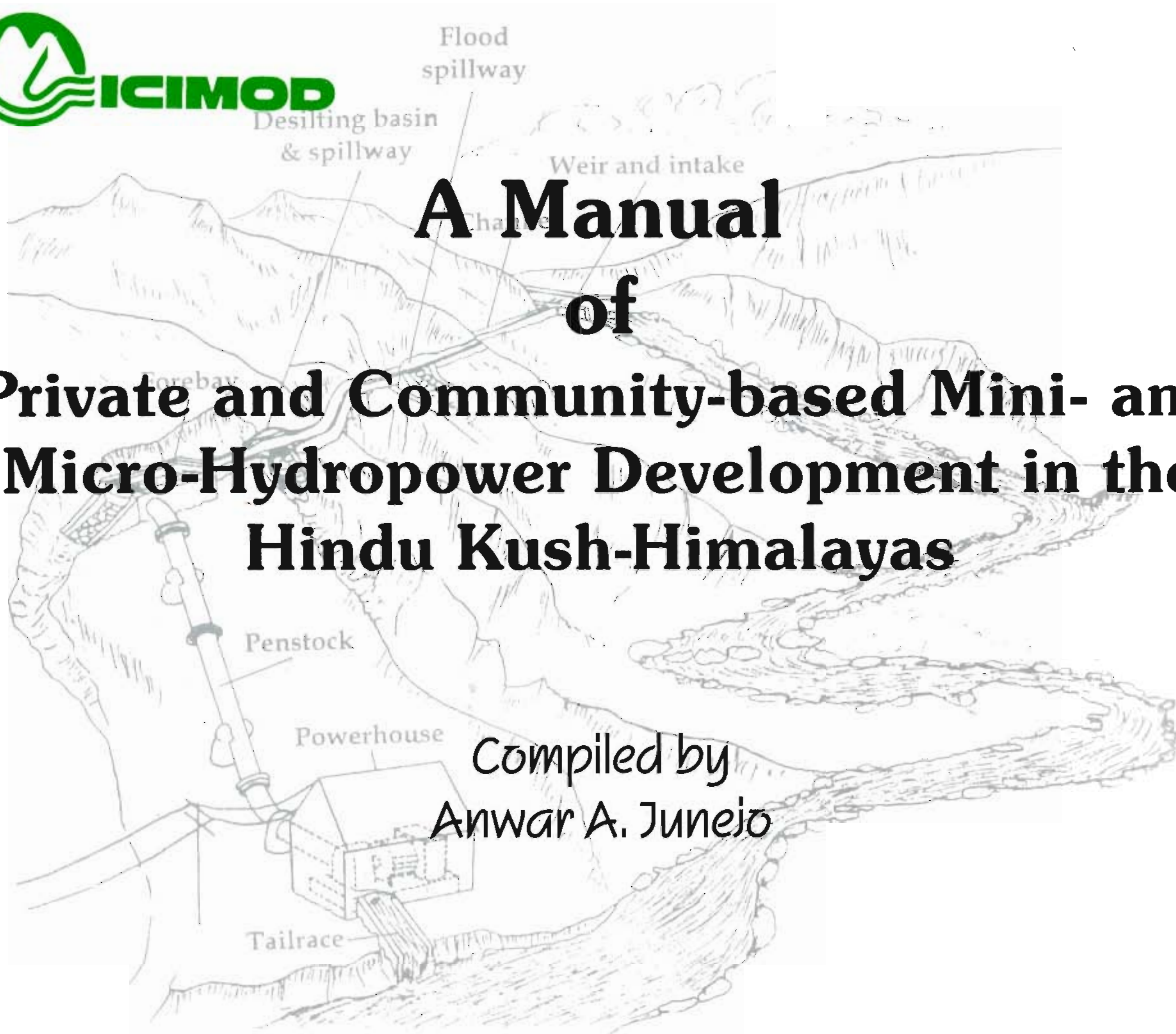
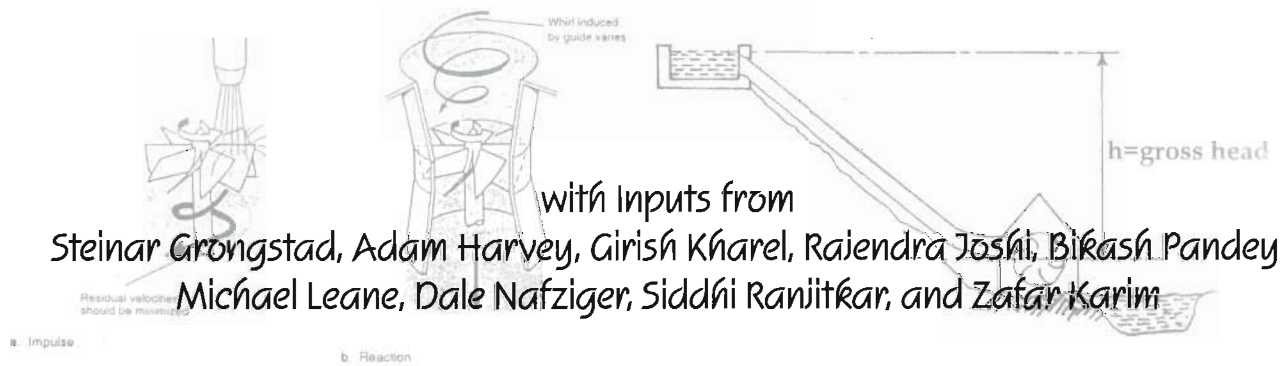


A Manual of Private and Community-based Mini- and Micro-Hydropower Development in the Hindu Kush-Himalayas

Compiled by
Anwar A. Junejo



with Inputs from
Steinar Grongstad, Adam Harvey, Girish Kharel, Rajendra Joshi, Bikash Pandey, Michael Leane, Dale Nafziger, Siddhi Ranjitkar, and Zafar Karim

International Centre for Integrated Mountain Development (ICIMOD)
Kathmandu, Nepal
1997

Published by

International Centre for Integrated Mountain Development
G.P.O. Box 3226,
Kathmandu, Nepal

ISBN 92-9115-631-0

Typesetting at ICIMOD Publications' Unit

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Foreword

In many of the discussions about the scale of hydropower interventions in the Hindu Kush-Himalayas and elsewhere, references are often made to mini- and micro-hydropower (MMHP), as being most appropriate for remote areas with scattered pockets of small settlements.

Over the past 25-50 years, various initiatives in this sector have been undertaken in different parts of the HKH, in particular in China, India, Nepal, and Pakistan. In several places this has been highly successful, in others, it has not been so successful. This discrepancy between the obvious theoretical advantage of using an indigenous renewable energy, appropriate for mountain areas, and the actual performance, has prompted ICIMOD to do an in-depth analysis of the scope for MMHP in the HKH. Various national and regional seminars have been organised over the past few years, out of which emerged a clear need for a comprehensive manual, on the basis of which sound judgements could be made about investing in MMHP.

The present Reference Manual on development of mini- and micro-hydropower in the Hindu Kush-Himalayan Region provides basic information on the current status of MMHP in the region and guidelines for making it more effective and sustainable. The Manual is intended for decision-makers, prospective financiers, planners, and assessors of the proposals, outputs, and impacts of such programmes. Keeping this target group in mind, the material assembled in this document is fairly wide ranging; from current status, practices, and policy support, to some specific case examples collected from the developing as well as the developed world. Basic information has also been provided regarding the implementation aspects, including project planning and feasibility, technology, financial analysis and assessment, monitoring and evaluation, and training. One chapter has also been devoted to the institutional structures needed for efficient and effective development of mini- and micro-hydropower (MMHP). Although the Reference Manual may not provide all the requisite levels of detailed information for field designers and implementers of MMHP schemes—for which some excellent manuals already exist—it attempts to provide the basic details for site survey, design, and selection of technology options.

The original version of this Manual was prepared mostly in the form of notes for individual lectures for the 'Orientation-cum-Training Programme on Mini- and Micro-hydropower Development in the Hindu Kush-Himalayan (HKH) Region', organised in 1995 for planners and decision-makers from this Region. The participants at the meeting considered the material quite original and useful and recommended wider dissemination, after some revisions and with the inclusion of a number of additional subjects. The revised draft was circulated to many experts, including the original contributors; and many valuable suggestions were received. Efforts have been made to incorporate these suggestions, as far as possible, in this final publication.

The original Manual was prepared by a group of experts; prominent among them were Mr. Steinar Grongstad of NORPLAN, Norway, and Dr. Adam Harvey of ITDG, U.K. A number of Nepal based experts also prepared or reviewed material for this manual; namely,Dr. R.D. Joshi (Institute of Engineering), Mr. Bikash Pandey (ITDG/Nepal), Mr. G. Kharel (Micro Hydro Consultants), Mr. Michael Leane (UMN), Dr. Dale Nafziger (BPC), Mr. Siddhi Ranjitkar (USAID), and Mr. Zafar Karim (ICIMOD). Dr. A. A. Junejo, the Project Coordinator (ICIMOD), organised and oversaw the preparation and rewriting of the Manual, in addition to writing some of the chapters himself. I am grateful to all these contributors.

Some contributors have made extensive use of materials from the Micro Hydro Manual (1993) prepared by the ITDG. Some of the data were also extracted from presentations of the participants and two guest speakers at the Orientation-cum-Training Programme. This inclusion of the material from the ITDG Manual and other papers is gratefully acknowledged. I would also like to take this opportunity to thank the Government of Norway (NORAD) for the continuous and generous support it provides to ICIMOD for implementation of the MMHP programme.

It is hoped that this Reference Manual will be of use to the planners and decision-makers associated with private or community based MMHP in the Region. ICIMOD welcomes suggestions from readers/users which may be incorporated in future editions.

Egbert Pelinck,
Director General

About This Manual

A draft of this Manual was circulated to many experts, including the contributors, for comments. While these experts suggested many corrections and improvements, they also raised two pertinent issues; i.e.,

- the manual was very long and the planners/decision-makers for whom it was intended would not have adequate time to read and assimilate its contents, and
- the above group was very diverse in terms of educational and working backgrounds and they needed particular and concise information.

Thus a very basic dilemma arose; i.e., should the manual be made very concise and simple so that decision-makers can read it in the minimum possible time, or should it have adequate information at the risk of being too lengthy. The third possibility was to break it into two or three sub-volumes. It was finally decided to provide simple but adequate information in one volume, at the same time avoiding excessive details. Also, keeping the above issues in mind, the following breakdown suggests which chapters are useful for different groups of users.

(a) Decision-makers interested in learning about the advantages, achievements, current trends, and other basic information about MMHP, in order to formulate their views regarding inclusion of MMHP in the overall energy scenario, may refer to Chapters 1, 2, 3, and 11.

(b) Similarly decision-makers who may wish to know more, particularly the relevant needs of the MMHP sector, may, in addition, refer to Chapters 4, 10, 12, and 13.

(c) Planners and analysts concerned with the implementation and economic aspects may refer to Chapters 4, 5, 7, 8, 10, and 11.

(d) Assessors of MMHP projects/programmes from economic and technical angles, may refer to Chapters 4, 5, 6, 7, 10, 11, 12, and 13.

(e) Planners and implementors wishing to prepare proposals and/or execute MMHP projects may read Chapters 3 through 13.

Abstract

This Reference Manual provides basic information and guidelines for developing and improving the performance of private/decentralised mini- and micro-hydropower (MMHP) in remote and underdeveloped areas of the Hindu Kush-Himalayan (HKH) Region. The Manual is targetted for the decision-makers, financiers, planners, and assessors of such programmes. It is hoped that the information and suggestions provided here will assist the target audience in formulating appropriate plans and implementation methodologies for using this environmentally friendly, indigenous and renewable resource to meet the energy needs of inaccessible and underdeveloped mountain areas.

The Manual contains information about the comparative advantages, current status, achievements, and impact of MMHP; and also about technology, implementation methodology, operation, management and other relevant aspects leading to optimising the benefits of MMHP programmes. The overall inference is that, for those remote areas in which grid extension is not viable and the water resource is available, small-scale, isolated private MMHP schemes may be introduced with appropriate supporting interventions, using the local manpower and technical base.

In addition, the Manual contains guidelines regarding the selection of appropriate technology choices, management systems, institutional arrangements, and other necessary inputs; which may be in the form of funding, training, or repair and backstopping facilities. Material on the financial analysis/assessment and monitoring of MMHP has also been included.

Some Local Terms

Bijuli Dekchi (Nepal)	A low wattage cooking pot with an electrical heating element and a thermostat designed to heat-cook various foods in a hot water medium
Dhiki (Nepal)	A foot-operated device used for dehusking paddy through pounding
Gharat (India, Pakistan) *Ghatta* (Nepal)	A traditional vertical axis, wooden water mill used mainly for grinding grains
Lokta (Nepal)	An indigenous tree which grows widely in the middle hills of Nepal. Its bark is used for making traditional Nepali paper
Kol (Nepal)	A traditional manually-operated pestle-mortar device for expelling oil from seeds through a crushing action
Okhal (Nepal)	A hand-operated pestle-mortar device used for dehusking paddy through manual pounding

List of Abbreviations, Acronyms and Local Terms

ACAP	Annapurna Conservation Area Project (Nepal)
ADB/N	Agricultural Development Bank (Nepal)
AKRSP	Aga Khan Rural Support Programme (Pakistan)
BEW	Butwal Engineering Works (Nepal)
B/C	Benefit/Cost Ratio
BTI	Butwal Technical Institute (Nepal)
BYS	Balaju Yantra Shala (Nepal)
CRT	Centre for Rural Technology (Nepal)
DCS	Development and Consulting Services (Nepal)
ELC	Electronic Load Controller
FAKT	Association for Promotion of Appropriate Technology (Germany)
GEF	Global Environment Facility
GIS	Geographic Information System
GTZ	German Agency for Technical Cooperation
GATE(GTZ)	German Appropriate Technology Exchange
HDPE	High Density Polyethylene
HKH	Hindu Kush-Himalayas
HMC	Heavy Mechanical Complex (Pakistan)
HMG/N	His Majesty's Government (Nepal)
HRC-SHP	Hangzhou Regional Centre (Asia-Pacific) for Small Hydropower (China)
ICIMOD	International Centre for Integrated Mountain Development
IGC	Induction Generator Controller
IREDA	Indian Renewable Energy Development Agency Ltd
IRs	Indian Rupees (US$ 36 IRs)
IRR	International Rate of Return
ITDG	Intermediate Technology Development Group (U.K, Nepal & Sri Lanka)
KMI	Kathmandu Metal Industry (Nepal)
kVA	kilo Volt-Amperes
kW	kilo Watts
kWh	kilo Watt-hours
L/S	Litre per second
LEDG	Ladakh Ecological Development Group (India)
MCB	Miniature Circuit Breaker.
MDPE	Medium Density Polyethylene
MHP	Micro-Hydropower
MHPG	Mini Hydro Power Group (An Association of Europe-based agencies associated with development of mini and micro-hydropower)
MMHP	Mini and Micro-Hydropower
MNES	Ministry of Non-Conventional Energy Sources (India)
MOM	Management Operation and Maintenance
MPPU	Multi Purpose Power Unit (Nepal)
MW	Mega Watt
NA-PWD	Northern Areas-Public Works Department (Pakistan)
NEA	Nepal Electricity Authority
NMHDA	Nepal Micro Hydropower Development Association
NORAD	Norwegian Agency for Technical Cooperation
NPV	Net Present Value
NRs	Nepal Rupees (1 US$=57 NRs)
NWFP	North Western Frontier Province (Pakistan)
NYS	Nepal Yantra Shala
O&M, O+M	Operation and Maintenance
OM&R	Operation Maintenance & Repair
O&T	Orientation and Training

PCAT	Pakistan Council of Appropriate Technology
PCSIR	Pakistan Council of Scientific and Industrial Research
PRs	Pakistan Rupees (1 US$ = 36 PRs)
PTC	Positive Thermal Coefficient
PV	Photovoltaic
PV	Present Value
RONAST	Royal Nepal Academy for Science and Technology
SCECO	Salleri Chialsa Electricity Co. (Nepal)
SDC/SATA	Swiss Development Cooperation/Swiss Agency for Technical Assistance
SEB	State Electricity Board (India)
SELUP	Salleri Electricity Utilisation Project (Nepal)
SHP	Small Hydropower
SHPD	Small Hydropower Department (Nepal)
SHYDO	Sarhad Hydel Development Organisation (Pakistan)
SKAT	Swiss Centre for Development Cooperation in Technology and Management
TWh	Tera Watt hours
UMN	United Mission to Nepal
UNDP	United Nations Development Programme
UNIDO	United Nations Industrial Development Organisation
USAID	United States Agency for International Development
UPVC	Unplasticised Polyvinyl Chloride
VDC	Village Development Committee (Nepal)
W	Watt
WAPDA	Water And Power Development Authority (Pakistan)

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Chapter 1
Introduction and Objectives

1.1: Introduction

Traditionally, development of rural areas, especially the more remote mountain areas, has lagged behind that of the preferred urban centres. Whereas substantial investments were made to develop adequate, sometimes even luxurious, infrastructure in the main urban centres; including the setting-up of special facilities; the rural areas did not even have basic facilities such as running water, sanitation, roads, schools, or health centres. Economic and employment opportunities, such as industries, local processing of rural produce, and transportation infrastructure, were practically non-existent in the past. The situation in mountain areas was even worse because of problems of accessibility; the relatively high cost of development activities; and, above all, the very dismal conditions of the people. It could be justifiably stated that the living conditions of people in remote mountain areas were far worse than those of the rural people in the plains.

The trend has been changing significantly during the past two decades or so, and remote mountain areas are now receiving more attention and inputs. The importance of conserving and rehabilitating of mountain ecosystems is also being realised, and governments as well as donors are increasingly providing more for the development of such areas. The level of such inputs, however, varies from area to area; and, in most cases, they do not meet the local needs.

A supply of energy in a suitable form is considered to be one of the main inputs required to raise the standards of living of the people in mountain areas and to minimise damage to the ecosystem. Per capita consumption of energy has to increase significantly in order to develop the systems and infrastructure necessary for improvement of living conditions and increase in incomes. For example, adequate irrigation systems would have to be constructed to increase agricultural productivity in many areas where rainfall is usually insufficient in some crucial months; even though the overall yearly rainfall may be high. In such cases, it may be necessary to pump water, and this would need energy. Similarly, the processing of agricultural produce needs mechanical power to run the processing equipment. At home also, more energy consumed in a suitable form would improve the quality of life and reduce drudgery as well as health hazards; e.g., for applications such as lighting, heating, cooking, washing, ironing, and for radios and television.

In many developed countries, electricity is regarded as a basic necessity. However, electricity is available to only a small percentage of the rural population in developing countries. In Nepal, for example, only ten per cent of the total population has access to electricity, and the figure for the rural areas is likely to be in the range of two to three per cent only.

At present, production, productivity, and employment opportunities in mountain areas are inferior to those in the plains. Large amounts of local produce, such as fruits and vegetables, go to waste or fetch very low prices, because of the inadequacy of transport facilities. Local processing facilities for such produce are also insufficient and rudimentary. This situation must be rectified if we hope to build a more equitable society and to counter the migration of the population from these areas to larger cities and towns.

It is known that energy is not the only input necessary for achieving development in mountain areas. Other inputs, such as comprehensive planning, investments, expertise, equipment, training, and incentives, would also have to be provided; for development of cottage industries, for example, or improvement of productivity. Nevertheless, the availability of energy, electricity for example, in a suitable form can provide modest benefits to communities, even at the outset; e.g., better lighting and replacement of kerosene (since the latter has many drawbacks related to transportation, environment, and health). Some entrepreneurs may also set up agro-processing units on their own to obtain additional benefits when electricity becomes available.

Experience has shown that the appropriateness of the source of energy for mountain areas is just about as important as the supply itself. The general tendency of government agencies in supplying electricity to mountain areas is to follow conventional practices such as grid extension or establishing diesel or larger hydropower plants. Very little attention is paid to other non-conventional resources such as mini-and micro-hydropower (MMHP), solar energy, and wind; even though many of the conventional energy systems are unsuitable and uneconomical for the more remote and inaccessible mountain areas.

MMHP is an indigenous and renewable source of energy for which potential exists in almost the whole HKH Region. Many countries, especially China, have exploited this environmentally friendly resource and benefitted significantly. However, in order to make it economically viable also, design, construction, and operation have to be low in cost; which is possible through indigenous technology and more informal operation and maintenance practices in the private sector. MMHP has many other advantages also; for example, the costs can be curtailed considerably by avoiding expensive control systems; the plants are comparatively easy to manufacture and install indigenously, thus boosting employment, economic activity, and the industrial base; organisation and management (O&M) costs are much lower than for other systems, especially in the private sector; and, above all, the adverse environmental effects are minimal. For example, even if an MMHP plant were to break down completely, damage to the surrounding areas would be minimal. An appreciable, indigenous manufacturing capability has also materialised in many countries of the Region.

Unfortunately, most of the governments in the HKH area have not recognised the advantages and true viability of MMHP plants, with the result that a very small proportion of the potential has been exploited so far. Nepal has made some novel advances in this respect and has formulated some favourable policies. Even then, the achievements are not so significant. Lately, many problems have also surfaced, particularly those concerning implementation and management aspects, and these are discussed elsewhere in this manual.

