Micro-Hydro Power in Nepal: Access to Electricity for Isolated Rural Population in the Hills and Mountains

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ABSTRACT

Hydropower plants in Nepal with installed capacity of up to 100 kW are defined as micro-hydropower plants. Apart from the potential for developing hydropower, Nepal does not have other significant sources of conventional energy such as fossil fuels. The combination of steep topography and about 6000 large and small rivers makes the country ideal for the development of hydropower. Since less than 2% of the potential has been realized to date, significant opportunities exist in exploiting hydropower in the country. Extension of the national electricity grid has been very slow and is unlikely to cover large rural areas in the near future. Also, for rural areas of Nepal located at some distance from the national electricity grid, micro-hydropower becomes a more appropriate option compared to grid extension. Nepal today has a micro-hydro sector that is growing strong and is a good example for other similar mountainous countries to learn from. There are 1760 micro-hydro plants in the country with a total installed capacity of 12.4 MW. Various institutions with donor support are actively involved in promoting the micro-hydropower sector. Along with increasing the number and capacity of micro-hydropower plants in the country, there is a need to establish mini-grids, incorporate new technologies and increase and diversify end uses so that the optimal benefit accrues from micro-hydropower.

1. INTRODUCTION

1.1 Country Setting

After about a century of autocratic family rule by the Ranas, Nepal's new political system opened itself to the outside world from 1950s onwards. The period also marked the beginning of the first Five-Year Development Plan (1955-1961) and a transition from a medieval to modern society. With the ninth Five-Year Plan concluding in 2002, in retrospect, the general assessment of its half a century of development efforts is generally perceived with a mixed reaction.

After nine five-year development plans and huge inputs of foreign development assistance, Nepal still remains an agricultural country. More than 80% of its population depends on agriculture; 69% of the farmers have less than 1 hectare of land [1] and 42% of the people are living below poverty line. Nepal has a very poorly developed infrastructure with majority of population without access to roads, water supply, health facility or electricity. Its main source of income is tourism, carpet and garment industries, and remittances from people working outside of the country. With per capita income of US$ 235 [2], Nepal is among the very low-income countries in the world.

The country, with an area of 147,181 km^2 has a total population of 23.2 million as per the 2001 census [3]. The average annual population growth rate is 2.27%. About 86% of the country's population reside in the rural areas. The literacy rate has been estimated to be around 52%.

The country can be broadly divided into three regions, namely mountains (35%), hills (42%) and Tarai or the plains (23%). With the Himalayas in the north stretching from east to west where most of the 6000 rivers originate, Nepal has one of the highest per capita hydropower potential in the world, but at the same time the least used with less than 2% potential being tapped.

1.2 Energy Scenario

Figure 1 presents the structure of energy consumption in Nepal for the year 2001 [2]. The total energy consumption in 2001 was 7912 thousand tons of oil equivalent (TOE). As can be seen from Fig. 1, biomass, primarily comprising of fuelwood, agricultural residue and animal waste are the main source of energy in Nepal (i.e., 86% of the total energy consumed). Electricity represents only 1% of the total energy consumption in 2001 whereas fuelwood represents about 77%. On the other hand, although petroleum products account for only 9% of the total energy consumed, one third of the foreign exchange earnings were spent to import these fossil fuels (mainly petrol, diesel and kerosene).

In the residential sector, biomass contributes about 96% of the total energy consumed. High reliance on biomass has been the main reason for deforestation over the years.

Apart from the potential for developing hydropower, Nepal does not have other significant sources of conventional energy such as fossil fuels. Currently, 43,000 MW of hydropower has been estimated to be economically exploitable, whereas only 515 MW has been installed.

