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Sustainability Assessment of Micro-Hydropower Projects

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***Abstract*—** Micro hydro Power Projects (MHPPs) have been receiving increasing attention in the face of the growing energy demands and the high proportion of population living without grid access in Pakistan. The government has initiated a project to install 356 MHPPs in the province in 2014, which has now been extended to 1200 such projects. Unfortunately a number of these MHPPs have not been able to produce the desired results, some failing to start generation and some despite producing electricity not bringing the social, environmental and economic changes that are ideally the outcome of such projects. This paper proposes a new quantitative sustainability model specifically designed for the peculiar socio-economic and cultural dynamics of the northern areas of Pakistan. Rooted in sixty one sustainability assessment indicators across four dimensions and twenty one sub dimension and especially minted for the socioeconomic conditions of the region, the model is meant for assessment of the sustainability of an MHPP. The indicators are rated on a scale of 1 to 5 as per the International Hydropower Association (IHA)'s Hydropower Sustainability Assessment Protocol (HSAP), the overall dimension score is aggregated from the individual indicators and sub-dimensional weightages. The end output of the model is a dimension score ranging from 1 to 5. In the case study the model was applied to the MHP project installed in the Kalam Valley of the province of Khyber Pakhtunkhwa and achieved scores indicative of basic good practices of sustainability along the social, economic, technical, and environmental lines. The quantification of sustainability assessment of the MHP projects would pave wave for informed and evidence based decision-making process for the future MHP projects installed in the region. The model, albeit designed for the KP region, can be tweaked for MHPPs of any socioeconomic region by adjusting the weightages of the indicators and subdimension as per the peculiarities of that region..

***Keywords*—** Sustainable development, Micro hydro power plant, Renewable energy.

I. Introduction

Close to one-fifth of the world population lacks access to electricity as of 2017 [1]. Majority of these disenfranchised populations live in remote localities, where grid access is hard to achieve. Over 84% of these off-grid people live in rural areas, particularly in sub Saharan Africa and South Asia [2]. Economic uplift is highly dependent on provision of energy [3]. Accordingly, economic development is gauged by the per capita energy usage of a country; energy and economic growth forming a symbiotic relationship where one parameter improves the other, as in countries like Pakistan [4]. However, in the contemporary world energy access is not considered an end goal, rather a pathway to social and economic uplift [5].

In addition to the economic uplift of a country, electricity access is a significant aspect of the sustainable development. Sustainable development Goals (SDGS 3, 5, 7), envisioned by United Nations are all incumbent upon the provision of cheap and environmentally clean energy to the poor communities [6]. Familiarization with the interdependencies of sustainable systems on energy provision and its environmental impact is pertinent in the building such sustainable systems [7]. It is posited that poverty alleviation purposed energy access is far more dependent on conceptualization of the positive impact of energy on people's lives than on the understanding of the technology itself. The impact of energy itself is an overarching concept ranging from education to health and agriculture to job creation which should be treated as such when formulating policies and programs [8].

One such policy consideration for electrification of a region is the choice of energy technology for specific locations. One has to consider a plethora of issues and challenges in the selection such as the major natural energy resource of the region; vicinity to national or regional grid; customer economic dynamics; and stage of maturity of the chosen technology [9]. Moreover, the energy access should not be treated as just for the sake of energy access but a part of grand scheme of development [10]. The alignment of the regional and rural electrification with the national policy objectives, and scrutiny and stakeholder engagement are the important aspect of the sustainability of the projects [11].

Sustainability is the major challenge in the fulfilment of projects related to rural electrification. Rural community based electrification projects are prevalent all over the world, implemented by both government and non-government institutions. For sustainable projects the social, technical, economic, and environmental sustainability assessment should be carried out under the feasibility study.

The energy mix of Pakistan is heavily tilted in favour of thermal electricity generation making 68.4 % of total generation, while hydro, renewable, and nuclear power plants contributing 23.8%, 4.1%, and 3.6% respectively, of a total capacity of 29,944 MW [12]. This puts a lot of strain on the national exchequer as the fossil fuels are predominantly imported.

In addition to the cost factor of hydro electricity resources, the abundant availability of rivers and streams throughout the country and northern areas, as shown in the figure 1 and 2, is a great gift which needs to be utilized. Run of the river small scale hydropower plants have proven an economically viable and environmentally sustainable power option for rural electrification in developing countries.

In Pakistan also, estimated at 1200 MW potential, the mini micro hydropower plants (MMHPPs) can prove a vital resource in alleviating the energy crisis facing the country in conjunction with the electrification on more than 30 % off grid community [13]. To tap this potential an ambitious project was started in 2014 by the provincial government of Khyber Pakhtunkhwa province to set up 356 MHPPs in the northern areas of the province spanning 12 districts [14].Till June 2018 more than 90% of these MHPPs have been completed and the project has been extended to 1200 MHPPs..

