

Micro-Hydropower Project for Enhancing Rural Livelihood

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Abstract: Energy is an entry point for socio-economic development of both the society and the country. Due to uneven terrain, scattered settlement and being landlocked country, economic development is a major challenge in developing countries like Nepal. Expanding grid, development of physical structure needs a huge investment and time that nation cannot afford excluding rural people from modern facilities and supporting enhancement of their life. Development of decentralized micro-hydropower projects is one of the best options for enhancing their livelihood and providing basis energy needs for lighting, running micro-small-medium enterprises and ultimately opening the avenue of business activities in the rural area. This paper critically assesses how decentralized micro-hydropower projects enhances livelihood of people living in rural part of Nepal.

Key words: decentralized, scattered, landlocked, livelihood, enhancement

1. Introduction

Nepal being one of the least developed countries and one fourth of the people are living below poverty line [7], enhancing livelihood is a major challenge in nepal.

Providing taste of modern development including energy services to rural people is an issue to all developing countries. About one fourth of Nepalese people who are mainly living in rural area are still out of access to electricity. Due to unfavorable geological condition and scattered settlements, extending national grid is not feasible solution for providing electricity services to rural people. Development of off-grid energy options is the only option, which is suitable for planning, developing, operating and managing at local level fulfilling the energy need, meeting the national targets of modern energy access and enhancing livelihood of rural people.

Due to lack of economic activities, socio-economic condition of rural people is very much poor [15]. The livelihood of rural people is based on subsistence agriculture, livestock and income from foreign labor. Thus, rural people cannot afford modern energy sources as a result they depend on less efficient traditional energy sources such as fuel wood, agricultural residue, animal dung, traditional water mill, kerosene lamp (Tuki) to meet their cooking, heating, agro-processing and lighting demand. Enhancing their livelihood, who are living in subsistence level is a major challenge for the Government of Nepal. In the mean time meeting UN's SE4All goal and fulfilling "...energy lies at the heart of all countries core interest", [24] is another need to materialize.

Energy from decentralized micro-hydropower is one the best options for not only providing energy access to rural people but also enhancing rural livelihood. Hydropower having capacity up to 1,000 kW [4] is being promoted by Alternative Energy Promotion Centre (AEPC) for providing electricity for lighting as well as running

micro/small and medium sized enterprises that help in enhancing rural economic activities.

Therefore, a review was done with an aim to understand how developed micro-hydropower project supports in enhancing livelihood of rural people in Nepal.

2. Objective

The study carried out the following objectives:

- 1) To assess enhancement of livelihoods of rural people with intervention from Micro-hydropower projects
- 2) To ensure impact the project on electrified area comparing with non-electrified area

3. Study Methodology

This paper is prepared based on relevant secondary data gathered from different online journals, research articles, book, study reports etc. These sources of information were reviewed and managed to prepare this article for better understanding on how livelihood is enhanced through the development of decentralized micro-hydropower in rural parts of Nepal. Impacts were mainly derived based on comparative studies between electrified by micro-hydropower project and non-electrified area. In most of the cases, responses from the users, operators, entrepreneurs were taken with the help of structured and / or non-structures questionnaires. Quantitative and qualitative data were found to be collected through household survey, focus group discussions and key informant interview.

4. Hydropower

Hydropower is a generation of power, mechanical or electrical using fall of water. Energy from hydro is considered a clean or renewable however, hydropower

from big dam is being a debate whether renewable or not due to high risk of environmental degradation and resettlement required in the locality.

Hydropower Classification: Classification of hydropower technology varies country to country and continent to continent. In Nepalese context, [DoED (Guideline and Procedures, http://doed.gov.np/license_procedure.php) and AEPC (Subsidy Policy and Subsidy Delivery Mechanism, 2013)] [4], [9], it is classified as per the following way: Pico-hydropower (up to 10 kW capacity), Micro-hydropower (up to 100 kW), Mini-hydropower (between 100 kW to 1,000 kW), Small-hydropower (greater than 1 MW to 25 MW), Medium-hydropower (greater than 25 MW to 100 MW) and Big-hydropower (greater than 100 MW).