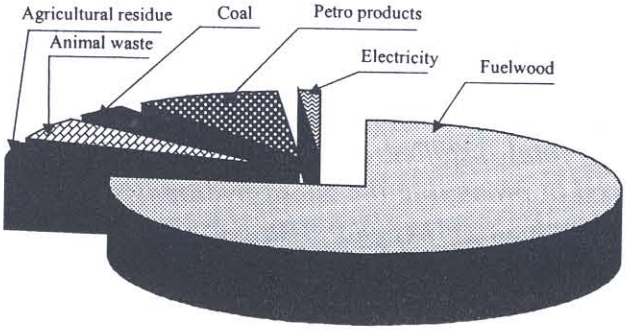

Fig. 1 Structure of energy consumption in Nepal in 2001

1.3 National Electricity Grid

The percentage of population that has access to the national electricity grid has reached 18% (an increase by 3%) within the last 10 years. Furthermore, most of the urban areas have been electrified and in the beginning of the Ninth Five-Year Plan (i.e., 1997-2002) only 4% of the rural population had access to the national electricity grid. This implies that the extension of the electricity grid has barely exceeded population growth and hence the slow expansion rate of 3% in 10 years despite the annual increase in the distribution system.

The target of His Majesty's Government of Nepal (HMG/N) Ninth Five-Year Plan is to double the rural population that has access to grid electricity [4]. Hence, about 8% of the rural population should have access to electricity at present if the Ninth Five-Year Plan's target has been fully realized. The target of the Tenth Five-Year Plan (mid-2002 to 2007) is to provide electricity services to 23% of the population [5]. It has been estimated that only 30% of the population will have access to grid electricity by 2020.

Table 1 presents the electrification trends in the developing countries [6]. From this table, it is clear that even if the Ninth Five-Year Plan's rural electrification target is fully realized, the percentage of the population (urban and rural) that will have access to electricity will still remain low compared to regional and global figures.

Table 1 Electrification trends in rural and urban areas in developing countries

Percentage of population in urban and rural areas connected to electricity in developing countries				
	Urban		**Rural**	
	1970	1990	1970	1990
Country/region				
North Africa and the Middle East	65	81	14	35
Latin America and the Caribbean	67	82	15	40
Sub-Saharan Africa	28	38	4	8
South Asia	39	53	12	25
East Asia and the Pacific	51	82	25	45
All developing countries	52	76	18	33
Total served (in millions)	320	1,100	340	820

At present the Integrated Nepal Power System (INPS) has a total installed capacity of about 585 MW of which about 515 MW is generated from hydro resources. Of the hydropower plants, only 92 MW (cascaded between Kulekhani I of 60 MW and Kulekhani II of 32 MW) is from seasonal storage plants and the rest is from run-of-river schemes. The annual energy generated from the grid in 1999-2000 was about 1700 GWh, which is an increase of about 15% compared to 1998-1999 figures. The entire system has about 670,000 consumers, which is an increase of about 8% compared to the previous fiscal year's [7].

1.4 Rationale for Micro-Hydropower in Nepal

Apart from biomass, the only significant source of energy in Nepal is hydropower. The combination of steep topography and about 6,000 large and small rivers makes the country ideal for the development of hydropower. Since less than 2% of the potential has been realized to date, significant opportunities exist in exploiting hydropower in Nepal.

The extension of the national electricity grid in the urban and semi-urban areas of the country has been a regular process and is generally able to meet the demand that arises from:

- Construction of new buildings in the urban and semi-urban areas where the grid already exists and all that is required is to provide electricity connections.
- Expansion of urban and semi-urban areas, which has resulted in establishment of new industries and residential areas at the outskirts. It should be noted that the expansion of these areas and extension of the grid are undertaken simultaneously.

Providing electricity to these areas is not a burden to the electricity authority as the cost of extension is low and given the relatively large consumer base compared to rural areas, the revenue streams make such extension financially attractive.

However, in the rural areas, the case is different. A cursory literature review will make it evident that rural electrification is more difficult and more expensive than urban electrification. The large size of the distribution system required, low density of customers, and the low commercial/domestic demand ratio, all combine to make rural electrification more difficult and more expensive. Even developed countries such as USA and Canada subsidize rural electrification (especially infrastructure) sector to date. The same applies for Nepal. It has been realized that for rural areas of Nepal located at some distance from the national electricity grid, micro-hydropower becomes a least-cost option compared to the extension of the grid. The remote widely scattered hilly settlements (without little basic infrastructure) and abundant streams make Nepal an ideal setting for micro- hydropower. Furthermore, since only 30% of the population is estimated to have access to grid electricity by 2020, the demand for micro-hydro will increase in areas far from the grid.

