

## Micro Hydropower: An Adaptive Technology in the Changing Context, a Case Study from Trans Himalayan District of Mustang, Nepal

Anju Pandit\*

DAI- USAID-PANI Program, India

### Abstract

Situated at an altitude of about 3,000 meters above sea level, Trans Himalayan district of Mustang categorized as water deficit arid desert has growing demand for electricity just like in rest of Nepal. As access to grid has become a major development agenda, National grid is penetrating remote districts like Mustang. In the face of grid expansion, the Micro Hydro systems installed 20-30 years to lighten the villages could be at risk of being nonfunctional if proper energy planning is not done. The study was conducted in the villages in phase of grid connection and having micro hydro commissioned 20-30 years ago. This study assesses the community perception on extending grid and their perception on preexisting micro hydro. The paper illustrates the role of MHP in the changing context of emerging renewable energy technologies and expansion of grid penetration across the Himalayas. Underscoring the relevance of local resource utilization and energy source diversification paper highlight the needs for proper planning of energy mix for promoting sustainable energy supply.

**Keywords:** Mustang; Energy mix; Diversification; Adaptation

### Introduction

Energy is backbone to modern society, where almost every sectors agriculture, health, transportation education and industry relies on it. Reliable and efficient energy services underpin the expansion of economic and employment opportunities, the continuing progress in social development, and the sustained improvement in standards of living. The development of industrial, agricultural production and people's standard of living are directly or indirectly related to increase energy consumption [1]. Access to electricity is vital for achieving the Millennium Development Goals (MDGs) aimed at alleviating poverty [2,3] and rural electrification presents a significant challenge in many developing countries [4-6].

Bestowed with 6,000 rivers, rivulets and tributaries within the small territory and accounting to almost 2.27% of the world water resources, Nepal has about 45,610 MW of economic feasibility for hydropower production. Extending grid across the rural landscape has been a priority development agenda. However, government has only been able to tap 731.92 MW [7] of the potential and provide electricity to 46% of the population, through grid electricity. Given the need for power co-existing with physical challenges to grid expansion, micro hydro technology, have been electrifying isolated villages through off-grid electrification since last four decade.

Micro hydro is a type of hydroelectric power that typically produces from 5 kW to 100 kW of electricity using the natural flow of water. The use of hydro power for milling purpose has existed in Nepal for immemorial times. However, government initiated development of modern micro hydro for electricity generation initiated just four decades ago [8]. Nepal has successfully generated approximately 28 MW of electricity and electrified more than 200,000 households in mountain [9]. These micro hydros have made great contribution in electrifying almost 10% of national population through off-grid electrification of isolated localities in absence of central line [10]. Nepal's adoption of micro hydro as renewable and decentralized energy system in rural landscape thus was also mentioned in the 2002 sustainable development report and was a model in the region.

Promotion of Micro- hydro in the mountains is regarded as a

sustainable mountain development agenda and lately also be regarded as one of the adaptation and mitigation strategies for communities to unlock opportunities for low carbon and climate resilient development. Over the last decades there has been a growing realization in developing countries that micro-hydropower schemes have an important role to play in the economic development of remote rural areas, specifically in mountainous regions. The electricity generation through micro-hydro plants has catered rural electrification need of remote mountain villages without national grid. MHPs were promoted in areas without grid, as an alternative energy sources, but now the grid has expanded and therefore the role of MHPs in this new context must be articulated.

Highlighting the implementation and importance of Micro hydroelectricity in the rural communities [11-13], number of studies conducted in region have revealed various (limitation in economic, water availability, environmental, institutional and financial resources) constraints to development [14-17] and struggle for existence of the micro-hydroelectric power plants [18]. However in the bulk of literatures, the state of Micro Hydro serving rural mountain communities in the changing circumstances (water availability, socio-economic, development changes and diversifying energy sources) is still crucial question to be answered. To aim for sustainable energy for the mountains and enhance energy security for the future, it is important to revise the role of local micro hydro plants in the changing scenario. Hence this study tried to better understand community perception and prospects of isolated MHP (commissioned 15-20 years ago) in the changing context and energy diversification perspective by undertaking a case study in Mustang district of Nepal.