This paper includes the projects up to 100 kW capacity, which is categorized as Micro-Hydropower Projects (MHPs). There are many support organizers for the development of the projects; AEPC is a nodal agency for promotion of renewable energy technologies including Micro/Mini-Hydropower up to 1,000 kW capacity. This paper explicitly covers the projects supported by AEPC.

5. Development of Micro-Hydro

Developers of micro-hydropower projects are primarily communities that are registered at District Administration Office under Non-Governmental Organization (NGO) Act of Nepal [12]. Negligible numbers of projects are belonging to cooperatives, private or other form of ownership. However, policy is open for all kinds of legal entities like cooperatives, private, public-private-partnership to be eligible for subsidy to develop a new projects in off-grid area of Nepal. Any project targeting for providing to non-electrified household and also option to be grid-connected is also eligible from recent subsidy policy [4].

The Government of Nepal through its Renewable Energy Subsidy Policy and concerned Delivery Mechanism, provides investment subsidy based on installed capacity and connected new households. Tentative per kW cost including generation and transmission - distribution is found to be Rs. 500,000 that includes nearly one-third of the share from transmission and distribution [22]. This is due to scattered settlements in rural area resulting in increased length of transmission and distribution lines and associated accessories.

Looking into the share of the the different components of Micro-hydropower projects (MHPs) the major cost is associated with civil works and transmission & distribution followed by electro-mechanical equipment. Refer the cost breakdown in the following figure-1 for details.

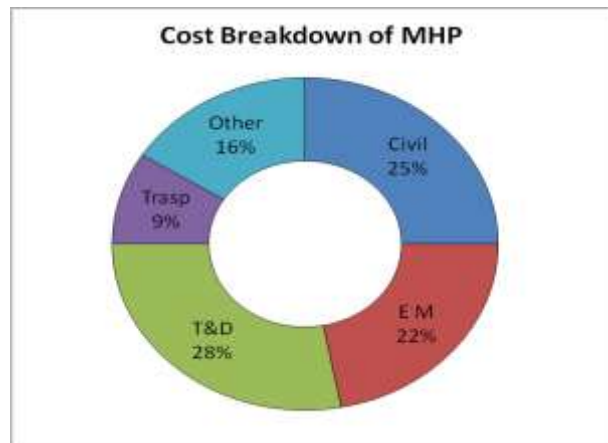


Figure 1: Cost Breakdown of MHP

Cost of civil and electro-mechanical equipment is found to be nearly one-fourth of the investment cost [22]. On average nine percent of the investment cost is necessary in transportation of the equipments, this figure increases by two to three folds if such equipments are to be transported in certain area where air lift is only option.

Looking into source of financing, AEPC subsidy covers nearly fifty percent of investment cost whereas the developer needs to manage rest of the amount. As per analysis of already implemented project (data from 110 MHPs), around 20-30 percent of investment cost is managed by equity (around 12 percent kind and rest cash), around 10 percent subsidy is received from local government (DDC, VDC) [22].

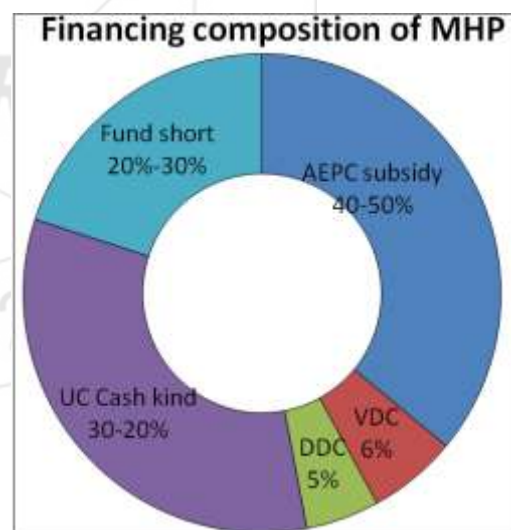


Figure 2: Financial mix of MHP

Implementation modality of MHP in Nepal is demand driven and Public-Private-Partnership (PPP). The projects is owned and managed by the local communities or cooperatives of local entities [23]. The communities, the Government of Nepal and financial institution invest on the project whereas the private sector carryout engineering, fabrication, supply, installation, commissioning and after sales service [21]. After or during installation of project, AEPC provides operators' training (22 days) and managers' training (8 days). Occasionally, refresher training is also provided to the operators who got

basic training and continuously engaged in the operation of the projects for more than three years.

