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A framework for evaluating the current level of success of micro-hydropower schemes in remote communities of developing countries

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ABSTRACT

Micro-hydropower (MHP) schemes can be a good option to meet the energy demands of remote communities in developing countries, particularly in mountainous areas with good water supplies. Physical (i.e. head and flow) and economic requirements are essential for MHP scheme feasibility, but social, environmental and political factors can also be critical for the performance and longevity of the scheme after its installation. MHP scheme feasibility evaluation, thus, requires a holistic approach, where the socio-economic characteristics of the community, electricity policies and other geophysical parameters of the environment have to be considered. This study identified the most important criteria for evaluating the success of MHP schemes from the communities' point of view based on site visits and interviews with developers, operators and key community members of 35 schemes spanning Nepal, Bolivia, Cambodia and the Philippines. Proper regular operation, ongoing support by the community, and long term support from the government or local developer were key factors for MHP scheme success. The most recurrent failure reasons were maintenance difficulties, extreme weather events, and the arrival of the national grid. A framework to evaluate the current level of success of existing schemes was developed and applied for cross country comparison.

Introduction

Micro-hydropower, understood as the generation between 5 and 100 kW, can be a cost-effective solution for the production of energy for small isolated communities (Blanco, Secretan, & Mesquita, 2008; Huang, Chang, Hwang, & Ma, 2014; Maher, Smith, & Williams, 2003; Mainali & Silveira, 2013). Positive environmental benefits as well as socio-economic advantages of community owned MHP schemes are widely recognized (Gurung, Bryceson, & Oh, 2011; Paish, 2002a; Pokharel, Khan, & Islam, 2008). MHP has also been adopted as a means to foster rural development with the help of the “free energy from water” motive (Murni, Whale, Urmee, Davis, & Harries, 2013). Furthermore, communities built around streams in mountain areas often meet the necessary requirements of water head and flow. These well documented reasons to adopt MHP have lead developers to install schemes, but often with insufficient consideration for the performance and longevity of the scheme after its installation (Fulford, Mosley, & Gill, 2000; Kabalan, Tamir, & Singh, 2014).

Nepal, with its rugged mountains and extensive hydrological resources, is the leading country on community owned MHP, with 1152 schemes built since 1962 and 22,830 kW installed (Nepal Ministry of Finance, 2015). Nepal's MHP development success is based on the foundations of pro-active governmental institutions, local expertise and a strong private sector, which have resulted in significant socio-economic advantages for MHP in Nepal (Gurung et al., 2011; Mainali & Silveira, 2013; Pokharel et al., 2008). Fifty percent of each MHP project cost is subsidized by the government and 30% is often provided by district government to account for the fact that Nepal's national electricity grid expands at a very slow rate due to difficult geographic characteristics. The Nepali MHP scene has been subject to numerous studies and has set standards that have been employed around the world (Chitrakar, 2004; Paish, 2002a; Pokharel et al., 2008).

Bolivia and the Philippines have seen the construction of approximately a hundred MHP schemes each since the mid 90's. In a study of 8 rural communities in Bolivia, governmental bias towards a central electricity grid and the lack of local financial and technical expertise were identified as the main factors hampering MHP development in the country (Drinkwaard, Kirkels, & Romijn, 2010). Geographic characteristics in many parts of Bolivia, however, are ideal for MHP and in a study of 9 different MHP schemes in Bolivia, communities showed significant enhancements in living conditions, such as education, health and comfort (González, Aristizábal, & Díaz, 2009). The Philippines, a country with extensive hydrologic resources, has numerous inhabited

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islands of volcanic origin, making the expansion of the national grid highly costly, but ideal for the creation of local MHP schemes (i.e. steep terrain). The two countries, however, suffer from a lack of governmental support for MHP, where no consistent subsidy system exists. The local expertise extends to a handful of NGOs dependent on international aid. There is no capability in private commercial industry to build schemes or manufacture machinery, forcing local developers to import equipment, hence increasing scheme cost.

In Cambodia, MHP development is in its most basic stage, even though good sources of water throughout the plains and hilly areas provide the necessary physical conditions for small scale MHP. There are presently no governmental or non-governmental organizations installing MHP schemes and governmental support or subsidy systems are inexistent. However, a few schemes based on local entrepreneurial initiatives exist in the country's Cardamom mountain range. There is no available literature on MHP in the country, making this study the first of its kind for Cambodia.

A number of detailed MHP design and installation guides have been written (CANRen, 2004; Singh, 2009), and several best practice guidebooks and papers are available on the installation and operation and maintenance of schemes (Blanco et al., 2008; Fulford et al., 2000; Khennas & Barnett, 2000; Mohibullah, Radzi, & Hakim, 2004; Smith, 1994). However, there is a lack of research into existing but non-functioning schemes and the reasons behind their failures. Multiple studies exist on the analysis of the status of few MHP schemes in a single country, but with no quantification of system failures.

