IMPROVING LIVELIHOOD OF RURAL MOUNTAIN PEOPLE THROUGH PROMOTION OF PICO-HYDRO TECHNOLOGIES: A CASE OF NEPAL

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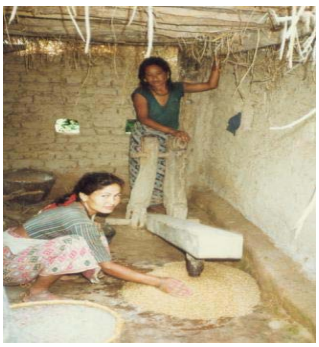
1. BACKGROUND

Nepal is a country with enormous water resources. It is estimated that the rivers flowing from Nepal contribute about 71% of the dry season flow and 41% of the total annual average flow of the Ganges. The annual average run-off within the Nepalese territory is estimated at 174 billion cubic meters. The change in elevation from the high Himalayas in the North to the plains in the South over a short width of 150 to 230 km generates substantial hydraulic head for development of hydropower. Nepal's hydropower potential has been estimated at 83,000 MW based on average river flow (Shrestha, H.M., 1966). The total potential in terms of installed capacity and annual energy of these identified projects are respectively 43,000 MW and 180,000GWh. Hydropower utilization is currently about 1.3% of the proven potential. The total installed electricity generation is about 613.5 MW out of which hydroelectric generation capacity is around 557 MW. Of this total generation of electricity, 603 MW are hooked to the national grid, As of mid-July 2007(Mini-Grid Year Book of Nepal, 2007) about 40 mini hydro plants (100-1000KW), about 651 micro-hydro (5-100KW) and about 1206 pico-hydro sets (up to 5 KW) serving remote areas of the country particularly in hill and mountain. The energy generated is utilized mainly by the urban population through central grid connection. Due to the difficult and mountainous terrains, national grid electricity has not reached to the majority of needy rural population. Thus they are left far behind from such centralized energy development efforts. Their energy requirements, mainly for cooking, heating and drying, are met from traditional sources such as fuel wood and other biomass resources. Energy requirements for lighting, agro-processing and other small scale industrial activities are also met through following traditional options:

1. Week lamp, locally called **"Kerosene Tuki"** for lighting**,**

2. Hand operated stone grinder locally called **"Jnato"** and traditional water mill locally called**"Ghatta"** for cereal grinding,

3. Hand and foot operated ponder locally called **"Dhiki**" for paddy hulling,



4. Manually operated oil press locally called **"Kol**" for extracting oil seeds

For this rural families spend enormous time and efforts mainly by women or they visit long distance to get their agro-products processed in **diesel mills.** Such a practice is neither efficient and productive nor desirable from environmental considerations as well as social justification. Therefore there is a need to develop alternative strategies to improve the traditional energy system by introducing alternative and decentralized renewable energy supply systems that are both appropriate and affordable for the people of hill and mountain of Nepal.

Micro-hydro and Pico-hydro are two such hydro-based improved technology systems that has potential for improvement with scope for local innovations that have been gaining momentum in the country. Up to 100 kW, it is considered as Micro-hydro while up to 5 kW it is considered as Pico-hydro. As compared to Micro-hydro, installation of Pico-hydro is much more suitable and affordable by the rural community due to it's comparatively low investment, disturbs little to local setting and can easily be operated and managed by local community. Peltric (small pelton turbine coupled with generator) and Improved Water Mill are two such twin and complementary Pico-hydro technologies that have been quite popular in Nepal, especially among the rural population in mountain. Generation of energy from Improved Water Mill is achieved mainly through the improvement of existing traditional water mills by replacing wooden parts with metal parts, to produce increased power, by more than 100 %, not only to operate mechanical appliances such as cereal (maize, wheat, millet etc.) grinder, paddy huller, oil expeller, saw mill etc. but also to produce electricity by coupling it with electric generator.

Peltric, on the other hand, is an in-built compact system where a Pelton Turbine is coupled with induction generator to produce electricity for households and community uses. Both these Pico-hydro technologies are site specific. Peltric system runs with high head and low water flow while Improved Water Mill runs with low head and high water flow.