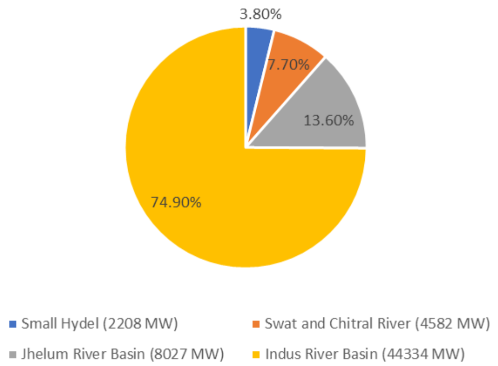

Figure 1. Distribution of Hydropower Resources of Pakistan [16]

Sustainability Assessment Tools and Studies for Hydropower Generation

Numerous attempts have been made to come up with a standard, all-encompassing definition of sustainability. For example, in one 500 plus concepts of quantification of sustainability accentuating the diversity of the concept and its measurement techniques have been compiled [17]. The world commission on Environment and Development, in 1987, published the most popular definition of sustainability as “meeting the needs of the present without compromising the ability of the future generations to meet their own needs”[18]. Besides the great many ways to define sustainability, it is usually gauged by various dimensions, which are chosen on the basis of the evaluation model used. For instance, the Three Pillar Model assesses the sustainability of a project on its social, economic, and environmental dimensions. In this study, however, the concept of sustainability is defined in the context of MHP projects as; the capacity of an MHP project in maintaining its operation with the guaranteed fulfilment of technical, economic, social, and environmental needs [19].

Since the MHPPs are usually completed with the participation and support of local population, the community ownership is the foremost deciding factor in the sustainability of the project [20]. Off grid communities, usually, are located in the far-flung areas, making it difficult to provide the resources necessary for electrification. In addition, the commercial financial sector is usually hesitant to finance off grid project. Consequently, the engagement of local community and private financial aid is a precursor for the completion and sustainability of these projects. The local community is quite adept in the art of surmounting the mobilization and transportation related challenges which to outsiders, would seem like an uphill task. On the other side, the average off grid community dweller is usually destitute and the financing of electrification projects are far outside his capacity. Therefore, the conception of innovative ideas for attracting capital for electrification projects is the crucial to the installation and sustainability, ultimately to rural development [21]. This, obviously, is not as easy as said in rural communities. The onus of such projects, eventually, falls on the government and non-government welfare organizations. The government and non-governmental organizations are not solely interested in the immediate gains from selling of the electricity; instead they strive for the social benefits and business stimulation accruing from the electrification, leading to new jobs and entrepreneurial endeavors [22]. The social benefits of electrification are not considered an automatic, and spontaneous output, rather it requires the complementary provision of avenues, and awareness to reap the maximum rewards [23]. Barring the parallel development and awareness programs, the electrification in itself is not an end to economic indigence [24].

In this study, a sustainability model for MHPPs has been developed for the niche socioeconomic dynamics of Khyber Pakhtunkhwa province of Pakistan. The sustainability model encapsulates the social, economic, technical and environmental aspects of sustainability assessment of the projects. The model is novel in the sense that the socioeconomic indicators, and resultantly the sustainability drivers, of any development project vary from region to region. This model is specifically equipped with indicators specially minted for the region capable of quantitatively assessing the sustainability of the MHPPs from the abovementioned dimensions. However with adjustments in the weightages of certain sustainability indicators in coherence with the region it is applied to, will make it applicable in any society.

II. METHODOLOGY

The study was conducted in the steps as shown in the flow chart in Figure 3.

Figure 2. Methodology of the model development

Physical survey of the MHPP site and community

The projects were physically visited by our team with surveys and questionnaires filled by the local population. A total of 100 surveys were filled out by the local populace. Based on the response to the survey questions and the physical observation scores were assigned to each indicator depending on their adherence to the good practices and the global best practices.

Table 1. Basic Information of the Case study site

Particulars	Details
Place	
Area Name	Kalam PC
District	Swat
Province	KP
Country	Pakistan
Map details	
Latitude	35_29'30.5" N
Longitude	72_34'47.5" E
Weather (Average)	13_C, 639 mm Rainfall
Elevation	2000 m above sea level
Population	
Total population	23,170
Total male	11,700
Total Female	11,470
Total no. of houses	2461

III. RESULTS AND DISCUSSION

The main result of the research is the groups of twenty two subdimensions of sustainability harboring sixty one indicators. The sub dimensions listed in the figure bear a weightage assigned on the basis of its pertinence to the overall sustainability in the particular dimension. For instance, the sustainability sub dimensions of health and education have been assigned a weightage of 25 each while the other sub dimensions carry relatively lower weightages. The weightages of these and other sub dimensions are the average of three scores assigned by individual person familiar with the projects and the social fabric of the communities where they are implemented. Each individual, usually belonging to the stakeholder institutions i.e. the provincial energy department, or the implementing nongovernmental organization, or the academia experts, also gave a rationale for assigning their respective scores. For instance, in case of education and health getting comparatively higher scores of 25 each the main argument given was that since the projects are financed by NGOs or government, with the foremost intention of all-inclusive development of the beneficiary community in which health and education improvement are the paramount parameters.

