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Off-Grid Energy an Option for Rural Energy Solution

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Abstract: *Although renewable energy technologies (RETs) were in practice since some decades, the Government of Nepal realized its value only after 1996 when the Alternative Energy Promotion Centre (AEPC) established with an objective of promotion of RETs in Nepal. Since then, RETs dissemination is regulated under governmental plan and policies. Different programs were executed with technical and financial support from different development partners. Micro/ mini-hydro systems and solar photovoltaic (PV) are two options for decentralized rural electrification whereas improved cook stoves and biogas plants are two options for decentralized cooking energy solutions in Nepal.*

This paper briefs some positive experience realized based on 19 years of experience in decentralized energy solution in Nepal. Nepal being a country of diversified geology, scattered households are not suitable for grid system for electrification. Decentralized option is only solution for the electrification of rural people. Micro/mini hydropower and PV systems are an effective complement to grid-based power, which is too costly for sparsely settled and remote areas. Potential of both the systems is enormous in the country (Practical Action, 2009) however rate of harnessing is too slow. The impacts of the program is seen in many fields like increased awareness, improved health & sanitation, increased income generation, increased literacy rate, decreased rate of deforestation, improved local integrity, improved access in information and communication.

Lesson learnt from past experiences, AEPC has focused in up scaling in terms of numbers, size, quality and investments in the decentralised energy solutions by accelerating the rate of renewable energy solution to rural people ensuring gender and social inclusion mainstreamed in policy, program and project level in a sustainable manner.

Key words- *electrification, decentralized, scattered, deforestation.*

1. Introduction

Providing an access of modern energy to rural people is a major challenge to all developing countries. One third 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 and meeting the national targets of modern energy access to rural people.

1.1 Situation

Looking into total annual energy consumption pattern of Nepal, majority is consumed by residential sector (89.1% out of 401 Million GJ of total national consumption), rest 10% is consumed in other sector i.e. transport 5.2%, industrial 3.3%, commercial 1.3% and other 1.1% (WECS, 2010). National fuel supply is dominated by the traditional fuel (77%: fuel wood, agricultural residue and agricultural waste) followed by commercial (20%: oil, coal, gas and grid electricity) and the rest from renewable (3%) (MoF, 2015). From this, it can be concluded that Nepal is in primitive stage of development due to negligible use of energy in industrial and commercial sector. In urban and semi-urban areas imported fossil fuel such as kerosene, LPG gas and grid-electricity are used for cooking purposes. Due to lack of transportation facility and poor economical condition[1](MoF, 2013) of rural people, these sources are out of reach for rural people. Extension of national grid is not economically feasible due to sparsely settlements and lack of possibilities of big industries in the area.

Due to lack of economic activities, socio-economic condition of rural people is very much poor (MoF, 2013). The livelihood of rural people is

[1] Per capita income US$ 717 and 3.56% GDP growth rate (Economic Survey, 2013)

based on agriculture, livestock and income from foreign labor. Thus, rural people can not 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. Providing affordable and sustainable energy access to rural people is a major challenge for the Government of Nepal.

1.2 Viable Option

Energy from hydropower and solar are the only two options for providing energy access to rural people.

Solar Photovoltaic (PV) is a suitable technology for fulfilling lighting demand and also to run small household appliances. Basically, solar PV having capacity $10W_P$, $20W_P$ and $50W_P$ are widely disseminated in rural parts of Nepal.

Hydropower having capacity up to 1000 kW is being promoted by AEPC for providing electricity for lighting as well as running micro/small and medium sized enterprises enhancing rural economic activities.

2. Energy Potential

Nepal has a huge hydropower potential having theoretical potential of 83,000 MW out of which only about 1 percentage is harnessed (NEA, 2015). Due to favourable geological conditions and abundant availability of streams and rives spreading all over the country, potential of off-grid as well as on-grid is high. Potential of micro-hydro power is considered about 100 MW though proper study has not been carried out to find out actual potential of micro and small hydropower.