Recently CRT/N has initiated a project on "Meeting Energy Need of Rural People of high hill for Household Lighting through Development and Promotion of Motor Dynamo Based Family Hydro (MDFH) in Nepal" with support from Lemelson Foundation, USA with a concept of generating electrical power of 60-100 Watt, on using a 12 V motor cycle/car dynamo, as a generator, a small pelton wheel runner as turbine and with discharge and vertical head of 1-2 liter per second and 20-30 meters respectively. The generated power can be used for lighting about 10- compact fluorescent lamps of 6-10 Watts each.

A number of organizations including government, donors, and non-government as well as private bodies have been involved in the promotion and dissemination of Pico-hydro technologies in Nepal since more

than a decade ago. By the middle of 2007, the country has about 1206 Peltrics supplying decentralized energy services mainly electricity facilities to the rural population of hill and mountain areas. The power output of each installed Peltric ranged from 0.5 kW to 5 kW. Likewise, with technical support from CRT/N the country now has about 5597 Improved Water Mills supplying decentralized energy sources, mainly for running mechanical devices to provide efficient agro-processing facilities and electricity generation to the rural population. The power output of each installed Improved Water Mill ranged from 0.5 kW to 3.0 kW.

Promotion of Pico-hydro technologies has brought positive changes not only in the life style of the rural people living in hill and mountain areas, but it also has positive impact at the national and global level. At the local level, it has helped the rural entrepreneurs to generate income and employment opportunities and improve their social and economic living standard. The entrepreneurs' technical and managerial capabilities have also been increased due to the application of these technology innovations. The technologies have helped in substantial reduction of local drudgery and improve their life style, especially of women who else would have to manage with traditional options or diesel mills requiring enormous time, efforts and money. The lighting facilities have helped them to increase their working hour, to combat health hazards else would have faced from wick lamp, to assist their children in study affairs, to improve their sanitation conditions, to run electrical appliances such as radio, TV, etc. The time and efforts saved to rural population especially to women, due to use of new agro-processing opportunities has been used for other socio-economic activities such as taking care of children, fodder/fuel wood collection, household sanitation, looking after the farm activities, running small scale enterprises etc.

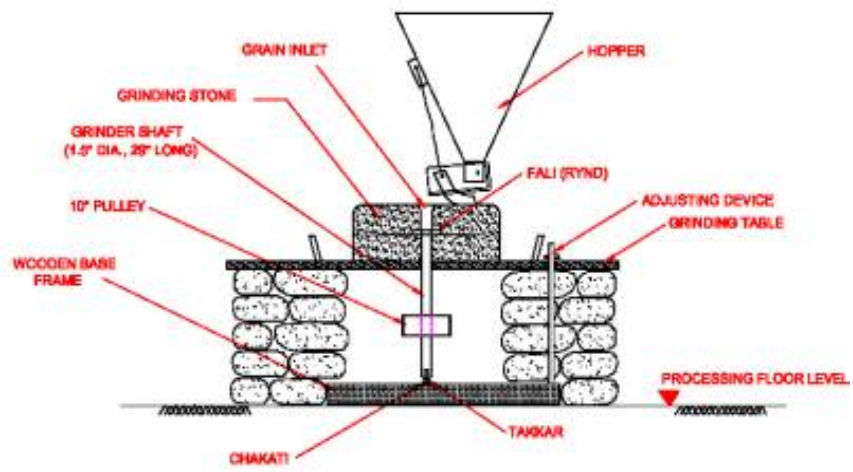
At the national level, promotion of about 6803 units of the Pico-hydro technologies in Nepal has contributed to produce about 8.98 MW of decentralized power. This provided the opportunity to serve about rural 25,000 households with lighting facilities and about 300000 rural households in hill and mountain areas with efficient agro-processing facilities. Undertaking various activities at the national level to promote these technologies has significantly contributed to add not only the national income but also the employment opportunities. Globally, promotion of the technologies has contributed to some extent in checking the environmental degradation by checking carbon emission in the atmosphere that would have occurred due to entering of diesel mills and required fossil fuels to meet the service demand of the rural population in the country. It has made possible to explore the feasibility of carbon trading in the world market for the benefit of the rural people in the country. The efforts to promote Pico-hydro technologies in Nepal have honored the view of Millennium Development Goals (MDGs) that stresses to use renewable energy as a means of economic development, poverty eradication, environmental protection and gender equity.