Considering the environmental and other benefits of MMHP, ICIMOD formulated a project[1] to promote the use of MMHP for development of mountain areas in 1992, funded by the Norwegian Agency for Development Cooperation (NORAD). Implementation of the project started in 1993. Its main objective was to assist the countries in the HKH Region to strengthen

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[1] The project was entitled 'Design and Testing of a Regional Training Programme on Mini- and Micro-Hydropower for Mountain Development in the Hindu Kush-Himalayan Region'.

their capacities for planning, design, construction, and management of MMHP schemes to meet the energy needs of remote communities by harnessing this clean source of energy. The project envisaged participation from four countries in the Region, i.e., Bhutan, India, Nepal, and Pakistan. In addition, the participation of Bangladesh, China, and Myanmar in some of the project activities was supported by ICIMOD through a special grant.

The project activities mainly concentrated on collection, review, and analysis of information from the Region, conclusions drawn, and dissemination of this information and conclusions to relevant agencies and experts in the participating countries through reports, meetings, and seminars.

An Orientation-cum-Training (O&T) Programme was also organised by this Project as the main and final activity. It was aimed at high-level decision-makers, with the main objective of apprising them of and orientating them to the suitability and role of MMHP in the development of the people of rural mountain areas; as well as the objective of addressing some environmental aspects. It was intended to highlight the role of energy in specific development aspects related to remote, underdeveloped, and sparsely populated mountain areas. A manual containing all the lecture materials was also prepared for distribution to the participants in the O&T Programme. Since the manual contained quite useful material for various groups of planners, decision-makers, and assessors of MHP/energy-related projects, it was decided to shorten and restructure it, so that it could be used for subsequent training and/or as reference material.

1.2: Energy Options for Rural Mountain Areas

Traditionally, energy in mountain areas has been used for domestic requirements (cooking, heating, lighting, and processing), for agriculture (ploughing, planting, irrigation, harvesting, threshing, etc), for cottage industries (processing heat & motive power), and so on. In almost all these cases, the predominant source of energy has been fuelwood, other biomass, and animal or manual power. Animal power is used to a much lesser extent in mountain areas than in the plains; the result being that humans have to work much harder, especially women. For example, traditionally, animal power is used for oil extraction in the plains; whereas, in many mountain areas, this hard job is also performed by the people. Similarly, most of the agricultural work (including ploughing, digging, planting, and threshing) is carried out manually. Unfortunately, the bulk of this manual work falls on women. The only modern fuel used in rural mountain areas, to any significant extent, is kerosene for lighting. However, many problems related to health, environmental damage, transportation, and availability are associated with its use. Kerosene is up to five times more expensive in some remote areas of Nepal than in Kathmandu. Consequently, the energy situation is far from satisfactory and something needs to be done to make more suitable fuel systems and allied appliances available in such areas.

Traditional sources, such as fuelwood and other biomass, are the principal fuels being used currently in many mountain areas; and their excessive use has caused considerable problems, e.g., forest depletion, depletion of organic matter, health hazards, and pollution. Although wood energy is now being promoted as a better fuel system than, e.g., coal and some petroleum products, adequate production systems have to be developed first to justify promotion of its preferred usage. At present, it is better to discourage the use of fuelwood and biomass (especially biomass) through replacement by other appropriate energy systems. Use of animal and manual power is also inadequate and undesirable, as discussed earlier. Commercial fuels, such as coal, kerosene, diesel, and petrol, have mostly to be imported and/or transported to the remote mountain areas; which is a fairly problematic task due to lack of adequate transportation facilities, the result being inconsistent and usually economically unviable supplies.

Therefore, more emphasis needs to be placed upon renewable, locally available, low cost, and environmentally friendly energy resources such as biogas, wind, solar, and MMHP; each of which definitely have specific advantages and limitations. Wind energy, for example, is very area-specific and varies with the seasons. Solar energy is fairly expensive; its availability also varies considerably with the seasons, and it is only available during the daytime. Biogas is one of the most suitable fuels for cooking and heating; however, its production volume is seriously affected by the cold weather in higher mountain areas. The different fuels or energy systems being used or considered suitable in mountain areas, including the more modern and desirable ones, have been enumerated in Table 1.1. Their level of suitability is also given by a point system (ticks). The level of suitability is based on experience, not on field studies. However, these levels can be considered as reasonable indicators for current comparison and evaluation of options.

Because of the versatility of applications and the many advantages outlined in Section 1.1, MMHP plants have been given the highest points (47 ticks), followed by electricity from other sources (45 ticks), and biogas (32 ticks) in Table 1.1. However, the number of ticks is based on suitability for a given use only, and the costs have not been taken into account. Similarly, the social and environmental benefits have not been incorporated in determining suitability. Due consideration has been given to the remoteness and inaccessibility of the areas in awarding ticks.

Admittedly, there are some disadvantages associated with MMHP also; e.g., higher capital costs over diesel engine sets for example; difficulty in transportation or relocation; and problems with repairs, especially in inaccessible locations. Most of these disadvantages are discussed in more detail elsewhere in this document. Suffice it to say here that many of the constraints can be suitably addressed through inputs such as training, development of repair facilities in carefully selected locations, and so on.

MMHP plants are also well suited for connection to grids with the necessary, synchronising equipment; or to other hybrid systems such as MMHP-diesel, MMHP-solar, or MMHP-wind. In many situations, such a combination of different sources improves the reliability of supply and may bring down the costs. For example, an MHP plant combined with a small diesel-powered generating set could run for 24 hours a day at constant load, whereas the diesel set may only be operated for a few hours during the peak period. In this way, installation of a much larger MMHP plant can be avoided, thus bringing the capital costs down; at the same time, the use of diesel fuel (which is also expensive) can be curtailed considerably, thus optimising the generating costs. Similar combinations can be developed incorporating other fuel systems for specific situations.

Different terms have been used for different sizes of hydropower plants in the various countries. UNIDO has categorised the sizes in the following manner: micro-hydro (MHP) up to a 100kW capacity, mini-hydro between 101-1,000kW capacity, and small hydro between 1001-10,000kW capacity. Many countries have allocated other size ranges to each of these categories. In India, for example, plant sizes between 101-2,000kW are defined as mini-hydro, and those between 2,000-15,000kW are designated as small, whereas, in China, mini-plants have a size range of 101-500kW and small plants have a range of 501- 25,000kW. In this document, the UNIDO definitions have been followed, unless otherwise stated.

Table 1.1: Appropriate Energy Sources for Various Activities in Rural Mountain Areas

Activity	Preferred Energy Form	Suitability of Sources									
A. Domestic		Charcoal/ Fuelwood	Biomass	Manual/ Animal	Kerosene	Diesel/ Petrol	Biogas	Solar	Wind	Electricity	MMHP-SHP
Cooking	Heat	✓✓✓	✓✓	X	✓✓✓	X	✓✓✓✓	✓	X	✓✓	✓✓
Lighting	Light	✓	X	X	✓✓	X	✓✓	✓✓	✓✓✓	✓✓✓✓	✓✓✓✓
Heating	Heat	✓✓	✓	X	✓✓	X	✓✓	✓	✓	✓✓	✓✓
Washing	Heat	✓✓	✓	X	X	X	✓✓	✓✓	X	✓✓	✓✓
Ironing	Heat	✓✓	X	X	X	X	X	X	X	✓✓✓	✓✓✓
Food/grain processing	Motive power	X	X	✓	X	X	✓	X	✓✓	✓✓✓	✓✓✓
Entertainment	Electricity	X	X	X	X	X	✓	✓✓	✓✓	✓✓✓✓	✓✓✓✓
B. Agriculture											
Ploughing	Motive Power	X	X	✓✓	X	✓✓✓	X	X	X	X	X
Other land preparation	,,	X	X	✓✓	X	✓✓✓	X	X	X	X	X
Irrigation	,,	X	X	✓	X	✓✓✓	✓	✓✓	✓✓✓	✓✓✓	✓✓✓
Harvesting	,,	X	X	✓✓	X	✓✓✓	X	X	X	X	X
Threshing	,,	X	X	✓✓	X	✓✓✓	✓	X	X	✓✓	✓✓
C. Small Industries											
Agro-processing	Motive Power	X	X	✓	X	✓✓	✓✓	X	✓✓	✓✓✓	✓✓✓
Drying/heating	Heat	✓✓	✓	X	✓	X	✓✓	✓✓	X	✓	✓✓
Bricks	Heat	✓✓	✓	X	X	X	X	X	X	X	X
Woodworking	Motive Power	X	X	✓	X	✓✓	✓✓	X	✓✓	✓✓	✓✓✓
Water supply	Motive Power	X	X	✓	X	✓✓	✓✓	✓✓	✓✓	✓✓✓	✓✓✓
D. Commercial (shops, lodges)											
Cooking/heating	Heat	✓✓	✓	X	✓✓	X	✓✓✓✓	✓	X	✓✓	✓✓
Lighting	Light	X	X	X	✓✓	X	✓✓	✓	✓✓	✓✓✓✓	✓✓✓✓
Washing/Water heating	Heat/Motive power	✓✓	✓	✓	X	X	✓✓✓	✓✓	X	✓✓	✓✓
E. Communications	Electricity	X	X	X	X	✓	✓	✓✓✓	✓✓	✓✓✓	✓✓✓

X Not applicable; ✓minor, not suitable; ✓✓ significant, acceptable; ✓✓✓ good, satisfactory; ✓✓✓✓ very good, most desirable.

Chapter 2
Status of MMHP Programmes

2.1: A Brief History

MMHP plants were introduced into the HKH Region by the electricity departments of the various governments. In Nepal, the first MMHP plant was installed at Pharping in the Kathmandu Valley in 1911. It had a 500kW capacity and went out of operation a few years ago. The first MMHP plant was installed in India in 1897 in Darjeeling and had a 130kW capacity and in Kunming, China, in 1912 (480kW). Most other countries in the Region also had MMHP installations by the 1920s. At that time, there was no particular distinction between larger and smaller plants. The basic equipment was the same and almost always imported. Therefore, MMHP plants tended to be costlier than the larger ones, in terms of both the installed and production costs per kW and the per kWh.

It was during the fifties in China and the sixties and seventies in other countries of the region that a new approach emerged; i.e., indigenous development and decentralised installation of MMHP plants. This new approach reduced the capital costs considerably and introduced informal management and operational practices. Consequently, the rate of installations increased substantially, and some really remote and inaccessible villages witnessed the advent of electricity, unthinkable under a government-planned and managed system. These MMHP plants, mostly in the three to 40kW range, are usually subsidised by some government development agency or an NGO, as in Nepal and Pakistan. In China, similar but larger plants are financed by a combination of government agencies (central, provincial, or local). After installation, the local communities own, operate, maintain, and organise the repair of these plants. In a way, the new approach MMHP plants were considered to be an extension of the traditional *ghatta* or *gharat* (water wheel) technology which was used in the region for many centuries, mostly operating small agro-processing units.

More recently, the funding and management systems of private/decentralised MMHP have diversified to achieve differing objectives, as delineated below.

1. Community-owned and formally-managed plants installed with the main objective of providing electricity to the rural and remote areas (mainly Nepal).
2. Informally managed local community- or individually-owned electrification MHP plants used mainly to provide electricity (Nepal and Pakistan)
3. Decentralised plants installed by communities or the lowest level of local administration to provide electricity to rural areas (mainly China).
4. Informally managed local community- or individually-owned milling only, milling plus electricity, or electricity only MHP plants; the main objective being profit (mainly Nepal).
5. Formally-managed investor (local or outsiders) - implemented electrification plants, mainly for the sale of bulk electricity to the grids or government agencies; the main objective being profit (efforts in India, Nepal, Pakistan).

Private MMHP plants have distinct advantages over the larger public sector versions. Therefore, although the larger government-owned MMHP plants are not excluded from the overall programme, the main focus of this reference work is on MMHP plants installed and managed by the private sector or communities.

2.2: MMHP Installations in the Region

There has been considerable progress in the five countries of the region in terms of the number of installations in the MMHP range, although their actual contribution to the energy requirements of mountain areas is still minimal. Details of MMHP installations in the participating countries, both in the public as well as in the private sector, are given below.

At present, there are 19 MMHP plants in **Bhutan** with a total capacity of 3.40MW, all installed by the Royal Government under various aid agreements, mainly with India and Japan. There are only three other hydropower plants in Bhutan, i.e., the Chukha (336MW)[2], Gyetsa (1.5MW), and Gidakom (1.25MW). Whereas the identified and economically feasible hydropower potential is estimated to be 16,000MW. Most of the electro-mechanical equipment has been imported, mainly from India or Japan. Plant design and installation are also undertaken by foreign consultants, and most of the funds (loans or grants) have been provided by foreign agencies. At present, about 20 per cent of the population has access to electricity. Ten MHP plants, varying in capacity between 20kW to 70kW, were handed over to user communities for operation, maintenance, and distribution of electricity recently. The communities also fix tariffs and collect revenues. This experiment has been introduced mainly because the government agencies were finding it very difficult to operate and maintain these plants. Responsibility for their repair, however, still lies with the Department of Power. The government agencies regard MMHP plants to be very expensive, and there is more emphasis on the construction of larger plants which could also bring in revenue from the export of electricity.

In **India**, 153 MMHP/SHP plants (up to 3MW), with a total capacity of about 114MW, have been installed so far by various government agencies, while 178 additional plants, with a cumulative capacity of 220MW, are under construction. Out of the above, about 100 of the existing plants are located in the northern Himalayan range; these have an installed capacity of about 70MW. In addition, 1,344 sites, with a total aggregate capacity of 1,171MW, have been identified and incorporated into a comprehensive database established by the Ministry of Non-Conventional Energy Sources (MNES). All the plants are managed by State Electricity Boards or by the Department of Power (in Arunachal Pradesh). In most cases, the tariff charged is the same as the general government tariff for the grid system, except in the case of Arunachal Pradesh where it is much lower. More recently, approval has been given for installation of some private-sector plants. NGOs in Ladakh and Uttar Pradesh have also started installing MHP plants. One NGO, the Ladakh Ecological Development Group (LEDG), has installed 15 MHP plants so far, and these have been handed over to the communities for operation.

In **Nepal,** 35 MMHP plants, with a total installed capacity of 8.5MW, have been installed and operated by the Nepal Electricity Authority (NEA), and five of them are connected to the grid. During 1993, five of the above plants (at Darchula, Bhojpur, Kandhabari, Jomsom, and Bhajang) were leased out to private commercial companies. The new companies are

[2] About 80 per cent of the electricity generated by the Chukha plant is currently being exported to India.

to be responsible for operation and maintenance of these plants, as well as for the distribution of electricity. They are also authorised to fix tariffs and collect revenues from consumers, but the tariffs fixed by them must not be higher than the prevailing NEA tariffs. This is a new initiative adopted by NEA in order to cut down losses from mini-hydropower plants, and it is expected to continue.

There are other formal but private MMHP plants in Nepal where electricity is distributed, tariffs fixed, and revenue collected by the management. The largest and the most important of these plants is the 400kW Salleri Chialsa Power Plant which was commissioned in 1988. The tariff system is somewhat complex, as it has three main components, designed to promote more uniform use of electricity. The first component is the initial connection fee which increases with the amount of power allowed, from NRs 250 for a 100W connection to NRs 1,500 for loads higher than 4,000W. This connection fee is automatically transformed into company shares. Secondly, there are fixed rates for admissible power, subdivided into eight levels: rates vary from NRs 50/month for the first-level 100W connection to NRs 500/month for the eighth level. Thirdly, apart from for the first two levels, an energy charge per kWh is also made; this ranges between NRs 0.90 to NRs 3.00. Another interesting MHP plant is the 50kW Ghandruk power plant managed by a Users' Committee under the overall patronage of the Annapurna Conservation Area Project (ACAP); here also a similar tariff system based on connected power rather than on energy used has been implemented. A cut-off device is installed in the connections to switch off power if the prescribed limit is exceeded. Other similar plants are also under construction or being planned. These new trends, although not perfect for solving the problem of sharp peaks and non-uniform usage, have come a long way from the energy-(kWh) based tariffs.

In Nepal, there are about 900 MHP turbine units owned and operated by individual entrepreneurs, mostly for powering agro-processing equipment; and about 100 of these units also have add-on generators. In addition, about 200 peltric sets, with an average power output of about one kW, have also been installed for electricity generation in various locations. The number of electricity-only MHP plants is quite small; about 20. Another interesting endeavour is the improvement of *ghatta*(s) or traditional water wheels. So far, about 200 *ghatta*(s) have been improved by replacing the traditional wooden runner with a steel one, with buckets similar to turgo turbines. As a result of this, efficiency is reported to have doubled. The expenditure was nominal at NRs 5,000 (US$ 100). During the 80s, turbines with designs similar to the improved *ghatta*(s), but with components made of steel, were also installed; these were called multipurpose power units (MPPU). The MHP are mostly concentrated around the two manufacturing centres; i.e., Kathmandu and Butwal.

Most private MHP plants were installed during the 1980s when the Government removed the requirement for obtaining licenses for MHP installations of up to 100kW and provided funding facilities through loans and subsidies. Subsidies of up to 50 per cent, 75 per cent, or 80 per cent of the cost of the electrical equipment only is given for accessible locations, more remote areas, or very special cases, respectively. In addition, loans were available for mechanical equipment and civil works as well as for allied agro-processing equipment.

Installation of MMHP/SHP plants in China began in the 1950s. At present, China has 48,300 MMHP/SHP plants (up to 25MW in capacity) with a total generating capacity of about 15,100MW; the energy generated annually being 47.00TWh. Out of these, 45,600 plants are in the mini- / micro-range (up to 500kW). About 35 per cent of the plants are grid connected; however, in terms of capacity, 93.5 per cent of the power from MMHP/ SHP plants is connected either to national or to local grids.

Most of the plants installed in China began, were constructed, and are managed in a decentralised manner, based on the policy of 'self-construction, self-management, and self-consumption'. The plants are managed and operated by local governments, which include village, township, or county administrations. Funding for the plants is obtained from various sources, including the Central Government, provincial governments, and many other administrative systems. About 35 per cent of the funds were also arranged through bank loans on an interest basis. The owners (individuals as well as communities) also contributed about 14 per cent of the costs. The energy charges collected from the consumers are fixed by the administration. However, the rates for sale to the national grid are government rates. At present, these rates vary between 0.05-0.08 *yuan*[3]/kWh (less than US one cent). The other rates are somewhat higher, but not known. Technical assistance for design and installation and training for operation and maintenance are provided by bureaus established for this purpose.

Like most other countries, the main government agency in **Pakistan,** the Water & Power Development Authority (WAPDA), has found it difficult to implement and run smaller projects below five MW in capacity. Therefore, MMHP plants installed earlier were handed over to the Irrigation Departments of the NWFP and Punjab. More recently, other organisations have been created or upgraded to undertake the installation and maintenance of MMHP/SHP plants. In the Northern Areas (Gilgit and Baltistan), the tasks of MMHP plant construction and operation are assigned to the Public Works' Department; whereas in the NWFP, a new organisation, Sarhad Hydel Development Organisation (SHYDO), has been established under the Provincial Government; and the older MMHP plants have been handed over to SHYDO now. There are 64 MMHP plants with a total installed capacity of about 17MW being operated by various government agencies.

Two organisations in **Pakistan** are engaged in the promotion of private sector MMHP; i.e., Pakistan Council of Appropriate Technology (PCAT) and the Aga Khan Rural Support Programme (AKRSP). Both of these organisations install plants in the hilly/mountain areas under a subsidy programme. All the plants installed by these two agencies are electrification schemes which are handed over after installation to the recipient community for operation, maintenance, and distribution of electricity. The PCAT, at present, provides a subsidy of about 40 per cent on the total cost of the plant. The villagers pay for and complete the civil works and the transmission/distribution system and provide all the labour and transport. Of late, the recipients also provide about 50 per cent of the cost of the penstock. In the case of plants installed by the AKRSP, however, the subsidy varies considerably, depending upon the situation. In one case, for example, about 80 per cent of the project cost was arranged by the villagers through contributions. On the other hand, another plant was almost entirely financed through funds provided by the Canadian High Commission.

Since 1975,the PCAT has installed about 160 plants with a total generating capacity of about two MW and an average plant capacity of about 12.8kW. About 90 per cent of the plants are within the five-20kW range. All the plants use an old cross-flow turbine design and supply electricity to a rural mountain population of about 10,000 distributed throughout 160 villages. In about 20 per cent of the cases, add-on agro-processing or similar units also receive power from the plants. Since 1986, the AKRSP has installed 26 MMHP plants with a total installed capacity of 600kW (average plant size 23kW), supplying electricity to about 1,100 households. Unlike the PCAT, the AKRSP has installed various types of turbines for their plants; these include the cross-flow, Tubular (propeller), Pelton, and Francis.

3 There are currently 8.32 *yuan* to the US dollar.

Table: 2.1 shows the number of MMHP installations in the public and private sector in each of five countries in the Region. Since the MMHP plants in China are managed and operated by village or county councils, they have been placed in part B of the Table.