Similarly, solar potential is also very high as mean solar irradiation is 4.7 kWh/m^2 with more than 300 days sunshine per year. Harnessing energy from solar in larger scale is not yet initiated though discussion is ongoing to generate electricity from solar in order to reduce load shedding. Recent

3. 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.

3.1 Hydropower Classification

Classification of hydropower technology varies country to country and continent to continent. In Nepalese context[2] (DoED, 2015) is classified as per the following way:

- **Pico-hydropower:** It is defined as schemes that generate electrical power upto 10 kW capacity which is then distributed to surrounding areas through a mini-grid.
- **Micro-hydropower:** It is defined as schemes that generate electrical power up to 100 kW but greater than 10 kW which is then distributed to surrounding areas through a mini-grid with an option to grid-connection.
- **Mini-hydropower:** It is defined as schemes that generate electrical power between 100 kW to 1,000 kW which is then distributed to surrounding areas through a mini-grid with an option to grid-connection.
- **Small-hydropower:** It is defined as schemes that generate electrical power up to 25 MW but greater than 1000 kW which is then connected to grid.
- **Medium-hydropower:** It is defined as schemes that generate electrical power up to 100 MW but greater than 25 MW which is then connected to grid.
- **Big-hydropower:** It is defined as schemes that generate electrical power greater than 100 MW which is then connected to grid.

3.2 Historical Development of Hydropower

Nepal has a long history in development of hydropower. Traditional water mills (Ghatta) that are used for agro-processing is considered indigenous technology, were in place since ancient time (THAPA, 2014).

Fig. 1 A typical Traditional Water Mill

The first hydropower was built in 1911 AD (1968 BS) by then Prime minister Mr. Chandra Shamser which is considered the second in Asia, by then

[2] DoED (Guideline and Procedures, http://doed.gov.np/license_procedure.php) and AEPC (Subsidy Policy and Subsidy Delivery Mechanism, 2013)

Prime minister Mr. Chandra Shamser Rana. The first micro-hydro having capacity 5 kW was established in Godavari as an end-use application for providing lighting to poultry (MATHEMA, 2013). So, it is said that the design and development of water turbines were initiated during 1960s. With support from United Mission to Nepal (UMN) and technical support from Germany, water turbines were designed and developed at Butwal Technical Institute (BTI) early 1980s. Similarly, with Swish support, turbines were designed and developed by Balaju Yantra Shala (SHRESTHA, 2012). These turbines were mainly used in agro-processing. Multi-Purpose Power-Units (MPPU) and add-on electrification were developed during 1980s which are the improved version of water mills.

Fig. 2 Improved Water Mill & Peltric set

Cross-flow, pelton and propellers ware also developed during 1980s from BTI and BYS which are the basis of established series of T12, T15 version of cross-flow and single and multi jet Pelton turbines widely disseminated nowadays.

Fig. 3 A typical cross-flow turbine

4. AEPC Achievements

Since establishment of Alternative Energy Promotion Centre, community electrification from micro/mini hydro is being a focus area. Different programmes supported by mainly the Danish Government, The Norwegian Government, UNDP and World Bank are continuously providing technical and financial support with the Government of Nepal for the development of Micro/Mini hydropower. Demand driven and public-private-partnership are the principles under which primarily community owned Micro/Mini hydro schemes are developed. The communities from rural areas not covered by national grid are the customers. Fig. 4 below, shows the completed micro/hydro projects (green dots) and grid-line extension (red lines) which illustrates the projects are distributed mainly in hilly areas. High hills and far remote areas are still the area to be focussed in future.