After installation of the project, Installation Company shall be responsible to repair its portion until one year of warranty period after that the developer is fully responsible for operation, maintenance and management of the project [21]. Promotion of economic use of electricity is in-built activities from its survey and engineering design, which will take place after the completion of the project by establishment of Micro-Small and Medium enterprises (MSMEs) in the project command with technical and partial financial support from AEPC [20]. Around 30 percent of investment subsidy is provided to potential entrepreneur with consideration of priority to women and disadvantage group.

Mainly the projects are developed to fulfill the lighting needs, from which the project will not be sustained for properly operate, repair and maintain the project by selling electricity for lighting load only. Until and unless daytime energy is not consumed, the financial status of the project will be very poor. Load curve of Barpak MHP (1998/99) is presented in Figure-3 below where daily load with and without ropeway (as an end-use) is analyzed [19]. The ropeway consumes daytime energy and capacity utilization factor is highly increased consequently helped enhancing financial soundness.

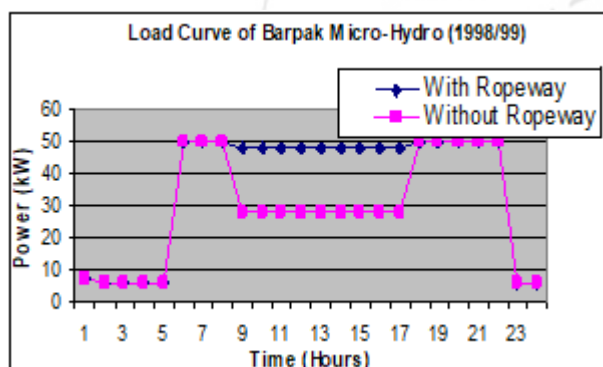


Figure 3: Load curve of Barpak MHP (adapted from Thapa, R., 2006)

6. Economic Use of Electricity

The term "Economic or Productive Use" is broadly defined as a range of activities such as Micro-Small-Mini Enterprises (MSMEs), agricultural and food processing etc that runs either directly indirectly by the energy produced by renewable energy sources. Efficient use of available energy ensures financial soundness of the project and helps enrichment in livelihood of rural people. Due to low economic status of rural situation, the demand for electricity may also low that results low utilization factor and subsequently poor return on investments from energy projects. The utilization factor of renewable energy projects can be significantly increased using demand side management with introduction of "economic or productive uses" as an additional use of electricity apart from lighting and cooking. Those enterprises that consume day time

energy, which is primarily the idle energy of the renewable energy technologies [8].

Thus, the developer and/or promotional entities should consider the best the economic use of available electricity. Before consideration of economic use of electricity, it is necessary to understand potential variables for electricity demand [20]. Based on available local resources and market potential in developing countries like Nepal, these variables could be categorized in four areas as per following Table-1:

Table 1: Electricity Demand Variables

<i>Sector</i>	<i>Electricity consuming sector/appliances</i>	<i>Electricity Demand Variables</i>
1. Domestic	Household lighting Electrical appliances	Number of households Paying capacity (income level) Tariff structure
2. Industrial (Small and Micro Enterprises)	Agro-processing Rural carpentry Bakery Poultry Video hall Battery charger Cold stores Water pumping	Information Raw materials Technical know-how/skills Entrepreneurship Investment (Equity and credit) Market Tariff
3. Tourism	Hotel/lodges Appliances	Number of tourist arrival and stay Use of appliances
4. Service	Photocopy Photo studio Cable network Telephone/ Telecentres Health post (refrigerators..)	Information Technical know-how/skills Investment (Equity and credit) Market Tariff
5. Education	Computers Laboratories Appliances	Number of schools/ students Information Technical know-how/skills. Investment (Equity and credit) Tariff

Source: Compiled by Author based on information (Thapa, R. and Adhikari D., 2008)

Some of potential economic uses that may possible to run from certain renewable energy technologies in rural contexts are presented in the following table as an example (Table-2). But it do not refer all possibilities technologies and probable enterprises as it depends on availability of local resources, skill, acceptability and market availability of certain location which varies from one place to other.