Socio-economically, apart from meeting the lighting requirements (which is the primary demand), micro-hydro technology also brings various tangible and intangible benefits to the rural people. For example, agro-processing units such as milling, grinding and oil expelling installed in micro-hydro system save time and labor required to perform such activities traditionally. Thus, women who are generally involved in these activities are relieved of the drudgery of having to spend hours in such household chores. Furthermore, electric lights offer opportunities for longer study hours for the children and additional income-generating activities for adults. The health status of the rural population is improved as the traditional kerosene lamp (Tuki), whose fumes cause eye irritation and affect the lungs, is no longer needed.

The national electricity grid extension has been slow (a growth rate of 3% in 10 years). By default rural electrification via the electricity grid will also be a slow process and moreover this will only be feasible for settlements close to the grid.

There are more than 40,000 villages in Nepal. The villages located in the hills and mountain regions, which are more than a day's walk from the nearest electricity grid, are unlikely to be connected (to the electricity grid) in the foreseeable future. Furthermore, studies show that for settlements located beyond 30 km from the electricity grid, development of isolated micro-hydropower becomes more economical than grid extension provided that this is technically feasible. As there is hardly any settlement in the hills and mountain regions of Nepal without a stream flowing by its side, technical viability of micro-hydropower is generally ensured.

Therefore, if electricity is to be made accessible to a larger rural population of the country, micro-hydropower would be the logical and more economical choice.

2. HISTORICAL DEVELOPMENT

Hydropower plants with installed capacity of up to 100 kW are called micro-hydro plants in Nepal. Micro-hydro plants were introduced in the country in the 1960s with the locally developed turbines to replace diesel engines used in the hills for agro-processing. Prior to the introduction of micro-hydro plants, it was an irony that the power from the abundant streams nearby remained untapped, while the villagers carried imported diesel on their backs from town centers, days away, to operate the diesel mills. With the success of production of locally-built turbines, and credit facility available from Agricultural Development Bank of Nepal (ADB/N), orders for micro-hydro came from village entrepreneurs who wanted to set up agro-processing mill business – a paddy mill, oil expeller and grinder, the most universal applications.

By early 1980s, a number of turbine mills with small dynamo were installed generating electricity for the operation of the mill during the nighttime and also supplying power to light a few houses nearby. The potential of a turbine mill to provide electric lights was demonstrated when the small town of Malekhu in the Prithvi Highway was electrified from a turbine mill owned by a local entrepreneur. Seeing this success, ADB/N began the promotion of electric generation from turbine mill by providing 50% subsidy on the cost of the electrical components of micro-hydro plant. While the government-initiated small-hydro development projects found it difficult to establish firmly, unable to raise enough revenue to pay for operation and maintenance, the private sector-led micro-hydro electric plants flourished with villagers in remote areas as the driving force. And the stand-alone micro-hydro had been utilized by villages in remote areas as far as Mustang, a mountain community located about 4 days' walk from the nearest road head. Once a village is electrified, the neighboring villages are encouraged to follow, seeing the benefits they could get from electricity. This is how micro-hydro spread - by the interest of the village people, in contrast to government-aided projects (like all hydropower plants) that were established with external support and grants.

As a result of four decades of efforts by NGOs, government, financing institutions, and private sector, including rural entrepreneurs, Nepal today has a micro-hydro sector that is growing strong and is a good example for other similar mountainous countries to learn from.

3. OVERVIEW OF THE MICRO-HYDRO SECTOR

The current status of the micro-hydropower sector, brief description and contributions of various institutions involved, and the research activities undertaken are presented in this section.