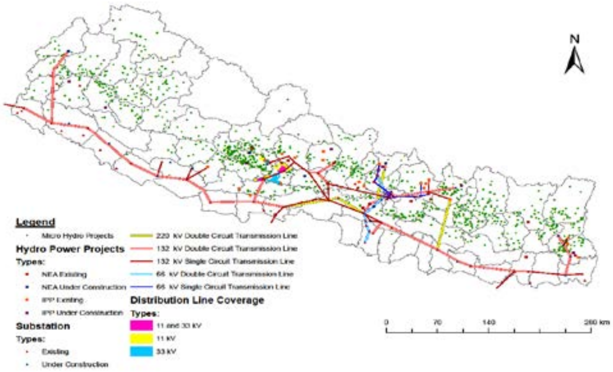

Fig. 4 Power (grid + off-grid) distribution of Nepal

About 42 MW is the installed capacity of Micro/Mini-hydro projects out of which about 26 MW is the contribution from AEPC. Similarly, about 9,000 numbers of Improved Water Mills (IWM) are developed throughout the country. Presently, about 650,000 rural households which is equivalent to 3.25 million peoples are benefited by hydropower technology including IWM. Current status of Micro/Mini hydro projects is illustrated in the following Table-I (AEPC, 2016).

TABLE I
PIPELINE OF PROJECTS (UNDER AEPC SUPPORT)

SN	**Status of Micro-Hydro**	**Nos.**	**Capacity (kW)**	**Beneficiary Households**	**Beneficiary Population**
1	Completed	1,500	27,874	350,000	1,750,000
2	Under construction	123	5,886	55,134	275,670
3	TRC Approved	262	8,863	55,134	275,670
4	DFS Completed	189	7,738	74,434	372,170
5	Preparation Completed	185	7168	56,573	282,865
	Total	**2,259**	**55,655**	**591,275**	2,956,375
	Status of IWM	**Nos.**		**Beneficiary Households**	**Beneficiary Population**
	IWM	9,000		270,000	1,350,000

Source: AEPC database (AEPC, 2016a)

Looking into growth trend of Micro/Mini hydro projects, increasing trend is seen after the establishment of AEPC. During full phase of programmes like Rural Energy Development Program (REDP), Energy Sector Assistant Program (ESAP) and Rural and Renewable Energy Programme (NRREP), the progress is steady whereas during bridging period, the trend is declined.

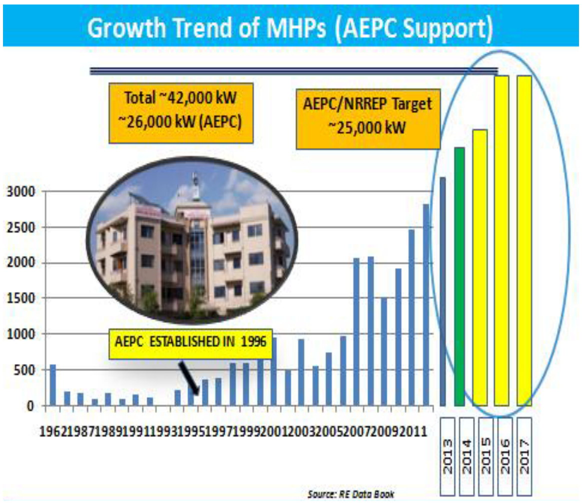

Fig. 5 MHP Growth Trend of Nepal

ESAP-Phase I phase period was 1999 to 2004 in which the growth trend is rising whereas in bridging period between ESAP-I Phase and ESAP-II Phase (2004-2007) the trend seems steady whereas it inclines after ESAP-II Phase.

AEPC's strategy is to develop isolated Micro/Mini hydro projects, then interconnecting them to make local-grid (mini-grid) in order to make it feasible to be connected in national grid when the grid is extended in the area of Micro/Mini hydro projects. Two local-grids are already completed-connecting seven MHPs in Baglung district and connecting two MHPs in Gulmi district. Interconnection of seven MHPs in Taplejung is underway.

Fig. 6 A typical Interconnection of MHPs-Taplejung Mini-Grid (Khoju, 2016)

Likewise, negotiation is ongoing with Nepal Electricity Authority (NEA) for grid-connection of MHPs as a result interconnection standard in in place. Recently, NEA board has decided to connect three MHPs developed by AEPC namely, Midim Khola MHP (100 kW), Lamjung, Leguwa Khola MHP (40 kW), Dhankuta and Syaure Bhumi MHP (23kW), Rasuwa. As soon as these MHPs are connected in national grid, door will open for other MHPs as well for grid connection when national grid approaches in the command area.