Table 2: Economic Uses and Technologies

SN	Economic Uses	Renewable Energy Technology
1	Coffee shop	Hydro, Biomass, Mini-grid
2	Saw Mill	Hydro, Biomass, Mini-grid, PV
3	Mechanical Workshop (grinder, welding)	Hydro, Mini-grid
4	Agro-processing (grinding, milling, hulling)	Hydro, Mini-grid, PV
5	Oil Expelling	Hydro, Mini-grid
6	Refrigeration (ice making, chilling milk,	Hydro, Biomass, Mini-grid

	fruit & vegetable and meat)	
7	Bakery	Hydro, Biomass, Mini-grid
8	Water Pumping (drinking, irrigation)	Hydro, PV, Mini-grid, Biomass
9	Battery Charging	Hydro, PV, Mini-grid
10	Telecom Towers	Hydro, PV, Mini-grid
11	Rural Carpentry	Hydro, Mini-grid
12	Drying (tea, coffee, vegetables etc.	Hydro, PV, Mini-grid, Biomass, wind
13	Herb Processing	Hydro, PV, Mini-grid, Biomass, wind
14	Poultry Farming	Hydro, PV, Mini-grid, Biomass, wind

Source: Compiled by Author based on information in DFID (2009) - Report on Productive User of Renewable Energy

6.1 Policy Intervention on Economic Use

Potential of renewable energy to contribute in increasing income-generation activities in rural area is currently recognized by national policy-makers and planners [10]. Economic use of electricity has been given prime consideration as its importance is increased in recent programs and plans compared with previous. During earlier program Renewable Energy Development Program (REDP) and Energy Sector Assistance Program (ESAP) - I Phase, there was only a little consideration which was mainstreamed during early RERL and ESAP-II phase. While it was a major component in National Rural and Renewable Energy Program (NRREP) which was implemented since August 2012 [5].

Economic use of electricity was mainstreamed during initial phase of Energy Sector Assistance Program (ESAP) - II phase when the author with consultation with Adhikari, D. prepared "A strategy paper for promotion of economic use of electricity" [20]. Before that, Rural Energy development Program (REDP) projects only used to get subsidy for promotion of economic or productive energy use (PEU) (so-called end-uses) [2]. Consequently, the Government of Nepal introduced a subsidy for potential entrepreneurs running business from the electricity produced by Micro-hydropower projects [3].

Table 3: Historical trend of subsidy on PEU

SN	Policy and Delivery Mechanism	Intervention	Remarks
1	Subsidy Policy 2006	Clause No. 3.14: mentions - * ...productive end-use will be encouraged. *At least 10 percent of energy should be used by end-use	No Subsidy allocation
2	Subsidy Delivery Mechanism 2006	An amount of Rs. 10,000 per kW but not exceeding Rs. 250,000	Only for REDP MHPs based MSME (Program Level)
3	REDP and ESAP-II Phase (007-012)	Productive energy use in micro-hydro only handled by technical component of AEPC	For all MHPs based MSMEs
4	Subsidy Policy 2009	An amount of Rs. 10,000 per kW but not exceeding Rs. 250,000	For all technology based MSMEs
5	NRREP 2012	Major component: - Central Renewable Energy Fund - Technical Component - Productive Energy Use	NRREP Program document
6	Subsidy Policy 2013	Subsidy Provisioned other RETS as well including micro-hydro	For all technology based MSMEs
7	Subsidy Policy 2013	Continued but increased the amount	

