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Feasibility Study for Designing a Standalone Community Based Energy System to Remove Energy Poverty in Rural Areas of Pakistan

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***Abstract*—Energy poverty is still one of the main issues in Pakistan. Many rural areas of the country are still without electricity. This leads to using conventional sources of energy which cause various health problems. One of the main reasons for un-electrified rural areas is the high cost of transmissions and distribution system due to a dispersed population. For increasing electrification process in rural areas government of Pakistan should invest in stand-alone and community-based energy systems. This paper discusses electrifying a rural community and the cost of designing an optimized community-based energy system for removing energy poverty in Pakistan**.

***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 Gilgit-Baltistan 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 2^{nd} 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

Two distantly located villages of district Skardu are focused in this study where electricity through the local grid is not available. Shilla Valley with 85 households is located on the east of Skardu city at a distance of about 60 km. It is characterized by a deep valley and snow-fed water streams such as Marko Lungma with limited resources of biomasses and forests. Site altitude is approximately 3,050 meters while the latitude and longitude are N 35°10´ E 75°50´. The other village is Domiyal Valley of subdivision Gultari, situated at an altitude of 4095 meters with N 34°45´ E 75°30´ latitude and longitude. This area is accessible through Deosai plain at a distance of 172 km south from Skardu city. Gultari area has several watersheds such as Shingo, Fultux and Karapchu rivers run across the Deosai plains towards district Skardu and Astore. In winter, this area cannot be accessible directly from Skardu city as Deosai plains remain closed due to heavy snowfalls. The alternate route through Astore district can be used in order to run the economic and military activities as it is located near to the line of control between Pakistan and India. In both areas, 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 Shilla Valley Skardu

B. Available Hydro Resources

The mainstream flows through the Shilla Valley site is Marko Lungma (Nallah), it is assisted by few sub-tributaries in summer season resulting maximum flow of 9.89 m^3/s in July while the minimum flow of 0.58 m^3/s in February. This stream falls in the Sermik Lungma that joins the great Indus River after passing through the pasture lands and agricultural fields of several villages in Sermik Valley. Similarly, Fultux Nallah falls into Shingo River near to Domiyal Valley and has adequate water flow throughout the year. It has a minimum flow of 0.538 m^3/s in January and a maximum 2.755 m^3/s flow in July. The monthly average water flow of Marko Lungma and Fultux Nallah shown in Figure 2 were collected from Water & Power Department, Government of Gilgit-Baltistan.

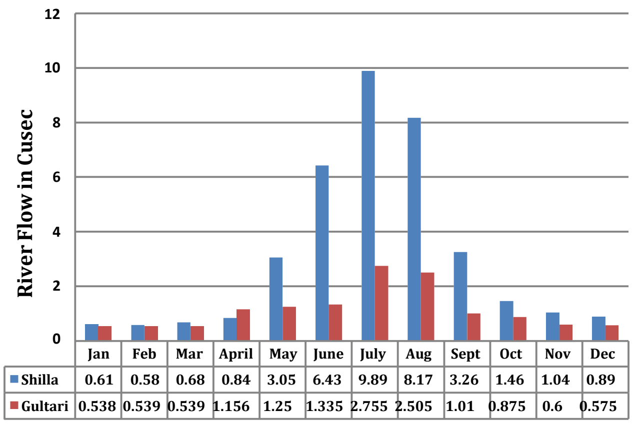

Fig.2. Average Water flow at Shilla and Domiyal Sites.

The proposed projects are run off river type hydro power development in Shilla and Domiyal villages of Skardu district.

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 January is twice more than that of July 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 Domiyal is about 200 kW and 85 households of Shilla is about 300 kW in winter.

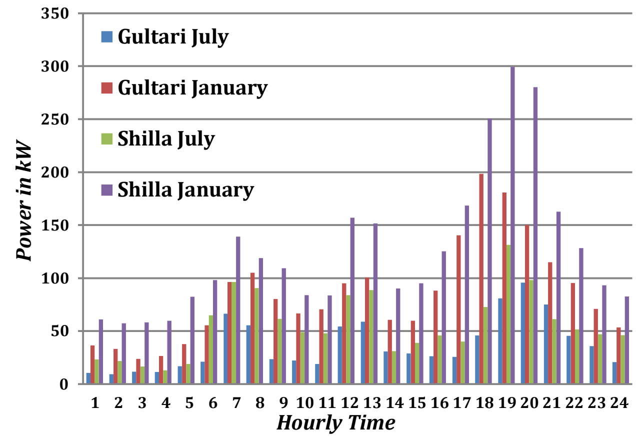

Fig.3. Hourly Average Load Profiles in Winter and Summer.

III. MODELING & SIMULATION

For modeling a community-based energy system on HOMER Pro software, annual data of available renewable resources and load are required. The available resource and load profile at the selected sites are already been discussed. Two scenarios i.e. inclusions of diesel generator and battery bank have also considered in order to critically analyze the system. 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.

