PROCEEDINGS OF THE

PAKISTAN NATIONAL SEMINAR ON MINI- AND MICRO-HYDROPOWER DEVELOPMENT IN THE HINDU KUSH-HIMALAYAN REGION

Edited by Wahaj-us-Siraj

Organised jointly by
Pakistan Council of Appropriate Technology (PCAT)
Ministry of Science & Technology, Government of Pakistan

and

International Centre for Integrated Mountain Development (ICIMOD) Nepal
Islamabad, Pakistan
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FOREWORD

The Hindu Kush-Himalayas are rich in natural resources, to a large extent still untapped. Most prominent are the water resources and their hydropower potential. While large-and medium-scale hydropower plants have received considerable attention and funding for development at the national level, the remote and inaccessible mountain areas have not benefitted from these developments. A new approach towards decentralised planning and implementation of independent power units is needed, therefore, to make use of the locally available water resources, management skills, and economic opportunities. Throughout the HKH region, mini- and micro-hydropower plants have been established in the past 10-20 years. While in many locations they have met with great success, it has also become clear that many others are facing problems of sustainability. It is also for this reason that in 1993, ICIMOD initiated, with the financial assistance of the Royal Norwegian Government, the project "Design and Testing of a Regional Training Programme on Mini- and Micro-Hydropower Development in the Hindu Kush-Himalayan Region". The project is aimed at strengthening the capacities of the countries of the HKH region in the development of Mini- and Micro-hydropower (MMHP) in order to improve its performance, viability, and impact.

The Pakistan National Seminar on MMHP Development in the HKH Region was organised with the main objective of presenting the information available from the region to a wider audience in a national context, and to discuss ideas and recommend ways of improving local programmes. The seminar also served another important purpose; that of bringing together experts, implementers, decision-makers, planners, entrepreneurs, manufacturers, and others to discuss various issues and establish contacts for mutual future benefit.

All the important agencies, government as well as non-government, associated with MMHP in Pakistan were represented at the Seminar. Valuable information was presented in the papers and during discussions. The seminar also gave impetus to MMHP promotion and new techniques were learned that could improve specific programme activities.

The seminar was organised in joint collaboration with the Pakistan Council of Appropriate Technology (PCAT) and the Ministry of Science and Technology, Government of Pakistan, who also provided financial support in addition to doing all the groundwork for organising and conducting the Seminar.

Thanks are due to Mr. Shehreyar Khan, Chairman PCAT, Mr. G.U. Sarhandi, Secretary PCAT, and a number of other PCAT Staff members. Special thanks go to Mr. Wahaj-us-Siraj, Assistant Technological Advisor, Ministry of Science and Technology, who worked very hard to make this Seminar a real success. Mr. Siraj also prepared the draft of the Seminar Report.

I hope very much that, with the publication of this report on the Seminar, further initiatives can be undertaken to ensure that locally available hydropower be of direct benefit to economic development and the improved well being of mountain people in remote areas.

Egbert Pelinck
Director General

LIST OF ABBREVIATIONS

AJK	Azad Jammu & Kashmir
AKRSP	Aga Khan Rural Support Programme
ATDO	Appropriate Technology Development Organisation
CUSEC	Cubic feet per second
D.C.	Direct Current
GTZ	German Agency for Technical Cooperation
HEPO	Hydro Electric Planning Organisation
HKH	Hindu Kush Himalayan Region
HMC	Heavy Mechanical Complex
ICIMOD	International Centre for Integrated Mountain Development
kW	Kilowatt
kWh	Kilowatt-hour
MAF	Million Acre-feet
MHP	Micro - Hydropower
MMHP	Mini/Micro Hydropower
MW	Megawatts
NA-PWD	Northern Areas Public Works Department
NGO	Non-Governmental Organisation
NORAD	Norwegian Agency for Development Cooperation
NWFP	North Western Frontier Province
PAEC	Pakistan Atomic Energy Commission
PARC	Pakistan Agricultural Research Council
PCAT	Pakistan Council of Appropriate Technology
PRs.	Pakistani Rupees (1.00 US$=30.5 PRs.)
R&D	Research and Development
SHP	Small Hydropower
SHYDO	Sarhadl Hydropower Development Organisation
TWh	Tera watt-hour
VO	Village Organisation
WAPDA	Water and Power Development Authority

INTRODUCTION AND OBJECTIVES

Background

Most of the northern parts of Pakistan, including parts of the North West Frontier Province (NWFP) and Northern Areas are traversed by the Himalayas, Hindu Kush, and Karakoram, three great mountain ranges, and have high rainfall characteristics. Consequently, many large rivers of Pakistan originate in these mountain ranges, and the area is rich in forests, minerals, and hydropower potential. These mountain ranges are inhabited by nearly two million people. Except for a few cities and small towns, these areas lack basic infrastructure and people are deprived of basic amenities such as roads, schools, electricity, and so on. Provision of energy to these areas remains a serious problem, and people have to rely on fuelwood to meet their domestic energy needs, resulting in deforestation and associated environmental hazards. The area is, however, blessed with an abundance of perennial streams and waterfalls which can be successfully exploited to generate electricity and motive power by using mini- and micro-hydropower (MMHP) plants. MMHPs provide several advantages over other conventional energy systems, including large hydropower. These decentralised power plants can produce the energy where it is required and can be operated and maintained locally by user communities. The level of technology is fairly simple, and the capital investment required for installation of the plants is low.

The International Centre for Integrated Mountain Development (ICIMOD), Nepal, has initiated a project on Mini-and Micro-Hydropower in five countries of the Hindu Kush-Himalayan (HKH) Region, namely, Nepal, China, Bhutan, India, and Pakistan. The objective of the project was to study the present situation in terms of the status of the programmes, policies, and problems of the participating countries in the MMHP field. After compiling country reports and case studies, this situation was analysed in an international consultative meeting of experts. Thereafter, National Seminars in selected participating countries were organised to propagate MMHP technology. The project concluded with a training programme for policy-makers, planners, financiers, and chief implementers, highlighting the salient features of MMHP and suggesting steps to enhance the future pace of installations and sustainability of programmes. A regional network of sustained information exchange in the Himalayan Region for MMHP development and management is being established.

As a part of this project, the National Seminar on MMHP Development in Pakistan was jointly organised by the Pakistan Council of Appropriate Technology (PCAT), Ministry of Science and Technology, Government of Pakistan, and ICIMOD. The Seminar was held in Islamabad on the 26th and 27th October, 1994.

Objectives of the Seminar

- To communicate information about the developments, achievements, impacts, economics, and prevalent problems of MMHP to a target audience of planners, decision-makers, implementers, assessors, manufacturers, consultants, and others.
- To discuss the local issues related to various aspects of MMHP propagation and its impact on the remote and isolated mountain development scenario in the overall regional perspective.
- To arrive at consensual findings and conclusions in order to improve the implementation of MMHP programmes and their impact.
- To bring together concerned personnel from various organisations associated with MMHP development and promotion, for future contacts and information exchange.

Seminar Programme and the Participants

The seminar was attended by the representatives of the implementing agencies, planners, donors, private and public sector manufacturers of MMHP equipment, policy-makers, and financiers. The programme is presented in Annex I and the list of participants is in Annex 2. A total of 45 participants attended the Seminar. Annex 3 contains summaries of the papers presented.

The Seminar was inaugurated on October 26, 1994, and the inaugural session was attended by a large number of people and addressed by prominent public representatives and government officials associated with MMHP development. This session was followed by Session I, in which the representative of ICIMOD presented his paper on development of MMHP in the Hindu Kush-Himalayan Region. The second paper presented in this Session was on the MHP programme of PCAT. In Session II on the same day, papers on community participation in Micro-Hydropower (MHP) development, selection of turbines for MHP plants, indigenous development of low-head MHP plants, and management of MHP plants were presented. On the second day, during the third session, papers on problems associated with MMHP plants, the socioeconomic impact of MHP plants, the Tyson turbine, mini-hydropower programme of the Northern Areas Public Works Department, and an economic feasibility study for a low head MHP plant at canal falls, were presented. This was followed by the preparation of Conclusions and Recommendations by a Committee. In the concluding session, the seminar recommendations were presented, followed by a brief discussion. The seminar was finally closed on the evening of October 27, 1994, with concluding remarks by the Chairman of the Session.

PROCEEDINGS OF THE SEMINAR

Inaugural Session

The seminar was inaugurated by the Federal Minister for Kashmir Affairs and Northern Areas, Mr. Mohammad Afzal Khan on the morning of October 26, 1994. In his introductory speech, **Dr. A.A. Junejo, MMHP Project Coordinator, ICIMOD**, Nepal, presented information on the background of ICIMOD and its activities in the Hindu Kush-Himalayan region. He informed the participants that ICIMOD has been a serious contributor to the development of appropriate energy resources particularly indigenous ones, in mountain areas. This seminar was a part of the project on MMHP in the Hindu Kush-Himalayan region, financed by the Norwegian Agency for Development Cooperation (NORAD) and implemented by ICIMOD. The main objective of this project was to collect information about status, policies, impact, and problems of the MMHP within the Region and to review and analyse this information to arrive at suggestions and proposals unanimously for the propagation of MMHP as a viable and sustainable energy option. Concluding his introductory address, Dr. Junejo thanked the Ministry of Science & Technology and PCAT for collaborating with ICIMOD in organising the seminar and providing significant and valuable inputs. He assured the full commitment of ICIMOD towards the development of remote and underdeveloped mountainous areas through the provision of appropriate inputs such as information packages, training programmes, and other such materials.

The welcome address was delivered by the **Chairman, PCAT, Mr. Shehryar Khan**. In his address, Mr. Khan briefed the audience about the MHP programme of PCAT. Highlighting its salient features, he stated that PCAT has been installing low-cost and indigenously designed and fabricated MHP plants in the difficult mountainous regions of Pakistan for the last 18 years. In addition to the generation of electricity, motive power from some of these plants was used during the day to run cottage-level industrial and agroprocessing units, providing income-generating opportunities. The remarkable feature of the MHP programme of PCAT was the participation of local communities to the maximum extent, from planning and construction to operation and maintenance. He stated that PCAT has installed a total of 181 MHP plants with a cumulative power generation capacity of 2.5 MW. Mr. Khan added that recently the public representatives of the area have allocated some rural electrification funds to PCAT for the installation of MHP plants.