Table 2.1: MMHP Installations in Five Countries of the HKH Region

A. Public Sector Plants (1994)

Country	Micro-Hydropower		Mini-Hydropower		Total	
	No.	Total Capacity MW	No.	Total Capacity MW	No.	Total Capacity MW
Bhutan	11	0.4	8	3.0	19	3.4
India	NA	NA	NA	NA	145	106.6
Nepal	12	0.72	23	7.78	35	8.5
Pakistan	NA	NA	64	17.12	64	17.12

Notes

- Micro-Hydropower plants are up to and including 100kW in capacity in all countries
- The Mini-Hydropower range is up to 1.0MW in capacity in Bhutan, Nepal, and Pakistan and up to 500kW in China and up to 3MW in India.
- All the plants in India and Pakistan have been shown to be in the mini-range, since figures are not available for micro- and mini-ranges separately.

B. Private Sector or Decentralised Plants (1993)

Country	Micro-Hydropower		Mini-Hydropower		Total	
	No.	Total Capacity MW	No.	Total Capacity MW	No.	Total Capacity MW
China	27010	880	18635	5123	45645	6003
India	~20	~0.2	-	-	20	0.2
Nepal	~900	9.00	1	0.4	~900	9.40
Pakistan	~190	~2.6	-	-	190	2.6

Notes

- There are no private MMHP plants in Bhutan; however, ten government-owned MHP plants have been handed over to communities for operation and use
- Plants in China are not privately owned; however they are installed and managed in a decentralised way.
- In China, plants having capacities of between 100kW and 500kW are designated mini-plants.
- The exact data are not available for private MMHP in India.

2.3: Main Features of Private/Decentralised MMHP Installations

Almost all private/decentralised MMHP plants installed in Pakistan, Nepal, and China are indigenously manufactured. In Pakistan, out of 186 turbines installed in the private sector (by PCAT and AKRSP), 177 are cross-flow. Only a few turbines installed by the AKRSP are Pelton or other types. In Nepal also, about 76 per cent of the turbines are cross-flow, followed by 20 per cent MPPU, and 13 per cent Pelton. During the past four years or so, Pelton wheels have also been designed and manufactured locally, especially the smaller version (~1kW) peltric set. These sets are standard designs in which the generator and turbine are mounted on the same vertical shaft. Their advantages are the small size, which can be easily transported, and that ordinary pipes are used as penstocks. In Nepal, the technology for casting Pelton buckets seems to have been mastered reasonably well. However, it is difficult to say whether the requisite quality and precision have been achieved to provide the desirable efficiency and durability. China has a very broad base for manufacturing different turbines (including Francis, Propeller/Tubular, Turgo, and Pelton). China also exports MMHP equipment to other countries within the region, as well as outside. Chinese synchronous generators, for example, have been used in Pakistani MHP programmes from the initial stages and have given a reasonably trouble-free service. Interestingly, the cross-flow turbine does not seem to be very popular in China.

The first manufacturer of MHP turbines in Nepal was the Balaju Yantra Shala (BYS) which was established in Kathmandu in 1960 with technical and financial assistance from the Swiss Government. After initial experimentation with the axial propeller turbine, the BYS settled for manufacturing cross-flow turbines in the seventies; which is its speciality still today. Soon afterwards, Butwal Technical Institute (BTI), sponsored by the United Mission to Nepal (UMN), also began to manufacture cross-flow turbines. Subsequently, a number of different companies was established to undertake site survey, layout design, plant design, manufacturing, and installations under the overall umbrella of the UMN. At present, there are ten manufacturers based in Butwal and Kathmandu involved in manufacturing and other technical aspects of MHP. They have a production capacity of around 1.00MW per year. However, the generators and instruments are imported (mainly from India). Considerable assistance has also been provided by other international agencies in R&D, promotion, installation, and monitoring and evaluation of private MHP plants in Nepal. Amongst them are SKAT (Swizerland), ITDG (U.K), GATE/GTZ (Germany), and FAKT (Germany).

Reports on the quality and performance of indigenous MMHP plants have been mixed. At present, a proper system for evaluating the quality and performance does not exist in Pakistan or Nepal. At the time of commissioning also, it is not normal practice to measure the power output or to check the maximum or rated power, especially for agro-processing only plants. In one of the surveys undertaken in Pakistan in 1988, it was found that 54 per cent of the plants installed by PCAT were non-operational at the time of the survey. The situation seems to have improved considerably now, and, according to current estimates, about 10 per cent of the plants were non-operational out of the total installed since 1988. PCAT still uses the old cross-flow design, and improvements in the design and manufacturing have been minimal. The failure rates also vary considerably in different areas, both in Nepal as well as in Pakistan. The rates seem to be higher where the number of plants is lower. In the case of Nepal, no study has been undertaken so far to determine the extent of plant failures. There have been some reports of serious breakdowns, e.g., bursting of penstock pipes, breaking of turbine shafts, excessive wearing out of bearings, and serious leakages. However, this situation cannot be avoided completely, since the indigenous manufacturing systems are not so well developed.

Almost all the locally produced equipment in the four countries is considerably cheaper than the equipment imported from abroad. Even the better quality Chinese equipment is cheaper by a factor of from two to four than European or Japanese equipment. The cost of privately-installed plants in Nepal at present varies between NRs 40,000 to 100,000 (US$

800-2,000), whereas, in Pakistan, the cost is around PRs 10,000-15,000 (US$ 300-500). Chinese and Indian equipment also fall within the same cost range.

2.4: Policies and Other Inputs for MMHP Programmes

All the five participating countries have announced some level or form of support for hydropower installations, including MMHP/SHP. They have also declared rural electrification to be a priority area. China, India, and Nepal have also given priority to the installation of MHP/SHP plants for remote and isolated areas. The approaches, however, vary considerably. In India, for example, the recent policy of privatisation aims through various incentives to induce the private sector to start generating electricity as a supplement to government efforts, and then to sell this electricity to the public sector for distribution. It is more likely here that, since private sector entrepreneurs take up installation primarily for profit, they would go for larger installations that could be connected to national/regional grids easily. Thus, the main benefits of such private sector efforts would accrue to the mainstream, mostly the urban/sub-urban consumers. The Government of China, on the other hand, has provided inputs for decentralised plants.

On many accounts, Nepal is ahead of most of the countries in the HKH region in formulating and adopting policies and plans that affect the renewable energy sector, in general, and MMHP/SHP, in particular. Some of the important supporting initiatives are provision of loans on easier terms; subsidies for electrical equipment; and delicensing of plants of up to a 1,000kW in capacity. The extent of subsidies and loans prevalent in Nepal has been enumerated in section 2.6. In spite of such support, however, judicious implementation was reported to be lacking. For example, the availability of funds for loans and subsidies has fluctuated considerably from year to year.

2.5: Planning and Implementation

In China, most of the planning concerning decentralised MMHP/SHP is carried out at the central and provincial government levels. Until very recently, planning for public sector MMHP installations in other countries was neither comprehensive nor long term. More recently, however, efforts have been made in many countries to prepare a Master Plan, or an inventory of the sites, or to collect data. For example, the SHPD (Nepal), in collaboration with GTZ, has prepared a Master Plan for MMHP sites with power potentials in the range of 100kW to 1,000kW. Similarly, the WECS (Nepal) is preparing an inventory of the 10-15 most viable MHP sites in each of the 63 districts in Nepal where MHP potential exists. Preparation of a similar Master Plan has also been undertaken by SHYDO (Pakistan). However, most of these planning efforts are usually concerned with larger mini- and small plants and not with micro- plants. As far as is known, no comprehensive planning effort has been undertaken for an area or part of a country to specify that such and such an area would be electrified through decentralised MHPs, this area through extension of a transmission line from an SHP plant, and these areas through extension of the main grid system. Sometimes, the result has been that MHP plants originally approved and financed by government agencies would go out of operation when the national grid was extended to that area. Many MHP plants were abandoned in this way, even in the public sector.

In the case of informal private MHP plants owned and managed by individuals or communities, the villagers or recipients usually identify a potential site and the water source. They then approach an implementing agency, such as PCAT (Pakistan) or ADB/N (Nepal), to arrange for the installation. Usually, in such cases, a proper assessment of the demand in the village or area is not made. The result being that demand may exceed the capacity, or vice versa. In both Pakistan and Nepal, comprehensive planning for MMHP installations may not be crucial at this stage, especially since the exercise may be quite expensive. More important is the need to integrate private MHP programmes into the comprehensive electrification schemes drawn up by government agencies, either for electrification or for energy applications leading to rural development (industries, employment, or other energy needs), which does not seem to be the case at present.

2.6: Funding Sources and Procedures

Different types of funding systems have been introduced in China, Pakistan, and Nepal for private/decentralised MMHP installations. These are described here briefly .

- Grants for installations have been provided by donor organisations in some cases. Such grants are not a regular feature and usually do not make much impact on the overall programmes.
- Subsidy funding is the main process in many countries. The level of the subsidy has been gradually reduced from about 70 per cent to the present level of around 40 per cent in Pakistan. The AKRSP, on the other hand, provides varying levels of subsidy. Subsidies are also provided by the ADB/N for the electrical equipment of MHP plants in Nepal. Varying levels of subsidy (up to 90%) are also provided in China for decentralised plants. India also subsidises MMHP/SHP plants at the rate of up to 50 per cent of the total cost.
- Loans for private MMHP installations are provided in Nepal, China, and India. There is an interesting combination of loans and subsidies being implemented in Nepal managed mainly by the ADB/N. The turbine machinery and civil works, as well as the agro-processing units qualify for loans only at slightly cheaper interest rates than commercial loans. However, they are higher than the rates applicable for small-scale industries. Loans of up to 80 per cent of the total cost may be provided. The ADB/N had invested more than NRs 100 million as loans and subsidies in the MHP programme up to 1992. However, the interest rate has varied considerably over the years.

As mentioned earlier also, the Government of India has announced various economic incentives for private sector MMHP/SHP plants of up to 15MW in capacity, including loans and subsidies. Loans of up to 75 per cent of the total plant cost at a simple interest rate of 12.5 per cent have been offered. The maximum amount of the loan varies with the credit ranking and type of security of the borrower; the current maximum limit being IRs 254 million. The MNES also offers 50 per cent subsidies for all MMHP installations, especially in the hill areas, for plants that do not qualify for loans. Some funding facilities are also available for MMHP installations under the GEF-UNDP sponsored hill-hydro project.

2.7: Plant Management, Operation and Repair

The formally-managed private sector plants in Nepal are run quite well by a competent and trained manpower and through occasional backstopping from experts, including expatriates. The Salleri plant has eight employees[4], while the 50kW Ghandruk plant has

4 One General Manager, one Adminstrator and one Accounts' Officer, three operators, and two helpers

three (one manager and two operators). Thus, these plants are doing remarkably well, having net incomes ranging between 2.4 to six per cent of the capital costs. The same size range NEA-managed plants, on the other hand, are losing money, even on a current account basis.

In the case of informally-managed plants, the owner, or a prominent person from the community, looks after the plants just like an owner/manager, overseeing the operation, and maintenance and handling financial matters. Generally, the owner/managers are not well educated, some may even be illiterate. Also, they may have almost no training, either technical or managerial. In many cases, they may not even have commercial instincts. Therefore, it is not surprising that poor management has been cited as one of the main reasons for the financial troubles of the mills in Nepal. In some districts of Pakistan, MHP plants are more successful than in other areas. These areas also happen to have a large concentration of plants. The general feeling is that, in these areas, the owners/managers and the technicians have learned enough through trial and error. Therefore, they are able to organise and carry out the maintenance and repair on their own without much difficulty. In some districts of Nepal also (e.g., Dhading District), where plant concentration is higher and they happen to be nearer and more accessible to the industrial centres, the plants tend to be more successful than in the more remote parts of the country. Here also, the managers seem to have improved their capabilities over the years.

Many studies, including some of ICIMOD's case studies, have generally pointed out the inadequacy of the capabilities of the owners/managers and operators. In Nepal, book-keeping of any kind was lacking, management of cash was also inadequate, and no amount was being put aside for loan repayment or routine maintenance. Similarly, the operators were not trained well enough to notice signs of impending trouble and take appropriate action to avoid a severe breakdown. Usually, the salaries of the operators were quite low; which could have prompted them to leave the job. These reasons, at least partly, might be responsible for more frequent and severe breakdowns. In some cases, the owners or their relatives were reported to be operating the mills as a secondary occupation. In such cases, the service was unlikely to be reliable, since these operators had to perform other duties also. This would affect consumer confidence, and they might be reluctant to bring their business there.

Almost all the plants in Pakistan are operated and managed as non-profit making enterprises. Therefore, the revenue generated is small and usually just about enough to meet the routine operation and maintenance costs; the normal charges being PRs five to 15 per bulb per month. In case of a serious breakdown, the principal person in charge spends from his own pocket to get the repairs done. He/they may, however, organise a collection for this purpose before or after the repairs have been completed. No serious attempts have been made, so far, to increase and/or diversify the end uses, mainly because profit-making is not the objective and the manager/in-charge does not benefit directly from increased power generation and additional working hours.

In most of the mountain areas, including those of Nepal and Pakistan, organisation of repairs is a difficult and time-consuming endeavour, which could aggravate due to incapable management. Sometimes, the damaged part has to be identified, disassembled, and transported to an appropriate repair centre. Alternatively, a mechanic has to be brought from the repairing establishment to undertake repairs or assembly/disassembly. All this necessitates a considerable level of organisational capability.

In Nepal, it has also been noticed that the add-on electrical equipment goes out of operation more often and the repairs and recommissioning take much longer. This might have something to do with much lower returns from the electricity, or there might be problems with repairs that require more sophisticated equipment or manpower. In this case also, adequate data are not available. Some problems have been reported concerning the collection of electricity revenues from consumers.

2.8: Plant Capacity Utilisation and End Uses

Plant capacity utilisation and the plant factors tend to be quite low for both public and private sector MMHP plants. Plant factors ranging between 10 per cent and 20 per cent are quite common for the electrification schemes. Reliable data about the plant factors of agro-processing units are not available. However, the values are anticipated to be quite low, approximately between 10 to 30 per cent. Since all the plants are run-of-the-river types, having negligible water storage capabilities, the available unutilised energy simply goes to waste. Therefore, low load factors for MMHP plants are a serious drawback.

As discussed earlier, the private/decentralised, formal electrification plants are doing relatively better in Nepal, in the sense that their incomes are higher than their yearly expenditure. The current plant factors are quite satisfactory, and chances of further improvement are high, as a result of innovative tariff systems and promotion of other end uses, including cooking during off-peak periods. Prior to the installation of the new turbine at the Salleri Chialsa Plant, the plant (station) factor was about 41 per cent, whereas the plant factor for the Ghandruk Plant was about 42 per cent.

Many reasons have been reported for the low level of utilisation for private informal plants. For example, the areas were usually remote and undeveloped and the people were poor. Therefore they used electricity for lighting only for three to four hours. Secondly, the supply might not have been so reliable or sufficient for industrial use during the day. In the case of MMHP plants powering agro-processing units, the reasons for low plant factors may be insufficient business, the inadequacy of the capabilities or skills of the operators to connect various units simultaneously, or poor plant performance due to a serious defect or improper maintenance/repair. Generally speaking, many plants have been observed to be running at much lower levels than the rated power.

In China, plant factors have improved considerably, as larger more reliable plants have been installed, replacing the older ones. Plant factors have also improved due to grid connections and considerable diversification of end uses. Electricity is being used for irrigation, agro-processing, rural industries, and so on. In this way, about 85 per cent of the electricity is used productively in rural areas. Nevertheless, low plant factors are still being cited as a serious drawback, especially for isolated MMHP plants.

Enhancement and diversification of end uses are considered important in order to make MMHP financially more attractive for private entrepreneurs. Some of the areas identified for other end uses are domestic cooking and heating, commercial uses in shops and lodges, and some small-scale industrial applications. Obviously, commercial and industrial applications of electricity are likely to be more attractive for consumers than domestic applications, since the former are likely to be more financially rewarding.

Some ground-breaking work has already been carried out by the management of Ghandruk, Salleri Chialsa, and Andhikhola Power Plants by introducing novel tariff systems to promote more uniform utilisation of the connected power. Some work has also been undertaken to develop and promote low power (wattage) devices such as cooking utensils and stoves. One example, the *bijuli dekchi,* is an efficient low wattage cooking pot heated by an electrical element and incorporating a thermostat. Wattage ranges may vary between 200W to 500W for pot sizes ranging between 2.5 to 20 litres. In air-heat storage cookers, a bank of packed pebbles is heated through a 250W element and the heat is stored at about 500°C. For use, air is circulated through the pebbles and supplied to the cooking chamber where it heats the pan. The *bijuli dekchi* is currently being distributed in some areas under a subsidy programme, and the storage cooker is undergoing field trials. Electronic load controllers (ELCs) automatically divert the excess power unused by the consumers to ballast heaters. Thus, they maintain a predetermined constant (maximum) load on the turbines and keep the supply voltage as well as frequency constant. ELCs, originally developed in the U.K. and elsewhere, are being assembled locally in Nepal. However, the main components, including the circuit board, are being imported.

The *bijuli dekchi* promoted in some rural areas in Nepal, through various subsidies, does not seem to have made a real impact on users as yet, in the sense that the demand has not increased. The cost of these low power devices tends to be a prohibitive factor; a five-litre *bijuli dekchi*, for example, costs NRs 1,326 and the air-heat storage cooker costs around NRs 6,000. AKRSP has also made efforts to use MHP electricity for drying fruit and vegetables. However, the achievements and impacts have not reached a significant level as yet.

Obviously, more R&D and promotional efforts are needed to make such alternative applications attractive and viable. A system for maintenance and repair of the plants and appliances, such as workshops in remote rural areas, would also be helpful. However, adequate efforts are not forthcoming in this respect.

2.9: Impact, Benefits, Acceptance and Demand

Decentralised public sector MMHP electrification plants have provided considerable benefits to the remote mountain areas in some countries. For example, decentralised MMHP installations in Gilgit (Pakistan) operated by a government agency seem to be more economically viable than the earlier efforts made by a centralised agency such as WAPDA. Here, the generating costs as well as the tariffs are lower than the mainstream rates. The operational costs are higher than the revenues in this case also, but not as bad as the NEA-managed plants; in this instance it is reported that, on average, only about 20 per cent of the recurrent expenditure is covered by the income.

The main benefit of electrification schemes is a better method of lighting one's house or place of work. However, the level of impact varies from country to country. In China, electrification through MMHP and SHP has progressed quite well (with an installed capacity of 15,000MW, which is about 37.2 per cent of the total hydropower installed capacity). Electricity is now available to about 87 per cent of the population. China has exploited the largest proportion of the MMHP potential in the country, and the pace of additional installations and replacement of small, less efficient and unreliable plants have been increasing steadily. About 977 counties (out of a total of 2,300) now predominantly rely on electricity from MMHP-SHP. On both accounts (% of potential exploited and % of people benefitted) the impact is remarkable. Surplus electricity is being used for lift irrigation as well as industrial applications such as agricultural production and processing (including tea and tobacco drying), with the result that in about 100 counties earmarked for prioritised exploitation of MMHP, the agricultural output has more than doubled, while the industrial output has more than quadrupled. In many cases, the electricity is also sold to the national or regional grid, thus earning an additional income. In the case of Dehua county, Fujian Province, the share of electricity generated from MMHP-SHP has risen from 7.7 to 68.5 per cent of the total energy used during the past decade or so, while the share of fuelwood decreased from 66.5 to 12.5 per cent. The level of income per capita has also doubled at least. The study and adoption of the Chinese experience and achievement in the promotion of MMHP in a decentralised way could be very beneficial for the whole region and even beyond.

The MHP plants installed in the private sector so far have very small overall capacities in both Nepal and Pakistan; about five MW in Nepal and about 2.6MW in Pakistan. The electrification capacity in Nepal is much lower, around 1.6MW. Nevertheless, considering the fact that financial inputs for both of these programmes are not large compared to the government-installed, imported plants, the achievements are quite significant.

In the case of Pakistan, the total amount spent by the Government on installation of 160 private MHP plants is around PRs 15 million. An additional amount of PRs five million has been spent by the AKRSP for installation of 26 of their plants. The communities benefitting have also contributed about PRs five million, mostly in kind. As a result, electricity has been provided to about 11,000 households, and about 200 jobs have been created in the most remote and inaccessible areas. Some business was generated for the manufacturers and installers; they also benefitted technically since they were able to undertake the manufacturing indigenously. Additionally, business was generated for milling units and other small industries. There have been significant benefits for the environment in the sense that the kerosene used for lighting has been replaced by electricity. Therefore, the benefits, although very small in terms of percentage of population affected or energy used, are quite considerable for the actual beneficiaries. Above all, the potential for substantive improvements in living conditions, including reduction of drudgery and improvement of earning opportunities, is sizeable. The people are by now quite familiar with the technology and have gained enough confidence to manage and operate these plants. The main impact, however, is the increasing demand from the people and their willingness to make large contributions, both in cash and in kind.

In the case of Nepal also, the overall impact of private sector MMHP plants is comparatively small in terms of electrification. However, there have been many other benefits and their impact is quite significant. For example, a number of new industries had been established to develop/manufacture MMHP plants between the 1960s and 1980s. Considering the fact that Nepal, at that time, was far behind in engineering and technology, especially indigenous manufacturing, this is an important contribution. Many of these industries have diversified their businesses, created new jobs, and enhanced their capabilities in the manufacturing sector. Another important aspect of private sector MMHP in Nepal is that the plants are meant to be installed and operated as commercial ventures. Many such agro-processing plants have exhibited that financial returns on investments can be quite lucrative; even though the problems facing these plants have not been overcome as yet. The electrification schemes are admittedly not performing well financially; even then, they are a better alternative to the government installed and operated plants which are losing money on a current account basis. There are also good prospects for improving the plant factors of private plants, thus improving the economic returns, and significant novel approaches are already being tested, including some innovative tariff systems.