Source: Compiled by Author from different sources

6.2 Strategic Intervention on Economic Use

If a rural energy activities is meant to reduce poverty, end-use activities must be thought of early in the project design to determine how best to provide energy services so as to optimize the poverty reduction impact [14]. Promotion of economic use of electricity is one of the prime concerns of the Government of Nepal through AEPC and other line agencies. It has been mainstreamed with systematic means based on project cycle including feedback system to adapt corrective measures. It is concisely addresses different activities, target group and roles & responsibilities in different phase of based on project cycle with feedback loop. The main phase for the development and promotion of economic use of electricity is following [20]:

- Conceptual phase
- Preparatory phase
- Development phase
- Implementation phase
- Follow-up and monitoring phase
- Revision phase-adaptation of feedback

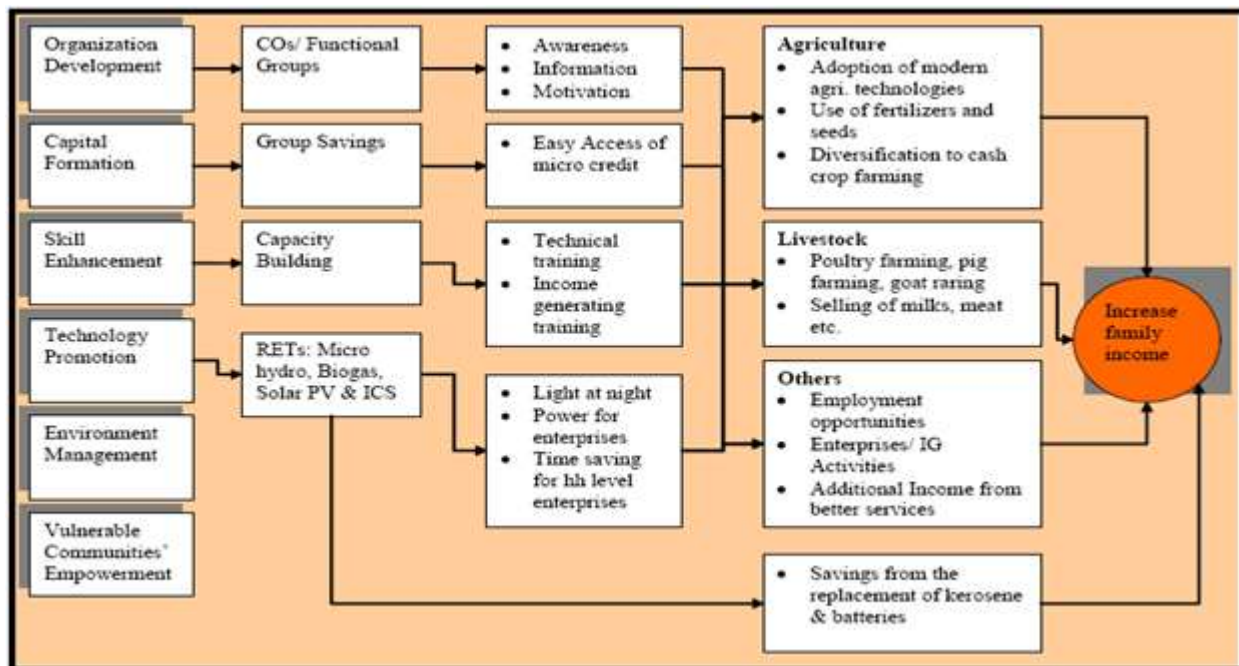


Figure 4: Pathway Interlink between AEPC/REDP's Initiatives and Poverty Reduction (adapted from Winrock International Nepal (2006): Assessment of REDP Impact on MDGs)

7. Livelihood Enhancement through Micro-Hydro

Five different research based studies were reviewed in order to get idea about different aspect of livelihood enhancement in the rural communities after intervention of micro-hydropower project. Mainly ten different criterions were taken into account namely: functional status of project, impact on time saving, impact on work burden, impact on employment generation, impact on income generation, impact on health and safety, impact on education, impact on environment, impact on living standard and overall satisfaction with the project. It was found that, most of the reference studies were done comparing the data from electrified and non-electrified area based on similar socio-economic conditions.

Major findings from the studies are tabulated in *Table-4* below which shows comparative findings from different research studies, different projects and different consumers covering varieties geography and installation years.

