A community based green energy solution to remove energy poverty in remote mountainous areas of Pakistan; a case study of Suk Village, Skardu

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Abstract—Energy poverty is still one of the main issues in Pakistan, where many rural areas are still without electricity. This leads to using conventional sources of energy which may cause various health problems and environmental degradation. Gilgit Baltistan gets 40 % of its energy mix from wood, resulting deforestation in the region. The study discuss electrifying a village "Sok" of 55 households in district Skardu with renewable energy at 8% annual load increment. The only stream flow through the area is Kachura Lungma (River) having a maximum flow rate of 7.88 m^3/s in July and minimum flow of 1.84 m^3/s in January. Two different sites have been selected with a head 28 m and 95 m for runoff river hydropower plant. The available green resources at the sites have been analyzed through HOMER Pro, which simulate all possible combinations of the system. Results for both sites show that standalone hydroelectric power system gives the most promising solution with the cost of energy $ 0.0221 and $ 0.0266, respectively. Micro-hydro plant coupled with battery storage becomes the 2nd favorable option with cost $ 0.0231 and $ 0.0271, respectively. This system has been designed at a minimum flow rate; this means no energy shortage throughout the year. In summer, about 70 % excess electricity in both cases is available that can utilize for economic activities such as fruit drying which is a major income source. This makes it the most feasible green solution for removing energy poverty from the area.

Keywords—*micro-hydro, community-based energy system, energy poverty.*

I. Introduction

Energy poverty has become a global issue. In Pakistan still, 51 million people are deprived of electricity. Energy poverty in Pakistan exists in rural areas where still half of the people don't have access to electricity [1]. The absence of modern energy services in these areas has made people rely on biomass to fulfill their energy needs. This increased dependence on poor energy sources has caused problems like indoor pollution [2].

Gilgit-Baltistan is a highly mountainous and remote region covering 72,496 sq. km with around 1.3 million populations. Population density is only 18 person/sq. km and road density is the lowest in the country. Adult literacy rate is 36% (national over 40%) and per-capita income is around 90% of national per capita income. In terms of rural poverty, a distinctive feature of GB is that over 90% of the people own some agricultural land as compared to 52% in rest of the country [3]. However, per capita holding is very small at 0.6-0.8 acres. Smallholdings and other physical challenges result in lower consumption (90% of the national average) and poverty is 29% as compared to the overall ratio of 21% in the country [4]. A Food & Agriculture Organization's survey in 2014 shows only 26% population as food secures, 41% as moderately food insecure and 32% as highly food insecure.

The region is bestowed with enormous hydropower potential, if this is carefully utilized, can ensure future energy security on a long-term basis. In Gilgit-Baltistan, the supply of electricity started in early 1960s when few micro hydropower stations were developed in the area. The supply of liquefied petroleum gas (LPG) from down country started in the late 1980s, present energy mix in GB is; Wood (30%): LPG (40%): Kerosene Oil (6%): Hydel Power (24%) [5]. Currently, this shows that maximum dependence is on fuelwood and LPG resulting in the deforestation of local forests.

Energy requirements will be met from hydropower resources and reduce dependence on import fuel, cutting of forest and fruit trees. Reduce extra cost and minimize the risk involved in transportation and fuel stocking [6]. Sufficient generation of hydropower will help to boost economic activities like cottage industries, tourism promotion, and all other business and commercial activities. Cheap energy available will open new paths for self-employment and business opportunities in Gilgit-Baltistan.

II. PROJECT AREA DESCRIPTION

The study area in this paper focuses on an un-electrified village of Skardu district and present a community based electrical energy system. The hilly northern region of Pakistan contains tall mountains with forests and valleys sandwiched between them. Gilgit-Baltistan is the homeland of fresh water which consists of 2nd largest glaciers. The population are dispersed and remotely located from each other, so they have no centralized power system and electricity is provided by local grids at sub-divisional level. The provision of electricity to hilly cold villages through transmission lines is very difficult and costly. Standalone community based electrical system thought to be the most acceptable solution in order to eliminate poverty and enhance financial businesses [7]. The indigenous renewable resources available at the site were analyzed through HOMER Pro (Hybrid Optimization Model for Electric Renewables developed by NREL) that gives most economically feasible solution on the basis of net present cost and cost of energy [8].