A study of 3 MHPs in the Philippines found that the experience of the installing organization, its capacity to balance installation costs with scheme performance, and addressing social issues were fundamental for the success of schemes (Kabalan et al., 2014). The most complete study available on MHP in developing countries, with 16 schemes studied in Zimbabwe, Mozambique, Sri Lanka, Peru and Nepal, found that properly identifying the purpose of the scheme and building it according to its task and location are critical factors for the success of a MHP scheme (Khennas & Barnett, 2000). A study conducted in Malaysia of six communities concluded that to be able to create realistic MHP installation guidelines to satisfy the needs of rural communities, more research is required into understanding the success factors of MHP (Murni et al., 2013). Furthermore, no research, published or otherwise, has been found proposing a system to evaluate the current level of success of an installed scheme.

The objective of this study is thus to create a MHP success framework and classify the schemes studied in Nepal, Bolivia, Cambodia and the Philippines by their level of success. Furthermore the most common MHP success and failure reasons were investigated.

Methods

Research methodology

This study is based on the evaluation of 35 schemes across Nepal, Bolivia, Cambodia and the Philippines during 2015 and 2016. For each country, relevant local developers were contacted to obtain detailed information on country specific MHP characteristics, current MHP development barriers and limitations, funding systems, and policies. In Nepal, the schemes were implemented by the Resource Management and Rural Management Empowerment Centre (REMREC – a local institution) and the United Nations Development Program (UNDP) in combination with the private sector. In Bolivia the schemes were implemented by PRODENER - Centro Integral para las Energías Alternativas y Productivas (a key local NGO specializing in MHP) and a government/private initiative. In the Philippines, the schemes were implemented by two local NGO's, Sibol ng Agham at Teknolohiya (SIBAT) and Yamog Renewable Energy Development Group Inc. (YAMOG) and one scheme was community developed. In Cambodia schemes were built by local entrepreneurs, and only one scheme had received external help by a local NGO, the Cambodian Rural Development Team (CRDT).

Informal interviews with developers provided additional information on known MHP schemes, technical characteristics, and community socio-economical characteristics. Community owned schemes were selected for site visits by considering their characteristics, operational state, location, and ease of access. The schemes selected contained a variety of power production levels, household numbers, location (geophysical characteristics), years in operation, and overall scheme performance (Table 1). Communities often use excess electricity generation for end-uses such as grain-mills (22), saw-mills (4), rice hullers (6), mechanic/electric shops (7), eco-lodges (4) and others (18).

The schemes selected for site visits fell under the micro-hydro category, with the exception of Nep.10, Bol.3, Cam.5, Cam.6 and Cam.7, which have a power production lower than 5 kW.

The socio-economic characteristics of all the studied communities were similar, with agriculture being the base of their economy and subsistence. While cultural values, languages and traditions were different, they shared the willingness to adopt and benefit from MHP technology.

During the site visits, a structured interview to one or several key members of the community provided qualitative and quantitative information on the actual performance of the scheme in regards to its power generation, water availability, operation and maintenance, environmental and social effects, community power demand, and community perceived value of the scheme. A semi-structured interview with present and past operators and key members of the MHP committee was conducted on site, while directly observing each one of the elements of the scheme, from water intake to electric transmission. This allowed for the recording of past repairs, malfunctions, replacements and present glitches as well as current maintenance requirements.

This research used a learning-based approach to design the data acquisition methods. Multiple interview questions, failure reasons, and success factors were explored in an effort to improve the quality of interviews reported in this paper. This research started in Nepal in 2015, were a vast number of informal interviews were held with local developers and MHP experts from the Kathmandu University and its Turbine Testing Lab. Redundant interview questions and uncommon failure reasons were filtered out for not being critically important, recurrent enough, or of concern to the community. The time spend in communities - and the informal interviews held with community members - provided critical insight on how communities value MHP schemes. The preliminary interview experience allowed for the identification and prevention of the most common interview bias (i.e., desirability and cultural noise biases).

Scheme Success Framework development

If success is to be measured, first it needs to be defined. Success can be defined as the degree to which a purpose or aim is achieved. A MHP scheme, however, can accomplish different types of purposes. MHP can be a means for a community to achieve electrification. Some schemes are designed to partially or totally meet the energy needs of an enterprise, and its success should therefore be analysed in regards to its specific objective (Khennas & Barnett, 2000).

Previous literature have addressed the technical and economic key principles for the successful construction, operation and maintenance and management of MHP schemes (Fulford et al., 2000; Khennas & Barnett, 2000; Mainali & Silveira, 2013) only from the point of view of the developer. Such reports present "best practice" guides that overlook, or not address directly, the social aspects of which the technical and economic principles depend on, perhaps due to the complexity on measuring such social aspects. This study, however, is focused on the evaluation of the success of a scheme at a particular moment in time, after its construction from the viewpoint of the community.

Success is here understood as how schemes provide what the community asks for, and thus it is defined as the measure of how schemes