Delivering the message of **Sardar Talib Hasan, Parliamentary Secretary for Science and Technology**, Mr. Abdul Rashid, Joint Technological Adviser, Ministry of Science & Technology, stated that the occasion reflected the continuity of a joint effort by PCAT and ICIMOD to bring on socioeconomic development in the region.

Emphasising the importance and need of indigenous low-cost technology, Mr. Rashid stated that this makes the technology easy to understand and maintain in remote and far-flung areas with scarcely skilled manpower. He highlighted the development of MHP and the activities of PCAT in this respect. He also appreciated the fact that the cost of installation and generation of MHP plants by PCAT were remarkably low compared to those installed by international donors. He expressed the hope that during the Eighth Five Year Plan, the MHP programme would be further enhanced with assistance from the Government of Pakistan, as well as from international donor agencies.

Mr. Parvez Ahmad Butt, Secretary, Ministry of Science & Technology, in his address, highlighted the importance of small hydropower for isolated and remote areas. Appreciating the efforts of PCAT and ICIMOD in organising the seminar, he stated that the MHP programme of PCAT benefits the low-income segment of the population and is, in fact, a real service to the rural people in terms of poverty alleviation through science and technology. He emphasised the need for adopting an integrated approach in providing energy to households and focussed on its productive use through cottage-level industries. Mr. Butt was of the view that efforts should also be made to exploit canal falls using low-head, high-discharge technology. He assured the participants of the full and continued support of the Ministry of Science and Technology for the MHP project of PCAT.

The **Chief Guest, Mr. Mohammad Afzal Khan, Federal Minister for Kashmir Affairs and the Northern Areas**, in his inaugural address, appreciated the efforts of ICIMOD in accumulating a wealth of information from the HKH Region in the field of mini-and micro-hydropower through preparation of country reports, case studies, and through the consultative meeting of experts held in Kathmandu in June 1994. He also lauded the efforts of PCAT in promoting MHP technology in the country's mountainous areas. Highlighting the efforts of the government in the power sector by involving the private sector in power generation projects, he stated that special attention was paid to the development of small hydropower plants and incentives offered to private entrepreneurs to invest in this field. Mr. Khan congratulated PCAT and ICIMOD for jointly organising this seminar.

SESSION I

Mini- and Micro-Hydropower Development in the Hindu Kush-Himalayan Region -- Achievements, Impact and Future Prospects

The first paper of Session I, presented by Dr. A. A. Junejo, MMHP Project Coordinator, ICIMOD, Nepal, described the present status of MMHP in the HKH region. Despite the considerable progress made in this field, the share of MMHP in the total energy generation of the countries in the region was still very low. China has exploited about 20 per cent of the potential, whereas in other countries, the exploitation rate is about one per cent. This is due to the fact that MMHP programmes in

Nepal, Pakistan, and India started only about two decades ago, whereas China has been working in this field for the last four decades. In China, there are 48,284 existing SHP/MMHP plants (of up to 25 MW in capacity), having a total capacity of 15,055 MW, of which 45,645 plants are in the mini/micro range (below 500 kW). In Nepal, about 735 private MMHP plants have been installed so far. In Pakistan, the number of private sector informal MHP plants is about 190, Bhutan has 19 MMHP plants with a capacity of 3.4 MW, and India has installed 145 SHP/MMHP plants with a total generating capacity of 106 MW.

MHP development in Pakistan is predominantly carried out by public sector agencies. In Nepal, the private informal sector leads the installation programmes, and, in India, China, and Bhutan, almost all the plants have been installed by various government agencies.

In Pakistan and Nepal, the cross-flow type turbine is used predominantly in MHP plants. Chinese plants are equipped with a variety of turbines, ranging from the Francis to Turgo, whereas India manufactures a range of different hydropower turbines of up to three MW in capacity.

The support for MMHP in the region generally comes from the respective national governments, whereas some international agencies have also been providing technical assistance. The energy from MMHP plants in the region is primarily used for domestic lighting, however, many installations in Nepal also use this energy for cottage-level industrial activities such as agroprocessing, paper making, saw milling, etc. Plant factors are quite low in all cases, ranging from 10 to 30 per cent, except in China where the plants are relatively bigger, more sophisticated, and the electricity supply is more reliable, which stimulates industrial and commercial use.

The installation costs of MMHP plants vary from country to country. In Pakistan the installation costs per kW are US$ 330-500, compared to US$ 800-2,000 in the case of Nepal. The economic returns from MHP plants are quite low, and returns can be improved by diversifying the end uses, especially the productive ones.

MMHP technology has achieved significant success in the region, the most success being achieved in China where more than one-third of the total country now relies on electricity generated from SHP/MMHP plants. Private MHP installations have also made considerable inroads in Pakistan and Nepal. However, there is a dire need for enhancing the pace of MHP installations in the rest of the region, keeping in mind the tremendous potential and demand. Also, the new plants need to perform better in order to supply reliable electricity which can be used for productive purposes by the rural industrial sector.

The Micro-Hydropower Programme of
Pakistan Council of Appropriate Technology -- An Overview

The second paper, presented by Dr. M. Abdullah, Consultant to PCAT on MHP, highlighted achievements in MHP installation and future plans. The objectives of PCAT are to survey and assess the needs and accordingly design and adapt appliances or technologies for common use. With this objective in mind, PCAT, formerly known as the Appropriate Technology Development Organisation (ATDO), started MHP programme in 1975 by installing the first plant with a three kW capacity. Since then, PCAT has installed a total of 181 MHP plants with an overall generating capacity of about 2,500 kW. The objective of PCAT's MHP programme is to provide electricity to the poorer segments of the population and to inculcate the concept of self-help and self-reliance in terms of installation, operation, and management of plants on a community basis. The plants are installed in the far-flung and isolated communities by distributing simple and inexpensive technology.

The programme is beneficial for local communities in a number of ways, including supply of electricity and motive power for domestic lighting and cottage-level industrial purposes. It requires little capital and stimulates socioeconomic development in the area. The costs of PCAT's MHP plants are in the range of PRs 10,000-15,000 (US$ 330-500) per kW installed and cost per kWh delivered is estimated to be PRs 1.55 and PRs 1.09, for 10 kW and 20 kW plants respectively. The MHP programme of PCAT is funded by the Government of Pakistan, and plants are installed by providing a subsidy of about 40-50 per cent. The plants are operated, managed, and maintained by a management committee constituted by the representatives of local communities.

Community Participation in Micro-Hydropower Development

This paper, presented by Mr. Ghulam Saeed Khan, Regional Programme Engineer, Aga Khan Rural Support Programme (AKRSP), Gilgit, described the AKRSP approach involving local communities in its MHP programme. The AKRSP started its programme in 1986, and plants were distributed to the selected village organisations (VOs). The rural development methodology of the AKRSP is based on intervening in rural society by holding a dialogue with community members/leaders and through the formation of a VO which acts as an interest group.

Once a VO is formed and enters into a partnership with AKRSP, a project is then identified. The basis of the project is that it should provide service /benefits to at least 75 per cent of the VO members. The members develop a financial system through collections, donations, and savings, and then one member is trained in the operation of the MHP plant and to manage the project. AKRSP provides technical assistance and plant equipment, whereas the labour and construction materials are provided locally by the VO. Once a project is completed, it is handed over to the VO for management, operation, and maintenance.

Larger VOs with bigger projects constitute an Electricity Committee for the management of project affairs, while smaller projects are supervised by the VO manager. The committees are responsible for all the affairs of the plants such as appointment of staff, collection of tariffs, and operation and maintenance of the plants. These management committees are responsible to the general body of the VO.

The installation of MHP plants stimulates community development, plays an important role in socioeconomic development of the area and provides entrepreneurial vision to VO members.

Discussion: On a query from one of the participants regarding the status of 28 MHP plants installed by the AKRSP, the author stated that all plants installed in Gilgit and Baltistan were in working condition, whereas the figure in case of plants installed in Chitral district was not readily available.

Selection of Turbines for Micro-Hydropower Schemes

Mr. Samiullah Khattak, Assistant Director, PCAT, presented his paper on the selection of turbines for MHP schemes. Each turbine type is best suited to a certain range of pressure heads and flow rates and has an associated numerical value called *specific speed*. The *specific speed* relates the power output of the turbine to its running speed and head, but does not depend on the size of turbine. A well-designed turbine has always the smallest runner permissible within the limit to handle the flow passing through it. The propeller, Kaplan, and Francis turbines are suitable for low head ranges, cross-flow turbines are suitable for low to medium head ranges, whereas Pelton turbines are mostly used in high head range applications. Cost comparison of various turbines types indicates that cross-flow turbines could be the cheapest, whereas propeller and Francis turbines cost more.

PCAT's experience indicates that cross-flow turbines can be fabricated in small workshops, are easy to repair and maintain, and are cheapest. The cross-flow turbine is manufactured with simple fabrication techniques, i.e., cutting, welding, and grinding only, and no casting work is involved. Sheet metal and readily available pipes are used to fabricate the blades of the turbine which are then welded with metal plates to form the runner. These turbines are manufactured at a small local workshop. Efforts are, however, underway to manufacture improved quality turbines by using precision manufacturing techniques.

Discussion: A query was raised regarding the testing facility for the turbines in the local workshop. It was felt by one of the participants that details of the power output of the turbine are not adequately covered. The author explained that, at a new workshop, which is being established by PCAT in Peshawar, turbine balancing and testing facilities would become available. In the selection of turbine criteria, only short cuts have been followed and engineering calculations/inputs have not been taken into account.