2. PICO-HYDRO TECHNOLOGIES

Improved Water Mill and Peltric Set have been quite popular in Nepal, especially among the rural population in the hills and mountains. Both the twin technologies are designed and developed within the country. The country has full technical capability to manufacture these Pico-hydro technologies locally as per demand from the potential entrepreneurs.

A. Traditional Water Mill (TWM)

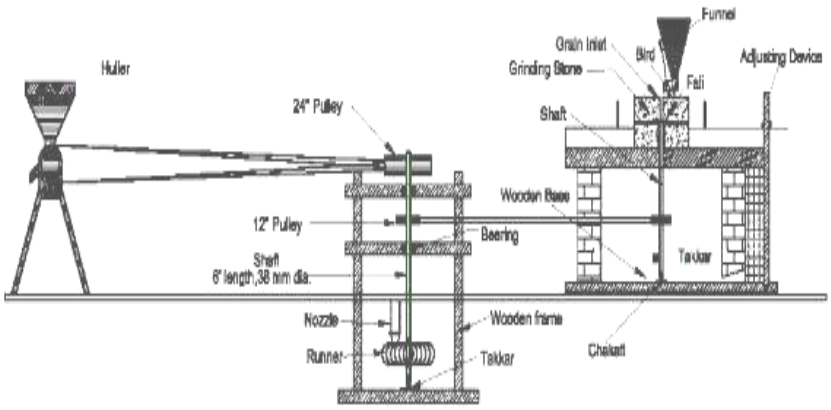
.More than 25, 000-30,000 traditional water mills, are in operation in the country and have been part and parcel of villager's life as source of rural energy and closely interrelated with their tradition and culture since age They have wooden runner and derives its power from the water pressure caused by its head. Water flows through chute to strike the wooden blades attached along the wheel. Operational efficiency is very low.



Sketch of traditional water mill

B.Improved Water Mill

Improved Water Mill is mainly the improvement of existing traditional water mills to produce increased power not only to operate mechanical appliances such as cereal (maize, wheat, millet etc.) grinder, paddy huller, and oil expeller, saw mill etc. but also to produce electricity by coupling it with electric generator.

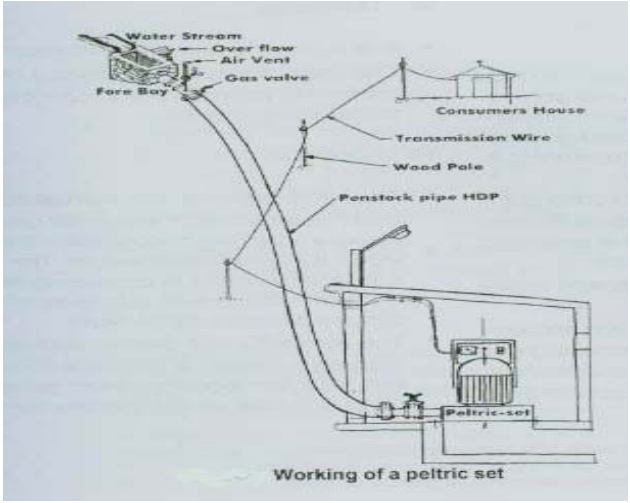


Sketch of improved water mill

The improved water mill is a modified version of traditional water mill. Improvement of traditional water mill is done by improving its various parts but the major break through is made by replacing the traditional wooden runner with hydraulically better shaped metallic runner having cup shaped blades. This increases its operational efficiency as well as making it more useful with additional machines. After the improvement, the water mills have increased capacity by more than 100 %.