\*Corresponding author: Anju Pandit, DAI- USAID-PANI Program, India, Tel: 977-9841016413; E-mail: [anjupandit16@yahoo.com](mailto:anjupandit16@yahoo.com)

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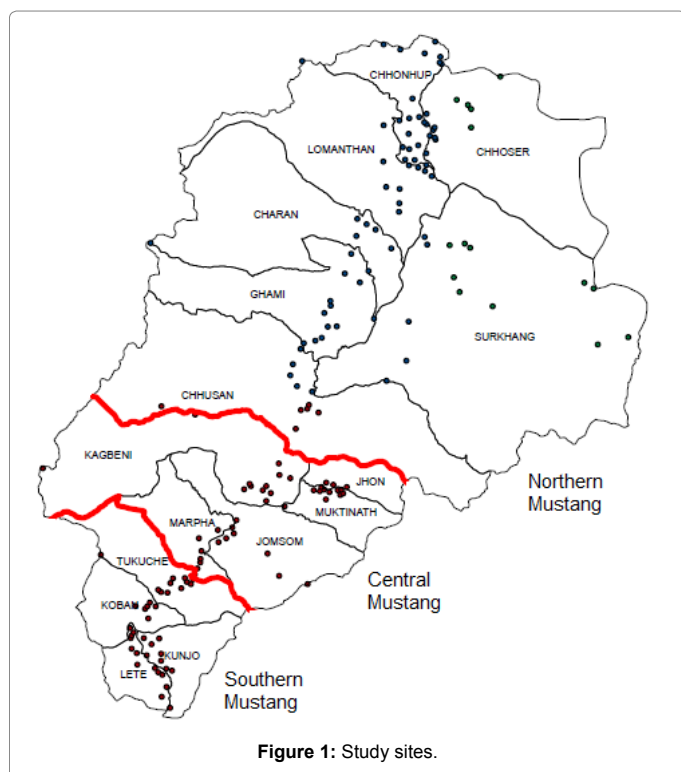
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## Methodology

The secondary data were collected from related institutions like alternative Energy Promotion Center (AEPC), Nepal electricity Authority (NEA), related journals, Central Bureau of Statistic (CBS) and relevant publications. Transect walk, observation, photographic evidence community interaction and FGD were used for primary data collection. Questionnaire check lists was typically used for feedback research to determine the current situation. Field observation was triangulated against the villager’s perspective. The questionnaire checklist was set as guide for collecting the required information. For further information key informant interview was also conducted with operators and ACAP officials. Field visit was conducted in the month of September 2015.

## Study Area

This study was carried out in Gandak River basin contributing to almost 41% of total energy production through micro hydro plants in Nepal. Among 19 districts in basin, Mustang, one of the highly impacted and vulnerable districts in terms of climate change, was chosen for the study. It is situated in the trans-Himalayan region of the country at an altitude of about 3000 meters. It has very low population density. Mustang district shows a high decreasing trend of maximum temperature [17] and is one of the highly impacted and vulnerable districts in terms of climate change. Annual average precipitation is about 300 mm at the lower elevation and most of which falls as snow. The river tributaries are entirely originated in mountain and fed by glaciers. Accordingly all the Micro and mini hydro operating in district have sources in glaciers and mountains. Among total 14 micro hydro installed to date three micro hydro projects commissioned approximately in same time frame (20 years prior to fieldwork) but situated in different state of energy source diversification were studied (Figure 1).