A. Unelectrified Villages under Study

A distantly located village of district Skardu is focused in this study where electricity through the local grid is not available. Sok Valley with 55 households is located on the north-west of Skardu town at a distance of about 45 km. It is characterized by a deep valley and snow-fed water streams such as Kachura Lungma with limited resources of biomasses and forests. Site altitude is approximately 3,050 meters while the latitude and longitude are N 35°40´ E 75°44´. This area is accessible through 8 km off road from Gilgit-Skardu road by jeeps and small vehicles.

In most area of Skardu district, animal dungs of domestic livestock, biomasses by the small agricultural patches and firewood from nearby upper region small forest are the main source of energy for domestic needs. While some household uses kerosene oil for lighting purposes. These primary resources not only disturb the ecosystem but also cause health issues which results in an extra financial burden on already economically deprived families.

Fig.1. Arial View of Sok Valley Skardu

With the developing trends the population is increasing and people in the villages tries to settle in their native region. That's why the energy demand also increases every year with other infrastructural developments. Thus, in this study we discussed two scenarios one gives short term solution and one for long term solution.

B. Available Hydro Resources

The mainstream flows through the Sok Valley is Kachura Lungma (Nallah), it is assisted by few sub-tributaries in summer season resulting maximum flow of 7.88 m^3/s in July while the minimum flow of 1.84 m^3/s in January. This stream falls in the the great Indus River after passing through the pasture lands and agricultural fields of several villages in Kachura Valley. The water in the Kachura Nallah is due to the large water catchment area of Deosai plain. This highest plain is not accessible through Sok valley and remains cover with huge snow for 6th month of winter. For this reason, the area has adequate water flow throughout the year and in summer fast melting occurs due to increase in temperature, which leads immense water to flow through the Kachura Nallah. The monthly average water flow of Kachura Lungma is shown in Figure 2, was collected from Water & Power Department, Government of Gilgit-Baltistan.

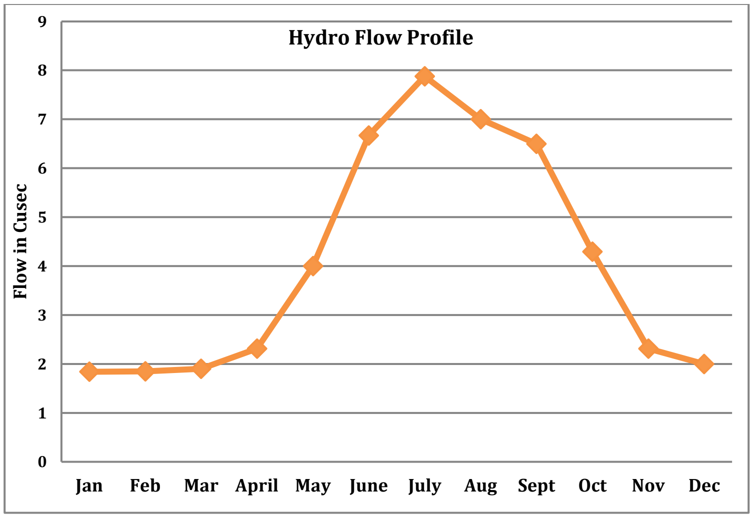

Fig.2. Average Water flow at Sok Sites.

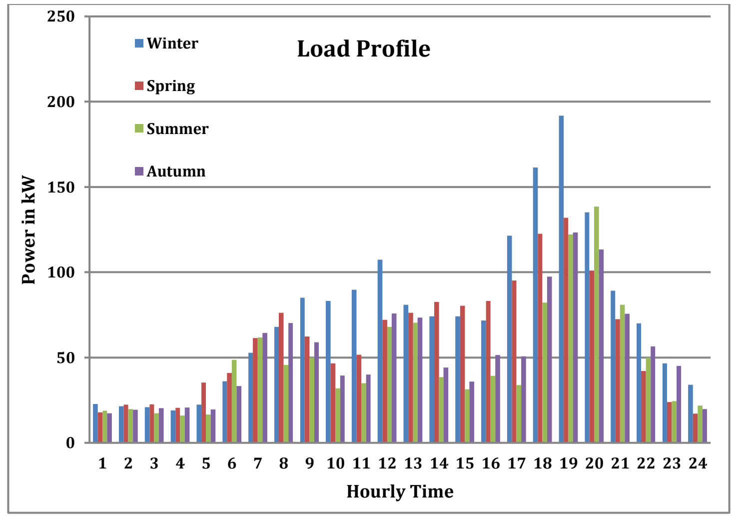

Fig.3. Hourly Average Load Profiles of Season.