C.Peltric Set

Peltric Set is, on the other hand, the simplest form of an in-built compact system where a Pelton Turbine is coupled with induction generator to produce electricity. The turbine derives its power from the water pressure caused by a high head which flows through a nozzle and strikes a number of especially designed buckets attached round the periphery of the wheel. The induction generator produces electric power when it revolves at its designed speed. A Peltric Set is suitable for installation also with multiple nozzles that lowers the cost per unit of power produced. The power generated is used only for lighting purposes.



Working of a peltric set

D.Motor Dynamo Based Family Hydro (MDFH)

Motor Dynamo Based Family Hydro (MDFH) is also an in-built compact system where a small Pelton Turbine (weighing about 1.25Kg.) is coupled with 12 V car dynamo to produce electricity ranging 60-100 Watt depending upon the site. Derives its power from the water pressure caused by high head of 20-30 meter with discharge of 1-2 lps. The power generated is used only for lighting and charging 12 v batteries


MDFH Set

3. Comparative technical parameters of the technologies

The Pico-hydro technologies, mentioned above, are site specific. Peltric Set runs with high head and low water flow while Improved Water Mill runs with low head and high water flow. The rpm of shaft in traditional water mill is very low while it is medium in the case of improved water mill and very high in the case of Peltric Set and MDFH. The intake, canal and penstock system for the technologies are similar. However their functions are different. The comparative technical parameters of the Pico-hydro Technologies are given in Table 1 while their functional features are given in Table 2.

Table 1. Comparative technical parameters of Pico-hydro technologies

Comparison Parameters	**Traditional Water Mill**	**Improved Water Mill**	**Peltric Set**	**MDFH**
Length of Canal	Not Specific	Not Specific	Not Specific	Not Specific
Working Head (Meter)	3-7	2-15	25-50	20-30
Water Discharge (lps)	30-100	10-100	2.5-20	1-2
Speed (rpm of shaft)	60-90	110-210	1500	1800
Output Power Capacity (kW)	0.2-0.5	0.5-3	0.5-5	60-100 watt
Grinding Stone	Local	Local	-	
Thickness of Grinding Stone (“)	3-10	5-15	-	
Diameter of Grinding Stone (“)	24-34	24-34	-	
Operational Efficiency (%)	Below 25	40-50	50-60	30-35
Repair/Maintenance	High	Low	Low	Low
Life Span	2 Years	10 Years	10 Years	10 years
Investment	Low (NRs.25000) US$.312	Medium(NRs.45000-50000) US$.625-650	High (NRs.150000-175000/KW) US$.1875-2187	Low(NRs.18000-20000) US$.225-250
Pay Back Period	2-3 Years	3-5 Years	5-7 Years	2-3 Years.

Table 2. Comparative functional features of Pico-hydro technologies

Technology	**Functions and Capacity**
Traditional Water Mill	Grinding of cereals (maize, millet, wheat, rice etc.), 10-20 kg/hr (maize)
Improved Water Mill	Grinding of cereals (maize, millet, wheat, rice etc.), 20-50 kg/hr (maize)
	Dehusking/partial polishing of paddy (50-70 kg/hr)
	Expelling oil from oilseeds (10-15 kg/hr)
Peltric Set	Generation of electricity (12V-DC and 220V-AC, 0.5-3 kW)
	Generation of electricity (220V-AC, 0.5-3 kW)
MDFH	12V-DC (60-100 Watt)

4. Possible end-uses with the power generated from Pico-hydro technologies

After the installation of Pico-hydro technologies, it is possible to operate a number of equipments for productive and income generating purposes. With Peltric Set, because of additional reactive power required for initial priming it is not possible to operate high power required equipments. However, in the case of Improved Water Mill, as the equipments are operated directly with mechanical driving, it is possible to operate various machineries and equipments requiring power up to 3 kW. Some of the possible end-uses that can be operated in Improved Water Mill are given in Table 3.