Indigenous Development and Manufacturing of Very Low Head Micro- Hydel Power Plants

This paper, written by Mr. Aftab Sarwar and Dr. S. M. Bhutta, was presented by Dr. Bhutta. The paper briefly described the water resources of Pakistan and the rural electrification programme of the government. The theoretical design of a very low head micro hydropower unit was presented in the paper based on a flow of five cusecs and with a head of three feet. The speed of the turbine is calculated, the runner diameter has been worked out, and it is confirmed that a turbine with a runner diameter of 10 inches with the above parameters would generate 1.0 kW of electric power.

Development stages of commercial plants include research and development, assessment, and other aspects such as engineering, industrial, commercial, managerial, economic, and financial. All these aspects have a strong interplay and are essential for successful manufacturing. The first step in manufacturing a plant is to build a prototype plant. This involves analytical investigations and research and development, in addition to identifying critical technical and economic parameters. During this stage, the design is evaluated; parameters adjusted; physical operation is confirmed; and equipment, material and apparatus are fabricated.

The next step in this process is the demonstration of the prototype technology in the field. There could be many concepts and designs for building prototypes, but only a few go on to demonstration and then into the commercial stage. The evaluation of the demonstration unit is made both in technical as well as in economic terms. After successful practical demonstration of the technology and its technical and economic feasibility, manufacturing of such plants on a commercial scale can be undertaken by the private sector.

These micro-hydropower plants can prove to be a viable service for the people in remote areas and can be self sustainable. The approach also offers several advantages over the centralised electricity supply systems. The economic analysis indicates that the cost per unit from thermal power plants for rural areas becomes PRs 3.50 whereas, in the case of MHP plants, it is PRs. 1.30.

Discussion. Replying to a question, the speaker stated that only about 15 per cent of the country's hydropower potential has been utilised, and sites with low-head potential have been completely ignored. The total length of canals in Pakistan is 58,500 km, and there are thousands of small waterfalls on these canals. There are 150,000 villages in far-flung areas, out of which 50,000 enjoy the facility of electricity. A question was raised regarding poor support from the government for the promotion of MHP technology. The speaker observed that high failure rates due to lack of repair and maintenance facilities have been giving a bad name to the technology.

Management of Micro-Hydropower Plants in Pakistan

This paper, presented by Dr. Habib Gul, Deputy Director, PCAT, detailed the management system of MHP plants adopted by PCAT. Applications for installation of MHP plants from the local people received by PCAT are accepted with the pre-condition that the applicants should be a group of four to six local people. In most cases, these applications are duly recommended by the elected public representatives of the respective areas. After surveying the site and determining its technical and social feasibility, the final decision to install a plant is taken by PCAT.

A management committee of four to six prominent persons is formed, and a written agreement is signed by the PCAT with this committee. In this agreement, the committee is clearly apprised of its responsibilities, which include the provision of free labour and materials for construction of the project, purchase of distribution wires, and subsequent operation and maintenance of the plant.

The plants are installed in close association with the community and the involvement of most of the villagers. Once the plant is installed, one or two operators identified by the committee are trained in its operation and maintenance. This on-the-job training is provided by the PCAT staff for seven days. Consequently, the plant is handed over to the management committee for operation and maintenance. The committee fixes the monthly tariff usually on a per bulb basis and arranges for collection. This amount is used to pay the salary of the operator and for routine operation and maintenance. In the case of major breakdowns, the recipients approach PCAT to provide technical assistance and also contribute the amount for this repair.

Discussion. The total contribution made by PCAT for the provision of energy to rural areas was questioned. The Chairman of PCAT responded that, despite the limited resources and manpower, the staff of PCAT has been working hard in the isolated and far-flung areas in order to serve the public. Efforts were being made to depute some additional staff to the PCAT Field Office, Peshawar, in order to accelerate the pace of installations. One participant was of the opinion that PCAT should chalk out an integrated and comprehensive long-term plan for MHP development. The PCAT staff should also be given due incentives to improve performance.

Problems Associated with Private/Decentralised Mini- and Micro-Hydropower Plants and Some Possible Redressals

This paper by Dr. A.A. Junejo identified the problems associated with private or decentralised MMHP systems in the HKH Region and possible remedies. Funding has been pinpointed as one of the major constraints for the distribution of MMHP plants. Lack of coordination among various implementing agencies is also a major problem with regard to policies, planning, and execution of MMHP schemes. Systems for plant performance evaluation are almost non-existent in the Region, and there is no integration of MMHP schemes with the national rural electrification schemes of the governments, except in China. MMHP technology is not recognised at national level as a viable and cheap source of energy for remote and isolated mountainous areas, and generally a commitment to develop MMHP at national level is lacking on the part of governments and related authorities.

The people associated with private/decentralised MHP programmes need to be adequately trained in various aspects of technology, including planning, community development, survey, design, construction, supervision, operation, maintenance, and in case of breakdown. In the specific context of Pakistan, major problems relating to MHP development include non-recognition of MHP by the government as an important source of energy supply, lack of coordination between various implementing agencies, the low level of indigenous technology development, and lack of training facilities for personnel involved in the implementation of MHP schemes.

The solutions to some of these problems include enhanced funding by the government and donor agencies for MHP programmes, dedicated government policies, and establishment of suitable liaison institutions to coordinate the implementing agencies, thereby avoiding duplication and overlapping. The cost of indigenously produced equipment also needs to be lowered, research and development activities need to be enhanced, and appropriate training facilities need to be established.

Discussion. It was pointed out that the tariff system in Nepal was based on connected power, rather than energy used. In the Pakistan context, concern was also expressed about the 200 pending applications with PCAT, responsibility for which was placed on government agencies. It was felt that the economic and living conditions of the recipients need to be improved by installing more MHP plants and government and non-government agencies should take the initiative. Private entrepreneurs need to be involved in power generation as was the case in India. A participant pointed out that the presence of 200 applications indicates the success of the PCAT programme.

Socioeconomic Impact of Micro-Hydropower Plants

Mr. Ghulam Umar Sarhandi presented this paper on behalf of the authors. Bringing a new source of energy into a hitherto inadequately supplied area results in a profound impact on the social and economic framework in a particular locality. This effect is the direct impact of the existence of the plant, its construction, and operation. It brings on employment, availability of a service, and stimulation of the economic activity. The indirect impact of electrification would probably be the same whatever the source of energy supply may be, although the price of the electricity and its price stability would be important for many consumers, and, here, hydropower appears to have a distinct advantage. It is difficult to conceive that any electricity supply can have a negative impact. The primary impact is limited to the consumers, and electrification supports the transformation of a subsistence economy to a monetary economy, which leads to an increase in national productivity and reduces the drain on national resources.

The main benefits of MHP in rural development, in general, include promotion of local industry, increase in the income of the rural poor, agricultural modernisation, mitigation of rural-urban migration, replacement of kerosene lamps, improvement in living standards, more job opportunities, and reduced damage to the environment.

The Tyson Turbine-Another Remote Area Power Supply and Water Pumping System:

Mr. Fazal Rehman presented this paper on behalf of the authors. The concept of the Tyson turbine, named after its Australian inventor, is based on harnessing the energy of moving water in a canal, stream, or river by the use of a turbine and without any use of civil works such as dams, reservoirs, etc. This turbine can pump water for irrigation purposes and generate a reasonable electricity supply for domestic use at low operating cost. Unlike conventional hydropower plants, this turbine operates on a zero head and utilises the river flow for the generation of power. The turbine is similar to the horizontal windmill and is the exact reverse of the ship propulsion system with propeller type blades operating in a set of mutually perpendicular axes to the river flow.

The runner of the turbine is made from polyethylene moulded material, either 1.5 or two metres in diametre. This runner can sustain the impacts of floating debris in water and is also highly corrosion-resistant. The pumping system of the turbine consists of a simple pump at very low head, and its output can exceed five litres per second. It can pump water up to a height of 100 metres. Alternatively, power of up to five kW can also be produced.

The electrical system of the turbine consists of an electrical generator supplying electricity to a control unit which monitors and controls the charging of a 48-volt battery system. The alternator used is a high efficiency, permanent magnet generator that produces a variable frequency and variable voltage output, which is then rectified to D.C. and used to charge the battery bank. A significant number of Tyson turbines has been delivered for water pumping and electricity generation in various countries.

Discussion: A question was raised regarding the cost comparison of the imported versus the indigenous turbine made in the country under a license agreement. Concern was also expressed about possible corrosion problems with the turbine parts. The speaker informed the participants that the cost of imported machines, including government taxes, would be around PRs 515,000. There would be enough demand from the private sector if the cost of the turbine was reduced to PRs 300,000. In the speaker's opinion, the cost of locally manufactured turbines would be around PRs 150,000. Corrosion problems with the turbine parts did not exist since high strength plastics and corrosion resistant materials were used.

Mini-Hydropower Programme of the Northern Areas Public Works' Department

This paper was presented by Mr. Abdul Amir, Executive Engineer, NA-PWD, a government agency which has constructed and commissioned 59 small hydropower and 11 thermal stations in the Northern Areas with a total generating capacity of 26.5 MW. Five plants with a capacity of 29.64 MW are presently being installed, and another five plants with a capacity of 85.3 MW are in the planning stage. About 300 villages, accounting for 40 per cent of the population of the total area, have been electrified through these MMHP/SHP plants. NA-PWD, in collaboration with NORAD, has also established a workshop in Gilgit to cater for repair and maintenance of these power plants.

The electro-mechanical equipment used in the SHP/MMHP plants is procured from the international market, and all the installed units are imported. A variety of turbine types including cross-flow, Francis, and Pelton are used in these power plants. Recently, NA-PWD facilitated an agreement between Heavy Mechanical Complex (HMC),Taxila, and Bi-Water of the UK, under which turbines would be manufactured at HMC through a successive deletion programme.

Discussion: Replying to a question on the cost of SHP/MMHP plants, the author stated that installed costs per kW were in the range of PRs 30,000-50,000, whereas cost per kWh was PRs 0.5-0.8. A point was raised about the shortage of water in the winter season and increased demand of electricity. Another question was raised regarding the proportion of equipment locally manufactured. The author stated that the design of plants was undertaken according to the minimum water available during the winter season. Only transformers and transmission lines were locally made. In the near future, turbines manufactured locally by HMC would be used.

