual income after BMG

Detail demand analysis was performed in the sample houses during the research. Demand of bulb, television, mobile chargers and other electrical equipment were noted . Annual energy consumption for present and future load were analyzed with respect to the annual income.

From figure 9 it is seen that every house ( irrespective of their income) are willing to add extra bulbs (i.e. 53 out of 55 samples). This increasing demand could rise the future demand by 44%.

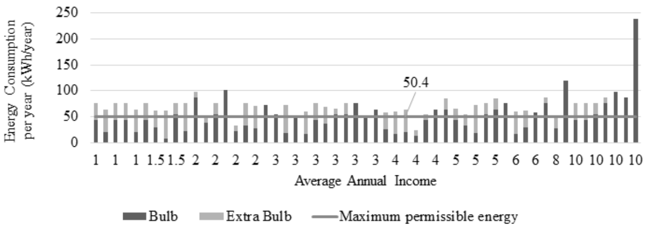


**Figure 9:** Current and Future Demand of bulb in term of energy

In figure 10, it is observed that 40 sample houses are willing to have a television. 5 sample houses already had a television set. There is no correlation with the income of the people and demand of television. This increasing demand could rise the future demand by 919%

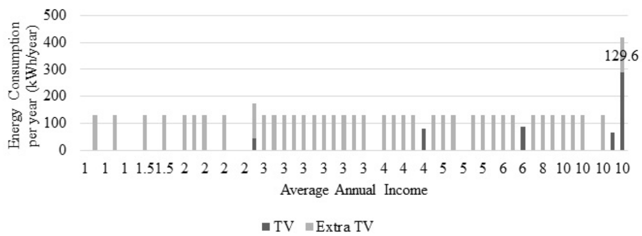


**Figure 10:** Current and Future Demand of television in term of energy

Figure 11 illustrates the current and future demand of mobile phone via current mobile charger sets. 7 sample houses had not got any mobile phone so they did not had charger either. And almost every one who already had a mobile is willing to have another set. It would be 64 % increment in future load.

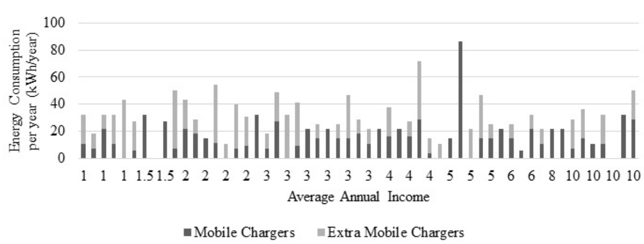


**Figure 11:** Current and Future Demand of mobile charger in term of energy

Figure 12 represents current and future demand of other electrical equipment energy consumption per year with respect to average annual income. Houses having more than 2 lakh of average annual income are willing to have other electrical equipment. Major demand of people is to have a rice cooker, fan , computer and fridge respectively. This demand on heating equipment would rise future demand by 1706% Number of extra equipment is presented in figure 13.

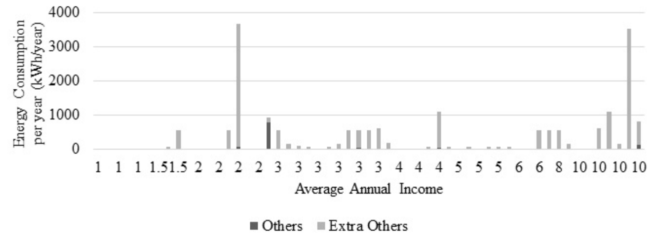


**Figure 12:** Current and Future Demand of other electrical equipment in term of energy

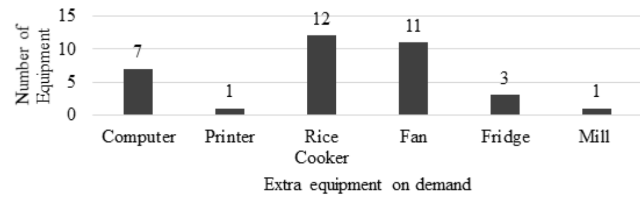


**Figure 13:** Number of extra equipment on demand

The recent energy consumption by the sample houses is 455 kwh per month and the extra demanded load could be 2,031 kWh per month which is 24,372 kWh per year. Recent supply of electricity from BMG is only 13,601.41 kWh per year. Present and future load is demonstrated in the figure 13 and 14 respectively.

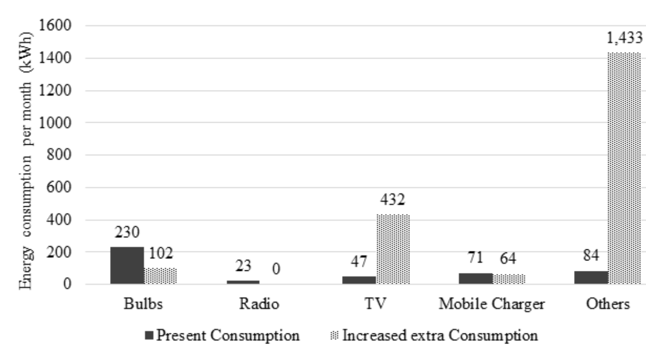


**Figure 14:** Present and Future Demand at BMG

### 3.3 Issues and Feedback

Few problems regarding electricity were noticed. 35 houses reported no replacement in bulbs after the initial installation whereas 15 houses has already replaced a bulb and 20 houses replaced more than 2 bulbs. Only 2 houses reported the dimness of their bulbs due to smoke generated from firewood consumption. 26 sampled household reported about the load shedding during two rainy season and two dry season in a year. To overcome this issue BMG charges only 50% of the normal fare. Few issues regarding illumination, insect and flickering were also noticed.

## 4. Conclusion and Recommendations

Annual energy generation from Baidi Micro Grid was 13,601.41 kWh. A maximum capacity utilization factor (CUF) of 18.49% was observed in the month of January 2017 with an annual average of 17.49%. The average performance ratio calculated was 36.98% with a maximum of 67.61% and had a minimum of 25.77% with respect to different reference insolation. The extra demand would be 30,006 kWh from the sample households of 55 out of 115. When this pattern of load distribution was generalized in the population then the total demand would be 64,992kWh per year. However, with an annual supply of 13,601.41 kWh the rising demand of the community would be very difficult to fulfill. In order to fulfill the increased demand the power plant must run at 82.44%.

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