Mini-and Micro-hydropower Development In the Hindu Kush-Himalayan Region Achievements, Impacts and Future Prospects

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Introduction

Mini- and Micro-Hydropower (MMHP) has been used for milling in the region for many centuries. Although modernisation in water mill technology started around the turn of the century in the West, its progress as an alternative energy source took place only after the oil crisis of 1973, along with that of other renewable technologies. China has been in the forefront of MMHP development since the early 50s and, at present, has 45,700 MMHP plants with a total installed capacity of about 6,000 MW.

Hydropower as such is considered environmentally-benign, and hydropower in the MMHP range is considered even more benign due to its ability to blend with the local environment and traditions. Hydropower in the MMHP range has comparative advantages over large hydropower; its appropriateness in integrating with rural development is an important one. It is possible to develop MMHP as decentralised systems. They are simple in design, can be installed quickly, and are easier to manage and operate. Unfortunately, only a small portion of the MMHP potential is utilised in the Hindu-Kush Himalayan (HKH) Region, where rapid development of a cheap and non-polluting source of energy to meet the challenges of development and a deteriorating environment are warranted.

Summary of the MMHP Installation Programme in the HKH Region

Considerable progress has been made in five countries of the HKH region, in terms of the number of installations in the MMHP range. In India and Pakistan, the share of MMHP is less than one per cent of the total harnessed hydropower, although its potential share could exceed 10 per cent. In China, this share is about 20 per cent.

Bhutan

Most of the electro-mechanical components of the 19 MMHP installations, with a total capacity of 3.40 MW, have been imported from and funded by Japan and India. MMHP plants in Bhutan were designed and installed by foreign consultants. The Royal Government of Bhutan does not have any future expansion plans for MMHP. Government agencies consider MMHP plants to be expensive and economically non-viable. Out of a total of 19, 10 MMHP plants were handed over to user communities for operation, maintenance, and power distribution. The communities were also

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empowered to fix the tariffs. Responsibility for repair of these plants, however, lay with the Department of Power.

India

There were reported to be 145 MMHP/SHP[2] plants in India, with a total capacity of 106 MW, which had been installed by various government agencies, while 159 additional plants, with a total capacity of 198MW, were under construction. Out of the 145 existing plants, approximately 100, with a total capacity of 70MW, were located in the northern Himalayan range. These plants are in 10 northern states, starting from Arunachal Pradesh in the east to Jammu and Kashmir in the west. All of these plants were being managed by the State Electricity Boards/Department of Power. In most of the cases, tariffs charged to consumers were the same as those charged to consumers connected to the grid. However, in some states, the tariffs were lower and were charged on a flat rate basis. For example, in Arunachal Pradesh, a fixed sum of IRs 9 per point[3] was charged to the consumers.

More recently, NGOs had also started to take part in the dissemination of MHPs in Ladakh and Uttar Pradesh. One of the NGOs had installed 13 MHPs, with a total capacity of about 200kW. These plants were handed over to the communities for operation.

Nepal

Thirty-five MMHP plants, having a total capacity of nine MW, had been installed by the government in Nepal. These plants were installed and operated by the NEA and five of them were connected to the grid. During 1993, five of these plants were leased to private companies for operation and maintenance so as to cut down NEA's losses from MMHPs. More MMHPs were expected to be leased out in the future. These companies were also empowered to fix tariffs, though not higher than those of NEA, and collect revenue on their own.

Some private MMHP plants were non-commercial and formally managed. These plants represented an effort to arrive at new forms of MMHP management. The effort was being supported by a number of donor agencies.

These plants also used innovative tariffs; one of the distinctive features differentiating them from public sector plants. For example, in the 400kW Salleri Chialsa Plant, the special features of tariffs were introduction of flat tariffs for certain categories of domestic consumer, based on committed/admissible power; relatively high fixed charges for the remaining categories of domestic consumer and all commercial consumers; introduction of cheap off-peak rates for industrial consumers; and differentiation of admissible power during peak and off-peak periods for industrial consumers. These innovative features of the tariff rates helped to reduce costs associated with meter

2 SHP or Small Hydropower includes installations of up to 3.0MW.
3 A point is defined as a bulb/tubelight, or power socket.

reading and, for some categories of domestic consumer, to reduce the peaks and to encourage industries.