Economic Feasibility of a Small Hydropower Station at Lower Bari Doab Canal, Mian Channu, District Khanewal

This paper, presented by Mr. Skaukat Khan, describes the economic feasibility of a low-head small hydropower plant at a canal fall, namely

Lower Bari Doab canal at VR Bridge, District Khanewal. The technical data of the site reveal that out of the total flow of 38.9 m^3/sec, about 3.4 m^3/sec have already been diverted to power 10 traditional flour grinding mills and about 35.4 m^3/sec flow are falling over eight weirs, each of 0.644 m width. Thus, a flow of 28 m^3/sec can be utilised to generate power. Eight sub-units (water turbines) with a total theoretical power generation capacity of 640 kW can be installed on the existing weirs.

The total investment cost of the plant would be PRs 32.30 million and annual operation and maintenance costs would be PRs 1.0 million. Assuming a plant life of 20 years, a discount rate of 20 per cent, an inflation rate of 10 per cent, and a yearly electricity production from the units at 3.96 TWh, the cost-benefit ratio varies from 1.19 to 2.99 for four various options with an energy selling price from PRs 1.00 to PRs 2.50 per kWh and a payback period of 19 to six years respectively.

Discussion: One participant commented that if the figures reflected in the analysis were correct, the government and private sector agencies should give serious thought to the installation of such power plants. It was agreed that the canal system is very important and useful for hydroelectric power generation, and provincial irrigation departments should be pursued to exploit this source of energy. A question was raised regarding the type of imported turbine/machinery proposed for use in the power plant. The co-author stated that Francis Open, German made flume turbine units with a 90 kW capacity were recommended for this particular site.

CONCLUSIONS AND RECOMMENDATIONS

A working group under the chairmanship of Dr. M. Abdullah was constituted to draw conclusions and recommendations for the Seminar. The papers presented in the Seminar and the resultant floor discussions identified the main issues relating to MMHP development in the country. The current role of various organisations involved in MMHP development was identified and suggestions put forth to enhance the activities and improve the outcome.

It was agreed that the government should exercise a dominating influence in devicing sustainable MMHP development programmes. It was, therefore, essential that the MMHP sector should be given priority by the government in its rural electrification programmes and the same should be stated explicitly in all energy policy documents and the Five-year Plans. It was noted that brief highlights of the salient features of MMHP development in Pakistan need to be prepared and presented to high-level decision-makers in order to appraise them of the importance of MHP and the contribution it could make to overall energy supply in the country.

It was also felt that this type of Seminar should be organised regularly, say once a year, to create awareness about MMHP. The need for carrying out an overall feasibility study for MMHP development was felt since data on MMHP potential were almost non-existent. It was also recommended that provincial governments should be fully involved in MMHP development, and an integrated approach to rural industrialisation based on MMHP should be adopted in close collaboration with Provincial Small Industries' Boards.

The Seminar emphasised the issue of establishing linkages between various implementing agencies in order to achieve better coordination and integrated planning. So far, various implementing agencies had been installing MMHP plants without consulting other agencies, and there were many cases of overlapping and duplication of efforts had been reported. Non-availability of qualified and trained manpower was one of the major concerns voiced in the Seminar. The current lowlevel of skills among those associated with MMHP development was observed as a major cause for breakdowns and an obstacle in accelerating MMHP development programmes. The Seminar recommended establishment of a training institute for personnel involved in MMHP development on a priority basis.

It was pointed out that the quality of private sector MHP plants has been very low, and, unless plants became more reliable and efficient, productive uses of electricity would not be forthcoming. The Seminar, therefore, endorsed the need for enhanced

R&D facilities and recommended that both the government and the private sector should make joint efforts in this respect. It was also felt necessary to encourage more private sector manufacturers to produce better quality MHP equipment at lower costs. However, these efforts would be effective only if the installation rates of the private MMHP plants increased significantly. It was, therefore, recommended by the Seminar that donor agencies should increase their support to MMHP by providing financial, as well as technical, assistance. The importance of low-head canal falls available in the country was underlined, and it was recommended that efforts should be made to exploit this vast resource of hydropower potential.

The specific **recommendations** of the Seminar are reported below.

POLICIES

- The government should clearly formulate support for MMHP, especially for mountainous areas, and this should be clearly indicated in the development plans and new policy documents. This support should be on the basis of desirability of MMHP in the remote and inaccessible areas and its environmentally-friendly character.

- In order to improve coordination of the activities and future extension programmes among the implementing agencies, a Coordination Committee should be formulated with representatives from WAPDA, NA-PWD, the Ministry of Water & Power, AJK Hydroelectric Board, AKRSP, SHYDO, and PCAT. Representatives of MMHP equipment manufacturers, such as HMC, Taxila, may also be included in this Committee. This could be initiated by the PCAT/Ministry of Science & Technology.

FUNDING

- The present rate of installations of MMHP is inadequate. It should initially be planned to double this rate and funding could be arranged for this purpose for all implementing agencies.

- Other financiers may also be identified, including international donors.

- Funding must also be enhanced for R&D, technical manpower training, and some quality control/testing equipment.

IMPLEMENTATION

- PCAT should prepare a long-term programme to increase the pace of installations and to improve the quality of plants.

- Efforts should be made to improve the quality, reliability, and safety standards of indigenous MMHP plants.

- Standardisation and interchangeability of components should be ensured as far as technically feasible.
- Management capabilities of recipients before sanctioning a plant should be assessed and a suitable methodology should be developed for this purpose.
- Systematic monitoring and evaluation by implementing agencies should be a regular feature for all MMHP schemes.

ECONOMIC RETURNS

- Management Committees/VOs of MMHP plants (in the case of privately-owned and managed plants) should be advised to increase the tariffs so that sufficient funds can be made available for major repairs in case of breakdown. This should form a part of the agreement.

END USE ENHANCEMENT

- Recipients should be advised about other productive uses of electricity such as:
  - water pumping and
  - cottage-level industries (Small Industries' Boards of provincial governments should be consulted on this aspect).

TRAINING

- Regular training programmes should be devised for various groups such as operators, plant managers, repairers, installers, layout designers, engineers, and surveyors. For this, appropriate institutions should be established which could undertake this vast and important task. PCAT should be strengthened for this purpose and a training cell should be established within PCAT.
- Appropriate guidelines should be developed in the field of operation, routine maintenance, and management.
- Repair and maintenance centres should be established/strengthened, in collaboration with local private workshops at Mingora, Chitral, and Gilgit.
- Mobile workshops should also be established by PCAT and AKRSP.

ANNEX 1

SEMINAR PROGRAMME
Day One
Wednesday, October 26, 1994

INAUGURAL SESSION

0900-0945	Registration
0945-1000	Guests to be seated
1000-1005	Recitation from the Holy Quran
1005-1015	Welcome Address by *Mr. Shehryar Khan*, Chairman, Pakistan Council of Appropriate Technology
1015-1025	Introductory Address by *Dr. A.A. Junejo*, Project Coordinator, International Centre for Integrated Mountain Development, Nepal
1025-1035	Address by *Mr. Parvez Ahmad Butt*, Secretary, Ministry of Science & Technology
1035-1045	Address by *Sardar Talib Hasan*, Parliamentary Secretary for Science & Technology
1045-1055	Inaugural Address by *Mr. Muhammad Afzal Khan*, Federal Minister for Kashmir Affairs & Northern Affairs
1055-1130	Refreshments

SESSION I

1130-1230	*Mini- and Micro-Hydropower Development in Hindu Kush-Himalayan Region - Achievements, Impact and Future Prospects* Dr. A. A. Junejo, Project Coordinator, International Centre for Integrated Mountain Development, Nepal.
1230-1300	*Micro-Hydropower Programme of PCAT - Status Review*, Dr. M. Abdullah, Consultant on Micro Hydropower, Pakistan Council of Appropriate Technology, Peshawar.
1300-1430	Lunch

SESSION II

1430-1500	*Community Participation in Micro-Hydropower Development*, Ghulam Saeed, Regional Programme Engineer, Aga Khan Rural Support Programme, Gilgit
1500-1530	*Selection of Turbines for Micro-Hydropower Plants*, Samiullah Khattak, Assistant Director, MHP Project, Pakistan Council of Appropriate Technology, Peshawar
1530-1600	Tea
1600-1630	*Indigenous Development and Manufacturing of Very Low Head Micro-Hydel Power Plants*, Aftab Sarwar and Dr. S.M. Bhutta, Ministry of Water & Power, Islamabad
1630-1700	*Management of Micro-Hydropower Plants in Pakistan*, Dr. Habib Gul, Deputy Director, Pakistan Council of Appropriate Technology, Peshawar.

Day Two
Thursday, October 27, 1994

SESSION III

0930-1000	*Problems Associated with Decentralised Mini- and Micro-Hydropower Plants and Some Possible Redressals*, Dr. A. A. Junejo, Project Coordinator, International Centre for Integrated Mountain Development, Nepal.
1000-1020	Socioeconomic *Impact of Micro Hydropower Plants in the Northern Areas of Pakistan*, Ghulam Umar Sarhandi and Rauf Ahmed, Pakistan Council of Appropriate Technology, Islamabad.
1020-1040	*The Tyson Turbine - Another Remote Area Power Supply and Water Pumping System,* Fazal Rehmaan, Rashid A. Sheikh, and D. Singh (Imperial Electric Company Ltd., Lahore & Horwood Bagshaw Ltd., Australia).