The village has steep topology and two sites at different places are most suitable for run off river hydro power plant. One site has a head of 28 meters; we called it as site A, while other has a head of 95 meters is called as site B. We examine both the cases and recommend the most suitable solution. The proposed project is run off river type hydro power development in Sok village of Skardu district and the project life is 25 years from the electricity provision date.

C. Energy Utilization Trends

The area has no provision of electricity thus the load profile was examined with the help of survey data from local bodies' organization and electricity usage trends in the nearby electrified areas of the district. The community based electric load module of HOMER Pro is used in order to suggest the load profile of the respective area. Due to harsh weather in winter, the demand increases extensively while the generation decreases due to slow melting rate of snow and glaciers. Figure 3 shows that average daily energy in winter is much more than that of summer month. Most of the households of this region utilize electricity for lighting and ironing purposes while in winter some electric heaters are used. The commercial businesses remain in good pace during summer season but in winter shortage of electricity and cold weather affects the local businesses.

In this study we are going to assumed that apart from lighting and ironing, electricity is also utilized in heating, cooking and daily life household activities in order to eliminate the environmental and health problems. For the energy from clean and atmospheric friendly electrical equipment, the average units utilized at the peak hour of winter is about 3.5 kW per household. Thus, the peak of 55 families of Sok village is about 192.5 kW while with 8% increment in yearly load the pe ak demand for this area will be 1220 kW in 25 years.

III. Modeling & Simulation

For modeling a community-based energy system on HOMER Pro software, annual data of available renewable resources and loads are required. The available resource and load profile at the selected sites has already been discussed. Two scenarios i.e., inclusions of diesel generator and battery bank have also considered in order to critically analyze the system. While a sensitivity analysis on the peak load is done to observe sustainable provision of electricity for the entire project lifetime. HOMER simulates the system with different combinations of the available sources. The output includes the capital cost, net present cost, energy per kWh cost, component size and other electrical characteristics. Available power sources are expected to be micro hydropower or/and diesel generator with/without battery bank scenario. There is no grid connection to the system. HOMER simulates the different combinations of these power sources and provides the optimal combination.

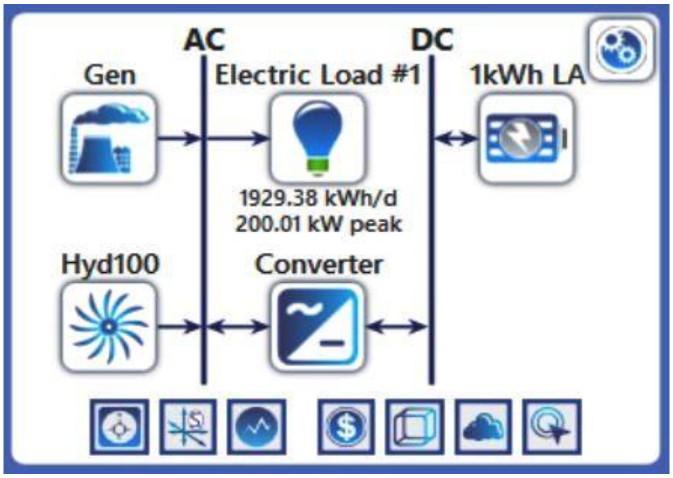

Fig.1. Schematic Diagram of Energy System

The capital cost of the micro-hydroelectric power plant is the sum of civil works and E/M (electrical and mechanical) works that vary according to location and market trends. The capital, replacement, and O&M costs of 200 kW site A hydro plant is about $ 144200, $ 120000 and $ 3800 /year while for 1500 kW site B hydro plant these are about $ 1101500, $ 900000 and $ 29026 /year respectively. These costs were estimated with the help of several feasibility reports of mini/micro hydropower stations. Similarly, the available heads are 28 m and 95 m while the design flow rates at the respective sites are 920 l/s and 1840 l/s. The intake pipe loss is about 15 % and the power plant has 80% efficiency.

DG set and battery bank were also considered to examine the most suitable model to fulfill the demand throughout the year. The per kW capital, replacement and O&M costs of DG are about $500, $500 and $0.03/hour respectively. Similarly, in case of 1kWh generic lead acid battery, the capital, replacement, and O&M costs for 10 years are $300, $300 and $10/year tapped with converter nearly same costs for 1 kW installation.