The Ghandruk Power Plant, with a capacity of 50kW, has introduced flat tariffs of NRs 0.50/W, NRs 0.75/W and NRs 0.25/W per month for domestic, commercial, and industrial (day time) consumers, respectively. The commercial and industrial consumers of this plant could also choose an alternative tariff of fixed components - NRs 0.25/W/month and NRs 0.08/W/month for commercial and daytime industrial consumers respectively and an energy component of NRs 137/kWh for both types of consumer.

Privately-owned Informal MMHP

This type of plant was owned and operated by private entrepreneurs. There were over 700 turbines in Nepal, of which 13 were stand-alone units for electrification and the rest were installed mainly for agro-processing, 100 of these had add-on units for electricity generation. In addition, about 70 units of the peltric type, having an average power output of one kW, had also been installed for electrification.

The number of improved *ghatta*(s), essentially traditional *ghatta*(s) with improved metal runners, was estimated at 200. Some improved *ghatta*(s) had add-on electrification facilities as well. Multipurpose power units, in the one to four kW range, represented the culmination of the efforts to modernise the traditional *ghatta*. Around 200 units of this type had been installed.

Equipment Development and Manufacture

The first modern turbine — a propeller turbine — was manufactured in 1960 by Balaju Yantra Shala (BYS) with assistance from the Swiss Government. After a few trials with propeller turbines and cross-flow turbines, which were developed subsequently, the cross-flow turbine was accepted for widespread dissemination in Nepal. Eleven companies were manufacturing MHP equipment, including turbines. Nepal was fairly advanced in manufacturing cross-flow turbines.

Manufacturers in Nepal had developed/adapted other MHP equipment and end uses such as pelton turbines, electronic load controllers, *bijuli dekchi*(s), electronic current cutout, and 'air heat storage cookers'.

China

China introduced MMHP/SHP plants in the 50s. It had installed 1,200MW of MMHP/SHP by 1979, which accounted for about 48 per cent of the total harnessed hydropower. Out of the total of 2,300 counties, 1,567 had considerable MMHP/SHP potential and 777 relied mostly on MMHP for electricity. Currently China had 48,284 MMHP/SHP Plants (of up to 25MW in capacity) with a total generating capacity of 15,055MW. Fifty-six per cent of the MMHP/SHP plants were in the micro-range (of up to 100kW), 39 per cent in the mini-range (100-500kW), and the rest were in the SHP range (>500kW).

About eight per cent of the plants were connected to the national grid and 30 per cent were connected to local grids. The remaining 62 per cent of the plants were run on an isolated basis. In terms of capacity, 93.5 per cent of the MMHP/SHP was connected to the grid.

Most of these plants were introduced, constructed, and managed by local governments in a decentralised manner with the help of various funding sources. Funding sources included the Central Government (51%), bank loans (35%), and local contributions (14%). Fifteen per cent of the plants were run by the counties and the rest by village administration.

Pakistan

The main organisation responsible for installing hydropower plants in Pakistan was the public-owned Water and Power Development Authority (WAPDA). There were altogether 64 MMHP plants within the public sector, with a total installed capacity of 17,115kW. The average installed capacities of these plants in the Northern Areas, the North West Frontier Province, and Azad Jammu and Kashmir were about 300, 225, and 95kW, respectively.

Private Sector MMHP

In Pakistan, mainly two organisations, the Pakistan Council of Appropriate Technology (PCAT) and the Aga Khan Rural Support Programme (AKRSP), were engaged in the promotion of MMHP. Both the organisations surveyed, designed, and installed plants. The PCAT provided a subsidy of about 40 per cent of the total cost, and the AKRSP subsidy varied between 20-80 per cent. Since the introduction of the programme in 1975, PCAT had installed 160 plants with a total capacity of two MW. The average capacity of these plants was 12.8kW. The plants were spread over 160 villages and provided electricity to 10,000 people. The cost of the plants ranged between PRs 10,000 to 15,000 per kW (US$ 350-500). AKRSP had installed approximately 25 plants, with a total capacity of 0.6MW.