1040-1100	*Mini -Hydropower Programme of Northern Areas' Public Works' Department,* Abdul Amir, NA-PWD, Gilgit
1100-1120	*Economic Feasibility of a Small Hydropower Station at Lower Bari Doab Canal, Mian Channu, District Khanewal,* Shaukat Khan and Wahaj us Siraj (Waterman Consulting Engineers & Ministry of Science & Technology)
1120-1145	Tea
1145-1300	Preparation of Conclusions by the Committee
1300-1430	Lunch

CONCLUDING SESSION

1430-1440	Presentation of Seminar Conclusions
1440-1530	Discussion
1530-1540	Remarks by the Participants
1540-1600	Concluding Remarks by the Chairman of the Session
1600-1630	Tea
1630	Closure

ANNEX 2

LIST OF PARTICIPANTS

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ANNEX 3

SUMMARY OF THE PAPERS PRESENTED AT THE SEMINAR

Summary

Micro-and Mini Hydropower Development in the Hindu Kush-Himalayan Region: Achievements, Impact, and Future Prospects

Dr. A. A. Junejo

Traditional water wheels for grain grinding purposes have been used in the Hindu Kush-Himalayan region for many centuries. The use and achievements of modern MMHP in various countries of the region; detailed analysis of the present status; and utilisation and future prospects of MMHP are discussed here. MMHP offers several advantages over the large hydropower systems and other sources of energy (thermal, biomass, and so on). MMHP is an indigenous and renewable source of energy, sizeable potential exists in the region; plants are more viable for remote and isolated communities; plants are easier to design and manufacture locally, and operation and maintenance costs of privately owned/operated plants are much lower.

Although the actual contribution to the energy requirements of mountain areas is still minimal,considerable progress has been made in the five countries of the region in terms of numbers 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, whereas the proportion of the potential may be around 10 per cent. In China, the MMHP-SHP share in overall exploited hydropower is about 20 per cent.

In Bhutan, there are 19 MMHP plants, with a total capacity of 3.40 MW, all installed by the government under various aid agreements, mainly with India and Japan; this is apart from the three small and medium hydropower stations with a total generating capacity of 338.75 MW. Most of the equipment for the MMHP plants has been imported from India and Japan and installed by the foreign consultants. Likewise, much of the funding has been provided by foreign donor agencies. So far, the government has no plans to allow the private sector to participate in MMHP installations.

In India, there are 145 existing SHP/MMHP plants (up to 3 MW in capacity) having a total capacity of 106 MW, all installed by various government agencies, while 159 additional plants with a cumulative capacity of 198 MW are under construction. About 100 installed plants with a capacity of about 70 MW are located in the northern Himalayan region. Some NGOs have also began to install MHP plants in certain areas.

In Nepal, the number of plants installed by the government sector is 35 with an installed capacity of nine MW, out of which only five are grid connected. There are some other MMHP plants managed and operated by private non-commercial establishments. The largest number of MHP plants (over 700) have been installed by the private informal sector. Another interesting endeavour is the improvement of the traditional *ghatta* (water wheels) which are mainly used for grinding purposes and about 200 units have been improved by replacing the traditional wooden runner with one made of steel and improvising with buckets similar to turgo turbines. This almost doubles the efficiency of the mill with a small expenditure of US$100.

Most of the MHP plants were installed in Nepal during the eighties, when the government provided 50 to 80 per cent subsidy for electrical equipment, loans were made available for mechanical equipment and civil works, and licensing requirements for MMHP installations were removed. No comprehensive survey has yet been carried out to determine the status of operational and non-operational plants. There is, however, a general apprehension that many of the units are not in operation due to various reasons.

The manufacturing of MHP equipment in Nepal is quite advanced, particularly in view of the country's weak industrial infrastructure. The first manufacturer of MHP turbines in Nepal was established in 1960 with the technical assistance of the Swiss Government. The number of manufacturers has grown to 11 over a period of time. Most of these are involved in the manufacture of cross-flow or Pelton turbines.

The Chinese MMHP/SHP programme was initiated in the fifties. At present, Chinese MMHP/SHP installations (up to 25 MW in capacity) total 48,284 with a total generation capacity of 15,055 MW, and an annual energy generation of about 47 TWh. Out of the total installed plants, 45,645 plants are in the mini- and micro-range (up to 500 kW). About 35 per cent of the plants are grid connected, and form 93.5 per cent of the total power generated from MMHP/SHP plants. Most of these plants are installed on a decentralised basis by the respective local governments, and funding is provided by different public sector agencies.

Hydropower, including MMHP, development, in Pakistan is predominantly carried out by the public sector agencies. Two organisations, namely, the Pakistan Council of Appropriate Technology (PCAT), a government agency, and the Aga Khan Rural Support Programme (AKRSP), an NGO, are involved in the private MHP development. The plants installed by these organisations involve a subsidy component and are operated and managed by the local communities. PCAT has installed a total of 160 MHP plants with a total generating capacity exceeding two MW. These plants are based on the cross-flow turbines, and no electronic load controllers are used to regulate the power supply or load on the alternator.

AKRSP has installed 26 MMHP plants with a total installed capacity of 600 kW. Unlike PCAT, AKRSP has installed various types of turbines for their plants, including the cross-flow, propeller, Pelton, and Francis. As in the case of PCAT, all the electromechanical equipment is manufactured locally, except for the alternators. Costs of MHP plants installed by PCAT are between PRs 10,000-15,000 (US$ 330-500) per kW, whereas AKRSP's costs are PRs 9,000-15,000 (US$300-500) per kW.

In Pakistan and Nepal, the cross-flow turbine dominates all other types of turbines used in MHP plants, while Chinese MMHP/SHP plants are equipped with a range of turbine types, i.e., Francis, Propeller, Tubular, Turgo and Pelton. India also manufactures a variety of turbines with outputs of up to 3.0 MW. The alternators are mostly procured from China (in the case of Pakistan) and India (in the case of Nepal and Bhutan) in the region. Quality and performance problems associated with the MMHP equipment produced indigenously within the region are usually considerable. Failure of civil work has also been quite severe.

All the public sector plants installed by various government agencies are managed and operated by them in a centralised way, whereas in the case of privately-owned informal plants, the total operation, management, and maintenance responsibilities lie with the owners. In the case of community owned plants, the management is assigned to one or two persons by the village organisations.

All the five countries in the region have announced some level of support for MMHP development. In Nepal, for instance, policy support and incentives have been provided to the entrepreneurs for MHP development. These include provision of soft term loans and subsidies, de-licensing of MHP plants, encouragement to private sector (local as well as foreign). Both the Governments of India and Pakistan have also announced incentives for investors interested in MMHP-SHP installations for power generation. These policies and incentives, if implemented properly, would help the programmes significantly.

The end use of MMHP plants in the whole region is primarily for domestic supply of electricity, except in Nepal where a majority of private plants are used for agroprocessing and other similar activities. In all cases, the plant factors are quite low and range from 10 to 30 per cent. The major reasons for such low plant factors include negligible commercial or industrial utilisation of electricity and the poor purchasing power of recipients to use the electricity, for domestic appliances other than lighting. As the plant sizes grow, as is the case in China, the reliability and quality of electricity improves and leads to grid connections and industrial applications, resulting in considerable improvement in the plant factors. The enhancement and diversification of end uses would make MMHP installation more viable financially for private entrepreneurs. Some other possible end uses include domestic cooking and heating, commercial uses in shops and lodges, and cottage-level industrial applications.

The costs of MMHP plants per kW installed vary considerably within the region. In Pakistan, these costs are US$ 330-500, whereas in Nepal the costs range from US$ 800 to 2,000 per kW installed. Electrification schemes are more expensive than agroprocessing plants, mainly because of the additional costs of transmission and distribution lines. The tariff system of the informal MMHP plants is usually based on a per bulb or per point per month basis, except for a few plants in Pakistan where energy meters are being used for this purpose.

The impact of MMHP has been significant in the region. In China, where MMHP activities started about 40 years ago, more than one-third of the total counties rely on electricity generated by SHP/MMHP plants. Private MHP installations in Pakistan and Nepal have also made considerable progress. It can be safely concluded that, if some level of financial support is continued for MMHP, the overall energy scenario of the rural mountain areas in the HKH region can improve significantly. The emerging trends for future MMHP installations clearly suggest that electricity supply from MMHP plants needs to be improved qualitatively and made reliable in order to attract commercial and industrial consumers. Other steps include uses of electricity for lift irrigation, rural industries, domestic and commercial cooking, and grid connections and proper management of the plants, including implementation of novel electricity tariffs.

Summary

The Micro-Hydropower Programme of Pakistan Council of Appropriate Technology - An Overview

Dr. M. Abdullah

The Pakistan Council of Appropriate Technology has been active in development and distribution of renewable energy resources and their application, food processing technologies, sanitation and hygiene, and income-generating activities for about two decades. In accordance with the appropriate technology concept, indigenous, small-scale and low-cost appliances and processes are developed/adapted and then transferred to those who are in need of such technologies. Technologies are adapted to suit the techno-economic situation of the target group.

The mountainous regions of Pakistan have been blessed with a lot of hydropower potential. The recoverable potential is estimated to be nearly 21,000 MW, out of which only 4,725 MW have been exploited. Besides large hydropower schemes, there are a number of perennial smaller streams which can be successfully exploited for the supply of electricity through small decentralised MHP plants to isolated and scattered settlements where grid extension is economically unattractive and the villagers have to rely on kerosene and firewood for lighting and other domestic needs.

Keeping this situation in mind, the MHP programme of PCAT was started in 1975 when the first three kW plant was installed in Qadir Nagar, NWFP. Appreciating the success of the technology, PCAT decided to go ahead with the project and a second 12.5 kW plant was installed in Lilloni, Swat District, NWFP. Since then a total of 180 plants have been installed with an overall generating capacity of about 2,200 kW.

The main objectives of the programme are to promote the use of small water streams, a renewable source of energy, for power generation; to promote the use of locally-produced equipment for power generation, which contributes to self-reliance; to provide electricity to selected villages in selected areas; and to provide opportunities for enhancement of economic activities through installation of small industrial units.

The MHP programme of PCAT aims at benefitting the communities of remote and inaccessible areas, which are far away from the existing physical infrastructure, by disseminating simple and low-cost technology. Costs of MHP plants are site-specific and directly related to the capacity of plants and extent of distribution networks. Typical values, based on average conditions, are in the range of Rs 10,000-15,000 per kW installed. The cost/kWh delivered is estimated as Rs 1.55 and Rs 1.09 for 10 kW and 20 kW power plants respectively.