Table 3. Power requirement for various end-uses

S.N	**Equipments**	**Required Power (kW)**	**Capacity**
1.	Cereal Grinder, No. 1	1.0	40 kg maize/hr
2.	Cereal Grinder, No. 2	2.0	70 kg maize/hr
3.	Paddy Huller, No. 1	2.0	80 kg paddy/hr
4.	Paddy Huller, No. 2	3.0	200 kg paddy/hr
5.	Baby Oil Expeller	2.5	25 kg mustard/hr
6.	Bitten Rice	2.5	75 kg roasted paddy/hr
7.	Paddy Thresher	1.5	100 kg paddy/hr
8.	Circular Sawing Machine, 350 mm	1.4	
9.	Pliers Machine, 150 mm	0.7	
10.	Lethe Machine, 300 mm	0.7	
11.	Dynamo, DC 12 Volt, 300 Watt	0.3	
12.	Dynamo, DC 12 Volt, 500 Watt	0.5	
13.	Induction Generator, AC 220 Volt, 1 kW	1.0	
14.	Induction Generator, AC 220 Volt, 2 kW	2.0	

5. Support made for promotion of Pico-Hydro Technologies

A. Improved Water Mill

In the case of Improved Water Mill, German Appropriate Technology Exchange (GATE) initiated its promotion and dissemination during 1980s as pilot in one of the hill district called Dhading. Centre for Rural Technology, Nepal (CRT/N), a national technical non-governmental organization established in 1989 with an aim to promote and disseminate appropriate technologies suited to rural conditions, took the lead role in the promotion and dissemination of Improved Water Mill during early 1990s with the technical and funding support of GATE and German Technical Cooperation (GTZ). After the termination of GATE/GTZ supported program in 1999, CRT/N continued its promotional efforts with the support from various development agencies within the country that included government organizations, I/NGOs, private entrepreneurs etc.The momentum of its promotion gained when CRT/N launched Nepal and Netherlands Government supported national “Improved Water Mill Support Program” in 2003. The Improved Water Mill has been recognized by

UK based Ashden Award in 2007 for contribution on enhancing the livelihood and checking of carbon emission in the atmosphere

B. Peltric Set

Agricultural Development Bank, Nepal (ADB/N) has played a very instrumental role in the initiation towards promotion and dissemination of Peltric Set during middle of 1980s, mainly with its technical and financing support, when Government of Nepal announced a provision of subsidy for its installation. The momentum for its promotion geared up only during late 1990s when Alternative Energy Promotion Centre (AEPC) of Nepal Government launched the national Energy Sector Assistance Program (ESAP) in the country for the promotion of RETs including Peltric Set with the technical and funding support of DANIDA.

C. Motor Dynamo Based Family Hydro (MDFH)

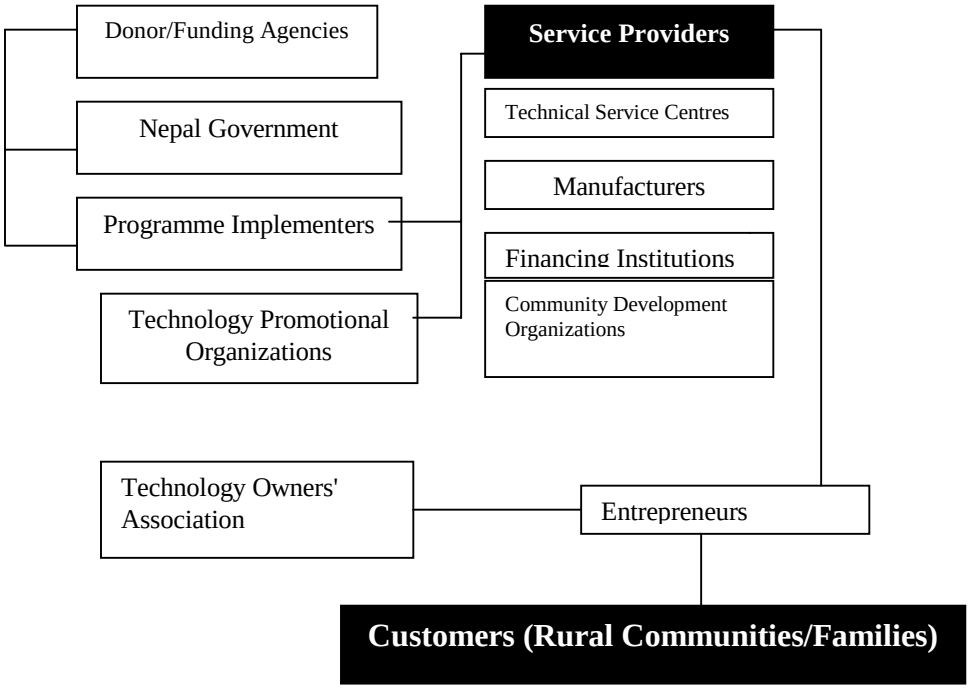
Center for Rural Technology with support of the Lemelson Foundation, USA, has conceptualized and implemented the project "Meeting Energy Need of Rural People for Household Lighting through Development and Promotion of Motor Dynamo Based Family Hydro (MDFH) in Nepal"; from January 2007.The pilot project has been successful to install 12 units of MDFH in hill and mountain areas. Family Hydro was installed at the average power generation of 60-100 W (DC Power), through the use of Motor Dynamo coupled to the shaft of a Pelton runner designed and developed in CRT/N with support from Katmandu University. With an aim to disseminate the technology, 100 more MDFH will be install in remote mountain of Nepal during 2008-09 with support from Lemelson Foundation, USA, through Local Partner Organizations. The overall objectives of the project are to familiarize the technology among the potential users and to create market for further promotion mountain areas.