3.1 Performance Review

Data as of mid-2000 records show a total of 1760 micro-hydro plants in Nepal, 753 of which are agro-processing plants, 169 mills added with generator, 727 Peltric sets (a micro-hydro plant using a Pelton turbine coupled with an induction generator and producing a maximum of 3 kW) and 111 (5 kW to 100 kW) stand alone electric plants [8]. The combined generation capacity of these plants is 12.4 MW. However, it should be noted that not all plants are operational and some are producing less than the installed capacity, especially the older ones, and thus the actual net generation capacity is less.

About one-fourth of the total micro-hydropower plants installed are performing well, both technically and financially. Another one-fourth are operational but have technical and managerial problems. Similarly, one-fourth operate intermittently, primarily due to lack of flows in the dry seasons. The remaining one-fourth have been closed down (either due to washing away by floods, lack of interest by owner, or having technical problems that were too costly for repairs) [9].

3.2 Institutions Involved

Nepal has a well-developed micro-hydropower sector that is mostly not present in most developing countries. The sector includes the Alternative Energy Promotion Centre (AEPC) under the Ministry of Science and Technology for policy formulation and support to national and local structure. AEPC is supported by the Energy Sector Assistance Programme of Danida. The sector also comprises of government and commercial banks for loans, non-governmental organizations (NGOs) that support community micro-hydro projects, private manufacturing companies that produce turbines, controllers and other accessories, installation companies, consulting firms, private entrepreneurs and communities which actually decide to put up a plant in their area. Activities of some of the major players in the sector are mentioned in this section.

Energy Sector Assistance Programme (ESAP) and Alternative Energy Promotion Centre (AEPC)

The Energy Sector Assistance Programme (ESAP), a bilateral assistance program of His Majesty's Government of Nepal (HMG/N) represented by the Alternative Energy Promotion Centre (AEPC) and Government of Denmark, through DANIDA, began in 1999 and aims to support alternative energy including micro-hydropower. The ESAP micro-hydro component aims to build onto the success of the sector. It also has an explicit goal to minimize the rate of failing plants. It aims to improve the quality of micro-hydro plants and their economic viability by providing support structure at the national and local levels. The AEPC is the apex body and the government agency for national policy formulation and promotion of alternative energy of which micro-hydro is a key component. His Majesty's Government has introduced a new subsidy policy, which provides a subsidy of NRs. 70,000 per kW for scheme above 3 kW and NRs. 55,000 for Peltric set (up to 3 kW). There is also transport subsidy of up to

NRs. 21,000 per kW depending on the location of the plants from the nearest road head to compensate for the heavy transport cost for plants in remote areas. No subsidy will be provided to plants costing above NRs. 150,000 per kW and in case of overtopping of subsidy.

The sector is now served by more than 15 AEPC pre-qualified manufacturing and installation companies, more than a dozen consulting firms and a pool of national experts.

The target of the AEPC/ESAP program is to install 1850 kW micro-hydropower plants in the first phase, which ends in March 2004. As of July 2002, 16 plants had been commissioned and verified by the program and the installed capacity has reached 286 KW.

Rural Energy Development Programme (REDP)

The UNDP-supported Rural Energy Development Programme (REDP) began in 1996. It works in 15 districts through the establishment of District Energy Offices. In each of the districts, the program covers 4 to 12 Village Development Committees (VDC). REDP's role is to facilitate community organizations to plan, implement and manage micro-hydro projects. 80 micro-hydropower projects generating 1138 kW had been completed as of March 2002.

Annapurna Conservation Area Project (ACAP)

Annapurna Conservation Area Project (ACAP) pioneered micro-hydro projects as key component of its conservation program with the primary aim of saving fuelwood by introducing electric cooking. Ghandruk (50 kW) is one successful example of this attempt. ACAP continues to carry out promoting micro-hydropower plants as the demand for lighting is high in the area of its operation. To date, ACAP has been involved in implementing 11 micro-hydropower plants with a total capacity of 469 kW.

Remote Area Development Committee (RADC)

The government's Remote Area Development Committee (RADC) has also been promoting micro-hydro in the remote areas of Nepal during the last decade; 22 micro-hydropower plants generating 300 kW have become operational and another 18 schemes are ready for installation. At present due to security reasons, the installation work has come to a standstill.