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4.1. Case Study

The developed model with all the weightages assigned to the sub dimensions and the respective indicators of sustainability was applied to an MHP project in the Kalam valley of Khyber Pakhtunkhwa Province of Pakistan. The valley is a major tourist attraction with influx of hundreds of thousands of tourists yearly. The site was taken as a case study owing to the significant population that resides within and is electrified by the MHP project being analysed. The total electrified population by the MHP project is in excess of 22000. This grants us with more diversity in terms of the challenges to the sustainability and analysis of this one MHPP site exhibits all the problems that any other MHPP in the province could come across. The aggregate dimensional sustainability scores achieved by the MHPP project are 3.19, 3.57, 3.32, and 3.79 for the technical, economic, environmental, and social dimensions respectively. A description of the various sub dimensional and indicator scores and the physical manifestation of these scores from what was observed on site is given in the following.

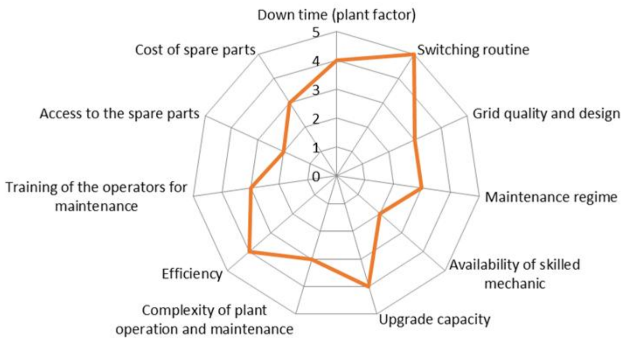

Figure 3. Technical sustainability indicator scores (Kalam MHPP)

The technical dimension with an aggregate score of 3.19 is skewed towards the lower side by the "Reliability" and "Ease of maintenance" sub dimensions with scores of 2.5 and 2.7 respectively as shown in the Table 3 and Figure 3. The reliability of operation scores less because of non-availability of skilled mechanic specializing in hydro turbine maintenance in the local urban centers.

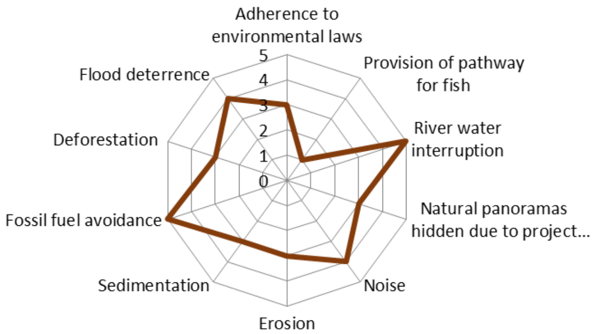

Figure 4.Environmental Sustainability indicators scores (Kalam MHPP)

This impacts the sustainability of the MHPPs quite severely as the maintenance problems which could take a few hours to fix in cases where skilled mechanics are immediately available are extended to days long downtime of plant and the subsequent electricity cutoff for the community.

Environmental sustainability, evidently is an important outcome of any renewable energy project, but in context of Kalam valley its significance is even more pertinent as it is a popular tourist destination for people in Pakistan. The environmental sustainability scores, as given in the figure 4, projects basic good practices in environmental domain. The sub dimensions "Wildlife protection" and "Climate Change Deterrence" hold the predominant weightage in the environmental sustainability potential of an MHP project for the Khyber Pakhtunkhwa province as per the experts.

The social sustainability of an MHPP is enshrined in the social welfare that is the part and parcel of the project. In this regard the Kalam MHPP project has a score surpassing basic good practices. With a score of 3.79, as shown in figure 5, on the social sustainability scale the MHPP has been bringing about positive generative social outcomes. Be it the impact of the project on local education, health, or the general perception of the local populace concerning the MHPP, the project has been a net positive. Poignantly the couple of areas where the project lacks are the equality of outcomes for the genders, and the spending of the surplus revenue generated by the project on local development projects. Albeit the women population of the beneficiary community have seen significant progress in their living conditions as a consequence of decrease in time collecting firewood, or general wellbeing from lighting in the house or heating water in the winter season burning firewood. Still the women are not involved in direct decision making affecting the operations concomitant to the MHPP. Social stigmas to women participation aside women in the community organization, for instance, could bolster the efforts to create awareness about extracting maximum social and economic output from the project by communicating with the women inside their homes, a luxury not afforded to males.