The MHP project of PCAT is funded by the Government of Pakistan under the Public Sector Development Programme through the Ministry of Science and Technology. Special funds have also been provided by the Government of NWFP on the recommendation of Members of the Provincial Assembly for installation of plants in their constituencies.

Summary

Community Participation in Micro-Hydropower Development

Ghulam Saeed Khan

The Aga Khan Rural Support Programme (AKRSP), established in 1982, is a private, non-profit organisation established by the Aga Khan Foundation to help improve the quality of life of the villagers in northern Pakistan. In 1986, AKRSP started a village electrification programme on a research basis through the introduction of micro-hydropower plants. The objective of this programme is to develop and test technological and managerial innovations needed for MHP potential realisation in small, remote and inaccessible villages. The electrification programme is not meant to replace the existing large electrification programmes of the government but to complement them wherever needed.

AKRSP extends MHP projects to the selected village organisations (VOs) and adheres to its preconceived methodology of intervening in rural development and holding dialogues with a number of VOs. A VO is a mass coalition of all those residents of a village whose continuing economic interests are best served by organising them as an interest group. Such an organisation can be created around a single activity of overriding importance to most of the villagers.

Once the VO is formed and enters into a partnership with AKRSP, the organisation has to meet as a general body on a regular basis, preferably weekly or fortnightly. Secondly, the VO members must make savings' deposits at their regular meeting in order to accumulate capital to offer collateral to credit and finance self-help projects. The VOs plan, identify, and implement projects supported by AKRSP on a grant basis and provide unskilled labour for execution of the projects. VOs also need to nominate members for training carried out by AKRSP in varied specialities such as agriculture, livestock, poultry, forestry, accounts, and appropriate technology. Once the specialists are trained, VOs need to utilise their services effectively and remunerate them from their own resources. Thus, VO members participate in the planning and identification of productive projects and the AKRSP engineers extend technical assistance to the planning process.

A project cannot be extended unless the VO members agree to take management responsibilities for the project. AKRSP follows the same methodology for the implementation of MHP schemes, holding the first dialogue to explain the concepts, the second dialogue to conduct a survey and prepare estimates, and a third dialogue to finalise terms and conditions between AKRSP and the VOs.

The terms and conditions are that the project should benefit at least 75 per cent of the VO members, who develop a financial system through savings, train one member in MHP technology, and manage the project on their own. The VOs also agree to provide unskilled labour and locally available material free of cost for the project. The plant machinery and some other costs are borne by AKRSP on a grant basis. AKRSP also assists VOs in site selection, survey, and preparation of cost estimates in order to install a MHP plant keeping in mind the minimum power requirement of the VO. The power generated from the MHP plants has promoted the introduction of other small industrial and household machinery such as saw mills, flour mills, welding machines, drilling machines, oil expellers, washing machines, and butter churning machines. Therefore, VO members also need to acquire skills in the operation and maintenance of these machines, training for which is also organised by AKRSP.

The management system varies from one VO to another, depending on the ground conditions. Larger VOs with bigger projects constitute an electricity committee for the management of project affairs, while smaller VOs having smaller plants manage them under the supervision of VO presidents and managers. On the whole, the management system is quite easy and does not demand sophisticated and expensive management techniques.

The committees, once formed, are responsible for all the affairs of the plants, including appointment of operators/guards. They also fix and collect the electricity tariff and approve new connections. The committees make sure that each pole has fuses fixed to avoid illegal use of energy. Those who are found guilty are fined. The records of the project and electricity are usually maintained by the chairmen of committees, or managers.

To meet emergency maintenance costs, the committees pool funds through compulsory contributions from consumer members. This is in addition to the income gained from electricity charges. In the VOs, where no committees have been formed, one member, on rotation, assists the president and the secretary in handling project matters. The committees and the office-bearers render honorary services. However, in some instances, they are exempted from paying electricity bills.

Small industries have been established in some villages where MHP plants generate sufficient energy. The MHP plants have given an entrepreneurial vision to VO members and provided some employment opportunities. On an average, the MHP plants have created employment for four members in VO industries, including the operators/guards.

The MHP projects have a positive impact on community exchange, particularly as the project management and maintenance are the responsibility of the community. MHP projects meet community needs and as such the community has to develop a management system through consensus to attain the benefits of electricity.

Summary

Selection of Turbine for Micro-Hydropower Schemes

Samiullah Khattak

Selection of a suitable turbine for any particular hydro site depends upon site characteristics such as available head and flow. Selection also depends on the desired running speed of the generator or of the device powered by the turbine. Other considerations, such as whether the turbine will be expected to produce power under part-flow conditions, also play an important role in the selection. All turbines have power-speed characteristics and tend to run most efficiently at a particular speed, head, and flow.

Often, the device which is driven by the turbine, usually an electrical generator, needs to be run at a speed higher than the optimum speed of a typical turbine and, then, speed increasing gears or pulleys and belts are used to link the turbine to the generator. It is preferable to minimise the speed-up ratio in order to reduce transmission costs, loss of mechanical power, and other technical problems.

Turbines can be broadly classified into high-head, medium-head, and low-head machines. Turbines are also divided by their principle of operation and may be either impulse or reaction types. Each turbine type is best suited to a certain range of pressure head and flow rate and has a numerical value associated with it called *specific speed* which characterises its performance. The *specific speed* relates the output power of the turbine to its running speed and head across it. It does not depend on the size of turbine. The turbine type can also be assessed by relating *specific speed* and the actual working head.

In general, smaller runners are cheaper because they use less material and can rotate faster, therefore requiring less gearing mechanism. Casing costs also tend to be less for a small diameter runner. In practice, there are limits to the lower size of the runner able to handle the flow passing through it, but a well designed turbine always has the smallest runner permissible within these limits.

Another significant factor in the comparison of different turbine types is their relative efficiencies at part-flow. Typical efficiencies of the turbines indicate that that Pelton, cross-flow, and Kaplan turbines retain high efficiencies even when running below design flow, while the efficiency of Francis turbines falls sharply if run below half of their normal flow.

In order to meet the objectives of the MHP programme of PCAT, complex structures and manufacturing processes are avoided by using cross-flow turbines. Locally available sheets and pipes are used in the fabrication of the runner, nozzle, and the housing, and they can be easily manufactured in simple workshops having facilities for sheet cutting, drilling, and welding. The turbine dimensions are worked out from the values of available head and flow at each site. No effort is made for the standardisation of any of the runner dimensions. The runner speed is designed to be in the range of 300-500 rpm in most of the plants. In some rare cases, especially at very low heads, speeds of about 200 rpm have been obtained. The runner diameter is usually 47 cm (18 inches) and the width ranges from 20 cm to 60 cm with 28-32 blades.

The turbine runner is assembled by a simple process, whereby end plates of specified diameters are cut from six mm thick, mild steel plates, and blades are cut from a suitably sized steel pipe. Blades are then welded to the end plates which, in turn, are welded to the shaft running through its centre. The nozzle is made from three mm thick mild steel sheet. It is fixed at the lower end of the penstock and is independent of the turbine. No automatic governor is included in the design. The flow is controlled manually by a gate valve mounted at the lower end of the penstock. The runner shaft is supported by the ball bearings which are secured in a housing fixed on the concrete pads. Cast iron pulleys of suitable diameters are used to couple the turbine to the generator through V-belts. Both locally made and imported pulleys and belts are available in the market.

PCAT has so far been overseeing fabrication of the turbine runner and housing in a private workshop at Peshawar. Recently, other workshops have also been identified in Rawalpindi and Lahore where cross-flow turbines of better quality and sophistication can be manufactured. Two units were tried at a Rawalpindi Workshop. Also, efforts are being made by PCAT to have access to a more established workshop where the engineering drawings are well understood, in order to manufacture more advanced and high quality turbines.

Summary

Indigenous Development and Manufacturing of Very Low Head Micro-Hydel Power Plants

Aftab Sarwar and Dr. S.M. Bhutta

Pakistan has a total annual surface flow of water of 144 million acre-feet (MAF), out of which the canal system withdraws an average of 106 MAF for irrigation. This irrigation system is the largest integrated network in the world serving 34.5 million acres of contiguous cultivated land. The total length of main canals alone is 58,500 km and water courses comprise another 1,621,000 km. In addition to this, there are several thousands of kilometres of *nallahs* and small tributaries in the hilly areas. The water courses get their supply of water to the outlets from the irrigation channels and distributaries where falls of three feet or so are very common. In spite of this huge network and hydropower potential, very few plants have been installed so far to make use of this running water for generation of electricity, despite the fact that most of the villages still go without the facility of electricity. If a hydroelectric turbine was developed to make use of such small falls ranging between one to two metres, the farmers could have access to electricity from a cheaper and renewable source of energy.

The design calculations of a very low head micro-hydropower unit show that theoretical power of one kW can be obtained from a fall of three feet and flow of five cusecs. This turbine would run at a specific speed of 739 rpm, and its operating speed would be 750 rpm. This speed can be increased to 1500 rpm by using 1:2 gear ratio, and an alternator with five poles would generate one kW electricity through this turbine. The runner diameter for this turbine type is calculated at 10.39 inches.

Since the theoretical estimates have confirmed the possibility of power generation at such a low head, appropriate prototypes need to be developed which would be tested and evaluated in the field, by a suitable R & D agency. Necessary improvements must be incorporated in the machinery through such field trials. In fact, improvement of turbines and other allied equipment through field trials and feedback should be a continous process.

It is imperative that engineering, operational, financial, marketing, and industrial evaluation of the prototype be carried out before proceeding further to the next stage of demonstration of the developed technology. When the technology is proven and practically demonstrated, the manufacturing of the units can be started on a commercial scale by the private sector.

The Water and Power Development Authority of Pakistan (WAPDA) is annually losing PRs five billion because of subsidised tariff rates for the rural areas. The annual loss to the government per village is about PRs 100,000. The cost of extending distribution lines to a village is about PRs 1.6 million, and annual recurring expenditure for its maintenance is PRs 35,000 per village. In addition to this, there are capital and recurring expenditures of the generation plants, transmission lines, and grid stations. The realistic cost from thermal power units in a village would be PRs 3.5 per kWh, whereas the cost of electricity from a micro-hydropower plant would be PRs 1.30 per kWh.