## Findings

### Energy scenario of Mustang district

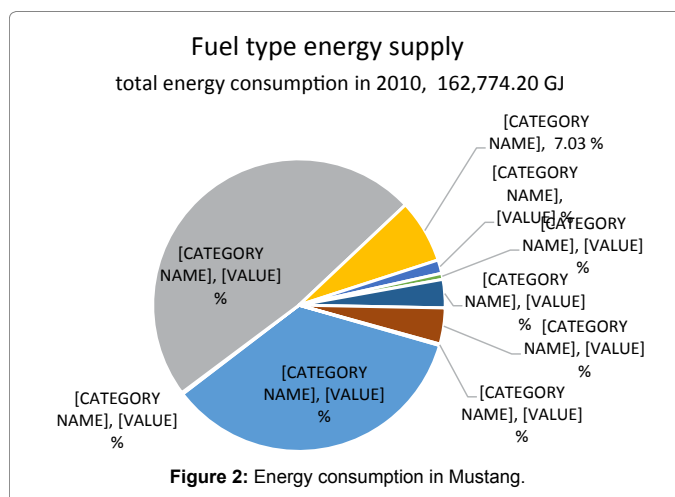
Situated at an altitude of about 3,000 meters above sea level, Mustang is one of the most popular trekking destinations in Nepal. The Kaligandaki River with about 137 rivers and rivulets, is the major river of Mustang. The district has hydropower potential of about 1,500 MW, out of which only 451 kW has been tapped so far [19]. Total energy consumption of Mustang is estimated at 162,771.20 GJ, which accounts for 0.04% of overall national energy consumption 401 million GJ [20].

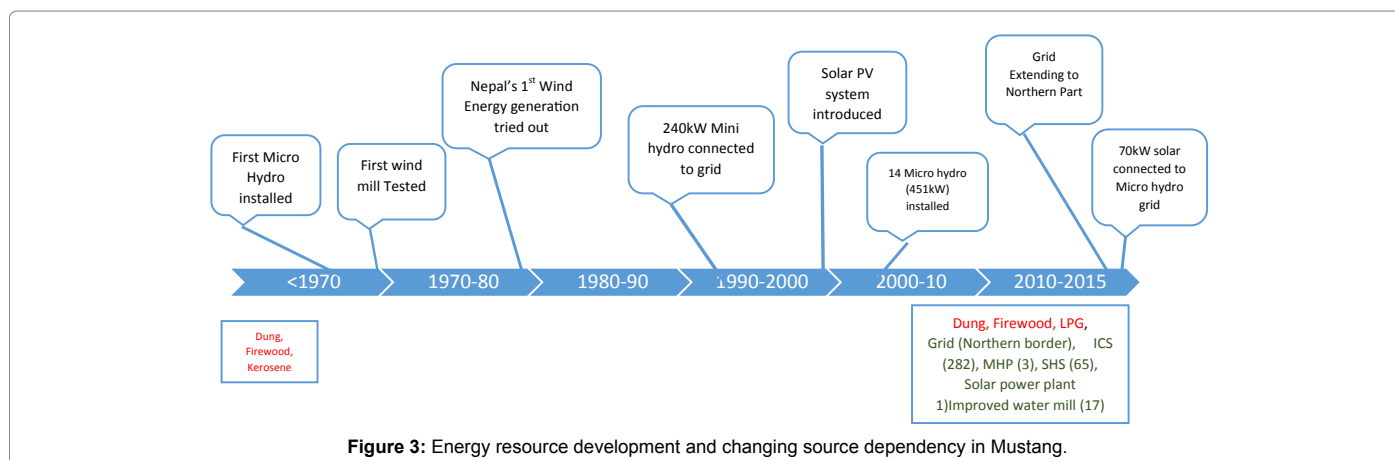
On supply side, animal dung provides almost 48.2% of the energy consumed, followed by fuelwood 35.2% whereas commercial sources supply only 16.35% (Figure 2). Among the sources renewable energy sources including electricity and solar contribute less than 5% of the total share.

Sector wise consumption revealed residential sector consumes 66.7% of the total energy, the largest share of energy, followed by Commercial sector consuming 29.48% and transport sector drawing only 3.80 [20]. The energy demand for cooking and heating in hotels and lodges in the district is exceedingly high and soaring rapidly. Given the business as usual scenario, without any intervention, the energy demand of Mustang is expected to increase up to 182,726 GJ by 2020 [20].