In Pakistan, MMHP plants which were basically for electricity generation were not commercial entities. The revenues generated were small and usually just sufficient to meet the routine operation and maintenance costs. The usual tariffs were PRs 5-15 per bulb per month for unmetered consumers and PRs 0.40 to 1.50 per kWh for metered consumers.

Main Features of MMHP Technology

In Pakistan and Nepal, the share of cross-flow turbines in private MHP was 97 per cent and 76 per cent, respectively. In Nepal, the other types of turbines in use were the MPPU type (20%), followed by the pelton type (3%)[4] Pelton turbines were gaining in popularity in Nepal especially in stand-alone plants. Micro pelton turbines used in popular one kW peltric sets were widespread in Nepal.

4 Excluding micro pelton turbines.

China manufactured all its own MMHP equipment. In China, MMHP equipment was manufactured in about 100 factories. It also exported MMHP equipment to countries in the HKH region, especially to Pakistan and Nepal. India also had a good capacity for manufacturing MMHP equipment.

Most of the MHP plants in Nepal did not have governors. Electronic load controllers, performing the function of governors, were gaining in popularity in Nepal.

Efficiency and Performance

Breakdowns of MMHP plants were fairly common. One of the surveys undertaken in Pakistan showed that 54 per cent of the plants were not operational. In Nepal, no study had been carried out in this respect. However, there was widespread belief that the plant failure rates were high. The failure rate for plants installed after 1988 in Pakistan was estimated at 10 per cent. The failure rates were declining in Nepal as well.

Civil works' failures were more responsible for MMHP failures than electromechanical equipment failures. There were no adequate facilities to test the efficiency and performance of MMHP equipment in Nepal and Pakistan. There were many MMHP plants that could not develop the rated power at the site.

Plant Cost

The cost of equipment manufactured in China, India, Nepal, and Pakistan was considerably lower than equipment imported from developed countries. Even the relatively better quality equipment from China was two to four times cheaper than European and Japanese equipment. The cost of privately-installed MHPs in Nepal varied between US$ 800-2,000 per kW, whereas, in Pakistan, it was around US$ 300-500 per kW. Chinese and Indian MMHP costs were compatible with those of Pakistan.

Management and Ownership

In publicly-owned plants, the participation of local people was minimal. The operators, in this case, were not sufficiently motivated to operate and maintain the plants successfully. The plants owned by entrepreneurs were relatively small and often operated and maintained by the owners themselves. In these plants, there was greater motivation for proper operation of the plant. In plants owned by communities, the responsibility for operating and maintaining the plant was delegated to an operator or manager to whom payments were made in cash or kind.

Review of Policies Concerning MMHP Programmes

All the countries in the HKH region provided some support to MMHP. The degree of support varied widely. The allocation to the renewable sector, including MMHP/SHP, still remained below one per cent in most cases. Policies of the specific countries are reviewed in this section.

Nepal

On many accounts, Nepal was ahead of the other countries in evolving and adopting policies and plans for the development of new and renewable energy, in general, and MMHP in particular. Bank loans, at priority sector interest rates were had been provided since 1977 for the installation of MMHP by private entrepreneurs. In 1984, plants with a capacity of up to 100kW were delicensed and, in 1985, a subsidy for the electricity component of MHP was introduced. According to the subsidy policy, MHP, in remote and non-remote areas, was entitled to subsidies equal to 75 per cent and 50 per cent of the electrical equipment costs, respectively. In 1992, the Hydropower Development Policy and Water Resources' Act was promulgated. The policy delicensed MMHP of up to 1,000kW. It announced a number of incentives for private sector participation in hydropower development. The private sector was already dominant in the MHP sector in Nepal. The Water Resources' Act, among others, fixed priorities for water use by various sectors. Nepal had been including the targets for MMHP development in its Five-Year Plans. For example, the Eighth Plan (1992/93 - 1996/97) targetted the development of five MW of new MHP capacity.