IV. Results & Discussion

Homer Pro simulates all possible combinations of generating components and storage system. The result in Table 1 gives a detail economical comparison of different combinations of Hydro, DG and Battery system at the selected village. On both sites, the standalone hydroelectric power system gives the most favorable solution when the financially analyzed but its reliability decreases due to a single driven source. The cumulative energy generation by hydro and DG with battery storage is the most reliable but cost increases as the system size also enhanced.

TABLE.1. COSTS OF DIFFERENT COMBINATIONS OF ENERGY SYSTEM

Resources	COE $	NPC $	OC $	Capital $
	0.0221	.193 M	3800	.144 M
	0.0266	1.48 M	29026	1.10 M
	0.0231	.194 M	3828	.145 M
	0.0271	1.48 M	29112	1.10 M
	0.0317	.277 M	1813	.254 M
	0.0382	2.12 M	20654	1.86 M
	0.0318	.278 M	1814	.255 M
	0.0422	2.34 M	41893	1.80 M
	0.496	4.35 M	.321 M	.190 M
	0.476	26.4 M	1.95 M	1.19 M
	0.538	4.71 M	.355 M	.110 M
	0.512	28.5 M	2.15 M	.70 M

Site A Site B

The most feasible solution in this study is using micro hydro alone, which gives $0.0221 COE for the people reside in Sok village from site A and $0.0266 from site B. Site B is little hard area and access to its site is difficult than site A, that's why per kW capital cost and O&M costs are little higher resulting in increasing tariff. The site A has installed capacity of 200 kW MHP which gives a quick and promising solution in the current scenario to eliminate energy poverty and poorness in the village. At 8% annual increment in domestic load [9] the peak demand in 25 years reaches up to 1220.6 kW and site A independently not able to handle this load. Thus, for long term solution site B is most noticeable, as it has capacity of 1500 kW and able to satisfy the increasing demand for more than 25 years.

Micro-hydro plant coupled with battery storage becomes the 2nd favorable option when skill workers and extra capital are available to purchase and monitor the storage system. This gives reliable clean energy with adequate economics. The standalone DG with/without hydro and storage system are the worst choice as these systems cost heavily and also causes greenhouse gas emissions. Table 2 shows the quantity of harmful gases emitted for standalone DG system for village electrification. These gases already cause health problems thus the issue of atmospheric pollution and medical complications continue in the same manner as before the technological advancement. On the other hand, the clean hydropower gives an eco-friendly solution and improves the health issues of the dwellings.

TABLE.2. HARMFUL GAS EMISSIONS BY DG SETS

Emitted Gases	Site A	Site B
	Kg/year	Kg/year
Carbon Dioxide	620905	3646156
Carbon Monoxide	3914	22983
Unburned Hydrocarbons	171	1003
Particulate Matter	23.7	139
Sulfur Dioxide	1520	8929
Nitrogen Oxides	3677	21590

Energy demand increases in winter season as there are heavy snowfalls and freezing temperature that increases the use of wood, heat stoves for heating and cooking. Similarly, the flow in the river also cut off to 50 %. But in this study, we have designed the micro-hydro plant according to its minimum flow rate thus there is no issue of energy shortage throughout the year. The only concern arises during high flow or flood case in summer which may lead to the collapse of the micro-hydro station. To deal with this problem, an extra channel has to be constructed which may lead to an extra cost on civil works. This cost can also be adjustable if the local community is persuaded to assist in civil works. The river flow in summer is very high, resulting about 70% excess electricity in both cases that can be utilized for economic activities to improve the living standard of inhabitants. With the help of different nongovernment organizations and government local bodies, their agricultural and livestock products can be provided with easy access to local and national markets.

V. CONCLUSION

A lot of initiatives like Poverty Reduction Strategy Paper, Pakistan Poverty Alleviation Fund, Roshan Pakistan etc. have been taken by the Government of Pakistan to increase electrification rate. Most of these steps have renewable energy as a prominent solution. Many developing countries have introduced mini-grids, microgrids and stand-alone systems to reduce energy poverty. But in Pakistan, a little to no work is done by the government to promote these systems. No formal policy at national and provincial level is made in Pakistan for rural electrification. The Government of Pakistan needs to take a closer look to develop a framework which will support stand-alone systems to reduce energy poverty. The study gives a cost of energy up to $ 0.0221 per unit for small community and $ 0.0266 per unit for medium household community that made it the most feasible solution in removing the energy poverty from the area under study. This community-based model can be owned by the locale through capacity building, which may further decrease the operation and maintenance cost of the project. Similar model could be implemented in other undeveloped areas of countries having the same resource potential and geography.

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