6. Institutional and technical support

The main focus of the Pico-hydro development programs was to develop institutional and technical capability of various local level Service Providers for sustainable promotion of the technologies. The other focus of the program was on providing the quality services to the end users.

In order to provide the required institutional and technical support services to the Service Providers, a number of stakeholders within the specific program on the Pico-hydro technologies have been involved. Nepal Government provided the policy guidelines and monitoring support while the donors such as GTZ and Netherlands Government in the case of Improved Water Mill and DANIDA in the case of Peltric Set provided the required technical and financial supports. ESAP and CRT/N implemented the Peltric Set and Improved Water Mill promotion program respectively. Various government line agencies, INGOs and NGOs provided the promotional efforts. All these stakeholders have played their respective roles to strengthen the capabilities of Service Providers such as Technical Service Centers, manufacturers, financing institutions, private companies, community development organizations etc. in a coordinated way to make them able to promote the technologies in an efficient manner. While the Service Providers provided required support services to local entrepreneurs and end users in the installation, operation and maintenance of the technologies. Presently, technology owners' associations such as Water Mill Owners' Association and Peltric Set Owners' Association are being formed for the sake of sharing their voice with the concerned bodies for their own security and benefit. The institutional linkages among the program stakeholders are presented below.

7. Institutional linkages among the program stakeholders



8. Subsidy Support

In order to expedite the promotional activities and also to support the entrepreneurs to make them able to invest in installing the technologies, the specific program has provided the subsidy support as given in Table 4. Rest of the investment cost required to install the units is borne by the entrepreneurs themselves.

Table 4. Subsidy support to the entrepreneurs

SN	Particular	Purpose	Subsidy available	Unit cost:
1.	Improved Water Mill Installation			
	On mechanical component (to install short shaft only)	Cereal grinding only	NRs. 12000 (US $ 150) per unit, additional subsidy for transportation in very remote districts	NRs.25000.00(US$.312)
	On mechanical component (to install long shaft)	Cereal grinding, paddy hulling, oil expelling	NRs. 27000 (US $ 337) per unit additional subsidy for transportation in very remote districts	NRs.50000.00(US$ 625)

	On add-on electrical component	Add-on household lighting facilities	NRs.60000 (US $ 750) per kW electrical power produced or NRs.6000(US$.75) per household	NRs.200000-350000 (US$.2500-4375)
2.	Peltric Set Installation	Household lighting facilities only	NRs. 97500 (US $ 1219) per kW electrical power produced or 12000(US$.150) per household.	NRS.325000-750000 (US$.4062-9375)
3	MDFH	Household lighting facilities only	NRs.6000 per unit(US$.75)	NRs.18000-20000 (US$.225-250)