Efforts to develop appropriate end-use devices, especially for cooking, have also been significant in Nepal. Although the impact of these devices has been small so far, the scope and potential are considerable, and the initial efforts indicate possibilities of a breakthrough in the foreseeable future. Some other innovative end uses, such as hot showers for tourists, are also making their mark both in terms of income generation as well as in availability of a service. There is also considerable scope for using the available electrical power for other productive activities such as lift irrigation and some small-scale industries such as paper-making.

An important contribution of the MMHP agro-processing plants is the alleviation of drudgery for women from tasks such as cereal grinding or dehusking of rice. Additionally, in many areas oil-expelling operations are almost exclusively carried out now by oil-expellers powered by MHP plants, and, in those areas, *kol*(s) (traditional manually-operated expellers) are no longer used. This is because the oil yield from modern expellers is up to 50 per cent higher than from traditional *kol*(s).

The demand for the installation of MMHP plants has been growing steadily in the region (mainly for electricity). In China, for example, the installed capacity of MMHP-SHP plants has been growing rapidly and has doubled during the past decade. Similarly, in Pakistan, requests for installations have been increasing and the number of pending applications has been multiplying. Sometimes, political pressure or influence is also used to get approval for plant installation. Similarly, funds are now being provided by members of national and provincial assemblies for installations in their areas. This clearly indicates the preference of the people for such installations.

The situation in Nepal, however, is a bit more complicated. Although the electrification of rural areas has also increased considerably, through public as well private sector installations, so has the demand; the rate of micro-hydropower installations has declined. It has been suggested that the main reason for this decline is non-availability of funds for loans and subsidies. It seems that there are some other problems as well, e.g., non- repayment of loans, financial difficulties faced by some owners, and lack of business in some areas. These problems are discussed in subsequent sections.

2.10: Current Training Arrangements and Needs

The data and analysis presented above indicate that, in spite of many achievements, some aspects of private MMHP are not functioning properly and need external interventions, including training. For example, managers and operators of private informal plants have been reported to be incapable of running the plants properly. This deficiency can be corrected through appropriate training programmes. The training aspects and requirements are covered in more detail elsewhere in this document.

2.11: Major Problems of Private MMHP and Some Redressals

Problems being faced by private MMHP installation programmes have been identified through various studies, especially in Nepal and Pakistan. The more serious problems and some redressals are discussed below.

- The present funding level is low and inconsistent. It is recognised that private MMHPs need funding support for the foreseeable future. Adequate amounts of funding are needed for implementation, R & D to improve MHP equipment/civil works, end-use appliance development, evaluation/monitoring, and so on.

- More effective methodologies have to be evolved to work out the appropriate level of subsidies and loans, as well as their judicious administration, on a long-term and consistent basis, in order to avoid problems such as non-repayment, declining rates of installation, and so on.
- Proper feasibility studies to evaluate demand and business in a given area must be undertaken based on wisely-developed methodologies, so that underestimations/ overestimations are avoided.
- The cost of indigenous MHP plants in Nepal has been going up. Studies should be undertaken to find out why and efforts to reduce/stabilise costs should be introduced, including R & D.
- Economic returns from MHP plants, in general, and electrification schemes, in particular, are very low. Adequate steps should be taken to increase end uses and economic returns.
- Frequent breakdowns are a very severe drawback of indigenous MHP plants, giving the technology a bad name and causing serious problems for the owners. While this problem may be caused by many factors, including lower quality equipment and the incompetence of the managers/operators, adequate measures have to be developed and implemented to improve quality and performance.
- The problems of water availability and usage are becoming increasingly serious due to local conflicts and to other preferred uses such as irrigation. Some policy decisions and legislative measures are needed to deal with this problem.
- Lack of coordination among the agencies implementing electrification in rural areas has been variously reported. Some government implementing agencies also do not recognise the private MHP as a viable option. Coordination needs to be improved in this respect.
- A system of competent assessment of applicants for MHP should be evolved and implemented, since it has been reported that many owners were simply not in a position to manage the plants well.
- Delicensing of MHP plants (say of up to a 100kW) should be introduced in other countries, such as India and Pakistan, also, since this seems to be the single-most important policy decision made by HMG/Nepal which contributed to the proliferation of MHP in remote rural areas.
- In order to improve implementation, management, and performance of MMHP plants, proper training of the concerned personnel should be organised and necessary training materials developed.
- The level of plant capacity utilisation is unsatisfactory for MHP plants. Strategies should be developed and implemented to improve plant factors and enhance end uses.
- It has generally been felt that an independent institution is necessary to organise the development and promotion of private MMHP (including provision of inputs such as training, guidelines, plant performance evaluation, and overall coordination).
- The need to establish such a centre has been emphasised, especially in Nepal. In other countries, existing institutions should be strengthened to carry out these functions.
- Guidelines/standards need to be developed for assessors, surveyors, manufacturers and installers, and supervisors of civil works.
- The quality of indigenous equipment and associated instrumentation and controls needs to be reviewed at this stage; for example, how reliable should the equipment be for a given site? and so on. Some countries are still continuing with rudimentary equipment without any automatic controls. This situation is obviously not helpful in the long run and needs to be reviewed.

- Similarly, the philosophy of charging minimum tariffs, barely enough to cover operational costs, also needs to be reviewed, so that the plants have some net income for major repairs for example, or to cover depreciation, and so on.

2.12: A Case Example of Barpak MHP Plant

This example illustrates the efforts and success of an entrepreneur in the installation of an MHP plant in a remote Nepali village. One feature of this example is the absence of direct involvement by development agencies specialising in energy; both local and foreign. The most significant feature of this case is not that local institutions (banks, manufacturers, surveyors) have functioned well to promote development in a village, but rather that they have apparently functioned in a haphazard way that might have actually inhibited development of this sort in another village. The determination of a young entrepreneur with a vision strong enough to move him to sell all his land in Kathmandu to invest in MHP in his village seems to be the most salient feature, and this perhaps tells us a lot about the ingredients needed for village development.

This case history is also notable in demonstrating the potential for development of economically productive activities directly associated with MHP installation. It demonstrates very clearly how end-use developments and MHP developments are progressive and interactive, moving from stage to stage and, therefore, requiring a considerable local capability for planning and business management and long-term committment to (or motivation for) local development. The case history also opens up questions concerning legislation and the role of local committees representing the public interest.

2.12.1: The Village of Barpak and Advent of Hydropower

Barpak is one-and-a-half day's walk north of Gorkha, a roadhead town close to the Kathmandu-Pokhara highway. The village has around 600 houses. Cash incomes are above average for rural Nepal because the village has traditionally provided recruits for the British Gurkha regiments.

In 1989, Bir Bahadur Ghale, a 21-year old villager living in Barpak, visited an appropriate technology exhibition in Kathmandu organised by ADB/N. It also included stands displaying MHP equipment. He was able to discuss hydropower with a Kathmandu manufacturer (BYS) who referred him to the ADB/N office to seek information on loans. From this point on, it appears that Bir Bahadur experienced a very long and repetitive process involving numerous visits to different ADB/N offices and to various surveyors and manufacturers. This took almost a year, because the local ADB/N office felt that the project was too large. Eventually, Bir Bahadur approached the ADB/N Head Office where the Director, who was pro-MHP, decided in his favour. Finally, Bir Bahadur obtained authorisation for a loan of NRs 11.5 *lakh*[5](s), and obtained a subsidy of NRs 4.9 *lakh* (s), representing almost 50 per cent of the estimated cost of electrical equipment held to a 10-*lakh* ceiling.

The interest rate was 15 per cent and the loan was to be repaid over seven years (the ADB/N had later reset the rate to 19 per cent and reduced it again to 17 per cent). Bir Bahadur sold his private land in Kathmandu in order to personally contribute NRs 3.8 *lakh*(s), and he later channelled further funds to the tune of NRs 4.5 *lakh*(s) into the scheme, for instance, those needed for purchasing land for the channel and powerhouse. The total

[5] A *lakh* is a 100,000. There are currently 56.75 Nepalese rupees to the U.S. dollar.

capital cost is estimated at NRs 24.8 *lakh*(s). In early 1990, Kathmandu Metal Industry (KMI) and Bir Bahadur completed installation of the scheme which had a rated power of 45kW.

In the first year or so of operation, the scheme produced power continuously. Fourteen kW were devoted to domestic lighting and three kW to an electric grain mill owned by Bir Bahadur and situated at his house. A *ghatta* that had operated an hour's walk from the village now stopped milling services. The domestic lighting load rose quickly to 24kW and stayed at this level for more than a year, as the generator was unable to deliver more power due to technical difficulties. The original generator was finally replaced (after a number of false starts with inadequate equipment and periods of severe lightning damage) with one capable of delivering the full scheme capacity of 45kW. By 1994, the domestic lighting load had risen to 41kW. Bir Bahadur had started on this venture with almost no technical knowledge, but, after four years of operation, he had learned a great deal about electricity generation.

In addition to village lighting and grain-milling, Bir Bahadur installed a television in his own house in a position which allowed viewing from outside. This attracted crowds as large as 150 people and has led to complications with respect to laws related to private and public viewing of television.

During late 1993 and 1994, Bir Bahadur planned and established, or assisted others with, a number of further businesses that depended on electricity from the MHP plant. The first to become operational, in addition to the grain mill, was a furniture workshop using electric tools. Subsequently, a paper-making business, owned by Bir Bahadur, using *lokta* bark collected in the neighbouring regions, was established as well as a bakery using an electric oven. The bakery and furniture workshop are owned by other villagers but have been established with help from Bir Bahadur. In early 1995, Bir Bahadur was exploring the possibility of a local metalwork shop, with a welding facility and an incense-making facility, since it is thought that raw materials can be found locally.

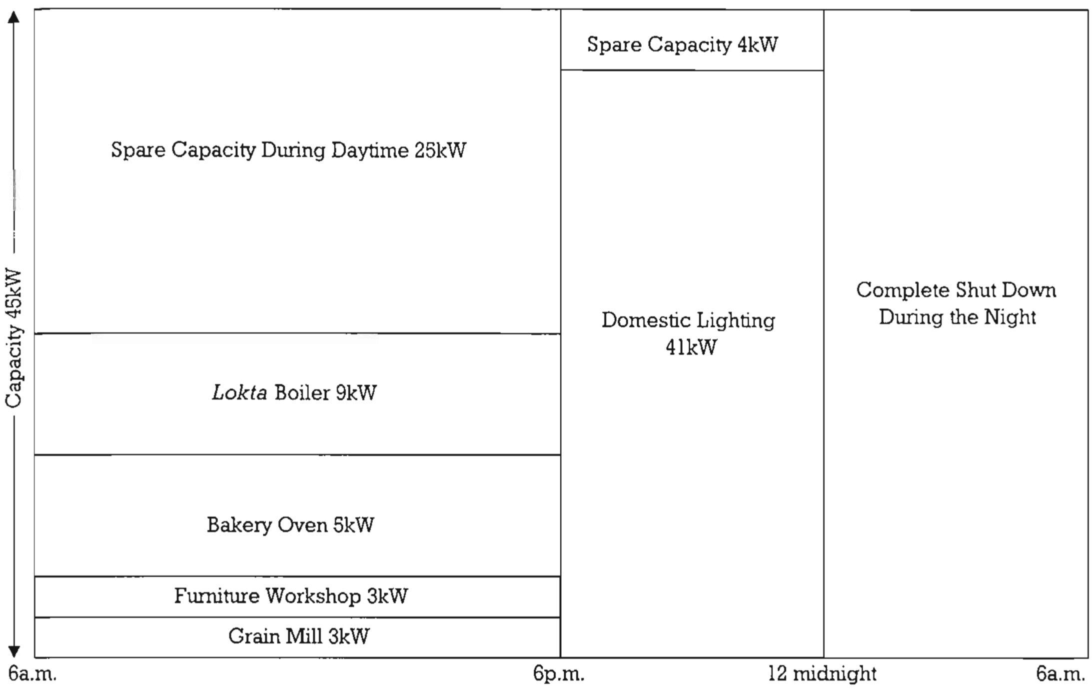
The distribution of electricity use is presented in Figure 2.1. Domestic lighting supply is only available in the evening, from 6 p.m. to 12 a.m. At night the turbine is shut down since constant supervision of the transmission poles is needed, and they are of inadequate quality for the local climate. During the day, the electricity is divided between a nine kW *lokta* boiler for paper-making, the five kW bakery oven, the three kW furniture workshop, and the three kW grain mill.

2.12.2: End Uses of Electricity

Domestic Lighting

Most domestic lighting in Barpak is fitted without meters in order to keep costs to affordable levels. Instead of meters, the householders choose how many bulbs they want and pay a fixed monthly tariff accordingly. If they choose to pay a tariff for 50 watts, for instance, they are dissuaded from fitting bulbs or other appliances that consume more than 50 watts by a special fuse which cuts off the supply when consumption goes above the designated amount. During this blackout, the householder must turn the main switch off, reduce consumption again to the correct level, and wait one or two minutes until the fuse resets and switches the power back on. The fuse, known as a Positive Thermal Coefficient (PTC) switch, costs NRs 200 to 400. Apart from buying bulbs and appliances the house-

Figure 2.1: Load Distribution for Barpak Plant



holder must also pay for wiring in the house, usually between NRs 400 and 1,000, and a small connection fee of about NRs 10. These consumers are allowed to use electricity in the evening hours only between 6 p.m. and 12 a.m. The rules and tariff levels are decided by means of negotiations between the plant owner and consumers, rather than by outside guidance.

There are already some wealthier households in Barpak that have electricity supplies identical to supplies in a town house, with energy (kWh) meters allowing larger amounts of electricity to be used all day and paid for according to the number of kWhs consumed. The businesses that use electricity, such as the furniture workshop and bakery, pay for electricity in this way.

Revenue from the 41kW of evening lighting is estimated at Rs 23,000/month. Costs include Rs 4,000/month for operators' wages (these include, 1 powerhouse operator; 1 administrative officer for collecting tariffs, keeping accounts, and reading meters; and 1 transmission line attendant and repair man). The surplus of Rs 19,000 is spent partly on replacing equipment and maintenance and partly on repaying the loan installment of Rs 18,000/month. The sale of electricity to the external businesses and the profits from paper-making and grain-milling also serve to recoup investment and pay for the operation of the plant.

Paper-making Business

Bir Bahadur attended a government training course in paper making using the Japanese method which involves moisture removal by pressing the paper. This produces a smooth quality product which can be used by offices. At present, a price is being negotiated for purchase of this paper by local government and bank offices. An export market for Nepali paper also exists. In recent years, this has grown rapidly since quality graphics and dyeing techniques have been introduced. Revenues are around Rs 70,000/month at present. There are 32 employees working part time. Electricity costs are insignificant, since in the day the electricity supply is under-utilised, and the power plant and paper factory are both owned by Bir Bahadur. The investment in equipment is in the order of Rs 170,000 (total investment including land and buildings is around Rs 500,000); so profits are used at present to recoup the investment. The long-term economics of paper making look very promising. Bir Bahadur is confident that the business will prove to be a more viable end use than lighting.

Furniture Workshop

This workshop practises a number of different processes, such as planing, which are novel introductions to the village. Production levels are not known but the machinery is used consistently; the MHP plant benefits from an income of Rs 700/month from sale of electricity at a rate of Rs 7/kWh.

Electric Bakery Oven

This business is still in the trial stages. It produces bread made with local flour which is not quite the import substitute product which is in great demand in the village. It does not make any profit and cannot yet pay for the investment costs incurred in installing the oven. Baking takes place in two shifts every other day, and revenues only just cover operational costs. The MHP plant receives an income of Rs 1,000/month from sale of electricity, at a rate of three rupees per kWh.

Grain Milling

This service is very popular in the village, attracting customers from considerable distances. It serves as a social focal point as well as a release to many women from long hours of hard physical drudgery. The revenue is in the order of Rs 7,000/month, and costs are mainly the wages of an operator at Rs 1,100/month and maintenance costs of Rs 500/ month.

2.12.3: Future of the MHP at Barpak

The demand for electric lighting already outstrips the supply capacity. The terrain offers many sites for further MHP installation; for instance, the tailrace of the present plant drops 90 metres to the river below. This means that the MHP is potentially providing an irrigation system for the hillside (at present not cultivated), or that a second power plant could be built below the first one. Bir Bahadur is considering the installation of another power plant, but first he is concentrating on securing revenue from the existing plant by increasing the daytime use of power. This will mean finding secure markets for the paper produced, encouraging other daytime uses of electricity (such as welding and metal working services), and possibly starting a business in incense making.

An important role for the MHP at Barpak is to act as a technical support centre for smaller schemes in the neighbouring area. An effective institutional framework for MHP might seek to build on local initiative of this sort in this way; certainly one way in which a return can be made on public investment in schemes like the Barpak plant is to make use of the technical and management capabilities established there to support further initiatives in the area.

2.13: The MHP Plant in Pida Village

The MHP plant in Pida village near Gajuri in Dhading District is situated along the Prithvi Highway, about 100km from Kathmandu. The plant, owned by Mr. Thir Bikram Basnet, is located about 100m from the main road. The rated capacity of the plant is 18kW, and it is coupled to a 12.5kVA generator. The original agro-processing plant was established in 1984, while the electrical generator was added in 1993. The prime mover is a multipurpose power unit (MPPU); a vertical axis, locally-evolved design, similar in some respects to the turgo turbine. The plant produces and supplies electricity to about 150 houses in the evenings for about five hours. In addition, some agro-processing units are mechanically coupled to the turbine; i.e., flour grinder, rice huller, and oil expeller. The owner has also installed a small ice or ice-cream making plant recently which he operates during summer. Both Mr. Basnet and his son, who has a diploma in engineering, manage, maintain, and repair the plant and sometimes even lend a hand to the two operator employees. The plant is well maintained and seems to be managed and operated properly. It provides a useful service to about 150 households through electricity supply and to another 500 through agro-processing. According to the owner, the net income from the plant is about NRs 150,000 (US$ 3,000) per annum, and this is a very good return on the investment of about NRs 600,000 (total). The owner is also planning to add other commercial units such as paper-making, saw milling, etc. He also intends to expand the water reservoir to increase the storage capacity and to establish a fish farm.

The owner, no doubt, has been working very hard and had faced considerable difficulties when the canal was washed away in 1993 due to heavy floods. He had to spend about NRs 200,000 to reconstruct it. However, in spite of these problems, he seemed to be quite happy with his endeavours and returns.

The MHP plant of Mr. Basnet is not typical; most other such plants were not so successful and were having considerable problems, both in terms of breakdowns as well as economic returns. However, plants such as these clearly demonstrate that MHP plants can be viable in some situations, and proper management seems to play a very important role. Since the capital costs of MHP plants are quite high, financial inputs, such as loans, subsidies, and reasonably low-cost technical support/advice and training services, will be necessary for quite some time to come.

2.14: Some Case Examples from Industrialised Countries

The Norwegian Example

The Norwegian programme for electrification of remote and sparsely populated areas should be of particular interest to the developing countries. Electrification started around the turn of the century in cities, townships, and at industrial sites. In 1930, there were 1,452 hydropower stations in operation, aggregating to 1,701MW; of which about five per cent was used directly as shaft power in operating grain mills, paper mills, sawmills, and mechanical workshops. One thousand and eight plants were less than 100kW in size, and only 35 were larger than one MW.

By 1938, it had become a hot political issue that the remote parts of the country did not enjoy the benefit of electricity, in spite of the fact that there was ample potential for hydropower development in those areas. The government electricity administration then proposed the implementation of a support scheme which was adopted by Parliament. The means required for the support was established through a levy applied on every unit of electricity consumed, collected by the existing supply utilities, and paid to a fund for rural electrification. The idea was that every electricity consumer should contribute towards the provision of electricity to people living in areas without electricity. The support schemes were managed by the electricity administration, in close cooperation with each supply unit, based on the policy guidelines approved by the Government. These are discussed in Chapter 3.

The financing of the projects was based on the revenues anticipated from the new customers. If the local government (municipality) or the county government was the formal owner of the installations, or if they provided guarantees, loans were obtainable from a state bank on favourable conditions. The estimated revenues were based on a relatively high tariff level, but comparable to the other similar counties. Part of the capital was also provided by the local governments and consumers.

The electrification of Norway went on efficiently, thanks to a number of favourable conditions: e.g., substantial hydropower potential on sites of various types; strong local initiative and involvement which enabled rural electrification to proceed in a decentralised framework; and adequate government involvement in the development of the main transmission network as well as other facilities. Emphasis was placed on creating a mechanism that encouraged the local population to involve themselves in the establishment of electricity supply schemes. The support programme greatly helped to ensure that the whole of Norway was receiving electricity by 1965. Today, the country supply is interconnected across rough mountains, fjords, and straits.