Even though the physical infrastructure of the national grid has been extended up to the border of Lomanthang VDC electricity is barely being accessed by communities in northern Mustang. In terms of energy access from the grid, almost sixty percent HHs in Mustang have grid connection since 1994, about 96.5 MWh energy per annum is consumed by the district through the grid however in upper Mustang almost nine percent of households in the district are making use of electricity from local MHPs.

Even though kerosene remained a prominent commercial energy used to illuminate and dung, firewood for cooking purposes in mustang until late 70s. Observing the energy shift timeline of Mustang district (Figure 3) it is evident that even being located in the Trans Himalayan region, almost all possible renewable energy technologies are being tried out over there. Currently, almost 90 percent population has access to electricity either, grid, micro hydro or solar.





### Micro-Hydropower in Mustang

Initiatives on small scale energy installations have a long history in Mustang. Initiation of first hydropower project in Ghatte Khola with installed capacity of 10 kW, in the year 1979, kicked off the MHP development in Mustang. Motivated by the initiation more than eight MHP have been constructed by community involvement during 1980s (Table 1). Main reasons for MHP development in Mustang are demand of residence, formation of clustered locality, lack of national grid and access to resources. Among all the MHPs constructed so far, MHPs in Upper Mustang including Lomantlang, Charang and Marang devoid of national grid electricity have community managed micro-hydro operating in full swing, whereas rest in the areas with grid electricity the MHP operation has halted and their sole dependency now is on grid electricity.

Among all three MHP were sampled for the study purpose (Table 2). All the projects were independently managed and operated within the community and with same type of management model (community group based). None of the projects in the study area required external financial assistance to meet their running costs but had shown progressive changes in terms of energy source diversification.

### Micro Hydro Complemented by Solar Home system

Charang VDC is a rural settlement with 112 households, with no access to grid electricity. Till Micro hydro plant has been installed in village, lighting was totally relied on Kerosene lamps (tuki and Laltin). However in 1989 16 kW run-off-river micro hydro plant was installed with active community participation in 1989 in Charang VDC of Mustang district. Micro-hydro in Charang VDC is meeting the need of reliable energy source for 55 households to address their major economic and environmental challenges. It was installed with 25% subsidy from government side and 75% amount arrangement as loan from Agriculture Development bank. The micro hydro was installed with motive of electrifying the isolated rural mountain setting with 55 households. In order to address the increasing electricity need, the capacity of the system was enhanced locally (doing canal improvement, pole arresting line improvement and wire capacity increment). After upgrading, the system is able to supply enough electricity for lighting purpose to almost two fold of the initial estimation.

The micro-hydro in Charang VDC is a climate resilient practice, which made best use of water resources to generate electricity for the communities. The micro-hydro completely replaced the kerosene

use and thus contributed in mitigation. The use of micro-hydro has saved their money otherwise spent to buy expensive kerosene. Most importantly it has helped to reduce the negative impact of kerosene burning to the environment and in the health of children, women and elderly. The women households expressed that the expenses of kerosene now can be utilized for productive use such as in children education and buying warm clothing for winter. It was also evident that in some of the households, the use of electric cooking appliances has decreased their dependency on traditional fuel sources like dung and firewood.

There are other socio-economic benefits of it as it contributed in enhancing children’s education, promoting rural tourism and enhancing local livelihoods. The access to electricity has allowed the children in the community to study comfortably at night, women to come out from the boundary of kitchen and men to be engaged in income generation activities. The present diversification of energy source (Solar home system supplementing micro hydroelectricity) has also become an important means to empower women and support in livelihood upliftment.