Other achievement of AEPC are establishment of Regional Centre of Excellence in Micro-Hydro (RCEMH) supported by USAID which is suitable for networking, coordination and exchange of knowledge in South-East and South Asia. AEPC has collaboration with Kathmandu University in establishment of Turbine Testing Lab and R&D activities. The lab has its 30 m natural head and also has 150 m closed head through two water pumps with 0.5 m^3 discharge. It can carry out prototype test up to 300 kW and model test is possible for larger sized turbines (Panthi, 2015). Similarly, it has collaboration with Institute of Engineering, Pulchowk for efficiency testing of IWM runner.

5. Implementation Modality

Demand driven and Public-Private-Partnership (PPP) are mainly two principles for the implementation of Micro/Mini hydro activities. A typical diagram of implementation modality is shown in Fig.7 below.

Users or the beneficiaries get product and services from private sectors fulfilling the demand through public sectors. Basically, designs/sizing, fabrication, supply, installation, testing & commissioning, after sales services and internal quality control are acquired through the private sectors. Information dissemination, capacity building, technical, financial and social facilitation support including coordination and assurance of quality is acquired from public sector. AEPC formulates policies, plans, develops standards, guidelines, manuals and implements accordingly in order to meet the demand of rural people by mobilising the resources from internal and external sources through the private sector and public sector as mentioned-above (AEPC, 2017).

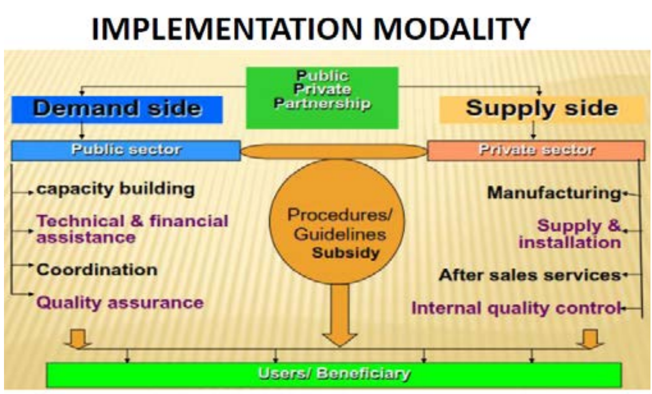

Fig. 7 Implementation Modality

Based on project cycle, support activities are categorised in nine steps as shown in Fig. 8. Depending on level of awareness of the users, demand creation activities used to be carried out during the initial stages but nowadays user are so aware that awareness campaign is not necessary. Users register the demand by filing standard demand form respective District Energy, Environment and Climate Chance Unit (DEECCU) or Regional Service Centre (RSC). They carry out the pre-feasibility study or the users may demand with pre-feasibility report carried out by consulting companies.

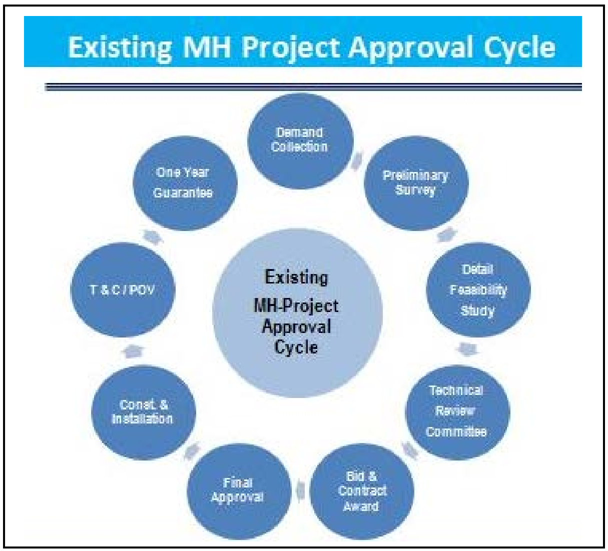

Fig. 8 A Micro/Mini Hydro project approval cycle

If pre-feasibility study is found feasible, detail feasibility study (DFS) is carried our by selecting consulting company in competitive basis. Partial cost of conducting DFS studies and preparing DFSR is provided by AEPC. If DFS is found feasible, it gets approval from Technical Review Committee (TRC) of AEPC. Then, conditional subsidy approval letter is issued to the developer with one year deadline for fulfilling the conditions for getting subsidy.