During a recent review of two counties of Norway (out of a total of 18), namely, Sogn and Fjordane, 29 private MHP plants ranging in size from 1.5kW to 100kW, and owned by individual households, cooperatives, industries, municipalities, and even hospitals, were still found to be working. The oldest plant was installed in 1899 and the most recent one in 1954. Many of the plants were later rehabilitated, some as late as 1983.

Recently, by revision of the legal framework, the system and the structure have been transformed to a state-owned main transmission grid; but still many regional and local monopoly networks exist. Approximately 60 independent owners of power plants are competing on a free power market, based on common use of the transmission network.

The MMHP Situation in the United Kingdom

Britain is one of the very few developed countries where installation of MMHP/SHP plants is being revived through deregulation and various incentives to induce the private sector. About 70 private MMHP and small-scale hydros, representing about 50MW in capacity, are presently in an advanced state of assessment in Britain. The incentives are given in order to reach the estimated untapped potential in MMHP-SHP of 300MW[6].

An important deregulation feature of the privatised industry is that power can be generated for on-site consumers, consumers can buy from any supplier, and any supplier can buy from any generator. This feature is being realised in stages: up to 1994 only consumers of above one MW could freely negotiate with any supplier, and only in 1998 will consumers of below 100kW have this freedom. In terms of diffusion of energy supply in the HKH Region, this approach would promote a least-cost consumer choice of type of electricity generation. This has the implication that consumers may choose diesel stations over renewable stations because of low start-up costs; and, therefore, that subsidy policies for

[6] The target for all new, renewable generating capacity in the UK is 1,500MW by the year 2000; this is 2.5 per cent of the present overall generating capacity of 58,000MW, of which large hydro installations contribute 83MW.

renewables, or access to loan finance, will be the key to development of hydro and will require facilitation by a regulatory or promotional body. Additional details of policies, including deregulation, are given in Chapter 3.

Chapter 3
Institutional Framework for MMHP Development

3.1: Introduction

It is now well known that the mountainous areas of the HKH Region have adequate potential for MMHP which can be exploited to meet the energy needs of the population, as well as to contribute towards the development of these areas. However, given the specific conditions of this region, i.e., very low level of development, poverty, scattered and sparse population, inaccessibility, and overall lack of infrastructure, physical and institutional, development of this appropriate and indigenous resource has not really taken off.

While grid extension is a standardised approach to electrification of rural areas, and favoured by the principal utility agencies, it is usually not economical under the specific conditions mentioned above, mainly because of widely scattered demand centres and very low levels of demand per capita. Therefore, isolated, indigenous, and relatively small MMHP plants, preferably initiated and managed by individuals or groups from the user communities, have been shown to be quite competitive with other available options. Many other countries, such as China, have actually made sizeable achievements in this area. Promotion and installation of such plants have also additional advantages with regard to environment, local development of the technical as well as managerial capabilities, and so on. It is also likely that, as the local economic, technological, and institutional systems develop and improve, some of the MMHP plants will be abandoned, replaced by bigger ones, and eventually connected to a grid system; either a local isolated grid or the national one. However, considering the current level of development and economic conditions of most of the sections of the HKH Region, isolated MMHP is the most cost-effective resource.

Given the unique type of resource and its implementation aspects, the required institutional arrangements are also quite different and, at present, inadequate or even non-existent in the region. For example, the local user communities are expected not only to use the available energy properly, but also to manage/operate the plants, to distribute electricity, to collect revenue, and so on. In order to enable them to accomplish all this efficiently and on a long-term basis, they have to be motivated, trained, and supported. Since these communities are living in isolated rural areas, having very few educational and technical skills or facilities at their disposal, except, perhaps, community cohesiveness and the will to survive under extreme conditions, this job becomes more complex. Consequently, the institutional structures have to have the requisite capabilities, especially in terms of decentralisation, flexibility, and capacity, to work with such rural populations.

In addition to electrification of different mountain areas, there has been a significant movement to invite the private sector to participate in the generation of electricity meant for the mainstream population. This advancement has caught on both in the developed as well as in the developing countries, and processes of 'deregulation' have been set in motion to encourage the introduction of the private sector in a formerly 'sacred' field. Many developing countries, including Chile, Malaysia, and Nepal, have introduced novel legislation and policy declarations in this respect to provide adequate assurances to private investors and to minimise or abolish the licensing/approval requirements. Appropriate institutional arrangements are also being considered for introducing similar measures in other countries of the HKH Region.

The small investor from a rural mountain community is likely to have some expectations regarding returns on his investments, in fact, similar expectations to the more resourceful city-based or international investor. Although, in the case of the small rural investor, he will have far fewer facilities at his disposal, e.g., technical, financial, legal, or administrative. This would necessitate the ready-made availability of institutional support, preferably on his doorstep, to sustain his endeavours and to meet at least some of his expectations. In fact, the rural community leaders or entrepreneurs have to be convinced, persuaded, and assisted to initiate, plan, install, and manage the plant.

The wide variation in income levels in the mountain areas is another important factor that needs to be given due consideration in planning and selecting energy options for such areas. While one community may be able to support a fairly expensive electrification scheme, another may only be in a position to sponsor and patronise a mechanical agro-processing plant. Given time to develop its economic system further, the other, poorer community may progress in subsequent years to be able to support an electrification scheme also. Thus, wide-ranging flexibility in the institutional system would really have to be inculcated, in order to enable it to play its role effectively.

3.2: Aspects Needing Institutional Arrangements

Considering the different nature of MMHP promotion and development, the required institutional structures have to be tailored accordingly. A number of different tasks and aspects, for which institutional arrangements are necessary, are listed in Table 3.1.

The above Table lists important aspects related to the development and efficient performance of MMHP plants for which adequate inputs have to be provided in a properly planned and consistent manner. Additionally, other related issues need to be debated and decided upon; for example, the size or level of sophistication of a plant, level of subsidy, etc. Quite often, a small community, or a cluster, may only be in a position to use a few kW of electric power, and, for them, micro-range plants may be the most suitable, given their current economic status and the available capability in terms of management and operation. Both the economic as well as the management capabilities would improve with time; and the same community may need a larger plant after a period of, 10 years, for example. However, the prevalent situation influenced by the affordability and capability factors would well justify the installation of a smaller MHP plant. In fact, installation of such smaller plants would assist in capacity building in the communities. Such decisions need to be taken within the appropriate institutional structures. Considering these factors, it is desirable to elaborate on some of the development aspects delineated in Table 3.1.

3.2.1: Policy and Legislation

Policy support and the accompanying legislation have been perhaps the most important contributory factor to the accelerated development of MMHP in Nepal. This included delicensing, subsidies, and loans and some concessions to the manufacturers. Other incentives for improving energy efficiency and the power factor and introducing special programmes for rural development, in turn, would enhance energy consumption. Similar

Table 3.1: Aspects and Tasks Needing Institutional Arrangements*

Aspect	Tasks to be Performed	Affected Personnel/ Agencies	Types of Implementing Agencies
1. Policy & Legislation	- Subsidies, soft loans, revolving funds	entrepreneurs, rural communities, implementing agencies, manufacturers, suppliers	- Govt. Dept./ Ministry
	- inclusion of MMHP as a viable option in overall energy planning		- as above
	- delicenging and/or procedures, concerning:	- as above	- as above
	• installation	- as above	
	• tariff fixing		
	• water & land use		- as above
	- Tax concessions		- as above
	- Environmental protection controls and incentives	- as above - as above	- as above
	- Terms and conditions to buy back rates and wheeling	- as above	- as above
	- Rural industry promotion incentives	- as above	
2. Finance	- Mobilisation of funds from different sources	- implementing agencies, recipients	- specialist agency
	- Fixation of level of subsidies, interest rates, recovery periods, etc	- entrepreneurs, recipients	- as above
	- Formulation of efficient and judicious procedures for disbursement of funds	- rural communities, lending agencies	- disbursement agencies
	- Proper disbursement	- as above	- as above
	- Formulation of adequate systems for loan recovery and their implementation	- ending agencies, overall programmes	- disbursement agencies, responsible specialist agencies
3. Beneficiary Participation	- Awareness raising and dialogue with beneficiary communities remerits/ demerits of MHP plants, their expected contributions and responsibilities	- communities/leaders, overall programmes	- promoting/ implementing agencies
	- Formation of village committees and identification of main factors from communities	- as above	- as above
	- dialogue with communities re.;	- as above	- as above
	• project planning • community contribution • fund procurement from other sources • land procurement • end-use development and utilisation • tariffs, incomes, and expenditure • integration/replacement of other energy sources • management of plant and income, loan repayment • saving for maintenance, repairs, future expansion, etc		

* See Section 3.2

4.Coordination	- Coordination among different agencies to minimise costs, overlap and conflicts and to avoid making similar mistakes.	- implementing agencies, overall programmes	- Specialist agency, suitable association
5. Promotion	- Sponsoring studies to assess/propagate potential, status, problems, new initiatives etc for entrepreneurs, as well as financial decision-makers/donors - promotion of end uses	- implementing agencies, recipients. overall programmes - communities, entrepreneurs	- specialist agency(ies) - promoting agencies
6. Technology	- Indigenous R & D • component standardisation • cost reduction • efficiency improvement • technology transfer and assimilation • end-use appliance development - Manufacturing methodology and quality improvement - Guidelines/manuals for equipment selection and manufacture - Training of manufacturer	- recipients, manufacturers, overall programmes - as above - as above - manufacturers, overall programmes	- specialist agency, manufacturers, R & D organisations - specialist agency, manufacturers - as above - specialist agency, promotors
7. Technical Implemen-tation	- Capability and needs' assessment of beneficiaries - Surveying and site selection - Planning and designing of the plant - Community participation in: • information transfer • planning & feasibility • plant design • tariffs & revenue management • construction and management - Appraisal of feasibility studies - Training of managers/operators - Quotations, invitation/processing - Installation and commissioning - Warranties, after-sales' services - End-use equipment selection and installation - Operation and maintenance manuals	- recipients - as above - as above - as above - implementing agencies - managers/operators - recipients, imple-menting agencies - as above - as above - as above - as above	- manufacturers/ contractors, implementing agencies - implementing agencies - as above - as above - implementing agencies, promotors - specialist agency, lending/promoting agencies - specialist agency, promoting agencies - implementing agencies - as above - as above
8. Repairs	- Preparation of a plan and methodology to identify locations and workshops/ technicians, requisite materials, capabilities, minimum tools/ equipment and training - Development of field repair facilities (implementation of above plan) - Working out agreements with workshops	- communities, plant owners, workshops/ technicians - communities, plant owners, workshops/ technicians - communities, plant owners, workshops/ technicians	- specialist agency - as above - as above

9. Monitoring & Backstopping	- Preparation of monitoring procedures & documents - Preparation of backstopping manuals - Training of personnel - Carrying out monitoring & backstopping - Reporting	- concerned personnel, implementing agencies, plant owner/managers - as above - concerned personnel - concerned personnel, implementing agencies, decision-makers - concerned personnel, implementing agencies	- specialist gency consultants/manfac-turers - as above - as above - implementing agency - specialist agency, promoting agencies
10. Training	- Preparation of training materials and regular organisation of training programmes for: • surveyors • plant designers • equipment manufacturers • equipment selectors/procurers • plant designers • feasibility preparers and evaluators • decision-makers, planners & financiers • owners/managers • operators • repairers • transmission and wiring technicians	- as in preceding column	- specialist agency, promoters, educational institutions

deregulatory measures have also been introduced in other countries such as Chile, Malaysia, Britain, and Norway. The examples of the last two industrialised countries are worth elaborating upon since they hold important lessons for developing mountainous regions.

During the late thirties, it was realised in **Norway** that the rural areas had lagged far behind the urban settlements in terms of electrification. Therefore, Parliament approved a special levy on the existing consumers to pay for electrification of rural areas. An equally important policy decision was decentralisation, whereby the county administration was made responsible for initiating plans for installations, although the electricity administration was responsible for overall planning and implementation of the schemes. Subsidies were also allowed for plants owned/implemented by cooperatives, share-holding companies, municipalities, and so on wherever such agencies were considered to be more appropriate (e.g., in more remote areas). Results of the achievements were reported to Parliament which approved the budget for the subsequent year. Thus, the involvement of the Government was at the highest level. The subsidy programme was later extended to cover grid system development. One other factor considered to be the backbone of local involvement in the electrification programme was the preferred recruitment of local people which improved local technical capabilities and accelerated the process. Thanks to this support programme, the whole country was receiving electricity by 1965, i.e., in just about 30 years. Today, more than 99 per cent of the electricity is generated through hydropower. In addition, the majority of trains run on electricity and many energy-intensive industries, such as aluminium and special alloy manufacturers, use electricity. Most of the cooking and heating are also carried out using electricity, and some power is even exported to neighbouring countries. There is no gas distribution system for cooking, in spite of the fact that Norway is a producer and exporter of natural gas as well as petroleum. Some private MMHP plants, which were closed down in the 50s and 60s, are now being rehabilitated by the owners as the government provides support in terms of expertise/advice and loans. Private producers can also easily sell their electricity to the grid or to customers directly using parts of the grid.

Recent policy and institutional changes introduced in the **United Kingdom** are also worth noticing as they can provide considerable guidance to renewable energy development in the developing world. Britain became, in World Bank terminology, 'unbundled' in 1990; i.e., electricity generation and distribution were no longer the exclusive function of a parastatal agency, but an open market activity. The private sector was invited to install and operate power plants as well as to sell electricity to the grid, or even to consumers, using a common transmission grid. Private entrepreneurs were also allowed to generate electricity in off-grid areas and sell it to consumers, while allowing for progression to grid connection at a later stage. However, this feature is being realised in stages, i.e., until 1994, only consumers of one MW or above could freely negotiate with any supplier, but, after 1998, every consumer will have this freedom. This model, therefore, should be of special interest for the HKH Region where the prevalent level of development requires off-grid generation, but where there is a possible future option of grid connection.

This deregulation process also applies to the MMHP sector which has been given some additional incentives: i.e.,

- local taxes and annual charges for water abstraction have been reduced or removed;
- subsidies to the extent of half the cost of feasibility studies (by accredited and approved consultants) have been allowed; and
- quality standards and guidelines for feasibility studies have been prepared and issued to the county authorities to assist them in assessing the proposals.

In order to ensure that everybody plays by the rules of the game, an electricity regulatory body has been set up. Its main task is to make sure that competition works towards the desired end of optimised performance and minimised cost. The regulator has the power to impose penalties wherever necessary and to arbitrate in case of disputes. The regulator also sets targets for emissions from power stations and enforces them. He also imposes levies to collect funds for subsidising renewable power stations. Thus, private producers have also to obtain licences that bind them to follow the electricity pooling. The licences cost very little and they are not needed for installations below 200kW not connected to the grid. Each supply company is also legally obliged to buy a certain amount of electricity from renewable sources (calculated so that the target of generation of 600MW from renewables is achieved by 1998). A subsidy is also available to bring down the cost of electricity from renewable sources to a level on par with other options. However, this subsidy will only be available up to 1998.

As mentioned earlier, the MMHP sector has benefitted considerably from these policies and incentives and the private sector has been encouraged to install small hydropower plants. The main point worth noting here is that there can be many types of approaches and inputs to provide for the energy needs of rural areas. The governments in the HKH Region may also consider imposing a levy on urban consumers to facilitate the provision of electricity to rural areas. This would mean reversing the current trend of subsidising electricity supplies to urban areas. One important input is an adequate and efficient institutional structure.

3.2.2: Finance

Although it is generally stated that MMHP, especially indigenously developed MMHP, is a low-cost option, its capital costs are still quite high compared to diesel generators. Also, considering the very low income levels of the people in most of the HKH Region, the provision of a sizeable proportion of the funding from external resources is unavoidable for the foreseeable future. Some of the financing systems are grants, subsidies, loans, and expert inputs (contributions in kind).

The institutional arrangements needed would have to undertake/oversee the following tasks in this respect.

- To procure fund allocations from different agencies (government[s]), donors, banks, etc).
- To formulate and oversee implementation policies and methodologies for funding (e.g., level of subsidies in different areas, interest rates, pay back periods/procedures for approval of loans, feasibility assessments, collateral and recovery of loans, etc).
- To identify and authorise different financial agencies to disburse loans, preferably from appropriate locations
- To implement procedures to recover loans from defaulters.

Thus, the main function of the principal specialist agency overseeing funding is to ensure adequate and consistent sources of funding and to facilitate its disbursement to deserving and capable recipients. In the long run, commercial loan financing is likely to be a better option, since it can become self sustainable in a few year's time. However, the prerequisite for this is the proper repayment or recovery of loans. Considering the current situation in Nepal, whereby loan non-repayment is at a level of 60 to 80 per cent, some other options may also be examined. For example, a higher level of subsidy may be allowed (e.g., 40% instead of the current 20%), if the entrepreneur does not take out a loan. It would be desirable for the various donor agencies to agree to follow the same rules in providing special grants to some communities. The current practice of providing grants of up to 90 per cent or more of the plant costs could help MMHP in a better way, if these grants were channelled through an agency already working in this field, such as ACAP (Nepal), by means of a predetermined methodology. Otherwise, if subsidies are provided to individual schemes at varying rates of up to 100 per cent of costs, this may actually impede the overall programme; since potential entrepreneurs may actually wait for such a windfall rather than subscribe to the on-going normal programme.

Some funding support is also necessary for manufacturers (equipment, quality improvement and control, training), for decision-makers, and for potential financiers to apprise them of the comparative viability and other advantages of MMHP, in addition to the other training programmes outlined in Chapter 13. Similarly, funding has to be secured and appropriate arrangements made to disburse it to establish or upgrade local workshops to enable them to undertake repairs of MMHP plants in surrounding areas.

Thus, a specialist agency, having a fairly independent mandate to solicit and procure funds and develop a methodology for disbursement, is needed. Whereas many other smaller agencies may be identified and strengthened to disburse the funds in a decentralised manner in appropriate locations.

3.2.3: Beneficiary Participation

Participation of beneficiaries in the installation of MMHP schemes is a very important aspect, and might make a difference between success and failure. Local villagers or an entrepreneur knowing about MHP plants may realise the need for one, locate a suitable water resource, and approach the implementing agency to support the installation. As is the case in Pakistan, the community may have to approach the concerned authorities many times until the approval is obtained. Clearly, they know fairly well that MMHP plants are quite useful for them, therefore such persuasion is justified. On the other hand, if an implementing agency approached a village offering them a plant, many villagers might not realise all of its implications, yet agree to the installation; and in these cases usually their commitment to such a collaboration might not materialise and waver at different times. The job of the promotional agency, therefore, would be to provide information to these villagers and organise a trip to some successful nearby plant, as well as providing them with written material. However, after this, they should be left to make their own decisions and finally approach the implementing agency determined to go ahead with the installation or to hold further discussions. It has also been suggested from more than one quarter that a written agreement should be signed between the implementing agency and the recipient. Another suggestion is that 'Rural Electrification Support Units' dedicated to assisting such entrepreneurs or communities should be set up at appropriate locations in different valleys or development regions. Such units could also undertake preliminary surveys of sites, assess demands, and consider other possible end uses in close collaboration with the villagers. The unit should inform them about the advantages and limitations of MMHP plants and guide them on how to get further information. The same unit, after due training of its employees, should also provide backstopping services to managers and operators and assist them in organising repairs .

3.2.4: Coordination

Coordination between different agencies engaged in rural electrification of mountain areas is almost completely lacking, and the overlapping or adverse effects of one scheme on another have been frequently reported. For example, the following five agencies are engaged in rural electrification in the northern mountainous part of Pakistan.

- WAPDA, a federal government agency, is mostly engaged in grid extension, as per its own plans, based on the philosophy that the transmission line may be extended to the next nearest and accessible demand centre.
- SHYDO, a provincial government agency is installing small- and medium-level hydropower plants, mostly in the Swat region for local consumption and grid connection.
- NA-PWD is installing isolated MMHP and SHP plants in Gilgit for local consumption of electricity.
- PCAT is assisting in the installation of privately-owned MHP plants in the whole area.
- AKRSP is also installing private MHP plants in the Gilgit and Chitral areas.

Thus, in any given locality, at least two or more agencies are working. However, they do not regularly communicate with each other or exchange plans. Even AKRSP and PCAT, which are carrying out similar work and in the same areas, are not communicating regularly. The usual result is that a new plant installed in some locality may affect the business of another. This is obviously a waste of resources. Therefore, there is an important role for a central specialist agency to play in coordinating the efforts of different agencies, in organising regular meetings, in exchanging future plans, and possibly in resolving some of the conflicts among such agencies. The central specialist agency may also coordinate between local donor (e.g., embassies) and implementing agencies to avoid various problems.

Another important aspect of coordination is that of the normal rural development programmes and rural electrification of the same areas. It is almost certain that tasks could be performed together to get better results and even reduce costs. Installation of an MMHP plant, for example, could be one of many activities under a larger rural development project to provide power for other economic development initiatives such as irrigation schemes, cottage industries, processing of local produce, and so on.

3.2.5: Promotion

It is usually necessary to prepare some promotional materials, e.g., posters, calendars, booklets, and reports, for various purposes. For example, posters can be prepared and distributed to existing MMHP installations, rural schools, VDC offices, etc for awareness raising among the local people and to provide a clear contact address for interested clients. Some informative booklets or short reports should also be prepared for public representatives, donors, investors, and so on. This type of work could best be undertaken by the central specialist agency or a larger development agency such as AKRSP or ACAP.

