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Framework to assess sustainability of micro-hydro projects in the Operation Phase

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Abstract
The rural electrification projects in Nepal are not only concerned about electrification alone, but are consciously promoted to touch the various dimensions of sustainability goals and foster overall contextual development of the community through one project. Though electricity access has significantly increased in current years, yet many rural energy projects and programs have failed to address sustainability from the start. The major focus is given on the delivery of the technology to the community but the sustainability status of such project, few years after its installation is ambivalent. This paper aims to develop the framework to assess the sustainability of the micro-hydro projects at its operational phase. Multi-criteria decision analysis (MCDA) approach has been used to formulate the constituent of the framework. The study is based on the guidelines postulated by OECD; Theoretical framework and Data collection, which is an iterative process with intensive literature review and several consultations with the experts and stakeholders. The refined framework encompassing five dimensions of sustainability (Criteria) i.e. technical, economic, and social, environment & Institutional and twelve energy Indicators (sub-criteria) has been crafted in order to evaluate the sustainability of micro-hydro projects. The paper further elaborates on the choice and determination of the key indicator on the basis of its relevance, analytical soundness, measurability, transparency and fairness.

Keywords
Energy Indicators – micro-hydro – sustainability – multi-criteria analysis

1. Introduction

Access to reliable and affordable energy services is fundamental to reducing poverty, increasing productivity, enhancing competitiveness and promoting economic growth [1]. However making clean and sustainable energy accessible to all remains one of the central political challenge for many developing countries [2] which is exacerbated by geographical variations, poor transportability; fragmented settlements, illusive energy development strategies and lack of adequate capital [3]. With such physiographic complexities, renewable alternative energy technology plays an important role in the context of rural electrification. In Nepal, over 70 percent of population has access to electricity. However there exist wide disparities in electrification rates between urban and rural areas with 96 percent of electrified households in urban areas, while the corresponding figure for rural households is only 63 percent [4]. About 16 percent of the total population get electricity through renewable energy sources [5] which is mainly through mini/micro-hydro and solar home system [6].

1.1 Micro-hydro sector Development in Nepal

The micro-hydro projects have not only been limited to providing lighting facility to the people but time and again promoted as a tool for developing the agriculture sector and small-scale industries, reducing the gap between urban and rural areas, emphasizing renewable technologies for economic development and environmental protection, enhancing the capacity of local bodies to plan, implement, promote, monitor and evaluate Renewable Energy Technology. Development of micro-hydro in Nepal has a long history which started from early sixties and being continuously established since then. The technology has proved to be one of the most successful model among several other RETs in Nepal for the rural electrification ([7]; [8]). ([9]; [10]; [11]) have addressed the history of development of micro-hydro sector; efforts and initiatives from the national level. The institutional architecture of the MHP primarily includes alternative energy promotion center the national agency, which closely works with the Micro hydro functional group, in coordination with the local government bodies like VDC and DDC, DEECCS & RSC, private pre-qualified companies, INGOs and donor agencies. Similarly the Government of Nepal has formulated various policies and regulations aimed towards rural electrification ([12]; [13]; [14]; [15]; [16]).

In order to implement the formulated plans, several programs have been initiated by AEPC and its development partners, Rural energy development program (1996-2011), Regional center for excellence in micro-hydropower (2010), National rural and Renewable Energy (2012-2017) and Renewable program for rural livelihood (2014) so as to increase the rural energy access as well as improve the livelihood of the people. By 2014 more than 1000 micro hydro power plants with a total capacity of 25 MW had been installed. The government of Nepal has aimed to provide electricity to an additional 150.000 households through National rural and renewable energy program [17]. Though electricity access has been significantly increasing yet many rural energy projects have failed to address sustainability from the start. Often the focus is given on delivering the technology, and success is measured in terms of number of number of kW installed [18]. In addition, the involvement of newer aggressive actors may boost project execution and delivery through large subsidy and do not pay attention to the long-term viability of the endeavour, or its overall economic sustainability [19]. Thus, in order to assure the success of the installed projects it is equally important to assess the sustainability of such projects at the phase.