China

The Government of China was following the policy of self-construction, self-management, and self-consumption for MMHP development. Government subsidies to MMHP installations covered 38 per cent of the capital costs, commercial bank loans contribute 35 per cent, and contributions from people and other sources the rest. China had had remarkable success in the field of MMHP by treating MMHP as one of the components of its rural development package.

India

The Government of India (GOI) accorded special recognition to MMHP/SHP development in its planning and policy documents. The GOI allowed private sector installations and had also announced special incentives, loans, subsidies, and tax relief. The Ministry of Non-conventional Energy had created a new institution — the Indian Renewable Energy Development Agency to channelise World Bank funds for MMHP. India was treating private MMHP/SHP as a supplement to the government electrification efforts. Private MMHP plants supplied energy either to the grid or to isolated areas prioritised by the public sector.

Pakistan

The Government of Pakistan had been supportive of rural electrification. About 40 per cent of the rural areas had been electrified and there were vast rural areas which could be electrified by using MMHP through private initiatives. The government was yet to formulate policies for the promotion of private MMHP. The efforts made by PCAT and AKRSP in MMHP promotion were still to receive due government recognition.

MMHP was being developed in Pakistan, mainly for electrification purposes. The MMHP plants were still non-commercial entities developed with the help of subsidies in the 20 to 80 per cent range.

Bhutan

Bhutan had not formulated policies or plans for private sector participation in the development of MMHP/SHP. However, the establishment of private sector power plants had been declared a desirable option. According to its Master Plan for Development of the Power Sector, MMHP/SHP had not received priority in Bhutan.

Management and Operation of Decentralised Privately-owned Plants

Formally-organised private sector MMHP - such as the Ghandruk and Salleri-Chialsa Plants in Nepal - had demonstrated the viability of operating MMHP in an organised manner. Decentralised MMHP in China was also being formally managed with reasonable success. These MMHP fixed tariffs independently except for the energy supplied to the grid, for which government rates applied.

In Nepal, informally-managed MHP plants were owned mostly by entrepreneurs and a few by communities. The entrepreneur-owned plants were commercial entities, whereas the community-owned ones were non-commercial. The financial and managerial capabilities of owners/managers and operators are generally poor and many MMHP failures were associated with this problem.

In Nepal, add-on MHP seemed to have more outage rates. This is partly explained by the poor returns on investments in add-on plants. Difficulties in the collection of revenues had been reported in Nepal. This was common in cases in which the supply was either not reliable or of poor quality.

In Pakistan, most MHP plants were owned by communities or families. In almost all cases, the owner or a prominent person from the community managed the plant. These community-owned plants, mostly for electrification, were non-profit enterprises. In most of the mountain areas, including Nepal and Pakistan, the organisation of repairs was a difficult and time-consuming endeavour.

Uses of MMHP Energy

Apart from in Nepal, most of the MMHP plants in the region were of the electrification type. In Nepal, many private plants operated agro-processing and other similar equipment directly with water turbines. The load factors of electrification plants were usually low (10-20%), whereas the load factors of agro-processing plants were somewhat better (10-30%). The reasons reported for the low load factors of MMHP plants were: i) use of electricity for lighting only; ii) unreliable or insufficient electricity supply, which hinders industrial and commercial uses; and iii) the installed capacity was higher than demand.

The load factors of formal private sector plants in Nepal, as well as in Pakistan, were found to be higher (up to 42%) and, consequently they were performing better financially than the regional average. The better performance could largely be attributed to end-use promotion activities.

In China, after the replacement of older plants, grid connection, and diversified end-use promotion, load factor improvement was observed in many cases. However, a low load factor was still a problem in isolated systems.

Enhancement and diversification of end uses were considered to be the thrust areas in the context of making MMHP financially more attractive. It is generally observed that electricity, or any other technology for that matter, is adopted more willingly when there are direct economic returns. Therefore, more efforts should be made to promote industrial/commercial uses of electricity.