The villagers use solar home systems to supplement the increasing power need especially during winter when the water freezes in canal. They have used the energy source for lighting and household purposes. Besides, it has also helped in flourishing local business like small furniture factory, flourmills, grinding mills and local shops. With changing demographic and weather variability, community is responsive in terms of energy diversification and use. Similarly in the present scenario of electricity crisis, even the people in capital city are living in darkness, people in Charang, one of the remote isolated villages in Mustang, are enjoying an uninterrupted source of electricity throughout year. Having reliable local sources of electricity, community have their own plans to increase the capacity of existing MHP and thus Extending grid is perceived as an opportunity to expand the energy mix rather than threat.

### Hydro-Solar Energy Mix

Micro-hydro plant of 29 kW capacity was installed in Lo-Manthang VDC in the year 1989 with assistance from ACAP. No different than Charang, the village electrification committee takes overall responsibility of water management and micro hydro operation. Since its installation Micro hydro has been serving almost 190 HH in the locality. Water is the major limiting factor for subsistence agriculture in the semi-arid land of Lo-Manthang but guided by well-organized water sharing setup clarified within village electrification committee,

S.N	Name of the project	Capacity (kW)	VDC	Source	Served settlement	Status	Remarks
1	Chhonup, MHP	15	Chhonup	Nyamdo khola	Nyamdo, Nhichung	-	1989
2	Choser MHP	10	Chhosar	Yara khola	Arka, Sisa, Bharcha	-	1986
3	Lomanthang MHP	29	Lomanthang	Kimiling khola	Durang, Namara, Dhikha	Running	1989
4	Charang MHP	16	Charang	Charang khola	Charang	Running	1989
5	Maran MHP	25	Charang	Marang khola	Saukre	Running	2001
6	Chhusan MHP	15	Chhusang	Narsin khola	Tetang	-	2003
7	Tangbe MHP	10	Chhusang	-	Tangbe	-	1986
8	Jhon MHP	15	Jhong	jhon khola	Jhong	Dysfunctional	1989
9	Muktinath MHP	25	Muktinath	Muktinath khola	Purang, Gumba	Dysfunctional	1991
10	RP serchan MHP	10	Kobang	Ghatte khola	Naurikot	Dysfunctional	1979
11	Koban MHP	10	Kobang	Larkyu khola	Larjung	Dysfunctional	-
12	Srot San Ayojana MHP	7	Kunjo	Panpu khola	Sari, Chuachu	Dysfunctional	1984

**Table 1:** Micro Hydro plant status in Mustang.

MHP	Lo-Manthang	Charang	Muktinath
Capacity	29 kW	22 kW	25 kW
Year commissioned	1989	1989	1991
No. Costumers	190 Households	112 Households	62 Households
Ownership	Community	Community	Community
Management	Village Electrification Committee	Village Electrification Committee	Village Electrification Committee
Technical operation	Experienced operator	Trained operator	Local employees
% Operation cost paid by users	100%	100%	100%
Status	Running	Running	Halted
MHP use	Lighting, mobile charging, Morning and evening time	Lighting, heater, charging mobile, radio, Agro processing. 10 h per day	NA
Solar plant use	Furniture factory, cooking and heating appliances, agro processing Television, Laptop, computer. Round the clock		
Energy mix	MHP-Solar Plant	MHP-SHS	Grid- few SHS
Community perception for MHP	Satisfied	Very-satisfied	Want to revive MHP
Perception to grid electricity	Still many years to go	Ready to welcome grid	Grid is not total solution
Future perspective	MHP-Solar-Grid	MHP-SHS-Grid	Grid-SHS-MHP

**Table 2:** Different aspects of studied Micro Hydro.

no conflicts have been noted since its commencement. In order to fulfill primary need for irrigation, electricity production has been limited for 3-4 hours during evening and morning time. Similarly 3 months of frozen water in spring during winter is like natural limitation for electricity production in the area. As an electricity production was limited to 3-4 hours during evening/morning time in a day and 9 months in a year, community were facing problem in addressing their local energy need.