Summary

Management of Micro-Hydropower Plants in Pakistan

Dr. Habib Gul

The micro-hydropower (MHP) programme of PCAT aims at benefitting the economically weak and underprivileged segment of the population in the remote rural areas. Untill now, 181 plants have been installed with an overall generating capacity exceeding two MW. Keeping in mind the resource constraints, coupled with increasing demand and popularity of the MHP plants, it is not possible to entertain all the applicants, and more than 200 such requests are pending with the PCAT. Efforts are being made to accommodate the applicants from different areas, and plants are now being installed on the basis of district-wise demand.

PCAT receives formal applications from the local community committee comprised of a group of four to six prominent persons, for the installation of MHP plants near their village. In most cases, these applications are duly recommended by the local public representatives (e.g., Members of national/provincial assemblies, district/union councils, senators, and so on).

The PCAT staff then undertakes an initial survey of the potential sites, discusses various possibilities with the villagers, and tries to identify those with a genuine interest and necessary capabilities. The approach to establish a local suitable, institutional set-up for the individual plant is, therefore, flexible. Two survey proformae, one for assessment of local capabilities and the other for assessment of the potential for the MHP plant are filled in which the head, flow, population, number of houses to be electrified, and other related information is recorded. Based on these reports, the consultant makes the final decision for installation of the MHP plant on a particular site.

Due to limited funds, the decision regarding the installation of MHP plants is based on district-wise allocation and, to some extent, pressure from the public representatives. Subsequently, a formal agreement is drawn between the PCAT and the recipients, represented by a committee or a designated individual, whereby they are clearly apprised of their responsibilities, e.g., undertaking the civil works, supplying and erecting power distribution lines, running and maintaining the plant, and so on. The recipients are also instructed as to what works have to be completed by them and how much money has to be collected for distribution lines. The recipients also agree to arrange availability of one/two permanent person/s for operation and maintenance on the basis of cash payment or other means; arrange for a distribution network to various houses, including in-house wiring; operate the plant within specified limits of load; and arrange for repairs through a local technician or through PCAT. The agreement also points out that the recipients have to pay the cost of repair in case of a breakdown.

Design of the turbine and other components is then undertaken by the PCAT Field Office, Peshawar. The machinery is fabricated at a local private workshop. The components are assembled for testing and then deattached for transportation to the site.

During and after installation, PCAT provides all technical information and installation expertise related to the plant, through training of one or two villagers for future operation of the plant. The necessary instructions for the operators regarding operation of the plant are provided in the form of a printed manual. At the time of installation, the turbine is tested for its speed and the alternator is checked for its voltage. Two completion reports, one for civil works, and the other for installation of equipment, are filed by the PCAT staff.

After installation, testing, commissioning, and proper training of the personnel, the plant is handed over to the community, and, from then onwards, the community becomes responsible for its operation and maintenance. In case a breakdown occurs, the community arranges for its repair on its own, or they may approach PCAT for replacement of a part.

Usually, nominal charges (PRs 10-20/month/bulb) are collected every month by the plant management for maintenance purposes. At some plants, the managers are now using energy meters and collecting the charges on a kWh basis. The committee is also responsible for all other tasks in connection with the plant. The ultimate institutional set-up may be a formally registered cooperative, or it may be an entirely private enterprise, depending upon the circumstances.

During the first few days, a technician from PCAT stays at the plant site to monitor its working and deals with any other unforeseen problem, as well as providing practical training to the plant operators. More recently, a decision was taken that PCAT staff would visit the plant after three and nine months of installation, to check whether the community was managing the plant reasonably well. In case some problems are observed in the running of the plant (technical or otherwise), a decision will be taken as to whether the plant should be left at the given site. Otherwise, steps may be taken to shift the plant (or the removable parts) from that site for future use in some other installation.

Summary

Problems Associated with Private/Decentralised Mini/Micro Hydropower Plants and Some Possible Redressals

Dr. A. A. Junejo

Identifying the problems associated with private and decentralised MMHP systems installed in the HKH Region and their possible remedies, it was found that funding is one of the major problems associated with private MMHP plants. Overall funding for such plants has been very low, and funds for research and development and testing facilities are almost non-existent. In Nepal, reasonable funds, including soft-term loans and subsidies, have been provided for installation of plants, but consistency in these allocations has been lacking. Non-repayment of loans has also become a serious problem. China and India have also spent considerable sums of money on various renewable energy options, including MMHP/SHP.

Lack of coordination among implementing agencies is another serious problem with regard to policies, planning, and execution of MMHP schemes. Proximity of two or more private MHP plants which affect each other's business has also been identified as a problem. Many MHP plants also fail because the owners/managers are not in a position to manage them properly. Some problems resulting from wrong estimations of the power that can be harnessed, load, or economic returns, during the survey and planning phases, have also been reported. Licensing requirements in many countries are not fully defined. Systems for plant performance evaluation are almost non-existent in most countries. There is no integration of MMHP schemes with national government rural electrification schemes, except in China. Many such problems have led to a considerable decline in MHP installations in Nepal.

The costs of indigenously developed MHP plants have also been increasing, particularly in Nepal. The capital costs of MHP plants are up to 10 times higher than the similar capacity, locally manufactured diesel powered prime movers, although these MMHP plants still cost considerably less than the imported equipment. Some of the cost escalations can be attributed to improvements in technology. Economic returns from the plants have been reported to be inadequate. These returns are mainly used for operation and maintenance costs of the plants, and actual profit for the owners is minimal. Technical failures have been frequently reported in all countries. The quality, reliability, and performance of indigenously manufactured equipment is lower than the equipment imported from industrialised countries.

Lack of management capabilities of recipients/plant owners presents another problem leading to breakdowns and financial difficulties. Repair and maintenance facilities in many cases are also inadequate. The level of expertise of operators has been very low, and many major breakdowns could have been avoided if they had been competent enough to sense the early signs of malfunctioning and to act promptly. The groups of people associated with private/decentralised MHP programmes need to be adequately trained on its various aspects, including planning, awareness-raising, survey, design, construction, supervision, quality control, testing, management, operation, maintenance, and trouble-shooting. The group of people ranges from policy and decision-makers; community leaders; technical personnel of the implementing agencies; including engineers and technicians; and plant owners, managers, and operators.

In the specific context of Pakistan, the problems relating to MHP development include non-recognition of MHP by the government as an important source of energy supply, lack of coordination between various implementing agencies, low level of indigenous technology development, low rate of plant installations, low tariffs, low plant factors, water rights and associated social problems, erratic electricity supply and inadequate training facilities for designers, installers, managers, operators, and repairers of the MHP equipment.

The solutions to the above problems include provision of adequate funding for MHP programmes, dedicated and clear government policies, provision of loans and subsidies, formation of coordination committees from various implementing agencies to avoid overlapping and conflicts, establishment of suitable liaison institutions, and proper capability assessment of the recipients. On the economic side, the costs of the indigenously produced equipment need to be lowered in Nepal, and economic returns from the plants need to be improved by proper management, training of operators and managers, and by adopting novel tariff systems. Research and development activities need to be enhanced to make the technology more reliable. Development of efficient end-use devices and establishment of adequate facilities for repair and maintenance of the plants are also needed. These recommendations, if implemented would result in most of problems being overcome, and progress and achievements would have a far reaching affect, as has been successfully demonstrated in China.

Summary

Socioeconomic Impact of Micro-Hydropower Plants

Ghulam Umar Sarhandi and Rauf Ahmed

Convenience and versatility of use have placed electricity in the forefront of the energy scene. Maintaining a reasonable standard and quality of life would not be possible without an adequate supply of electric power, and economic growth would be hampered without it. The demand for electricity is still growing faster than the demand for energy as a whole, especially in countries like Pakistan where the average specific consumption levels are still very low. Hydropower, on whatever scale, provides one of the options for meeting the growing electricity demand, a limited option because of its strict dependence on the characteristics of particular sites and on the location of such sites in relation to the load centres.

Small-scale hydropower implies local generation for small-scale use and can be a better alternative to a centralised supply in far-flung areas where demands for such a scale still exist. Costs of small hydropower schemes in these areas are inherently high, not only because of the scale effect but also because of the remoteness of the sites and difficulties of access, with the result that their economic merit, assessed on conventional criteria of comparative costs alone, often falls short of acceptable levels.

A hydropower scheme differs from other conventional means of power production mainly in its direct impact, i.e., a better lighting source, employment generation, stimulation of economic activity, and improved communications. The added advantage is minimum damage to the environment.

Broadly, the primary impact is limited to the consumers in the immediate supply area of the scheme, whereas the secondary impact results from the induced effect of the primary impact. The secondary impact can be far-reaching even when the restricted supply area of the small hydropower scheme has no more than a marginal affect on the economy, at large. Electrification also supports the transformation of a local subsistence economy to a monetary economy, at least partially, if other necessary inputs are also provided.

Opinions differ regarding the extent to which electrification reduces the consumption of traditional fuels, such as firewood and agro-waste, and hydrocarbons, principally kerosene. Electrification of outlying areas has not always led to the expected reduction of firewood usage nor has it materially reduced the demand for kerosene. Training and consumer-side investment would be needed to alleviate this situation. Any change will probably be very gradual, even where consumers' response is positive.

Summary

The Tyson Turbine - Another Remote Area Power Supply and Water Pumping System

Fazal Rehman, Rashid A. Sheikh, and D. Singh

The principle of operation of the Tyson turbine has been investigated in the 1980s through a number of studies. Various conceptual turbines have been tested, but, except for the Tyson turbine, none of the designs have reached the commercialisation stage. The concept is based on harnessing energy from moving water in a canal, creek, or river by means of a turbine but without the use of dedicated civil structures such as a dam or restriction to increase water flow or head. The Tyson turbine is similar to a horizontal windmill and is the exact reverse of a ship propulsion system with propeller type blades operating in a set of mutually perpendicular axes to the river flow.