The developer manages the resources and selects installer / manufacturer company in competitive basis, fulfils the subsidy criteria and applies for final subsidy approval. After fulfilling subsidy criteria Central Renewable Energy Fund (CREF) approves the subsidy and releases final subsidy approval letter. Then, the construction and installation works starts. Generally, civil construction is carried out by the users under supervision of selected company and installation of elecro-mechanical equipments is done by the company.

After completion of construction/installation works, testing and commissioning is done by the company and developer in presence of AEPC/CESC representative. During warranty period (one year after the date of testing and commissioning), power output and household verification (PoHV) is done through independent consultant hired by Monitoring and Quality Assurance Unit (MQA) of AEPC.

After the completing of guarantee period, the company and developer carry out one-year guarantee check in presence of AEPC/CESC representative. Then after, the project is fully handed over to the developer.

The major institutes involved in the implementation of micro/ mini hydro project are shown in the Fig. 8. The roles and responsibilities are highlighted in the above sub-section.

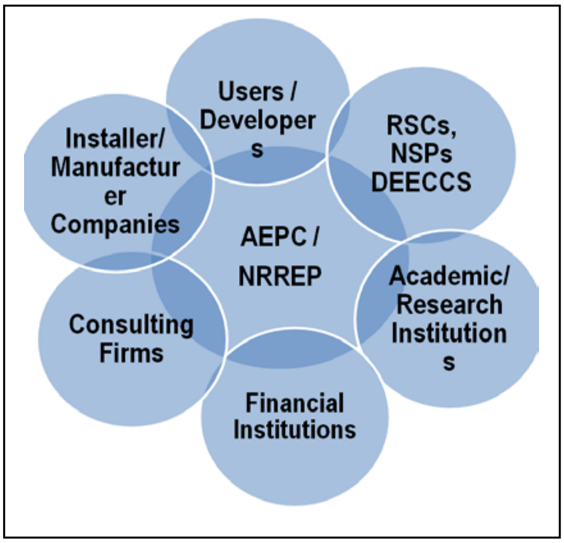

Fig. 9 Major institutions involved in development of MHP

6. Impacts

Impacts of decentralized energy option can be shown in the Fig.9 below. The major impact is providing access to modern energy to rural people which is the prime demand from the demand side and also one of the major objectives of the government. Besides, access to information and communication technologies, which gives an opportunity to acquire knowledge in modernization and easy access to information. Increase in education time due to availability of clean lighting solution for the rural people which enhances the quality of education and also carry out the rural economic activities. Literacy rate of children living in MHP command area has 2 percentages higher than non-electrified areas (Abhiyan, 2011). Significant respondents (80%) felt time had saved mainly from agro-processing which was used for income generation works (HCPL, 2006). Similarly, considerable participants responded that 50% time saved after electrification (AEPC/NRREP, 2017).