3.2.6: Technology Improvement

Most countries of the HKH Region with sizeable MMHP potential have, by now, acquired adequate manufacturing capabilities to meet almost all the needs of the sector. Obviously, having a local manufacturing capability is a necessary ingredient for the types of programme implemented in the HKH Region. For example, locally-produced equipment is usually much cheaper, ordering and procurement are easier, and the manufacturer can be reached or called to the site easily in case of a serious problem. Additionally, maintenance as well as supply of spare parts and access to the knowhow needed for operation, maintenance, and repair services can be achieved easily.

However, it is also known that the quality, performance, and reliability of locally-produced equipment are quite low. Therefore, improvement in quality is recognised to be necessary for improving MMHP in terms of the performance, life, and economic returns. Quality can be improved by using better raw materials, better manufacturing equipment and processes, adopting stringent quality control procedures, and through research and development to improve designs. All these operations are components of the manufacturing establishment; except perhaps the R & D which can be undertaken by specialist R & D organisations. Therefore, in order to improve the technology, the capabilities of the manufacturers have to be improved through training, especially on-the-job training, and through improvements in manufacturing machinery. Larger manufacturing establishments usually develop and adopt their own quality standards. However, in the HKH Region, the manufacturers need assistance in this respect, through, e.g., guidelines for manufacturing, quality control, and testing of finished components.

The specialist agency would be required to evaluate the capabilities of manufacturers and assist in their improvement by organising training programmes, preparing guidelines or standards, facilitating transfer of technology, and so on.

3.2.7: Technical Implementation

Technical implementation of MMHP schemes, right from site identification to commissioning and training of managers and operators, is currently being undertaken by different agencies in different countries. These agencies, especially the manufacturers in Nepal, have been criticised to some extent for not acting in the best interests of the clients; perhaps due to the very low emoluments involved, or to other reasons. Therefore, it has been suggested that the initial survey, plant capacity determination, and commissioning and testing should be assigned to some other independent agency or to a consultant. Unfortunately, no such agency exists in Nepal at present. Perhaps the best possible agency would be the Rural Electrification Support Units discussed earlier, but non-existent at present. Alternatively, NGOs such as ACAP or the Centre for Rural Technology (CRT) could take up some or all of these assignments after their personnel have been adequately trained in this field. In fact, such training may also be needed for the staff of PCAT and AKRSP. It may also be appropriate to assign the job of final testing and certification regarding the performance of a plant to some other independent agency such as the Nepal Micro-Hydropower Development Association (NMHDA), the Royal Nepal Academy for Science and Technology (RONAST), or even ITDG/Nepal. All the other functions could be performed most suitably by the installers, whether the manufacturers or some other capable party.

3.2.8: Repairs

The importance of establishing and strengthening repair facilities in appropriate locations, within the easy reach of plant owner/managers, cannot be over-emphasised. Identifying such locations with requisite facilities in Pakistan would not be too difficult: although more efforts are needed in Nepal to identify such locations, i.e., towns and prospective workshops and/or technicians who could be trained. In case no such technician can be found, young people could be selected from a suitable town/village and trained and assisted in establishing workshops. All this (search and implementation) has to be undertaken by the specialist agency but with appreciable assistance from other agencies working in that area.

3.2.9: Monitoring and Backstopping

This aspect has been described along with the institutional support involved in some detail in Chapter 12. Institutions are almost non-existent at present, although some expertise for monitoring and backstopping that can be called upon to develop regular facilities does exist. In Nepal, many commercial consultant agencies have been established for many years; some of which have also accumulated considerable knowledge and expertise in the field of MMHP. Experts from such firms could receive further training to undertake monitoring and backstopping more professionally and efficiently.

However, the central specialist agency has also to play an important role by preparing the necessary materials, identifying experts and/or establishments, training them, and allocating their assignments.

3.2.10: *Training*

Various training needs, priorities, and the current level of availability have been discussed in Chapter 13. Here, only the institutional aspects have been outlined. Almost all the training programmes have to be organised under the overall sponsorship/leadership of the specialist agency. However, the actual training programmes can be organised/conducted by some other agency such as the DCS Butwal. Similarly, an international agency, such as ICIMOD, could organise orientation for decision-makers from the region. The National Specialist Agency has also to play its part in coordination, capability assessment and/or strengthening, preparation and assessment of training materials, and, above all, in finding funding for such programmes.

3.3: A Suggested Institutional Framework

The tasks outlined in the previous sections might create an unsettling impression that a sizeable number of new institutions has to be established and the allied manpower, equipment, and facilities acquired, involving considerable expenditure. In fact, many organisational set-ups already exist, although they may vary significantly in their extent and effectiveness from country to country. For instance, in Pakistan, PCAT and AKRSP look after all the stages of implementation, while, in Nepal, the WECS formulates policies and programmes and the ADB/N manages financial aspects, but with little capacity to contribute professionally during the implementation. Therefore, in some countries, e.g., Pakistan, very few additional institutions would be needed. However, this may not be the case for Nepal.

Referring to Table 3.1, various tasks were listed and some suitable agencies were suggested. In the following Table, 3.2 (p. 40), the process has been reversed and agencies considered necessary to look after various tasks have been listed along with their present (existence) status in Nepal and Pakistan where many private MMHPs serve remote communities. The main reason for this second Table is to present the institutional framework more clearly.

Several agencies in Nepal are engaged in promotion of MMHP, and they sometimes also organise useful inputs such as training programmes, technology transfer, sponsoring of studies, seminars, etc. Examples are ITDG, DCS, and ICIMOD. Although no such specialist agencies exist in Pakistan, the two implementing agencies are also doing promotional work, and by now almost every community in the northern part of the country is aware of MHP. Therefore, special efforts to raise awareness are not needed. The existing agencies can take adequate steps in this respect. Due to this reason, no recommendations have been made to establish additional promotional agencies.

One thing which needs to be given serious attention is that the rate of installation has to increase considerably in order to have a desirable effect on the overall rural energy scene. The current rates of installation are too low to contribute significantly towards improving the energy situation in rural areas; or, indeed, to sustain and justify the additional infrastructure. In addition, the available funding as well as rates of installation fluctuate tremendously from year to year. Therefore, the installation rates have to go up considerably to, e.g., a cumulative capacity of one MW per year (about 50 plants with an average capacity of 20kW), in both Pakistan and Nepal. Otherwise, the suggested institutional arrangements will not be justifiable on economic grounds.

Table 3.2: Desirable Institutional Set ups in Nepal and Pakistan

Name and Function	Status	
	Nepal	Pakistan
Government Federal/Central (Ministry, Division/Deptt./Directorate) ▸ policy and legislation formulation ▸ planning ▸ fund procurement from donors ▸ fund allocation	exists	exists
Provincial/State Govt. (wherever applicable) ▸ policy formulation ▸ policy implementation ▸ programme implementation	not applicable	exists
Central Specialist Agency ▸ mobilisation of funds ▸ promotion ▸ preparation of implementation methodology ▸ fixation of subsidy levels, interest rates ▸ advisory service to the government ▸ master plans ▸ technical standards/guidelines ▸ oversee overall implementation ▸ coordination ▸ initiating/sponsoring relevant studies ▸ initiating and arranging R & D, including end uses and appliances ▸ training programmes and materials ▸ development of field repair facilities	does not exist	exists*1
Rural Electrification Support Units ▸ site identification ▸ assistance in planning, installation, and commissioning ▸ promotion ▸ monitoring and backstopping ▸ advice and assistance in repairs	does not exist*2	does not exist*2
Fund Disbursement Agencies (banks, finance corporations, NGOs) ▸ appraisal and approval of subsidy/loan applications ▸ disbursement of funds ▸ monitoring ▸ loan recovery ▸ completion certificates	exists *1	exists *1
Implementing Agencies (GOs/NGOs, Manufacturers, Consultants) ▸ site survey/assessment ▸ plant and layout design ▸ planning for installation ▸ mobilisation of community participation ▸ installation, commissioning, and testing ▸ equipment transportation ▸ initial information package, including operating manual ▸ training ▸ participation in monitoring and backstopping	exists *1	exists *1

Manufacturers ▸ design of components and machinery ▸ manufacture ▸ procurement of other parts/systems ▸ quality control and testing	exists *1	exists *1
R & D Organisations ▸ improvement of quality performance and reliability ▸ cost reduction ▸ improvement of assembly/disassembly and installation	exists *3	exists *3
Repair Facilities (at appropriate locations) ▸ undertake repairs	does not exist*2	does not exist*2
Monitoring and Evaluation (consultants, technical agencies, experts) ▸ undertake monitoring & evaluation	exists *3	exists *3
Training Organisations (manufacturers, educational institutions, specialist agencies, promoting agencies) ▸ organise and conduct various training programmes ▸ prepare training materials ▸ evaluate and improve training programmes	partly exists*4	partly exists *4

Explanatory Notes

*1 Organisations already exist doing this type of work in this field. However, they need to be orientated and strengthened.

*2 Such units do not exist at present. However, PCAT and AKRSP in Pakistan are working in a relatively smaller area than Nepal. AKRSP also has two or three field offices which could be easily strengthened to become support units. Therefore, only one or two additional units/offices need to be set up. In the case of Nepal, only one small office has been set up by a private manufacturing establishment in the north-western region. Therefore, about four or five such units have to be established eventually. As a start, one or two such units could be established, either as subsidiaries of the central specialist agency or of some other appropriate institution.

*3 In this case, although appropriate agencies, other than the manufacturers, do exist (e.g., RONAST in Nepal and PCSIR, HMC, etc in Pakistan), they are currently not engaged in R & D activities related to MMHP to any significant extent. Thus, their capabilities have to be improved considerably to enable them to undertake worthwhile R & D work. In Nepal especially, manufacturers are making a considerable effort, usually with sizeable assistance from ex-patriate expert agencies. Still it would be more helpful if some R & D agencies were also involved in this field.

*4 Some regular training programmes for operators and managers are being organised in Nepal; however, they are not meeting the needs. Pakistan is considerably behind in this field. Proper arrangements need to be made in both countries. Most of the work, especially preparation of training materials, needs to be undertaken by the central specialist agency. At the same time, some other agencies, such as technical education institutes in appropriate locations, can also be involved in organising the training programmes (after assessing their capabilities and interest and providing them with the necessary strengthening inputs).

Chapter 4
Site Selection and Feasibility Study

4.1: Site Selection

4.1.1: Introduction

Selecting a suitable site is crucial for the success of any MMHP scheme. Many factors need to be taken into account, but data on flow and topography provide the base for establishing suitability as well as the power generation capabilities of proposed sites.

Long-term data on hydrology and meteorology are used in determining river discharges, seasonal variations, floods, and similar occurrences. Such data are needed to assess site potential and plant design and are also used to design regulatory and flood control systems.

Knowledge of the geomorphology of the project area and sites is needed to plan project layout and to design the structures and facilities that make up hydropower projects. Having sufficient and reliable data and knowledge of geotechnical, geological, and seismic conditions and sediment loads and so on enable the planning and design of practical sound layouts and structures. The amount of information needed and type of investigations depend on the type and size of the plant and the required life and reliability.

4.1.2: Tentative Layout Design and Power Calculation

Usually the first planning step is to determine which part of the stream is of interest, by means of existing maps and site surveys, and then to establish the river profile by field measurements; i.e., its course and gradients along the course. For quick reference, barometric levelling is used; but, as soon as possible, more reliable and accurate levelling must be carried out.

If planning parameters were to be ranked in order of importance, hydrology would probably come out on top. The head (together with the flow) determines the power of the water resource. All planning involving hydrology is based on the assumption that past history will be repeated in the future. Hydrology data are therefore based on long-term flow records. If such data are available, the work is relatively easy.

In the case of low-cost MHP plants, however, adequate hydrological data are usually not available and measurements of flow (discharge in some countries) three or four times a year, especially during the lean period, are considered to be adequate. Similarly, extensive geotechnical investigations are not considered necessary; mainly due to the lack of availability of such services as well as economic considerations. Use of local expertise in constructing water channels for irrigation has mostly been made in constructing the power channels as well. The thinking is changing now, as the average plant sizes are increasing and the reliability issue has become more crucial.

To determine hydropower capacity, the main characteristics of water resources are flow (Q) and head (H) which need to be determined or estimated as demonstrated in the following equations:

Power: $P(kW) = C \times H(m) \times Q(m^3/s)$

Energy: $E(kWh) = P(kW) \times T(hrs)$

P = power in kW

H = head (difference in height between the water levels at the forebay tank and the turbine outliet)

Q = waterflow in m^3/s through the turbine

$C = g \times n_w \times n_t \times n_g$

Where,

$n_w \times n_t \times n_g$ are efficiencies of penstock, turbine and generator (usually, the value of cons tan t, C lies between 5 and 7. In the case of indigenous equipment, and for initial calculations, the value of C is taken to be 6). g is the gravitational cons tan t ($9.81 m/s^2$).

T = time in hours

4.1.3: Prefeasibility Study

Planning and design of hydropower projects involve a number of different technical, environmental, social, and economic areas of expertise. Investigations have to be organised in a rational and structured manner. The result of project investigations may prove negative and investigations are therefore arranged in phases, so that unnecessary investigation of an unviable project is avoided. In each phase, the project is investigated to the depth necessary to reach conclusions concerning capability and suitability for the stated purpose.

The first step, in this respect, is to prepare a prefeasibility study. Based on the available data and information, the investigators define the main project elements and prepare a tentative layout of the project. Appropriate maps are needed for the study. Aerial photographs, if available, are of great value, especially for geological assessment. The initial field survey and the flow/head measurement and collection of hydrological data from other sources, if available, are a part of prefeasibility.

The prime concern of this study is to establish the main elements or parameters for the project, including power demand, power potential, and environmental constraints. The objective is to decide whether or not to go ahead with project implementation or additional detailed studies involving sizeable expenditure and risk.

Flow can be measured by using a large pipe and a measuring bucket or other container when the flow volumes are fairly small (e.g., up to 20 L/S). Many other devices and methods are adequately described in other technical manuals. Measuring head is easier than measuring flow, less expensive, and more accurate. The simplest method is the use of an altimeter. New digital altimeters are easier to use and more accurate than previous designs. The other simpler and less expensive method is the use of a transparent water-filled tube and a measuring rod.

The flow pattern can be improved and controlled by constructing water reservoirs and regulating gates. However, this is not a normal practice for MHP plants which are mostly 'run-of-the-river' types; meaning, having no storage capacity. The head can be increased or decreased by changing the length of the channel, and it is also affected by other factors such as appropriate location of intake, forebay, and powerhouse, as well as the path of the channel. Thus, head selection is usually a trade-off between many such factors. Once the locations for the forebay and powerhouse are selected, the head cannot be altered, whereas the flow may vary during different seasons and according to the regulatory systems installed.

Determining the highest possible flow is also important for making adequate arrangements to avoid damage from floods. Floods and their flow paths are also given due consideration in designing the layouts and locating the important components of the installation such as the powerhouse, penstock, forebay, and so on. For the purpose of plant design, normally the minimum flow available for nine to 12 months of the year is used.

Current and future demands for power need to be determined and matched to the potential of a given site. A methodology for demand assessment and matching is briefly described in Section 5.1.

For MHP installations in remote hilly regions, environmental effects are usually too small and not investigated. However, in the case of mini plants, such factors may be sizeable (e.g., length, size, and route of the power channel, area occupied by the forebay/reservoir, location of penstock and powerhouse, etc). In such cases, some investigations may be undertaken during the field survey and layout design.

In many cases in the HKH Region, only part of the available flow is diverted from the stream for power generation; and a small dam or other type of simple restriction (say, an arrangement of boulders) is constructed across the main stream to assure adequate flow of water to the power plant during the lean season. Subsequently, a basic design of the plant and its layout is prepared and costs estimated.

To summarise, the following factors need to be given due consideration in finalising decisions on site selection for installation of an MMHP plant.

- Demand for electricity or energy (e.g., for agro-processing)
- Potential and technical viabilities of site and plant
- Costs
- Estimated incomes and economic viability
- Other influencing factors (e.g., other uses of water, geology, flooding or landslide possibilities, and environmental consequences)
- Capability and keenness of beneficiaries (regarding cooperation, contribution, organisation, management, operation, payment of bills, etc).

If the overall results of the above considerations are positive, then a decision can be taken either to go ahead with a more thorough feasibility study or to initiate installation procedures and collect more detailed information to improve the design and reduce costs.

4.1.4: Sequential Study

When many potential sites are available in an area, time and money can be saved if the less attractive options are screened out in the early stages. Each step is based on the findings and results of the preceding steps. This gradual development of plans will ensure that all probabilities have been investigated and examined. It will also, when conducted in a rational manner, ensure that unsuitable projects are not pursued longer than necessary. Thus, the main objective is to select the most suitable site from more than one possibility in the minimum time possible.

The stepwise and sequential development of hydropower project planning is, while being technically sound and economically prudent, very time consuming. If projects are urgently needed, the time element must be given priority. Reduction of planning time is often achieved through reduction of planning steps. However, a certain amount of the reliability may be lost in the process.

4.2 Feasibility Study

The second stage, or feasibility, involves a more comprehensive investigation and analysis of the parameters of the contemplated project, directed towards its ultimate approval/rejection, financing, design, and construction. It is carried out in order to determine the technical, economic, and environmental feasibility of the project; especially if the prefeasibility study had left some questions unanswered, which is usually the case. The feasibility study report will provide the necessary information based on which owners/decision-makers can decide whether or not to implement the project, i.e., to proceed with the final design and construction. It is usually a necessary documentation/annexure to applications for loans, etc. The feasibility study addresses the issues of viability, economic returns, and other benefits in adequate depth and looks at the technical design, costs, expected life, and so on.

If the investigated project can be constructed, equipped, operated, and maintained over the life of the project and does not, in any way, represent any danger or risk (except calculated risks) to the environment, the people concerned, or the public in general; such a project is said to be 'technically feasible'.

The second main criterion for feasibility is that the project is economically and financially viable. This means that the project must be able to generate sufficient income to repay the loan; cover operation, maintenance, and rehabilitation costs; pay taxes and other public expenses; and create funds for depreciation or further investment. It must be sufficiently attractive in economic terms to convince potential investors that they should invest in the project. Keeping these aspects in mind, a suitable format for the feasibility study has been described below.

4.2.1: Key Elements of a Feasibility Report

Based on studies conducted, the following are the main components to be included in a feasibility report for MMHP.

1a. Summary — Briefly present all the major conclusions reached in the report; include requests for grants or subsidies; state whether or not the financial requirements are typical or exceptional and whether they conform to a general policy for financing schemes in the region; and include economic comparisons with other energy options.

1b. Key illustrations — For instance, a simple sketch map of village houses/lanes and transmission lines, diagrammes of the layouts of turbines and driven machinery, etc; include simple energy supply/demand graphs.

1c. Key data

Some of the key data may be presented on the diagrammes/ sketch maps, including ratings of turbines; generators; part flow arrangements; and tables showing loan requirements, connection charges, subsidies, and so on.

2. Energy demand

Summarise the results of the supply capability and demand study. Also show the estimated future demand trends over the next five or 10 years, stating how far into the future the proposed scheme will meet the estimated demand. This should also include estimates of the competing uses of the water.

3. Water demand

Summarise the requirement for water from the hydro catchment for irrigation. Include any other uses of water, such as domestic or industrial, which may compete with MMHP. Comment on the possible multiple use of water.

4. Energy supply options

Include brief survey and costing tables of various energy inputs, including traditional fuels currently in use. Comment on the future trends in fuel supply, e.g., prospects for fuelwood replanting, kerosene price fluctuations, etc. Compare the costs of energy sources that are alternatives to hydro (or could be used as auxiliary sources in combination with hydro) - e.g., diesel, solar photo-voltaics, and biogas.

5. Management capability

Briefly reproduce the results of the capability assessment and stated interest of the recipients, e.g., to contribute towards installation costs and electricity bills, to install industries, to deal with social conflicts, to operate and manage the plant adequately, and to collect and manage the revenue. An assessment of institutional arrangements, physical infrastructure, and repair facilities in the neighbourhood should also be included.

6. Hydro potential

This section should contain a hydrograph showing irrigation and other non-hydro water demands and a Flow Duration Curve. Both graphs should have axes showing the conversion of flow to hydropower. In cases where variable flow turbines are being considered, the graph should allow for variation in system efficiency at part flow. Data sources and site measurements should be included. Comment on the effect of irrigation water requirements on the ability of the system to supply power when needed. Calculate the anticipated plant factor.

7. Plant design

This section sub-divides into civil works, penstock, turbine, generator, control equipment, and distribution system. For each part, present a design philosophy, e.g., "*the channel is constructed from local materials in order to facilitate maintenance.*" State sources of materials (names and locations of manufacturers) and include sketches that present the dimensions and characteristics of each major component. Detailed calculations and drawings can be put into an appendix. For larger plants (e.g., 50kW or above), a more detailed design may be prepared later. However, for smaller plants, the design should be complete, as far as possible, at this stage.

8. O&M costs

All aspects of O&M should be costed (e.g., spare parts, wages, and training) and a contingency sum included. If experimental (or newly-designed and manufactured) equipment is used, allow for a full replacement cost. Allow for rising prices of spare parts and transport. Include requirements for training, e.g., translation of documents into local languages, visits by equipment manufacturers, refresher courses, future training for newly recruited operators.