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 250 kW Domiyal hydro plant are about $78750, $55250 and $8850/year while for 300 kW Shilla hydro plant these are about $86500, $63550 and $9600/year respectively. These costs were estimated with the help of several feasibility reports of mini/micro hydropower stations. Similarly, the available heads are 55 m and 60 m while the design flow rates at the respective sites are 520 l/s and 660 l/s. The intake pipe loss is about 15 % and the power plant has 80% efficiency.

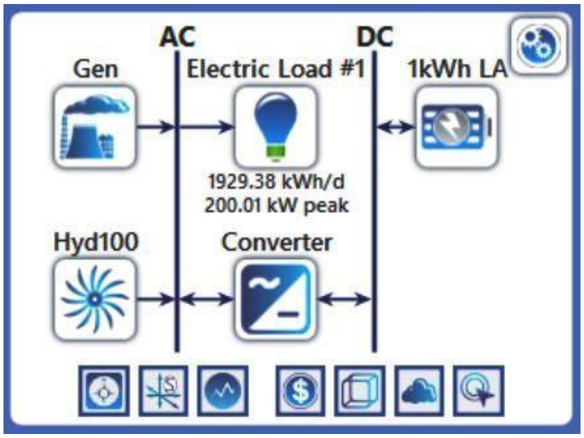

Fig.1. Schematic Diagram of Energy System

DG set and battery bank were also considered to examine the most suitable model in order 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 villages. 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.

The most feasible solution in this study is using micro hydro alone, which gives $0.0206 COE for the people reside in Domiyal and $0.018 for Shilla. Domiyal valley is hard area and access to its site is difficult than Shilla, that's why per kW capital cost and O&M costs are little higher resulting in increasing tariff to the inhabitant of Domiyal. Micro-hydro plant coupled with lead-acid battery 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.

TABLE.1. COSTS OF DIFFERENT COMBINATIONS OF ENERGY SYSTEM

Resources	COE $	NPC $	OC $	Capital $
	0.0206	202118	8850	78750
	0.018	220323	9600	86500
	0.0207	202843	8879	79065
	0.0181	221058	9630	86822
	0.0303	297038	7410	193750
	0.0285	348258	7658	241500
	0.0303	297763	7439	194065
	0.0286	348994	7688	241822
	0.497	4870000	335421	198588
	0.508	6200000	424878	281594
	0.539	5290000	371040	115000
Dc	0.558	6820000	477820	155000

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 by using DG 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	**230 kW DG Domiyal**	**310 kW DG Shilla**
	Kg/year	Kg/year
Carbon Dioxide	644648	810562
Carbon Monoxide	4064	5109
Unburned Hydrocarbons	177	223
Particulate Matter	24.6	31.0
Sulfur Dioxide	1579	1985
Nitrogen Oxides	3817	4800

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 76% 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 $ 0.018 per unit for small community and $ 0.0206 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 decreases 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.

REFERENCES

[1] Ezzatti, M. and D. Kammen. 2001b. Quantifying the Effects of Exposure to Indoor Air Pollution from Biomass Combustion on Acute Respiratory Infections in Developing Countries. Environmental Health Perspectives **109**(5): 481-48.

[2] Awan, R., Sher, F., & Abbas, A. (2013, December). An investigation of multidimensional energy poverty in Pakistan. Paper presented at the 29th AGM of the Pakistan Society of Development Economists, Islamabad.

[3] World Bank, Government of Gilgit-Baltistan & Asian Development Bank (2010): Pakistan Gilgit-Baltistan Economic Report (PGBER), Broadening the Transformation. Retrieved on March 01, 2018 from http://documents.worldbank.org/curated/en/939151468062972670/Pakistan-Gilgit-Baltistan-economic-report-broadening-the-transformation.

[4] Emerging Pakistan-An Initiative of Ministry of Commerce, Government of Pakistan. Retrieved on March 04, 2018 from http://www.emergingpakistan.gov.pk/sectors/.

[5] Planning and Development Department, Government of Gilgit-Baltistan: Multiple indicator cluster survey 2016-17 final report. Retrieved on February 27, 2018 http://www.gilgitbaltistan.gov.pk/DownloadFiles/PDD/MICS_GB_1617.pdf.

[6] Juan I.Pe´ rez-Dı´az n, Jose´ R. Wilhelmi, "Assessment of the economic impact of environmental constraints on short-term hydropower plant operation." Department of Hydraulic and Energy Engineering, Technical University of Madrid (UPM), c/Profesor Aranguren s/n, 28040 Madrid, Spain 0301-4215/$ -see front matter &2010 Elsevier Ltd.

[7] Carmen L.T.Borges and Roberto J. Pinto "Small hydro power plants energy availability modeling for generation reliability evaluation" IEEE transaction on power system, volume 23, No.3, August2008 pp 1125-1135.

[8] M. T. Yeshalem and B. Khan, "Design of an off-grid hybrid PV/wind power system for remote mobile base station: A case study," AIMS Energy, vol. 5, no. 1, pp. 96–112, 2017.