1.2 Sustainability and Energy Indicators

Sustainability assessment of performance is often quantified through sets of variables known as sustainability indicators. One of the major reasons for the increasing adoption of indicators is the ability to convert large statistical data and extensive reports into comprehensive and succinct messages [20]. The issues of sustainability or sustainable development have been discussed in different domain since the irreversible impacts of development process have been realized. [21]. Since the publication of the Brundtland Report in 1987, various international and national organizations have been developing sets of indicators to measure and assess one or more aspects of sustainable development [22], [23], [24], have formulated manual and toolkits to assess sustainability, however they are more suitable for national or stratrgic level [25]. Similarly several studies have come up with framework to assess the sustainability of rural electrification at the local level ([24]; [26]; [27]; [28];) but they are rather general and requires more exercise to synthesize case-specific indicators. Defining appropriate set of indicators to capture the performance of the technology within sustainability boundary is a challenging job [29]. As sustainability is multi-dimensional and multi-faced issue the required indicator framework demands a strong foundation of an appropriate methodological and theoretical framework to come up with valid able result.

1.3 Objective

This paper aims to develop a framework to assess the sustainability of micro-hydro projects in the operational phase.

- To identify the criteria and the corresponding indicators that relevantly defines the sustainability of MHP projects.

2. Methodology

Decision making to ensure the sustainability of RETs systems can be a difficult task because of the complex interaction of multiple sustainability dimensions and stakeholders thus Multi-Criteria Decision Analysis (MCDA) tool has can be applied to this kind of decision making as it provides well-reasoned and inclusive solutions [30]. It can seamlessly process both qualitative and quantitative data while also drawing out responses and priorities from experts. In the absence of direct data sources, the method can deal with experimental or calculated data as effectively [20]. The methodological framework and guiding steps developed by OEDC [2] has been adopted for the study.

Indicators were selected on the basis of the conceptual framework which was reviewed by stakeholder and experts. The iterative process was conducted to come up with more refined framework and precise key indicators as shown in Figure 1.

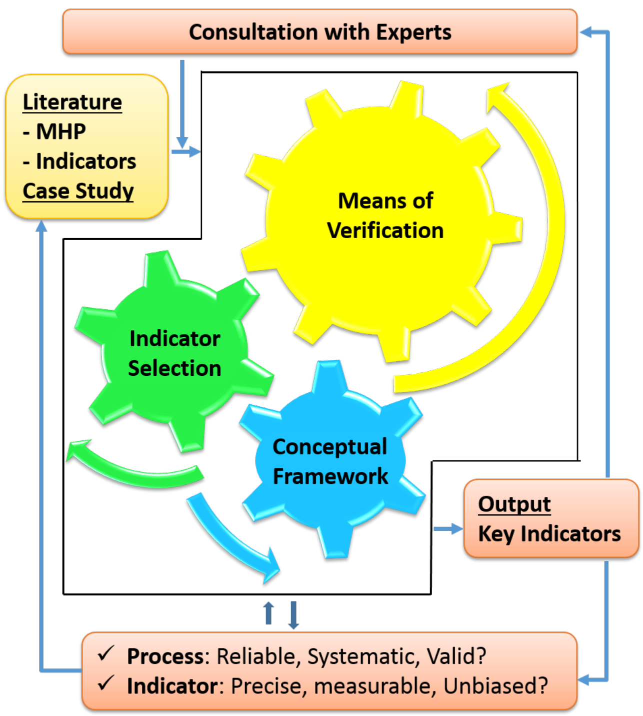

Figure 1: Iterative Process Indicator selection

2.1 Theoretical Framework

Theoretical Framework provides the basis for the selection of variables under a fitness-forpurpose principle i.e. the process should ideally be based on what is desirable to measure and not on which indicators are available [2]. The constituent of the framework should effectively define the sustainability of the rural energy in this specific context [31]. Sustainability is often linked with triple bottom line as coined by Elkington in 1994 i.e. economic, environment and social. Technical and Institution dimensions are also taken under consideration mainly while assessing the sustainability of the projects in rural sector. ([25]; [31]; [19]; [32]; [33]). Research on rural electrification is a matter of putting together the perspective of not only electrification itself, but also the impact it has on the development of a community and its context. [25]. RET offers several benefits to the rural areas that include environmental and social aspects, which are linked to energy access and poverty reduction in the developing countries. [34]. In fact, rural MHP projects in Nepal are also consciously promoted so as to touch various dimensions of sustainability goals thus it is very important, these dimensions are addressed while assessing sustainability of such projects.

A micro- hydro project in its operational phase is likely to be sustainable if it is technically effective, economically self-reliant, inclusively fosters social benefits within the community, reduces environmental impact and is efficiently and ethically organized. Under this conceptual framework a number of criteria and the respective indicators were selected which has been discussed in the section 2.2.