Lo-Manthang being famous tourist destination with limited electricity supply, community members were not able to meet the optimum electricity need round the clock. To end this electricity drudgery, solar power plant of capacity 70 kW installed in village with aid from Chinese Government. The community has greatly benefited from the dual affordable electricity. After Solar power station installation since September, 2015, just 30% of total electricity produced has facilitated the households to enjoy round a clock electricity from solar -micro hydro dual system. Mechanical agro processing aided by continuous electricity supply has saved labor and time investment required otherwise. In the scenario of high migration

rate existing in remote localities reduced labor dependency has opened doors for opportunity for local households. Each households having access to electric cooking and heating appliances, is expected to reduce dependency on traditional biomass and make their life comfortable especially during the winter season.

With 70% of presently unused electricity from solar and 29 kW of electricity from micro hydro plant communities are now motivated to develop energy utilization plan in near future. Equally, increased access to modern cooking (like mixture, grinder, toaster, oven, coffee machine), heating (electric heater, water heater, water boiler) appliances and means of communication (television, mobile, internet) offered by dual system is expected to uplift the quality of service to the tourists and benefit to locals which was out of reach through isolated micro hydro operation in the area. Community perceives the hydro-solar energy mix as the source for sustainable tourism and step for economic development. Fulfilling the local needs and opening doors for economic prosperity, dual system operation of solar plant and MHP has revealed hope for energy security through path of energy resource diversification.



## Micro Hydro Planning for System Revival

The Muktinath Micro Hydro located at Purang VDC was commissioned over a community initiation in the year 1989. It had been efficiently serving 62 households in the locality till the grid expansion took place in year 2005 and few years ahead. Even after grid operation, the MHP has been operating well, the electricity from micro hydro was supplied free of cost to local monastery and marginalized household to meet their electricity need. Likewise the electricity had also been supplementing the local electricity need during power cuts in the national grid. However easy access to grid electricity eventually brought about declined community attention towards the local electricity source and finally Muktinath micro hydro came into halt in the year 2013.

Since then, after facing hours of darkness and comparing the utility of Micro hydro in the changing local context, villagers opted to revive the Micro hydro in near future. Furthermore, villagers requesting for technical assistance rather than economic support is reiterating their willingness on reviving the system. Referring to the huge investment made in past along with community sentiments attached with the system, community has acknowledged the role of micro hydro as a local adaptive technology to fight the increasing electricity crisis. Having experience of over 20 years of Micro Hydro electricity consumption, almost 8 years of dual source use and 2 years of sole dependency on national grid, community strained on need of electricity source diversification.

## Local Perception to MHP: Reflection from Ground

Providing significant support to the isolated localities devoid of grid electricity, Micro Hydro plants in Mustang have been contributing a lot for socio economic development. Locals reported of drastically declined dependency on kerosene for lighting purpose after MHP introduction. By lighting up dark evenings, children in the villages got opportunity to read comfortably, evening household jobs have been much easier and villagers can even think about utilizing their leisure time in productive way. Similarly, women also felt empowered by utilizing the leisure time in socio-economic activities which used to be spent doing household works otherwise. In addition to these direct impacts, community reported of greatly benefitting from local Micro Hydro plants with associated effects on sanitation, health, and agro processing, agriculture and social involvement. Diversified use of electricity in these isolated localities has not only brightened their house and community but as a whole they felt being enlightened eternally.

Apart from the huge benefits communities also reported of technical/ economic constrain, and weather adversity as the limitations faced. The frozen water has been limitation for producing winter electricity and drinking water. Till date this limitation has been tackled with the aid of individual solar home systems installed in almost all households. Increasing natural hazards like landslide, flashfloods are the climate related hazards communities are facing. These disasters are supposed to increase the overall repair and maintenance cost ever year and thus require more financial resources for MHP management. Despite some of these minor challenges, the micro hydro technology has been successful climate resilient practices in Nepal. The two-decade long experience of community in Mustang, in modifying and upgrading the system to suit their need and address climate change stresses, is a good learning to other parts of Nepal.