9. Integrated water use

Describe how management of the MMHP will be integrated into or coordinated with the management of irrigation and industrial and domestic uses of the available water supply. Detail the extent of involvement of farmers and other water users in the planning, implementation, and management of the plant.

10. Management details

How are the O&M procedures and the integrated water use procedures to be implemented? Who pays the operators and recruits new ones? How is the fund for O&M kept up, and who will keep the accounts? How are the conflicting interests of the plant and irrigation needs going to be resolved?

State what management skills are lacking and therefore which training may be required and how much it will cost. The salaries of the manager and operator should be included in O&M costs. This might include a bonus scheme for high plant availability. These problems are simplified in cases of private ownership but must be spelled out very carefully in cases of collective responsibility.

11. Schedule of operations

Provide a time chart (divided by months and years) starting with the planning and design approval stages, through to commissioning. Include the first year of operations during which monitoring and O&M training procedures will still be required.

12. (a) Costs & income

Provide a one-page cost sheet. Include running costs, contingency, plant factor, and unit energy costs (or other comparative economic indicators).

Outline the various ways in which the hydro scheme will generate revenue; for instance, via sale of energy to a mill owner or other commercial enterprises and by tariffs for fixed-wattage domestic electricity supplies. Specify what the certainty of this revenue is in each case, and how it will change over time.

12.(b) Tariff structure

The tariffs (prices paid by householders and entrepreneurs for use of electricity) to be charged should be outlined. Some justification for the tariffs should be given by detailing the outgoing costs such as loan repayments, O&M costs, etc. A request for a grant or subsidy to reduce the tariff can be made on the basis of this cash flow analysis. State in this section whether the tariff structure has been discussed with the villagers and whether agreement in principle exists. Does the tariff structure reflect the willingness and ability of all villagers to pay for the scheme? Does it include workable provisions for disadvantaged households?

13. Financial analysis

This section presents the financial future of the scheme, for example, by a cash flow analysis and by presenting economic indicators. It answers the question, is the scheme economically viable or not?

14. Sources of finance

This section states the recommended basis for financing the scheme. It may recommend a level of subsidy along with suggestions concerning where a subsidy or grant may be available. Also note whether the recommendations are in line with current government policy and whether or not a similar approach has been successfully adopted elsewhere.

15. Welfare

Comment on the potential of the MHP scheme in increasing the economic security of the village as a whole; in introducing new jobs and in bringing benefits to the less wealthy members of the community. Also comment on possible dangers; for instance, the creation of dissent due to unequal distribution of advantages and opportunities offered by the MHP plant and possible loss of existing jobs due to substitution of fuels. Propose methods to ensure welfare benefits and protect against disbenefits (for instance, some members of the community may be provided with electricity without payment of connection charges because they do not have cash income; people due to lose jobs may be chosen for new jobs associated with the MHP installation).

16. Monitoring

Describe how the proposed structures will be monitored and what alternative ownership, management, and O&M provisions could be made should these structures prove to be ineffective in forthcoming years.

4.2.2: An Example Explaining Applicability

Let us assume that an isolated MHP scheme is considered for construction to supply electricity to one village in a particular location. A well-informed village leader has realised the need for such an installation and started contacting other villagers, financiers, and manufacturers. A nearby stream is considered to be an adequate source for power generation. Finally, a contact is established with an expert development agency (GO/NGO/Consultancy) to look into the possibilities of establishing such a plant, investigating and analysing the various relevant parameters, and taking decisions[7]. The first task for the expert agency would be to determine the level of interest of the applicant/beneficiary community; their willingness to contribute in cash as well as in kind; and their capacity to collectively undertake the management, operation and maintenance of the plant, distribution of electricity, fixation of tariffs, and collection of revenue. Then, an initial site survey and measurements are undertaken and power estimates made. Thus, a prefeasibility study is initiated, including assessment of the demand and matching it with the available power. The first design of the plant is prepared, including a map of the layout. Costs and projected yearly expenditure are estimated to attempt a financial analysis (Chapter 7). If the Internal Rate of Return (IRR) or Benefit Cost Ratio (B/C) are adequate then the project is viable. Some environmental aspects may also be given due consideration, e.g., possibility of floods and resulting damage or landsliding due to construction of the channel, forebay, and penstock. Based on this study, the project may be rejected if any of the following can be foreseen.

- The capabilities and interest of the recipients are inadequate
- Costs are too high
- Technical viability (including geological considerations, water availability, etc) is suspect
- The current (estimated) demand is much higher than the available power.

However, if the results of the above prefeasibility study are positive, two things can be done.

a) A decision is taken to construct the plant and more accurate information from the site is collected from the recipients, investors, manufacturers, etc to improve design, economise on costs, and provide for future extensions. In this way, a more formal and expensive feasibility study is avoided; especially if the plant is small (say under 20kW in capacity) and is to be used mostly for agro-processing.
b) A more comprehensive feasibility study is authorised for larger plants, particularly for electrification, since their technical, operational, and economic aspects can be more complicated and problematic.

When a feasibility study is to be undertaken, the details can be adjusted according to the size and importance of the plant. The amount of detail in each of the elements (Section 4.2) should be matched to the size of the plant. For a scheme below 30kW, many elements will obviously be amalgamated or not required at all; for example, items No. 9, 14, and 16 can be dropped altogether in this case, while some parts of items 4, 6, and 11 can be ignored. Perhaps some aspects, e.g., 5, 12, 14, and 15 have been adequately covered in the prefeasibility study. For a one MW plant, even more details will be required than mentioned in the preceding section.

4.3: The Geographical Information System (GIS)

A relatively new method of carrying out 'desk studies' involves the **Geographical Information System (GIS)**. It deals with information that is predominantly geographical in nature. GIS can be thought of as representing a model of the real world which can serve as

[7] The procedures followed in different countries are usually different. In Nepal, for example, a manufacturer would be contacted to undertake the technical feasibility study and the plant/layout design, while the ADB/N would be approached to approve a loan and subsidy. The above example, therefore, is a desirable course of events. In some countries, e.g., Pakistan, a procedure quite close to the one described here is followed.

a test bed for anticipating the possible results of proposed actions. GIS can be technically defined as "a system of hardware and software and procedures designed to support the capture, management, manipulation, analysis, modelling, and display of spatially referenced data for solving complex planning and management problems." In short, it is "a computer system that can hold and use data describing places on the earth's surface."

GIS is a powerful tool for resource managers and planners dealing with map making and integrating other data therein. Its applications are limited only by the quality, quantity, and coverage of data that are fed into the system. Some of the standard GIS applications are integrating maps made on different scales, overlaying different types of maps which show different attributes, and identifying required areas within a given distance from map features, e.g., administrative boundaries, roads, and point locations.

GIS can be used for many applications such as planning rural infrastructure, identifying market towns, assessing and managing forests, designing irrigation systems, and so on. In MMHP also, GIS can be used for site identification, estimation of potential, and indication of demand from the neighbouring villages. GIS is not being used at present for this purpose, mainly due to the lack of quality data and expertise. However, its applicability holds considerable potential for the future.

Chapter 5
Plant/Layout Design

5.1: Demand Assessment

5.1.1: Prevalent Methodologies

The following are the usual methods for demand assessment that are mainly used for larger plants.

Time trend extrapolation. This consists of extrapolation of past growth trends, assuming that there will be little change in the growth pattern of the determinants of demand such as incomes, prices, consumer tastes, extra appliances, etc. The main advantages of this approach are its simplicity and modest requirements in terms of both data and analytical skills. The major disadvantage is that no attempt is made to explain why certain electricity consumption trends were established in the past.

Econometric forecasting technique. This method correlates past electricity demand with other variables such as prices and incomes; and then future demands are related to the predicted growth of these other variables. This method is more sophisticated and could be more accurate than simple time trend analysis, but there could be problems in acquiring the relevant data.

However, these methods are usually not suitable for MMHP plants, which are almost always isolated systems, and where the distribution network is small. Also MMHP plants usually always supply electricity to areas that did not previously have any electricity.

5.1.2: A Method Suitable for MMHP Plants

Because of the small network, it is possible and convenient to assess the demand by the direct survey methods. Questionnaires should be designed to solicit accurate information from the customers on their present and future patterns of energy use, affordability, willingness to pay, etc.

Since lighting is the first and main use of the power from MMHP plants, demand for lighting is the largest factor in determining plant size. Therefore, demand is assessed by counting the number of bulbs (usually 25W or 40W) required by each customer. Additional power may be required by a household to operate radios, TVs, or cassette players if the number of watts requested for lighting is insufficient to cover this requirement as well. The sum of the power demand of each household gives the maximum power demand, and the plant is sized accordingly.

The advantages of assessing demand by the direct survey method are simplicity and accuracy. However, it does require some skill to design, complete, and interpret the survey questionnaires to get meaningful results.

5.1.3: Suggested Questionnaire Format for a Demand Survey

For domestic demand

- How many bulbs do you wish to install? Family size/land holding/no. of animals?
- Are you willing to pay Rs XX per bulb? What is the maximum you are willing to pay for lighting?
- What kind of lighting do you currently use? What is the consumption? - kerosene lamp/ pressurised kerosene lamp/resinous wood/electricity/candles?
- How much do you currently spend on lighting?- kerosene/resinous wood/candles?
- How much do you spend each month on batteries for radios, torchlights, tape recorders?
- How much do you pay for your fuel requirements(cash and/or kind)? wood, kerosene?
- Do you collect your own firewood? How many hours are spent on this?
- Do you hire someone to collect your firewood? What does it cost you?
- How much alcohol do you produce? How much wood do you use for making alcohol?
- What are the sources of income from outside the village? Remittance from family members working in the city or abroad, pensions, government job in the village(e.g., teacher), portering?

The above questions should give an indication of the energy consumption and the willingness and ability of each household to pay for electricity.

For industrial demand (to existing industries, community leaders, development workers, NGOs, etc).

- How are current energy needs met? e.g., for grain milling, rice hulling, oil expelling?
  - manual, animal, traditional water mill, turbine mill, diesel mill, etc?
- What industries are currently running in the village?
  - How is the energy requirement of the industry met?
  - How much does it cost?
  - How likely is it that they will use electricity to meet their energy needs, and to what extent?
- What industries could be established using the electric power?
  - Are there sufficient raw materials to run the industry?
  - Who are the prospective entrepreneurs who will run these industries?
  - Do their backgrounds/experiences/motivation indicate that there is a good possibility that these industries will in fact be established?

There is no standardised or generally accepted format for assessing load demand for MMHP plants. So far, it has been left to the entrepreneur or his consultant to determine the current and future demands. This has led, in some cases, to plant sizes far in excess of what was needed.

5.2: Determination of Optimum Plant Size

When considering what plant size is required to meet the demand, it is useful to consider the following ratios.

$$\text{Power ratio} = \frac{\text{Power used (peak)}}{\text{Power installed}}$$

$$\text{Plant factor} = \frac{\text{Energy used over a period}}{\text{Energy available}}$$ (The period is usually a year)

An MMHP plant should be designed to have as high a plant factor as possible. A high plant factor means increased energy sales, hence higher income, which increases the possibility of the plant being financially viable. Since there is very little additional cost incurred in generating power from an MMHP plant for additional hours (unlike, e.g., a diesel plant), increasing the plant factor means a reduction in the unit energy cost. This should make the energy more affordable and lead to increased sales, which in turn lead to lower energy costs.

Other factors to be considered in determining the size of the MMHP plant are given below.

1. The natural resources available to generate power; i.e., head and flow. The available parameters might not be sufficient to meet the power requirements of the users.
2. The users' demand for power. The output of the plant should be able to meet the real or expected needs of the users for lighting, running industries, irrigation, etc.
3. The users' ability and willingness to pay for the plant's installation and operation. Regardless of how much power the users may want; it must be within their ability and willingness to pay. If the plant is too large, it may cost beyond what the users are willing and able to pay. This will result in the plant not being built or, if built, lead to closure/ losses due to insufficient income.
4. The users' ability to manage the plant; the size of the plant must be within the capacity of the users to manage it properly.

5.2.1: *Meeting the Current Demand*

Once the power requirement of the customers is known, the process of deciding the plant size can begin. The size of the plant should be the optimum possible that is capable of meeting the needs of the consumers. Building a larger plant than required means that both the capital and operating costs will be higher. However, a larger plant makes it possible to increase revenue by increased sales in future. If there are a number of machines which the plant is expected to operate (e.g., a flour mill, a huller, an expeller), it is essential to ascertain whether it is really necessary to have all the machines operating simultaneously. If all the machines need not be run simultaneously, then the size of the plant can be reduced considerably, thus reducing the capital investment.

In the case of electricity supply, it is usually the requirements for lighting that determine the plant size. In this case, it is worthwhile considering the use of fluorescent lights, instead of ordinary incandescent bulbs, to reduce the power demand but still meet the lighting needs.

5.2.2: *Meeting Future Demand*

It is sometimes advisable to incorporate the near-term future demand also by installing a larger plant. To assess the future demand for power from an MMHP plant, the direct survey method is used. For MMHP plants, demand assessment for five to 10 years is sufficient. The main factors that need to be considered in assessing future demand are:

a. increase in household numbers in the service area;
b. increase in demand for electricity because of additional income due to increase in economic activity, e.g., tourism, industrial activity, etc; and

c. increase in demand for electricity in order to run small industries, processing facilities, etc.

There are a number of options in plant design when building for future growth in demand.

- Build a plant large enough to meet the projected demand. This is advisable only for small plants (up to 15kW) for which the projected demand growth is fairly small; e.g., less than 50 per cent of the current demand.
- Build the intake and head race for the larger flow necessary to generate the extra power. The forebay, penstock, and powerhouse equipment can then be added when required. This assumes that there is extra water available in the river to generate the needed power.
- Build all the structures for the extra power as well, apart from the powerhouse equipment. Add these when the demand reaches its peak.
- Build a new power plant. Assuming that there is extra water or head available from the same or a different river, a new plant can be built to meet the extra demand.

5.2.3: *Meeting Demand when Supply is Less than Demand*

Usually not many difficulties are faced if the available power is more than the demand. Of course, efforts are made to increase end uses. However, sometimes, because of the constraints on available potential, the plant's power capacity is smaller than required to meet the demand. In such cases, innovative ways must be found to meet the demand of the consumers.

One method is to use compact fluorescent lights (CFLs) for lighting instead of incandescent lights. As the peak demand is for lighting in the evening, using CFLs that consume up to 80 per cent less power for the same amount of light could meet the demand.

Another method is to use batteries to supply lighting. This also has the advantage of saving on transmission costs. Discharged batteries are brought to the powerhouse for recharging. They are then used for lighting. This permits a larger number of customers to be served, since off-peak power is used to charge batteries. However, this is a cumbersome process for the consumers as batteries have to be carried to and from the charging point.

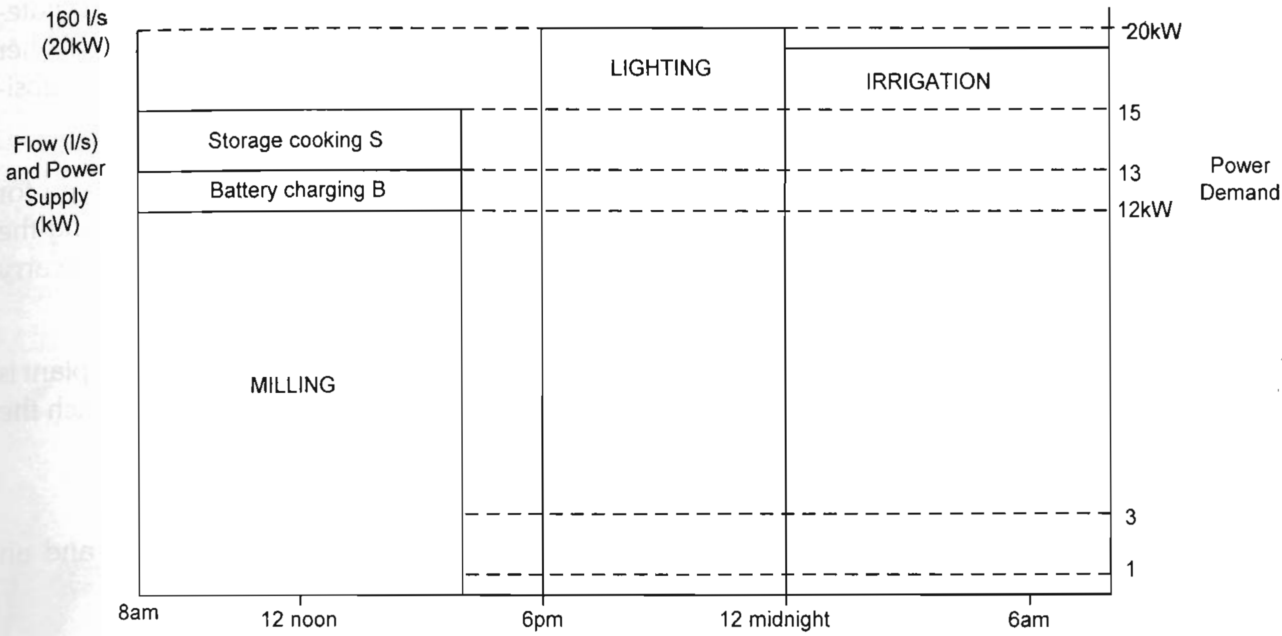
For industrial loads, a system of taking turns to use the power needs to be devised. For example, a bakery, sawmill, and flour mill might use the available power; e.g., bakery, 0400 to 0600 hrs; sawmill, 1000 to 1300 hrs; flour mill, 1300 to 1600 hrs; and so on.

Sometimes less water is available due to seasonal variations, or due to diversion for other purposes. In these cases, demand may be matched by using a daily graph such as the one shown in Figure 5.1.

5.3: User Participation

User participation is essential for the successful implementation and management of an MMHP plant. Insufficient involvement of the users can lead to delays in project implementation due to lack of manpower for construction, delays in house wiring, etc. The operation and management of the plant will also suffer if there is not enough participation from the users. In the absence of the close commitment and involvement of the community, when things go wrong, as they sometimes do, the users are liable to regard the breakdown as someone else's responsibility, and this could lead to the plant being shut down for long periods.

Figure 5.1: A Demand/Supply Graph for a Typical Day in the Dry Season for a 20kW MHP Plant



Notes

- The milling, battery charging and storage cooking demands are 8 a.m. to 6 p.m.
- All the supply is consumed by lighting from 6 p.m. to 12 a.m.
- The plant is shut down between 12:00 a.m. till 8 a.m., and water is used for irrigation.

5.3.1: Discussions with the Users

Planning. The users of an MMHP plant must be fully involved from the very beginning. Participation in planning takes place through discussions with the villagers concerning the results of the demand survey, feasibility study, project size and cost, operation and maintenance costs, and tariffs. Detailed design and construction should begin only when they are fully aware of the costs and responsibilities involved in building and operating an MMHP plant and are willing to bear their share of the costs and responsibilities.

Factors to be considered in the planning discussions are as follow.

- What are the end uses which the MMHP plant is supposed to fulfill?
- Will the MMHP plant fulfill this demand?
- Will everyone in the village receive electricity? If not, why not?
- Is the purpose of the MMHP project clearly understood by all prospective consumers, including the tariff structure?
- What are the other competing development projects and does the MMHP plant have sufficient priority?
- What are the alternatives and how does MMHP compare with them?
- What demand growth rate should the plant be designed for? How many years into the future?
- Is everyone in the village willing and able to put in his contribution to building the MMHP plant?
- Have discussions been held with people who represent all sections of the community in

terms of geography, sex, age, income levels, electricity subscription, education, occupation, caste/ethnic/religious/social group, etc?

Construction. Up to 15 per cent of the project cost can be met by local labour and material contributions. This is a significant portion of the project cost. Possibilities of higher contributions, perhaps in accordance with a policy laid down to reduce/standardise subsidies, must also be discussed.

Involvement of the users in the construction can also partly provide an opportunity for training the operators of the MMHP plant. Involvement of the operators in installing the pipes, the machinery, and transmission will give them confidence and experience to carry out repairs and maintenance.

Operation and management. Involvement in operation and management of the plant is brought about by training the personnel identified for this purpose. The areas in which the concerned persons will need to be assisted/trained are:

- election of a committee to manage the plant;
- setting up tariff rates, other regulations regarding connections, misuse, etc – and an accounting system;
- plant operation and record keeping;
- maintenance, repair, stock of spares; and
- consumer services and public relations.

5.3.2: Agreements among Users

To successfully implement and run the project, it is essential to have consensus among the users about the MMHP plant.

The areas in which agreements are desirable, preferably in writing, are given below.

- The size and cost of the plant, the contributions from the users to build the plant, and the external sources of financing such as loans, grants, etc.
- Agreement on the use of water if it has to be shared between power and other uses such as irrigation
- Agreement on membership of the committee, the operators, and their salaries and terms of employment
- Agreement on the tariff structure and rates
- Fines for possible misuse

5.4 Layout Design

Figure 5.2 shows the various components of a micro-hydro scheme.