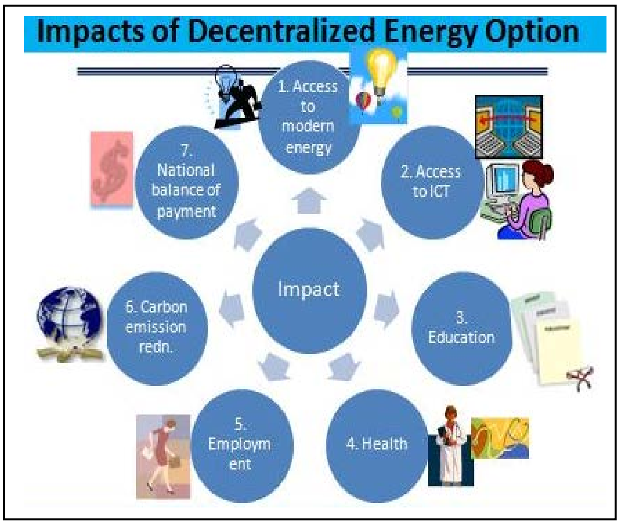

Fig. 10 Different impacts of decentralized energy option

Due to availability of energy, medical equipments available in rural health posts and smoke free lighting services enhance the health of rural people. Incidence of illness related to respiratory and eye irritation is reduced by 1.4 percentages in the electrified area (Abhiyan, 2011). More than a half respondent felt that improvement in their respiratory problems (HCPL, 2006). Nearly 10,000 employments are generated in different sectors like direct employment from the project, employment generated in private sectors, public sectors and increased electricity based micro/medium/small enterprises (MSMEs).

It has a positive impact in environment due to replacement of kerosene, diesel and dry cell battery. Monthly replacement of kerosene, diesel and dry cell battery is found to be 3.8 litres, 0.46 litres and 2.5 pairs per household (HCPL, 2006). Similarly, another study prevailed that monthly kerosene saving per household is 2.9 litres (Abhiyan, 2011). As all most all fossil fuels (diesel, petrol, kerosene, gas) are imported that cost more than half of national income in each year. By replacing such products, it helps in balance of national payment and also reduces the carbon emission. One Clean Development Mechanism (CDM) project is already registered for a bundle of 450 Micro-hydro projects which has already earned US$ 5,0000 from issued Certified Emission Reduction (CER) of 66,354 and shall be issued another 27,092 by end of March 2016. Other CDM project for for improved water mill is registered and under process of approval (Pokharel, 2015).

7. Sustainability of Decentralized Energy Option

Projects are considered sustainable if it is technically sound, environmentally friendly, economically viable and socially acceptable. Looking into the case of Micro/Mini hydro projects, mostly design, fabrication, installation, after sales services are available within the country satisfying the technical criteria. Negligible items like generators and few valves are imported though their repair and maintenance know-how is available within the country. One of the studies reported that majority of the micro-hydro projects (86%) are functioning more than 310 days in a year (SETM, 2014) which shows reliability of MHP is very high as the projects are designed for operation of 300 days in a year.

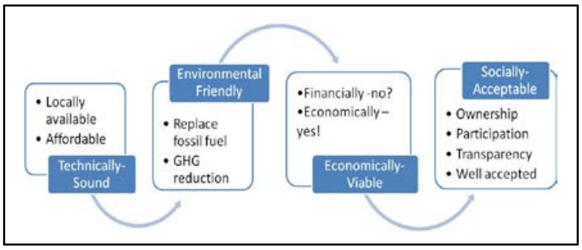

Fig. 11 Sustainability of Micro/Mini hydro projects

It has positive impact on the environment that are mentioned under Section-7. It has negligible impact in landslide in canal area and has no impact on downstream flora and fauna (Abhiyan, 2011) and (HCPL, 2006). Considering the financial viability, very negligible MHPs (1/5th MHP feasible) are found feasible (HCPL, 2006). So, Government of Nepal is providing subsidy on investment in order to make MHPs financially feasible. Considering the economical feasibility, all most all MHPs are feasible as it has versatile aspects of benefits comparing with alternative means.

Considering social acceptability, it is well accepted by the users due to sufficient energy availability not only for lighting but also running MSME in the rural area. Due to ownership on the users, participation in all decision making processes, high level of transparency is maintained amongst the users as a result it is well accepted technology. More than two third (68%) of the users were found satisfied from electricity services from MHPs (SETM, 2014) showing level of acceptance. 50% of women workload was reduced after electrification in the command area (AEPC/NRREP, 2017).