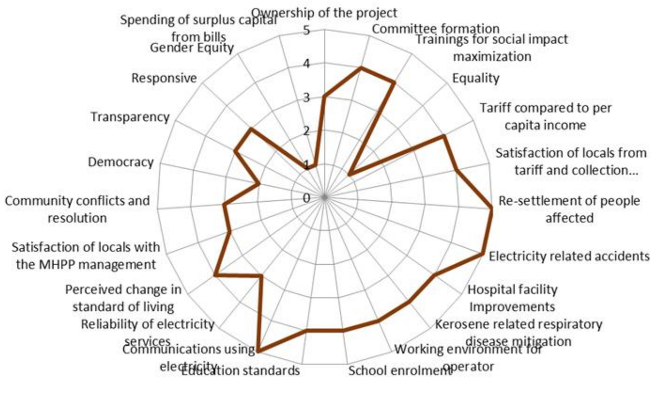

Figure 5. Social Sustainability Indicators Scores (Kalam MHPP)

Economic Sustainability of the MHPP is concomitant with two aspects: the employment of sustainable practices in the power plant installation and operation, and the economic benefits in the beneficiary community that stem from the electricity. Both of these aspects are essential parts of MHPP economic sustainability. The indicator scores presented in the figure 9, gives an overall economic sustainability score of 3.57. The figure of 3.57 can be interpreted in multiple ways such as one could say that there is a 71 percent likelihood of the sustainability of the project to complete its long term economic goals envisioned by the implementing and funding authorities. Alternatively one could say that the basic good practices are being met by the MHPP in its economic impact. The financing of the project scores 4.3 owing to the unconditional grant that financed the project as well as the local population contributing towards the project, albeit a small amount. The commercial and domestic tariff slabs in dispatching the electricity observes sustainable practices. The majority of beneficiaries were satisfied with the collection process as well.

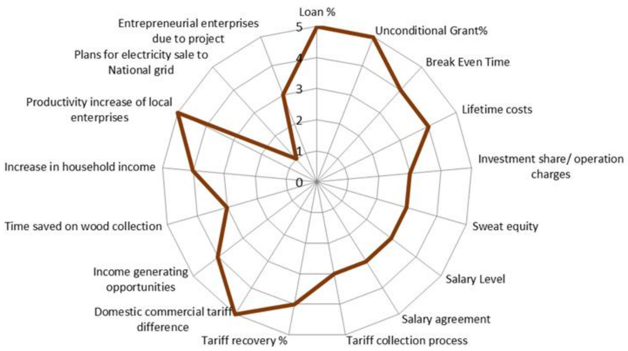

Figure 6. Economic Sustainability Indicators Scores (Kalam MHPP

In light of the scores obtained by the various sustainability indicators and dimensions, the operational strategy for a particular MHPP could be modified in the relevant indicators. Funding organizations or government could set up threshold scores based on their vision for the sustainability dimensions to streamline their monitoring of the project already installed. They can further aggregate the scores of the four dimensions as per their priorities in to a single sustainability score for an MHPP which will make the selection of the more sustainable and outcome oriented project more systematic rather than the conventional monetary cost/gains comparison.

CONCUSLION

There are no two opinions in the assertion that the MHPPs are a lifeline to the beneficiary communities. To make their fruits long lasting a sustainability assessment model was developed for the socioeconomic outlook of the hydro rich region. The model consists of 61 sustainability indicators aggregated to 22 sub dimensions resulting in a sustainability score in the range 1-5 for the social, economic, technical, and environmental dimensions of sustainability. The sub dimensional and indicator weightages could be set up according to the vision of the implementing authorities. The model was applied to the case study of an MHPP in Kalam valley of Pakistan. The MHPP obtained sustainability scores of 3.19, 3.32, 3.79, and 3.57 for the technical, environmental, social, and economic dimensions. The indicators with low scores could be stressed upon for better performance in the future to make the projects more sustainable. The sustainability model utilized here could prove a precious resource for the future projects planned by the provincial government and NGOs alike. The decision-making process involved in the selection of MHPPs out of proposed projects will become a lot simpler and well informed by the employment of such a quantitative mechanism. Although some of the indicators used here are commonly available in the literature, still they have been modified and molded in to the domestic needs and considerations. One thing to consider in the employment of this model is that it is specifically designed for small and micro scale projects and its application to large hydro projects could result in severe inaccuracies.

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