3.3 Research Activities on Micro-Hydropower

There have been several efforts of indigenizing micro-hydro technology and developing new end-use products particularly low wattage cooking. Some of the most successful examples are cross-flow turbines, Peltric set, low wattage (300/400 W) cooker known as Bijuli Dekchi, Sundhara oil expeller - a low weight, low power oil expeller which can be carried in the mountain due to fabricated parts. More than 500 Bijuli Dekchi cookers are being used. However its manufacture has been ceased due to small market.

During the recent years, the Nepal Hydro and Electric Pvt. Ltd. (NHE) in Butwal, south Nepal has developed a 200 W propeller turbine, PT02. Figure 2 shows the complete assembly of PT02 and the village end users. The 200 W turbine has been claimed to perform much better than the Chinese and the Vietnamese versions which are widely used. NHE is scaling up the capacity of the propeller turbine. The Pico Power Pack which has a single shaft that couples a horizontal axis Pelton wheel with a generator, has this shaft extended to allow tapping mechanical power to run a grinder. The product is a further development of Peltric set of Nepal carried out at Nottingham Trent University, U.K. The first Pico Power Pack was locally manufactured and a pilot test was successfully carried out in Nepal in recent years. A turbine test facility though expensive has been deemed essential in Nepal to provide impetus both to the university researchers and manufacturers in testing and improving local turbines, which would improve the local products and increase export potential.

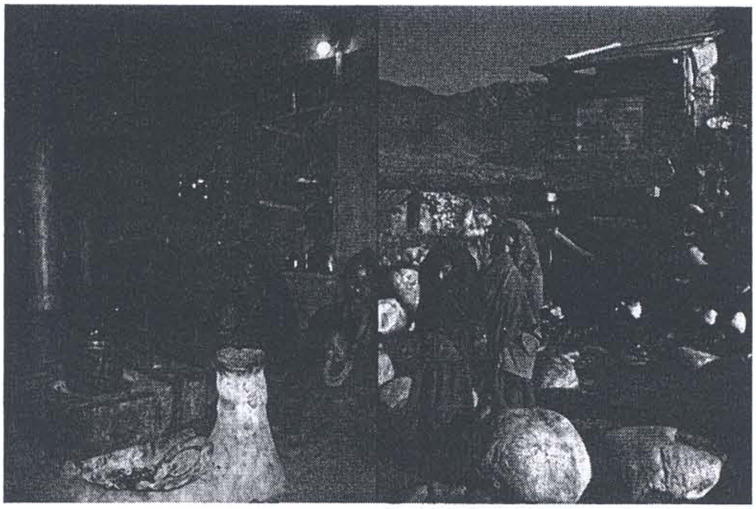

Fig. 2 The complete assembly of the 200 W propeller turbine in operation (left) and the end users in Thalpi Gau, Jumla.

4. FUTURE DIRECTION OF MICRO-HYDROPOWER SECTOR

Given the increasing demand for micro-hydropower by the rural communities, active donor support, and the economic benefits gained from this option compared to grid extension (i.e., more economical as the distance from the grid increases), the number of micro-hydropower plants will increase over the years. Along with increasing numbers and capacities (kW) of micro-hydropower plants, some of the options that need to be considered to increase its access to the rural communities are: (a) establishment of a mini-grid, (b) incorporation of energy efficient technologies, and (c) optimizing and diversifying end uses.

Establishment of a Mini-Grid

Isolated micro-hydropower plants closely located can be connected into a mini-grid so that the system can cater to more consumers and be more reliable, i.e., if one plant is shut down, another plant that is connected to the mini-grid can still serve its consumers. This approach should be taken for plants that are not too far from the electricity grid (say 30 km to 50 km) but its extension is unlikely within the next 5 to 10 years. The establishment of mini-grid will also ensure the quality of individual micro-hydro plants that are interconnected since to be able to hook into the mini-grid certain technical standards (e.g., constant frequency of 50 Hz and voltage level) would have to be met. Similarly, the managerial capabilities of the entrepreneurs would also be enhanced as the modality of power exchange in case of different power producers and grid operators, PPA, grid management, etc. would have to be arranged. Furthermore, this would also prepare communities for connection to the national grid, e.g., electricity market will have been established and technically grid connection would be simple.