2.2 Selection of the Indicators

The strengths and weaknesses of sustainability indicators largely depends on the quality of the underlying variables. Indicators should be selected on the basis of their relevance, analytical soundness, accessibility [2] and strong means of verification. Above all it should describe sustainability phenomenon of the renewable projects in the rural context and should be transparent and unbiased [25]. The indicators were selected concerned to the required features of the key indicators, the procedure originally resulted in the more numbers of indicators which has been reduced through iterative process. The refined version of the criteria with the corresponding key indicators, their evaluation and sources is as enlisted in Table 1.

Technical sustainability focuses on the system's capability of providing the efficient and reliable energy service throughout its economic lifetime. Capacity factor shows the proportion of effective capacity compared to installed capacity that is expected to be delivered by the MHP to the community. It is linked the availability of Service and Share of electricity in Productive use. Availability of services assesses the ability of RE system to meet community's demand for electricity in timely and reliable fashion. It also indicates if there is any prolonged repairing time due to some intensive damage or lack of supportive infrastructure. Technical losses address the transmission and distribution losses.

Economic sustainability fundamentally focuses on the viability of the project to generate and adjust the revenue required for the smooth operation of the project and strengthen financial capability by providing the electricity service to the commercial productive use so that it can independently address all kind of repair and restore expenses when needed. Operation and maintenance cost also includes the employees salary, repair and all the miscellaneous cost throughout the year. Tariff lag indicates if the project is unable to update its tariff rate with respect to the inflation rate which is very high in developing countries. Share of electricity in business assesses the consumption of energy for the commercial use. The indicator is directly linked with the employment generation, local entrepreneurship and also indicates the profitability of the project.

Social sustainability focuses on the equitable distribution of the benefits offered by electrification [24]. That can be captured by enabling the technological intervention in the fundamental social services like health, education, agriculture, communication & information and contributing to poverty reduction, by fostering income generating opportunities to the locals so that with the leveled platform everyone irrespective of any economic, social or gender disparity can make the use of service provided. Access to energy is linked with Sustainable development goal 7. Upgrade in social infrastructure addresses the social development of the community. It is linked with SDG 5 and signifies the provision for gender mainstreaming and reduction in human drudgery. Employment generation addresses the economic development, with the availability of electricity and is linked with SDG 1.

Environmental sustainability aims to reduce global impact in the environment. This is captured by considering contributions in the reduction of the greenhouse gases[26]. Several micro-hydro projects are under carbon financing program that monitors the reduction of GHG emissions through the replacement of diesel fuel used for lighting and milling. The indicator is directly linked with capacity factor and load factor of the Micro-hydro plant.

Institutional sustainability focuses on efficient managerial capability of the organization to maintain its smooth functionality within the legal framework which is possible if it is locally managed and has measures to monitor the system against unethical activities. Electrification projects can be privately owned by local entrepreneurs or local community. In any case, the sustainability of any kind of off-grid rural electrification usually requires active local participation in the development and implementation of the electrification projects [7] with is captured by community acceptance and involvement. Ability to monitor the system addresses the provision to inspect against the corruption activities such as unethical abuse of public power, law violation and misuse of resources for personal gain through internal/external/public audit.

3. Discussion

3.1 Choice of the energy Key Indicators

3.1.1 Relevance of the variable

The set of indicators developed by several organization and researchers are holistic but direct adoption of such framework is not suitable while selecting key indicators as they are compilation of many indicators, which in one or other way intends to measure same thing creating repetitive indicators so the intra and inter-dimensional linkage of the indicators must be well determined. In other hand, selection of key indicator demands a very strong theoretical framework to differentiate the important variable and general variable. For instance, for an operating MHP, conformation of the equipment with the national standard could be substantial for its technical sustainability however the market characteristics of micro hydro includes high system cost, long delivery time but standardized high-quality product from prequalified companies [35] at this note it can be excluded. Similarly, as the assessment is for the operational phase the activities at the design and construction phase has been assumed to be technically correct.