9. Major activities performed during the implementation of the programs are:

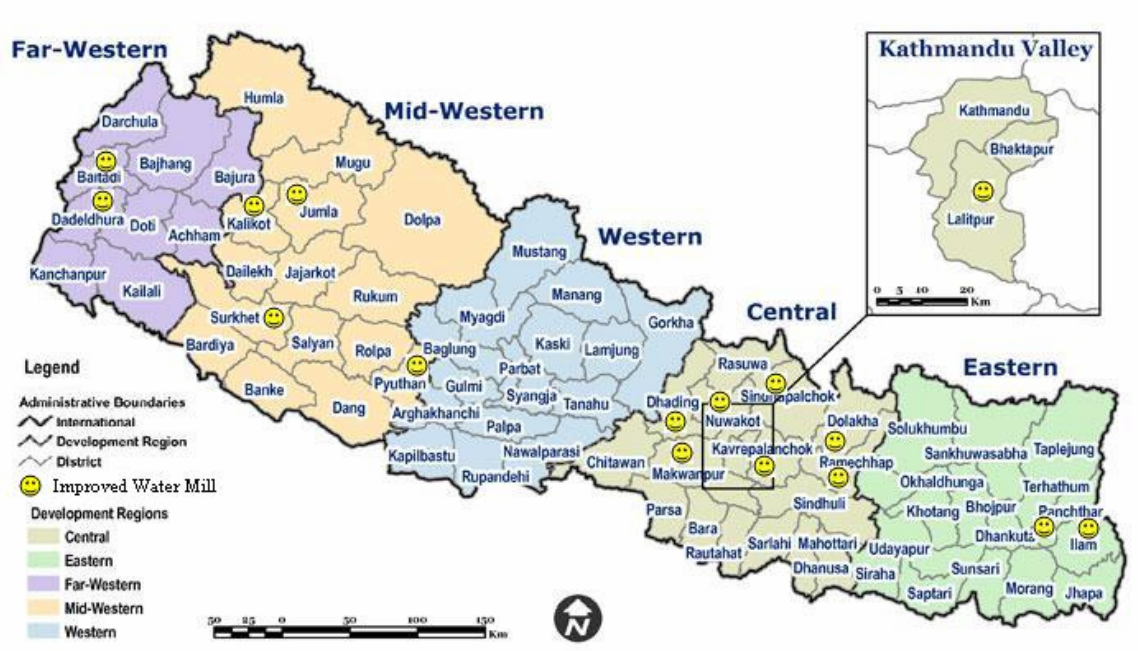
- Identification of potential stakeholders of the program and developing linkages among them
- Establishment of Support Units in the program districts/areas
- Identification and selection of local level Service Providers
- Making awareness among the potential rural entrepreneurs and users about the technologies through organization of Orientation/Demonstration activities
- Capability development of Service Providers
- Inventory making of the potential demand
- Feasibility survey
- Arrangement for financing support, subsidy support and hardware supply
- Installation of the technologies
- Capability development of the entrepreneurs for efficient operation of the technologies
- Monitoring and follow up of the technologies installed

10. Achievement and its implications

A. Improved Water Mill

By Dec, 2008, the country has about **5597** Improved Water Mills supplying decentralized energy sources, mainly for running mechanical agro-processing devices to facilitate the rural population and to reduce the drudgery of women population. There are also a few units that provide electrical facilities to local population. The power output of each installed Improved Water Mill ranged from 0.5 kW to 3 kW that is substantially high as compared to the power output of traditional mill having power output generally below 0.5 kW. This has made the Improved Water Mill possible to operate various devices that operate within the range up to 3 kW. The total power generated so far from the installed sets is about 6730 kW, the average power output per unit being about 1.2 kW. The distribution of Improved Water Mill installations by year is given in Table 5.

Districts Wise Installation of Improved Water Mill



B. Peltric Set

By the middle of 2007, the country has about 1206 Peltric Sets supplying decentralized electrical facilities to the rural population. The power output of each installed Peltric Set ranged from 0.5 kW to 3 kW. The total power generated so far from the installed sets is about 2248 kW, the average power output per unit being about 1.86 kW. The distribution of Peltric Set installations by year is also given in Table 5.