Incorporating Energy Efficient Technologies

Rural consumers utilize energy mostly in form of electricity for lighting. For all micro-hydropower plants and for most urban areas, lighting accounts for the majority of the system load. Therefore, it is worth assessing different lighting technologies to see if extra benefits can be gained from their use. The lighting technology that shows the most potential is the compact fluorescent lamp (CFL).

In the last 10 years, CFLs have advanced in terms of efficiency, design, reliability and cost-effectiveness. A CFL is now typically 5 times as efficient as an incandescent bulb – that is, a 12W CFL will give as much light as a 60W bulb. The life of a good quality lamp is now typically 8,000 to 15,000 hours, which is equivalent to 4 to 8 years if the lamp is used for an average of 5 hours per day. Based on Nepal Electricity Authority's current tariff or general prevailing rate of NRs. 1 to NRs. 2 per watt per month for isolated micro-hydropower plants, an equivalent 7W CFL of good quality (approximate cost of NRs. 300) would be able to pay for itself within two years. The lamp should last 4 to 6 years, and can play a significant role in reducing peak power loads. Thus the advantages of using CFLs are:

- For isolated distribution systems, more consumers can be served from a micro-hydropower plant.
- Similarly for grid-connected schemes, any power saved during the peak load is equivalent to not building new hydropower plants (of the capacity equal to the power saved) which reduces the investment costs.
- CFLs can be cost-effective both for the consumers, since they receive higher lumen and pay less for the tariff, and for the distributors, since peak power is attenuated and more consumers are served for a given power level.

Apart from incorporating CFLs the micro-hydropower sector needs to keep abreast with emerging technologies in order to efficiently supply electricity to the rural population.

Optimizing and Diversifying End Uses

Micro-hydropower plants need to be utilized as much as possible. If these plants are used only for household lighting (i.e., 4 to 5 hours a day), they may not be able to generate sufficient funds for repair, maintenance and replacement. Thus, increasing end uses (apart from household lighting) need to be promoted so that revenue streams are increased ensuring sustainability of the plants. To some extent agro-processing plants, bakery and cottage industries are being powered by micro-hydro plants. However more effort in terms of technology promotion, entrepreneur trainings and end-use diversification are required. Furthermore, the plants should also be linked with information technology (IT) so that electricity is used for higher value activities. Electricity generated from micro-hydro could be used to operate computers, fax machines and other communication devices and thus contribute positively in the academic and IT sectors. In some isolated mini-hydro systems such as the 400 kW Salleri-Chalsa Electricity Company (SCECO) which is about two-days' walk from the nearest road head at Jiri, computers are being operated using the electricity generated [6]. Thus, apart from meeting part of the rural energy and lighting needs, micro-hydro could also make contribution in the academic sector in the rural areas.

5. CONCLUSIONS

Nepal today has a micro-hydro sector that is growing strong. Since less than 2% of the hydropower potential has been realized to date, significant opportunities exist in exploiting hydropower in Nepal. It has been realized that for rural areas located at some distance from the national electricity grid, micro-hydropower becomes a more appropriate option compared to the extension of the grid. The remote widely scattered hilly settlements (without little basic infrastructure) and abundant streams make Nepal an ideal setting for micro- hydropower. Furthermore, since only 30% of the population is estimated to have access to grid electricity by 2020, the demand for micro-hydro will increase in areas far from the grid.

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There are currently 1760 micro-hydro plants in the country with a total installed capacity of 12.4 MW. Various institutions with donor support are actively involved in promoting the micro-hydropower sector. Along with increasing the number and capacity of micro-hydropower plants in the country, there is a need to establish mini-grids, incorporate new technologies and increase and diversify end uses so that the optimal benefit accrues from micro-hydropower.

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