Functional status: Majority of the projects were found to be functional opening door for reliability of electricity for running micro-small-medium enterprises (MSMEs), providing better lighting and eventually improved acceptability from the end users.

Impact on time saving: Remarkable time was found the saved from all studies. Most of the respondents revealed that the saved time is used for income generation activities.

Impact on work burden: mainly women and children are benefited from reduction of work burden in fuel collection and assessable facility of agro-processing facility from available electricity. Mostly improved cook-stoves are promoted in MHP command area and about 10 percent of

the household are using rice cooker, which helped to decrease the consumption of fuel wood.

Impact on employment generation: On average, more than six employment generations was created from the installation of each project, which prevails that development of micro-hydro creates a major role in employment generation in rural parts of the country.

Impact on income generation: Majority of the household respondents felt that their income level is increased after electrification from MHP. This could be a result of increased access in information and communication technology (ITC), time saving from fuel collection and agro-processing. Small and medium business entrepreneurs responded that their income was increased up to two folds after electrification comparing with previously diesel based MSMEs.

Impact on health and safety: Most of the household respondents felt that there is improvement in safety for domestic animals from wildlife attack. Similar respondents felt improvements in eye irritation. Especially health of women and children were found to be improved after electrification.

Impact on education: It was observed that individual households are investing double amount in education after electrification. Study time of students was also found remarkable increased as a result literacy rate was also found 2 percent higher than non-electrified area.

Impact on environment: on average each households saves 3.5 liters of kerosene, 3-pairs of dry cell batteries, and 40 kg firewood per month that ultimately have great impact in national economy by supporting in reduction of fuel imports, national balance of payment, reduction in

deforestation and conservation of environment. With the help of reduction of CO₂ by replacement of diesel and kerosene, Micro-hydro projects are bundled for developing a small-scale Clean Development Mechanism (CDM) project that is registered in UNFCCC. Till date 148,0000 tones of CO₂ equivalent of Certified Emission Reduction (CER) is verified by UNFCCC and US\$ 650,000 amount is earned by selling of most of these CERs generated from Micro-Hydropower Projects. Income from latest 56,000 tones of CERs is yet to be received [16].

Improvement of living standard: The majority of the households are felt that there is a slight improvement on their living improvements after electrification. Their overall socio-economic condition seems to be better that the people living at non-electrified area.

Overall satisfaction with project: More than the two-thirds of household beneficiaries responded that they are very satisfied from the projects. In some cases, they are less satisfied from the service from support organization like Regional Service Centres (RSCs) and Installer companies.

Table 4: Impact on Livelihood through Economic Use of electricity from Micro Hydro

SN	Criteria	Findings from Different Studies				
		HPL (2006)	AEPC/UNDP (2010)	Samuhik Abhiyan (2011)	Gurung et al. (2011)	IRMC (2017)
1	No. of samples taken	64 projects from 29 different districts	6 projects from 2 districts	20 projects from 10 districts	1 project	25 projects from 25 districts
2	Functional status	95 percent operating well, 5 percent shutdown permanently and under construction	3-functional and 3-under construction	100 percent functional	100 percent functional	NA
3	Impact on time saving	80 percent respondent (470 samples) felt that time had been saved due to MHP (p.32). 75 percent of male and 65 percent of female responded that saved time was used for income generation activities (p.33)	Use of project to operate agro-processing enterprises allows households to save up to 240 hours per year (p.44). The income equivalent of the time saved can reach US\$37 annually per household (p.44, 45).	Remarkable time saved due to its efficiency in operating holler mills, saw mills and others (p.35)	Average 8 hours saved	NA
4	Impact on work burden	Reduced work burden of women	Reduced work burden due to less amount of fuel collection, agro-processing	Reduced work burden of women mainly in fuel collection and agro-processing	Reduced work burden of women	50 percent of women work load has been reduced after electrification (p.21)
5	Impact on employment generation	NA	More than 90 percent of MSMEs were created after electrification creating self and induced employment opportunity (p.ix, 20)	7 employment per projects (3 direct, 4 from MSMEs)	Yes, but not quantified	7.6 employments per projects (2.4 full and 3.8 partial) (p.6, 33)
6	Impact on income generation	Majority of the respondents felt there had been slight improvement (58 %), and a quarter felt that there had been a big improvement. Only 14 percent felt there had been no change (p.34)	Household income is more than 25 percent higher in communities with electricity (p.ix, 26) and Average agricultural production per household is almost 65 percent greater (p.ix, 22)	Income from SMEs is Rs. 2,115 (50 percent) higher for electrified households compared to non-electrified (p.23)	Yes, but not quantified	Income of electrified households is 18 percent higher than non-electrified (p.7, 18)
7	Impact on health and safety	Over two-thirds of respondents felt that there had been improvements regarding safety of domestic animals from wildlife attack (p.34). A large majority (87 percent) of the respondents felt that there had been at least a slight improvement to fire safety electrification (p.35). Nearly all (90 percent) of the respondents felt that there had been at least slight improvements in eye problems (p.25)	Found improved but not quantified	Incidence of illness is lowered by 1.4 percent (p.23). Incidence of water borne diseases is 6 percent points lower for the electrified households (p.25)	Yes, but not quantified	Found improved health of women and children (p.27-28)
8	Impact on education	NA	Household expenditure on education is twice as much in communities with electricity	Children living in electrified are have 2 percent points higher	Secondary school is able to	Average study time increased by 19 minutes per day