Some ground-breaking work has already been undertaken in Ghandruk, Salleri-Chialsa, and Andhi *khola* with the aim of improving the load factor. These include promotion of low wattage cookers, introduction of tariffs stimulating daytime industrial activities, and so on.

Plant Economics

Public Sector Plants

Public sector MMHP plants were usually three to five times more expensive than private sector ones, mainly because public sector plants used imported equipment for greater reliability. The cost per kW installed in Pakistan varied from US$ 1,330 to 2,000, whereas, in Nepal, it ranged from US$ 1,550 to US$ 6,000. The financial performance of most of these plants was poor. In Nepal, this kind of plant was able to generate revenue that covered only about 20 per cent of the annual operating costs.

Private Sector Plants

It has been demonstrated that operation and maintenance costs can be lower than revenues in the formal private sector, e.g., Ghandruk and Salleri-Chialsa in Nepal. In Ghandruk, the net income equalled six per cent of the total capital costs and in Salleri, in 1992/93, the net income was equal to 2.4 per cent of the total investment.

Most private sector plants in China, however, were not doing well due to a rise in plant installation and operating costs. With an increase in tariffs, from 0.05-0.08 *yuan*[5] per kWh to 0.20 *yuan*/kWh, it was estimated that plants might need a payback period of about ten years.

In Pakistan, informal plants were non-profit entities. Therefore assessment of financial viability was not easy.

5 There were eight RMB *yuan* to the US dollar at the end of 1994.

In Nepal, in some cases, the returns on the investments in agro-processing units were high. For example, the return was 90 per cent in one of the case studies carried out by ICIMOD. Among agro-processing units, oil expelling units were most profitable. In other studies reported, the return rates were 20-35 per cent. Generally, the returns on agro-processing units were much higher than those on electrification units. The profits on electrification plants varied from three to 11 per cent.

In a few cases in Nepal, diesel-driven agro-processing units were found to be competitive with agro-processing micro-hydro units.

Future Trends and Prospects for MMHP

The indigenous and decentralised development of MMHP technology had been continuing for more than four decades in China and about two decades in the other countries of the region. More than a third of the counties in China relied on MMHP/SHP for domestic as well as industrial use. Most of these MMHP/SHP plants were also connected to main or local grids. Pakistan and Nepal had also experienced significant achievements in spite of limited inputs and efforts.

At the same time, a number of serious problems urgently in need of redressal had surfaced. One of the problems was the lack of firm commitments at government level due to the belief that "small may be beautiful but large is cheap." Hence, it was likely that future MMHP development would take place mainly in the private sector in a decentralised manner.

The high demand for MMHP in Pakistan and progress in the industrial applications of MMHP in Nepal and China were indications of the future scope for MMHP. There was a lot of scope for further progress in MMHP development in all countries of the region, apart from in China.

Based on the experiences so far, it was reasonable to conclude that some level of financial support would be necessary in the foreseeable future for the desired level of MMHP proliferation in the HKH region and to gain a strong foothold in the overall energy scene in the rural mountain areas. The support needed was mainly in the fields of promotion, R&D, and training.

Based on the conclusions of the Consultative Meeting of MMHP experts, as well as on other experiences, the following factors should be considered in promoting MMHP.

- Electricity supply from MMHP needs to become more reliable quantitatively and qualitatively, to encourage industrial applications.
- Use of electricity from MMHP should be diversified into existing traditional uses, e.g., irrigation.
- Cottage industries could consume sizeable amounts of MMHP power for process heat and motive power. Efforts should be made to identify and promote new industrial end uses.

- China has reported significant achievements in cooking with electricity whereas Nepal is yet to pick up in this area. It is desirable that difficulties associated with electric cookers, such as unreliable supplies, lack of adequate cooking devices, and high capital and energy costs, be carefully studied before making further efforts in this direction.
- Developed countries have witnessed the shift from small isolated plants towards grid-connected larger plants. This trend should not be copied in the HKH region without adequate research.
- Performance and reliability, which are the primary concerns of promoters and entrepreneurs, need to be enhanced through R&D efforts and promotion and distribution of appropriate design and manufacturing manuals.