Table 1: Selected Indicators for assessing sustainability of MHP project

Criteria	Sub-Criteria	Description	References
Technical	Capacity factor	Proportion of electricity generation capacity to the actual designed capacity of the plant (%)	[26] [28] [32]
	Availability of Services	Proportion of hours of electricity supply to the total hours actually planned to be supplied (%)	[25] [26] [27] [28] [19] [32]
	Technical Losses	Transmission and distribution losses (%)	[25] [28] [32]
Economic	Operation and Maintenance Cost	Includes all the expenses per year for the generation of per KWh of electricity (Rs./KWhr)	[25] [26] [28] [19]
	Tariff Lag	Change in the monthly tariff w.r.t change in inflation rate	[25] [20] [32]
	Share of electricity in business	Percent of electricity consumed for the commercial use (%)	[25] [20] [32]
Social	Access to energy	Percentage of households in the catchment area that has access to electricity (%)	[24] [25] [27] [28]
	Upgrade in social infrastructure	In reference to the general pathway of technology, addresses level of technology intervention in social infrastructure.	[25] [32] [35]
	Employment generation	Percentage of household involved in the economic activities due to availability of electricity. (%)	[25] [27] [28] [32]
Environment	Emission avoided by replacing dirty fuel	Contribution of the project to reduce the global impact (GHG emission) in the environment	[20] [35]
Institution	Community Acceptance and Involvement	Proportion of the local men/women involved in the management committee (%)	[27]
	Ability to monitor the System	Assesses transparency in decision making/information sharing. i.e. internal/ external /public audit	[27] [28]

3.1.2 Analytical Soundness of the variable

Very often there are substantial issues that has strong impact on sustainability but may lack the reliable theoretical basis for the evaluation. For instance, Interconnection and compatibility of MHP projects with national grid has been at the limelight. Though the fourteenth development plan has this agenda and similarly some pilot projects are at the edge of initiation however no reliable policies and guidelines are available to evaluate it. The technical guideline is only available for mini hydro (100 KW-1MW). Other option is mini grid formation by interlinking MHPs, which has only been implemented at pilot level and more research is required to come up with any valuable conclusion. In other hand, it is a multi-dimensional issue in itself. Similarly effect of climate change on the availability of resources for micro-hydro is another cross cutting issue however there is no proper means of verification to confirm the effect.

3.1.3 Measurability of the variables

An indicator can only be measured effectively it the data are readily available, quantifiable and updated periodically [2]. The evaluation of the indicator 'Upgrade in Social infrastructure' was relatively complex as availability of electricity is not the only factor that contributes for the upgrade in social infrastructure like health, education, agriculture and communication. So technology intervention was taken as the considerable driving force, yet there was difficulty in quantifying and grading the variable. The indicator was evaluated and graded on the basis of the general pathway of technology adaptation in the electrified rural community. While selecting the indicator we also have to bear in mind the context in which the surveys are to be formulated. In the real field the availability of all the required data is a myth. Thus, for the selected indicator, either data should be accessible or there must be some provision to make proxy evaluations. For instance, 'Share of electricity in business', in many projects direct records are not available, even more tariff collection is based on flat rate or power based. In such condition the indicator is calculated through the total power rating of the equipment used and number of hours of operation.

3.1.4 Transparency and fairness of the variable

The MHP projects in Nepal are either managed by community or privately owned by companies/local entrepreneur. Generally objective of private and public project is different yet there is no significant difference in technical, social, economic and environmental dimension as profitability in community projects and upgrade in social services of private projects are likely to make them more sustainable. However, the line is clearly visible in institutional dimension. For instance, Sense of ownership from the locals or degree of ownership is a substantial indicator for sustainability but as it manifests very differently for private and community project such indicators make biased framework. So as the project is to serve the community, whatever decisions (like tariff rate fixation) are executed it should be under the acceptance of the local people. Similarly, the involvement of the expert and stakeholder during the iterative process enhances the validity of the framework.

4. Way Forward

Decision making to ensure the sustainability of RETs systems can be a challenging task because of the intricate interaction of various sustainability dimensions and stakeholders. On the other hand, sustainability is multi-faced issue that can be defined and applied in various manner thus the required assessing framework should come through the foundation of an appropriate methodological and theoretical framework to come up with validated result. The strengths and weaknesses of sustainability indicators largely depends from the quality of the underlying variables thus indicators should be selected on the basis of their relevance, analytical soundness, accessibility and strong means of verification. Above all it should describe sustainability phenomenon of the renewable projects in the rural context and should be transparent and unbiased. In addition, experts and stakeholders have to be systematically engaged throughout the iterative process to come up with the accountable refined framework to assess the micro-hydro project at the operational phase.

Research

This paper represents excerpt from the M.Sc. thesis. The comprehensive work includes weighting & aggregation of the selected Energy indicators and testing with the field data for the validation of the framework.

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