			(p.30). The rate of enrolment in secondary education is about 50 percent higher in communities with electricity (P.27). Children living in electrified communities spend an average of three additional hours per week on educational activities (p.29)	literacy rate (p.26). 9 percent affirmed that they were using rice cookers as a replacement for firewood for cooking purposes resulting saving fuel wood (p.24, 31).	maintain a 80 percent SLC success rate. Due to increased education time due to better light and ICT	(p.29)
9	Impact on environment	On average one household saves about four litres of kerosene, three pairs of dry cells and 40kg of firewood per month as a result of MHP installation	Having electricity reduces use of using dry-cell batteries by more than 85 percent (p. 40) and reduces consumption of kerosene by more than 80 percent (p.41). An annual reduction in CO ₂ emissions of 4 tonnes per kW installed (p.42).	Electrification has replaced burning of 2.90 liters of kerosene per household per month (p.31). 40 percent of beneficiaries currently use ICS (p.36)	Yes, but not quantified	Remarkable fuel wood saved (p.23)
10	Improvement of living standard	The majority of users (61 percent) felt that there had been slight improvements and about 31 percent felt, there is a big improvements to their living standards following MHP installation. Only 8 percent felt that had been no change.	In communities with electricity, households are able to meet their energy needs with high quality services at less than half the price (p. 24).	Enhanced living standard	NA	NA
11	Satisfaction with project	Nearly two-third of respondents (463 samples) are very satisfied with the project. 8 percent are not satisfied (p.37)	Yes, but not quantified	Expectation of lighting before installation is met for almost all households (p.38). 61 percent highly satisfied and 30 percent moderately satisfied (p.40)	NA	NA

Source: Compiled by Author based on information from different research based studies (HPL-2006, AEPC/UNDP-2010, Abhiyan-2011, Gurung et al.-2011 and IRMC-2017)

8. Conclusions

In conclusion, Micro-Hydropower is a reliable option for enhancing rural livelihood in the developing countries like Nepal. About two decades of experience of AEPC in the formulation of policies, plans, standards, guidelines, manuals and proper mobilization of resources from public and private sectors for both in the development of decentralized Micro-hydropower projects and promoting economic activities, the sector is well recognized as a priority sector by the Government of Nepal and international community as well. Different studies show that life standard of rural people is electrified area is better than the people living in non-electrified area. Therefore, it is concluded that development of MHPs enhances the livelihood of rural people.

Users' participation, ownership and acceptance are the key parameters for the sustainability of MHPs that satisfies not only transparency but ensures continuous operation of the projects. It ultimately boosts up awareness, health and sanitation, education, economic activities and eventually improves the living standard of rural people. This will definitely support meeting national as well as UN goal of enhancement of livelihood and reduction of poverty.

9. Acknowledgement

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