Districts Wise Installation of Peltric Sets

Table 5. Distribution of Improved Water Mill and Peltric Set installations by year

Improved Water Mill			Peltric Set		
Year	**Installation No.**	**Power Generation (kW)**	**Year**	**Installation No.**	**Power Generation (kW)**
1984-88	80	101	1991	46	43
1991-93***	54	62	1992	13	12
1993-95***	211	221	1993	-	-
			1994	79	100
			1995	115	171
1996	40	49	1996	130	203
1997	18	21	1997	84	144
1998	94	96	1998	97	185
1999	124	128	1999	123	226
2000	91	97	2000	112	214
2001	107	134	2001	36	81
2002	58	73	2002	61	141
2003	65	85	2003	80	184
2004	634	761	2004	66	140
2005	886	1063	2005	48	101
2006	868	1041	2006	46	101
2007	1164	1397	2007*	70	202
2008**	1168	1401	2008	NA	NA
Total	5597	6730		1206	2248

*Till mid-July; ** Till mid Dec ***Breakdown not available

C. Implications

The promotion of Pico-hydro technologies has resulted into positive changes in the socio-economic conditions of not only the entrepreneurs but also the local community members, especially the rural women. The technologies have changed the total settings of the villages. They have also significantly helped in checking the environmental degradation of the rural areas that would have happened due to encroachment of non-renewable energy sources. Some of the major implications brought by the promotion of the technologies are highlighted below.

- **Implications at the community and village level**

Promotion of Pico-hydro technologies has helped local level entrepreneurs to generate substantial income and increase their living standard. Their social status in the society also increased as they provided enormous services to the local community. The entrepreneurs' technical and managerial capabilities also increased substantially to run the enterprises efficiently.

The technologies have helped in substantial reduction of local drudgery, especially of women who else would have to manage with traditional options by spending enormous time and efforts.

Or they would have to travel long distance to have access to diesel mills for their grains and oil seeds processed. The lighting facilities have helped them to increase their working hour, to combat health hazards else would have faced from kerosene wick lamp, to assist their children in study affairs, to improve

their sanitation conditions, to run electrical appliances such as radio, TV, etc. The new agro-processing opportunities have helped the communities to save their substantial time which they have been using for other socio-economic activities such as taking care of children, fodder/fuel wood collection, household sanitation, looking after the farm activities, running small scale enterprises etc.

The technology promotion programs have given chances to the local Service Providers in the villages with more employment and income generating opportunities with their increased and efficient service delivery capabilities. Furthermore, promotion of the technologies has helped the villages to maintain its ecological settings by checking the entry of diesel and kerosene operated machineries and appliances.

- **Implications at the national and global level**

At the national level, promotion of the Pico-hydro technologies has contributed to produce about 9.00 MW of decentralized power. It has provided the opportunity to serve about rural 25,000 households with lighting facilities and about 300000 rural households with efficient agro-processing facilities. Such services have drastically reduced the drudgery of rural population, especially of the women, and enhanced their life style. Promotion of the technologies has supported the national policy to develop more renewable energy technologies to reduce dependency on imported energy. The efforts have also helped to indirectly integrate with other development activities for rural poverty alleviation. Undertaking various activities at the national level to promote these technologies has significantly contributed to add not only the national income but also the employment opportunities as well.

Globally, promotion of the technologies has contributed to some extent in checking the carbon emission in the atmosphere that would have occurred due to entering of diesel mills and fossil fuels to meet the service demand of the rural population in the country.

11. CONCLUSION

The efforts to promote Pico-hydro technologies in Nepal have substantially contributed in the development efforts of the country as a whole. As such, more efforts are required to cover more and more rural villages of the country within the setting of decentralized energy supply systems. There is potential for the transfer of these technologies among the mountainous countries all over the world. Expanding access to energy services for the poor in developing countries requires a range of efforts such as strengthening policy, regulatory, institutional, infrastructural, financial and human resource conditions. Capacity development at all levels - local, district and national - is critical to successfully expanding access to decentralized modern energy services. Once the capacity has been built, it becomes a resource, which the country can continue to build upon, continuously strengthening a country’s capacity to deliver or improve energy supply system.

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