8. Way Forwards

From two decades of experience, AEPC is now focusing on up scaling the sector in terms size, number, investment, service of Micro/Mini hydropower sector by enhancing the quality in the same time to make it compatible to national grid. Grid connection and interconnection issue is still in primitive stages therefore AEPC is focusing on formulation of relevant policies, procedures and enhancing the quality of MHPs, which shall be compatible to grid connection and interconnection.

Mainstreaming the cross-cutting issues like mainstreaming gender and social inclusion in all level of implementation processes is another focus area. Similarly, enhancing economic use of electricity and collecting revenue from climate and carbon trade is other area that AEPC is focusing at the moment and will continue in the future as well. Up scaling technology in terms of size, investment, quality, service delivery is another focus area. Refining service in line with federal concept as per recently prolonged constitution of the country is another challenging area to be addressed in close collaboration with local units.

9. Conclusions

In conclusion, decentralised energy option is a reliable option for the developing countries like Nepal. Two decades of experience of AEPC in the formulation of policies, plans, standards, guidelines, manuals and proper mobilisation of resources, public and private sectors for the development of decentralised Micro/Mini-hydro projects is now acknowledged from establishment of Regional Centre of Excellence in Micro-Hydro (RCEMH) supported by USAID.

Users' participation, ownership and acceptance are the key for the sustainability of MHPs that satisfies not only transparency but ensures continuous operation of the projects.

AEPC still needs to focus on formulating suitable policies, plans, standards and procedures in grid connection and interconnection. Mainstreaming the gender and social inclusion, enhancing economic use of electricity and addressing climate and carbon is other area that needs continuous focus in the implementation of off-grid energy sectors which ultimately ensures the sustainability of the projects in a long run.

Rehabilitation of damaged projects affected by natural calamities including earthquake, landslide, flood etc is another challenge.

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11. References

[1] Abhiyan, S. (2011). *Impact of Mini Grid Electrification.* AEPC.Nepal
[2] AEPC. (2016a). *Database*. Lalitpur. Nepal
[3] AEPC (2016b). Renewabele Energy Subsidy Policy
[4] AEPC (2017. September 18). Retrived from www.aepc.gov.np
[5] AEPC/NRREP. (2017). *Impact Study of Community Electrification.* Lalitpur.
[6] AEPC/NRREP. (2012). NRREP Program Document. Nepal
[7] DoED. (2015, December 30). Retrived from www.doed.gov.np.
[8] ESHA (2004). Guide on How to Develope a Small Hydropower Plant
[9] H. Harvey (1993). Micro-Hydro Design Manual-A Guide for Small-Scale Water Power Scheme
[10] HCPL. (2006). *Impact Study with Consumer Satisfaction Survey of Micro-hydro Power Projects in Nepal.* Kathmandu: AEPC.
[11] Khoju, J. (2016, January). *Taplejung Mini-Grid*. Kathmandu.
[12] Mathema, S. (2013). *Role of Private Sector*. Kathmandu, Bagmati, Nepal.
[13] MoF. (2013). *Economic Survey*. GoN.
[14] MoF. (2015). *Economic Survey*. GoN.
[15] NEA. (2015). *Annual Progress Report.* NEA, MoEn, GoN.
[16] Panthi, A. (2015). *Country Presentation in Small Hydro Training. Hanzau, China*.
[17] Pokharel, P. (2016, February 21). Program Officer. (Self, Interviewer)
[18] Practical Action, N. (2009). *Study to Determine Outline Plans for Eliminating Energy Poverty in Nepal.*
[19] SETM. (2014). *Study on Performance of REDP/RERL Supported Community Managed Micro Hydropower Projects.* AEPC/RERL.
[20] Shrestha, R. (2012). *Lecture Note of IOE, Pulchowk*.
[21] Thapa, R. (2014). Role of Stakeholders in the Development of Renewable Energy Technologies in Nepal". *Urja Awaj, Year 2, Volume 3* , 40-41.
[22] WECS. (2010). *Energy Sector Synopsis Report.* Kathmandu, Nepal: GoN