## Results and Discussion

Given the distances and topography involved in construction and

the greater operational costs involved in distributing electricity in rural areas is not an easy task. Further backed up with generation capacity shortages resulting in frequent black-outs (up to 14-16 hours a day) or 'brownouts (voltage drop), extending the national grid to rural areas is not always the most effective or cost efficient way to alleviate poverty in developing countries [21]. In such case using locally available renewable energy sources, to increase access to electricity is the synergetic strategies of contributing in poverty reduction and improving community resilience against climate change without limiting opportunities for human and economic development [21].

The demand for electricity is ever increasing with modernization. The energy mix and state of diversification is evolving as concept for sustainability, to achieve the drive for cleaner renewable energy sources [22]. Correspondingly, case from Mustang indicates that initiated with the concept of standalone systems far away from grid, micro hydro now are emerging as opportunities for energy source diversification. The new source of electricity solar or national grid are extending to these localities. However community's preference for micro hydro has not gone down. Community interest on reviving even the dysfunctional MHP has shown community attachment to local micro hydro and preference for energy mix rather than sole dependency on one form.

Communities in Mustang are also trying to make optimum use of available resources without compromising the ability of preexisting system. They are using solar PV, SHS, Micro hydro and hydropower as energy mix. These sources have been optimal means for extending electricity provision and achieving sustainable development in the remote localities [21] like Mustang. Even though, off-grid renewable energy solutions PV technologies [23-26] have been criticized for cost and use diversification options, for remote localities with rural population. Nevertheless their role in rural electrification, utilizing local energy sources and expanding energy mix cannot be denied.

Sole dependency on one source could have chance of greater threat of supply vulnerability [27]. Whereas spread dependency on varied sources translates into improved resilience of local communities to external shocks like climate change [28]. Correspondingly communities in Mustang are diversifying their energy dependency. As a result rather than having tradeoff between the electricity sources, communities are taking local micro hydro as backup systems to supplement their energy need. The energy diversification and modification in local system is expected to increase community resilience against climate change. The energy security in fact helps in generating adaptation and mitigation co-benefits.

Interconnection of a diverse range of renewable energy technologies is thought to improve energy security. It is also important point, as substantial poverty reduction can only be achieved if a wide range of sources and uses of electricity are established. Therefore ensuring diversified energy mix integration into off-grid renewable energy system allow a developing country to leapfrog towards a more advanced electricity system that will be more reliable, environmentally benign and responsive to local needs [29,30]. The diversified energy mix choice of community in Mustang is thus expected to increase their adaptive capacity to weather related shocks. Moreover, improving energy security and local resilience, diversified use of renewable energy technologies can lead mountain communities in the path of sustainable development.

## Conclusion

The micro hydro as decentralized energy systems has provided vital energy for pushing sustainable mountain development agenda

since last four decades. Today in the changing circumstances, of wider penetration of national grid and solar power systems becoming more affordable than a decade ago, micro hydropower are now finding itself admits other technologies such as national grid and solar. In some instances, micro hydro powers are regarded as obsolete and as a result communities have stopped maintaining them and consequently many have become dysfunctional. As the country is reeling under acute electricity shortage, quality and quantity of electricity supply from the grid has become very unreliable. In the changing context of energy use and rural electrification, where many of these micro hydro in country are struggling for existence, following the example of Mustang shows that carefully identifying their resources and choosing appropriate energy mix, will reinvent the utility of MHPs again. Using MHPs together with grid and solar power systems will be the future of MHP in the changing context and this will be the key to harnessing the energy security of mountain communities in the future.

The number of innovative energy source combination tried out by the communities is expected to help them to adapt to the changing situation. This paper presents the location specific adjustment tried out by community in Mustang. Even though communities have shown their preference for operating MHP, they need to be guided and supported by suitable energy mix. Communities and local level planning must be trained to identify energy mix options and potentials and how to plan so that their energy security needs can be better met in the future.

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