The production model of the turbine is a well designed unit for long service life. It is a mechanically balanced and structurally stable system aimed at handling all mechanical forces and stresses that would be encountered during the course of its service life. By carefully choosing materials for its construction, high corrosion resistance and high strength with low mass weight are achieved. The runner is a 1.5m diameter, polyethylene moulded unit. High strength metallic turbines can not sustain impacts of floating debris such as logs, whereas resilient polyethylene material handles these rough conditions extremely well.

In addition to generation of electricity, the Tyson turbine can be equipped with a suitably designed double acting piston pump that has a life between maintenance in excess of 10 million cycles. The output flow rate can exceed five litres/second at very low head, and water can be pumped up to a 100 metres in height. In order to achieve this, the stroke of the pump is made adjustable and two sizes of barrels (cylinders) have been incorporated into the design.

The electricity generator provided in the system is a high efficiency, permanent magnet alternator producing a variable frequency and a variable voltage output that is later rectified to D.C. and used to charge a 48-volt battery bank. At a water speed of three m/s, the electrical system is able to supply 2.35 kW of power continuously. If this power is stored in a battery bank for over twenty-four hours, the battery will have a 56 kWh storage capacity and will be able to supply a peak load of eight kW for five hours continuously. In addition, by sizing the battery for two days' peak load (i.e., ten hours at peak load) the battery will only be discharged to 50 per cent and have a significantly longer life. Furthermore, in the event of the generator being rendered inoperative, an electrical supply will still be available for two peak demand periods.

Quite a number of Tyson turbine systems has been delivered for pumping and electrical power generation purposes in various countries. An order for 200 electrical power generation units is on the way from India where arrangements for collaboration with a local manufacturer are almost final. Pakistan Council of Appropriate Technology (PCAT) has imported four machines with funds from the Australian International Development Assistance Bureau. These include three water pumping versions and a combination for water pumping and electrical power generation.

Further research on the Tyson turbine in tidal flow applications is also underway in an Australian University. Therefore, given that the world's resources in fossil fuel are limited, a time may come when the current, relatively high cost of this form of renewable energy will become economically competitive.

Summary

Mini-Hydropower Programme of the Northern Areas 'Public Works' Department

Abdul Amir

Northern Areas' Public Works' Department (NA-PWD), a federal agency, is responsible for planning, implementation, operation, and maintenance of development projects in the field of communications, housing, water supply, irrigation, power, and construction of residential/non-residential buildings, such as educational institutions, hospitals, and so on, for other government departments.

Northern areas of the country, covering approximately 73,000 sq.km., are inaccessible from the national electricity grid. Nevertheless, the area is richly endowed with mountains, streams, and rivers which make hydropower development most feasible. So far, 59 small hydropower and 11 thermal stations have been constructed by NA-PWD, generating 26.5 MW of power. Five plants with an installed capacity of 29.64 MW are under construction. In addition, five small hydropower plants with an expected installed capacity of 85.30 MW are in the planning stage. The power generated from these plants is used to provide electricity to about 300 villages, covering about 40 per cent of the population of the Northern Areas.

WAPDA, in collaboration with GTZ, is working on a feasibility study to determine the hydropower potential along various tributaries of the Indus. On completion of this study, it is expected that a number of promising sites will be indicated, and these will then be added to NA-PWD's overall planning.

The NA-PWD has been appointed the executing agency for the rural electrification programme under a grant from the Norwegian Government. NA-PWD has commissioned a workshop for repair and maintenance of hydroelectric equipment and it is used for refurbishing turbines. Staff training is also in progress at this workshop. Apart from this, a 1.2 MW hydroelectric power station has been commissioned in Gilgit and is operational. The second unit of the same capacity is in the final stages of establishment at Hassanabad (Hunza), and a third unit of the same capacity will be commissioned for Tangir (Diamer) by the end of 1995. Within two to three years, after completion of the projects under construction, about 60 per cent of the population will have access to electricity. Planning, implementation, and operation of these hydropower plants are being carried out by NA-PWD engineers.

The turbo-generating sets are either procured from China through barter trade between the two countries or the equipment is purchased through international tendering. The department has installed German, British, Norwegian, Swiss, Austrian, and Chinese units at various plant sites having cross-flow, Francis, and Pelton turbines.

The NA-PWD has also tried to achieve the transfer of technology and indigenous production of turbines through collaboration between the Heavy Mechanical Complex (HMC), Taxila, and Bi-Water of the UK. HMC has successfully manufactured almost all turbine parts except runner. It is hoped that, in the near future, HMC will acquire this technology, and turbines will be designed and manufactured locally. This will boost the country's hydropower activities.

To solve the water rights' problem, NA-PWD normally selects sites either ahead of the headworks of irrigation channels or water from tailraces is again fed to irrigation channels. To tackle the operation and maintenance problems, NA-PWD trains its operators on the job, and they are supported by a Task Force from the workshop. Since technicians and engineers are readily available on the spot, technical problems are, therefore, no longer prolonged.

It is worth mentioning that only one power station was damaged due to boulder slides from above; the rest of the plants throughout all over the valleys, have been functioning satisfactorily for the last 30 years.

Summary

Economic Feasibility of a Small Hydropower Station at Lower Bari Doab Canal, Mian Channu, Khanewal District

Shaukat Khan and Wahaj us Siraj

This paper describes the economic feasibility of a low-head small hydropower plant on a canal fall, namely, Lower Bari Doab canal at VR Bridge, Mian Channu, Khanewal District. The technical data on the site reveal that out of a water flow of 38.9 m^3/sec, about a 3.4 m^3/sec flow has already been diverted through 10 traditional flour grinding mills and about a 35.36 m^3/sec flow is falling over eight weirs, each having 0.644 m in width. A flow of 28 m^3/sec can be taken for practical purposes. The crest level is 149.8 metres, the upstream water level is 152.1 metres, and the downstream water level is 148.7 metres. With a net head of three metres and turbine efficiency of 80 per cent (imported units), eight sub-units (water turbines) can be installed, one on each of the existing weirs, to generate 640 kW of power (80 kW from each unit).

The total investment cost on the plant will be PRs 32.30 million which includes PRs 21.80 million as equipment costs, PRs 2.50 million as civil works and installation costs, PRs 1.80 million for transmission, and distribution costs, and PRs 1.50 as planning and management costs. The annual operation and maintenance costs for the plant will be approximately PRs 1.00 million. Assuming a plant life of 20 years, a discount rate of 20 per cent, an inflation rate of 10 per cent, and yearly electricity production from the units at 3.96 TWh, the cost-benefit ratio varies from 1.19 to 2.99 for four varying energy selling prices, i.e. PRs 1.00 to PRs. 2.50 per kWh and a payback period of 19 to six years respectively.

A comparison of electricity charges actually paid by the consumers to WAPDA indicates that one unit of electricity costs the consumers PRs 0.80, PRs 3.22 and PRs 2.20 for domestic, commercial, and industrial consumers. If an industry consumes less units of electricity, the actual charges per unit could be as high as PRs 32.57. The cost of electricity generated by the SHP plant will, therefore, be more economical, particularly for commercial and industrial consumers.

ICIMOD Workshop Series

The International Centre for Integrated Mountain Development began professional activities in September 1984. The primary concern of the Centre is to search for more effective development responses to promote the sustained well-being of mountain people. One of the continuing activities of ICIMOD is to review development and environmental management experiences in the Hindu Kush-Himalayan Region. Accordingly, International Workshops/Meetings are organised in major fields to review the state of knowledge and practical experiences and also to provide opportunities for the exchange of professional expertise concerning integrated mountain development. The reports published in this series are given below.

- **International Workshop on Mountain Agriculture and Crop Genetic Resources**
  16-19 Feb., 1987, KTM, Nepal
- **International Workshop on Women, Development, and Mountain Resources: Approaches to Internalising Gender Perspectives**
  21-24 Nov., 1988, KTM, Nepal
- **International Expert Meeting on Horticultural Development in the Hindu Kush-Himalayan Region**
  19-21 June, 1989, KTM, Nepal
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  21-21 June, 1989, KTM, Nepal
- **Regional Workshop on Hydro-logy of Mountainous Areas**
  11-15 Dec., 1989, KTM, Nepal
- **Consultative Meeting on Mountain Risk Engineering**
  20-22 Feb., 1990, KTM, Nepal
- **International Workshop on the Role of Institutions in Mountain Resource Management**
  1-4 May, 1990, Quetta, Baluchistan, Pakistan
- **Seminar on Rural Energy and Related Technologies in Nepal**
  26-28, Mar., 1991, KTM, Nepal
- **International Workshop on Mountain Off-farm Employment**
  17-20 Feb., 1992, KTM, Nepal
- **Inspirations in Community Forestry**
  1-4 June, 1992, KTM, Nepal
- **ICIMOD Methodology Workshop on Rehabilitation of Degraded Lands in Mountain Ecosystems of the Hindu Kush-Himalayan Region**
  May 29 - June 3, 1993, KTM, Nepal
- **International Workshop on Institutional Strengthening for Sustainable Mountain Agriculture**
  28-30 July, 1993, KTM, Nepal
- **Remote Sensing Applications to the Planning and Management of Environment, Natural Resources, and Physical Infrastructure**
  Oct. 10 - Nov. 6, 1993, KTM, Nepal
- **Indigenous Knowledge Systems and Biodiversity Management**
  13-15 April, 1994, KTM, Nepal
- **Mini- and Micro-Hydropower for Mountain Development in the HKH Region**
  13-17 June, 1994, KTM, Nepal
- **Evolution of Mountain Farming Systems**
  3-6 Oct., 1994, Pokhara, Nepal

These Workshops were attended by experts from the countries of the Region, in addition to concerned professionals and representatives of international agencies. A large number of professional papers and research studies were presented and discussed in detail.

Workshop Reports are intended to represent the discussions and conclusions reached at the Workshop and do not necessarily reflect the views of ICIMOD or other participating institutions. Copies of the reports are available upon request from:

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