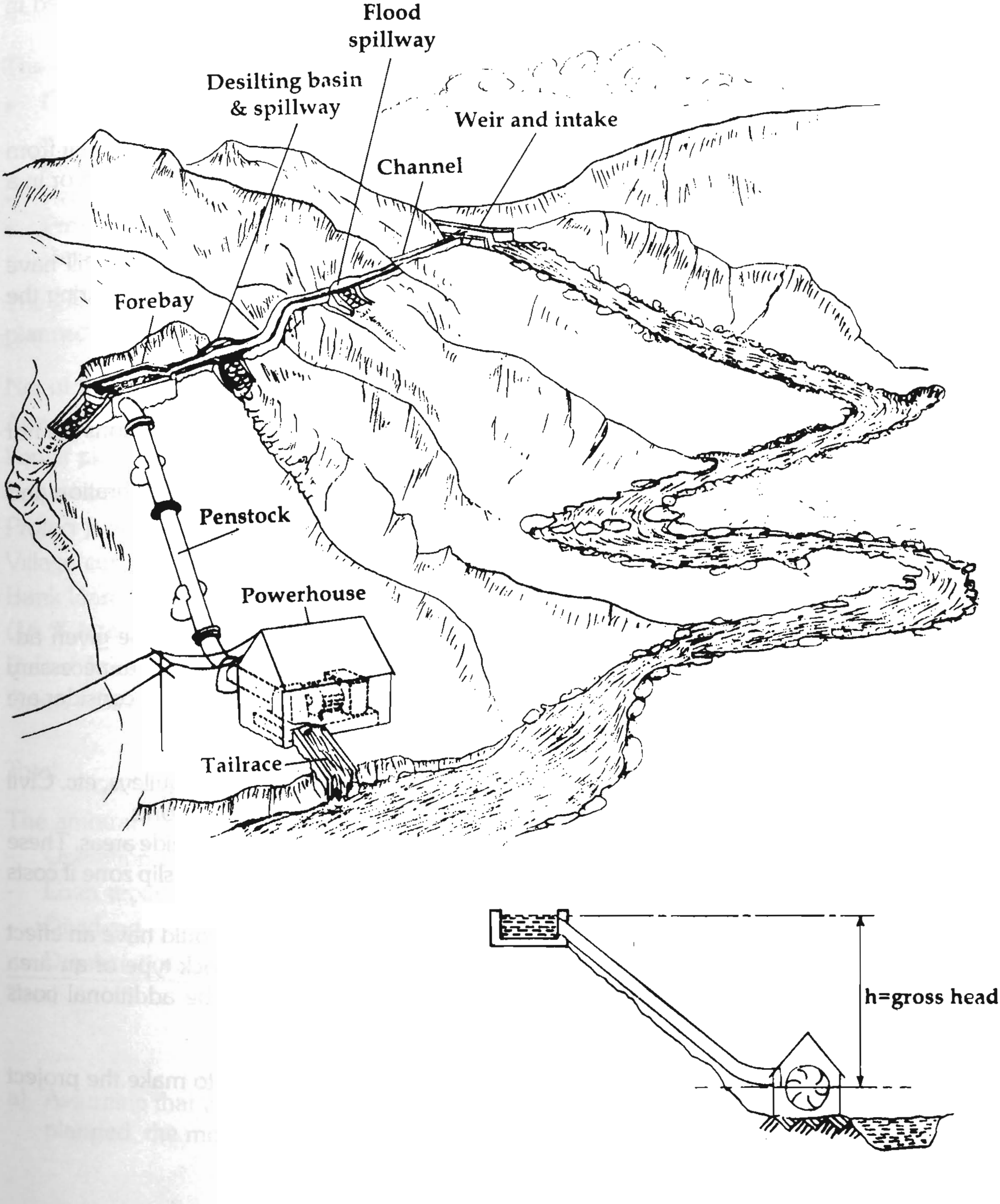
These components, their type, and their functions are described in more detail in the following chapter. However, some suggestions regarding the location of various components are given below.

5.4.1: Diversion Weir and Intake

In selecting the location for an intake the following points should receive attention.

- Wherever possible the natural features of the river, such as a pool, a rock bed, or rock bank, should be used so that expenses can be reduced.

Figure 5.2: Components of a Micro-hydropower Scheme



- The intake should be located where there is minimum likelihood of silt deposition or other damage.
- The intake design should be such that excessive flow is prevented through the channel during flood conditions.
- Locations with poor geology should be avoided (see Section 5.1).

5.4.2: *Head race (Power Channel) and Forebay*

Where possible, the path of the channel should be chosen so that it traverses stable ground. Storm gulleys, steep unstable soils, and landslide prone areas should be avoided. The forebay and the desilting basins, which are relatively expensive structures, must also be located in stable places and away from the paths of floods, landslides, etc.

5.4.3: *Powerhouse*

The powerhouse must be located above the 20-year flood level, at least, to prevent it from being damaged by flooding. It should not be located where water is liable to collect or in a place where there is the possibility of flash floods or landslides.

The powerhouse should be large enough for the equipment to be placed and still have sufficient space for the comfortable movement of people while operating or repairing the equipment.

Other important factors to be considered are:

- provision of adequate drainage around the powerhouse so that the foundations are not eroded or saturated with water, and
- the machine foundations must be large and strong enough to withstand vibration and hydraulic forces.

5.4.4: *Geological Considerations*

In designing the above components of the MMHP, geological factors must be given adequate consideration. If this aspect of the MMHP is neglected, there could be unnecessary costs for repair and maintenance, or even loss of the plant. The main areas to consider are as follow.

- Future surface movements: loose rock slopes, areas of mudflow, storm gulleys, etc. Civil works must be protected by slope stabilisation above and below the works.
- Future sub-surface movements: possible landslips, subsidence, and landslide areas. These areas must be avoided, if possible. Aqueducts can be built to traverse a slip zone if costs permit.
- Soil and rock types: different types of soil and rock in the area that could have an effect on the design considerations of the MMHP plant. If the soil and rock type of an area proposed for locating the civil works are unsuitable, there could be additional costs involved in preparing the foundation works.

In extreme cases, the overall geological conditions may be so poor as to make the project site unfeasible.

5.5: Initial Tariff Design and Income Assessment

The tariff structure of an MMHP plant must be designed so that the cost of operating the plant(including loan repayment, reserves for equipment replacement, etc) is covered by the revenues raised. The tariff must also be fair and affordable for various types of customer.

Working out the tariff is part of the process of working out the feasibility of the MMHP plant. An example is given here of a possible approach to financial decision-making suitable for coordination between village bodies, banks, technologists, and expert advisors. This gives a specific illustration of the general point that proliferation of independent MHP schemes will depend ultimately on facilitation of financial decision-making at the local level. The following examples illustrate how tariff rates can be designed and used to find out how much the recipients should pay for the electricity.

The tariff charged must be able to recover the following costs.

- Operation and maintenance. This includes staff salaries, maintenance costs, and costs of keeping spare parts in stock. For an MMHP plant this is taken to be three per cent of the plant cost per year.
- Repayment of any loans taken to build the plant.
- Profits on investments made by the entrepreneur or community.
- Depreciation - money to be set aside for eventual replacement of the plant.

The following **example** illustrates a methodology for designing a tariff for an MMHP being planned and having the following characteristics.

No. of households	200
Average watts per house	100
Power plant size	20kW
Project cost	$32,000 ($ 1,600 per kW)
Project fund breakdown	
Village contribution	$5,000
Bank loan	$9,000
(16 % interest rate, to be repaid over 5 years)	
Raised from entrepreneur/shareholder (dividend 15%)	$10,000
Grant/subsidy	$ 8,000
Total	$32,000

The amount which needs to be raised each year from the tariff is as follows.

- Operation and maintenance costs	$960(3 % of $32,000)
- Loan repayment	$3,000
- Dividend	$1,500
- Depreciation, 5%	$1,600
Total	$7,060

a) Assuming that the electricity is sold on a flat tariff basis and that all the output is sold as planned, the monthly charge per watt will be

$$\frac{\text{Amount to be raised}}{12 \text{ x watts available}} = \frac{\$7{,}060}{12 \times 20{,}000} = 0.03$$

Therefore, for a household subscribing for 100W, the monthly cost is $ 3.00.

b) However, if only 75% of the electricity is sold, then,

$$\text{Change per watt} = \frac{7.060}{0.75 \times 12 \times 20{,}000} = \$0.04$$

If the power is to be used for lighting only, then the simple method outlined above is adequate. If there are other daytime users as well, then one day (24 hours) is divided into an adequate number of blocks of hours and power allocated accordingly, as has been shown in Table 5.1.

Table 5.1: Tariff Calculation Form

Time	**Customers**									**Total Revenue per Month**	**Total Power Allocated**
	Domestic Households			**Tea Shops**			**Industry**				
	No.	**Watts /hh**	**Tariff**	**No.**	**Watts/ Shop**	**Tariff**	**No.**	**Watts/ In.**	**Tariff**		
Evening hours (6 p.m.- 12 a.m.)	200	100	$0.02	-	-	-	-	-	-	$400	20kW
Morning hours (6 a.m.- 12 p.m.)	-	-	-	5	600	$0.03	1	5000	$0.025	$215	8kW
Afternoon hours (12 p.m.- 6 p.m.)	-	-	-	5	600	$0.03	1	5000	$0.025	$215	8kW
Night hours (12 a.m.- 6 a.m.)											Plant closed
Total Revenue per Month										$ 830	
Total Revenue per Year										$ 9,960	

The tariff is set in such a way that the annual revenue collected is equal to or greater than the amount needed to keep the plant running and to meet all the financial responsibilities. Setting the tariff is a process of iteration between the project cost, how the project is financed, and what tariff rates the customers can bear. Tariff rates for commercial and industrial consumers are usually higher than domestic tariffs. This process can also be used to work out, for example, what the level of subsidy should be or how big a loan can be taken.

Chapter 6
Plant Components and Technology Options

A micro- or mini- hydropower scheme can be broken down into components in order to understand how the overall system operates. The following is a description of the various components. Section 6.1 deals with the water flow from the intake to the tailrace, followed by descriptions of turbines, governors/load controllers, and then generators. The chapter concludes with a discussion about quality and cost trade-offs as the relative advantages and disadvantages of locally manufactured machinery versus imported equipment are compared. As mentioned earlier also, it is beyond the scope of this manual to provide detailed and technical descriptions of the components here. The main purpose is to familiarise the readers with the essentials of the technology. Some excellent literature already exists on this subject (e.g., Harvey 1993).

6.1: Civil Works

Figure 6.1 shows the various components of the intake system and the water flow route. These components are given below.

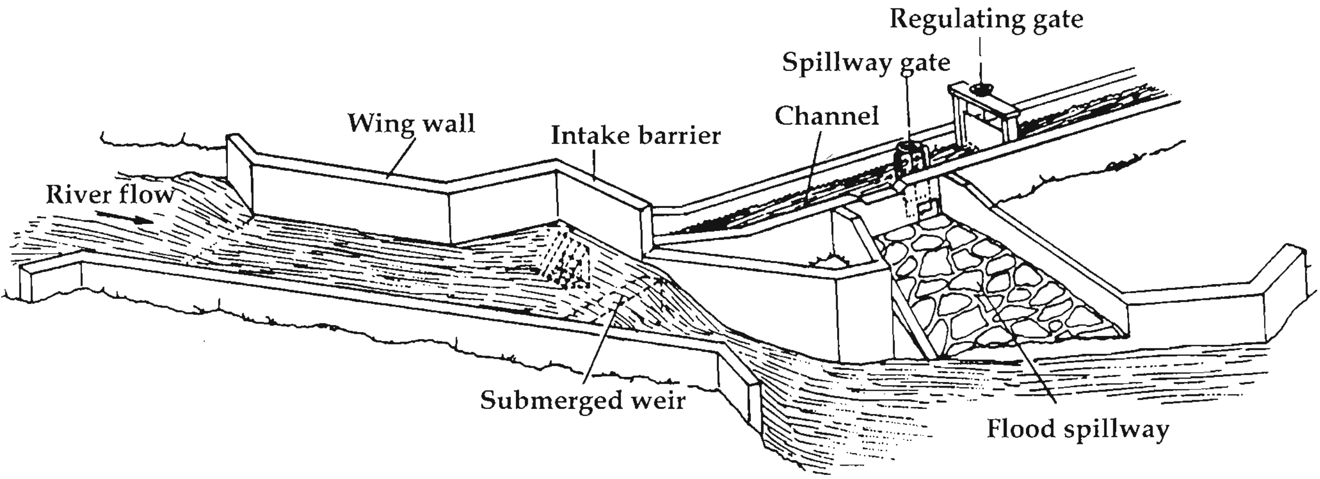
- Diversion weir
- Intake mouth
- Regulating gates
- Spillways
- Spillway drains
- Silt basin
- Channel
- Forebay tank
- Channel crossings
- Penstock
- Penstock supports
- Penstock anchors

6.1.1: Weir and Intake

An MMHP scheme must extract water at a fairly constant rate from the river in a reliable and controllable way. The water flowing in the channel must be regulated during the high and low flow conditions. Sometimes it is possible to avoid the expense of building weirs, using, instead, the natural features of the river. A natural permanent pool in the river may provide the same function as a weir, which acts as a barrier to the flow along the normal stream and diverts adequate flow into the power channel through the intake or the mouth.

Many variations in intake and weir design are possible, from simple boulders placed every dry season, which may get washed away during the monsoon, to expensive concrete or gabion structures. An example of a simple intake is shown in Figure 6.1

Figure 6.1 Example of an Intake Structure



6.1.2: *Headrace*

The headrace (or power channel) carries water from the intake and desilting basin to the forebay tank at the head of the penstock pipe. Various designs are possible to suit the type of the route or a part of it, including:

- simple earth excavation, no seal or lining;
- earth excavation with clay lining or stabilised soil lining;
- masonry lining or concrete channels; and
- flumes or aqueducts made from galvanised steel sheets, wood, pipes cut in half to form troughs, and plastic pipes.

6.1.3: *Desilting Basins*

The water drawn from the river and fed to the turbine will carry a suspension of small particles of solid matter. This 'silt load' will be composed of hard abrasive materials, such as sand, and will cause expensive damage and rapid wear to the turbine runners. To remove this material the water flow must be slowed down in desilting basins so that the silt particles settle on the basin floor where the deposits can be periodically flushed out. Figures 6.2 and 6.3 show simple designs for the desilting basins.

Usually, one or two desilting basins are provided to settle and remove the harmful solid particles. One desilting basin is provided a short distance after the intake and another some distance before the forebay. For short channels one basin may be enough.

6.1.4: *Forebay Tank*

The forebay tank is located at the end of the headrace. Water slows down here for a short time (depending on the size of the tank) to allow any entrapped air to escape and any silt collected in the headrace to settle out. The forebay also controls the flow into the penstock, ensuring that it enters smoothly without turbulence. Usually reinforced concrete or lime masonry is used for the forebay construction.

Figure 6.2: Silt Basin at Channel Entry

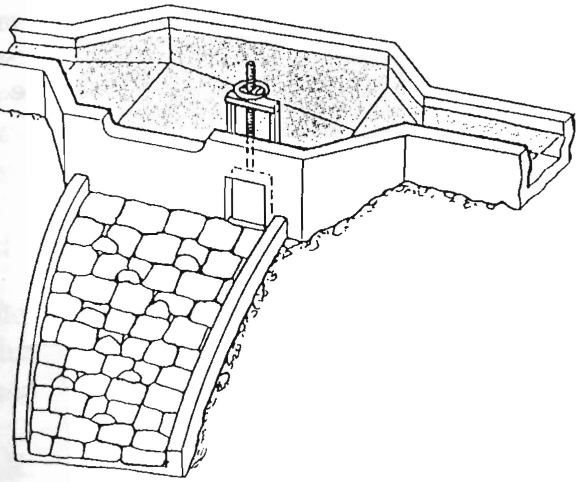
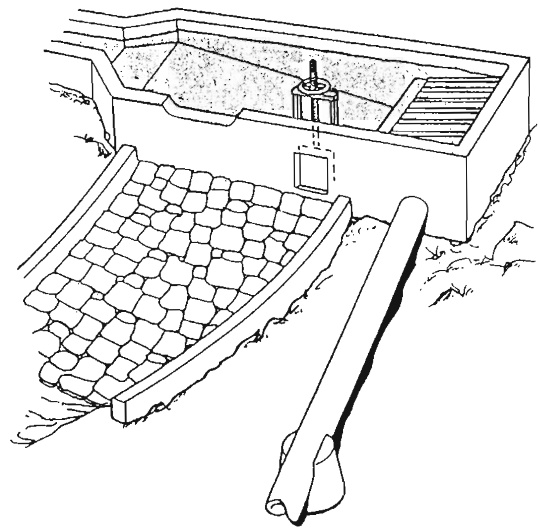


Figure 6.3: Forebay Basin



The design and construction of the forebay tank and desilting basin should be carried out according to the following principles.

- Within the limits of cost and size, the length and width must be sufficient to settle the silt particles.
- Design and construction should allow for easy flushing out of deposits undertaken at sufficiently frequent intervals.
- Water removed from the flushing exit must be led carefully away from the installation. This avoids erosion of the soil surrounding and supporting the basin and penstock foundations. A walled and paved surface, similar to that of a spillway drain, will do this.
- Flow turbulence, caused by introduction of sharp area changes or bends, and flow separation should be avoided.
- Sufficient capacity should be allowed for the collection of sediment.
- The depth of the forebay tank should be sufficient to avoid vortex formation.

Trash racks are also used at the mouth of the penstock to stop floating objects from entering the penstock.

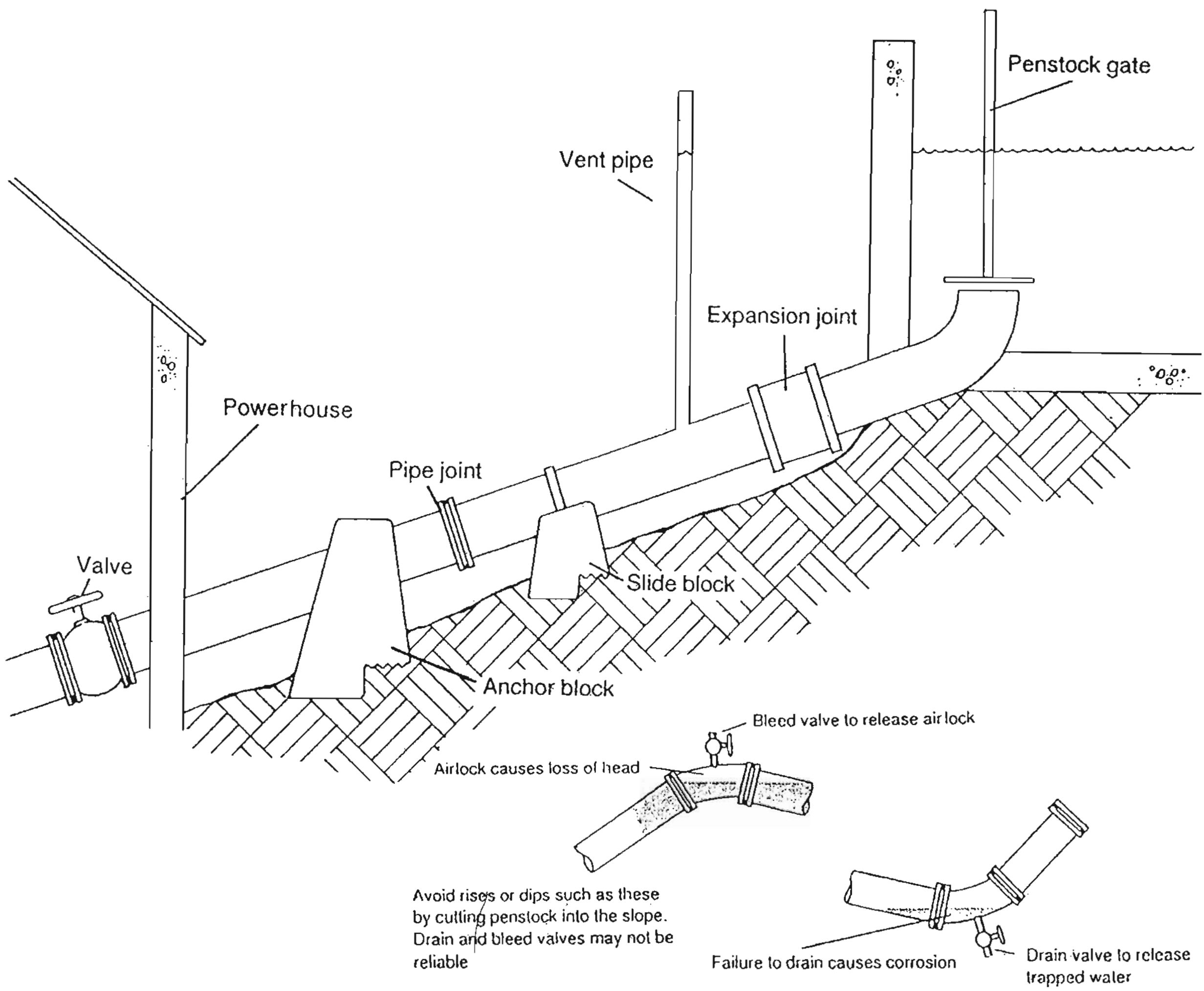
6.1.5: Penstock

The penstock is the pipe that conveys water from the forebay to the turbine, developing water pressure as it drops. The major components of the penstock assembly are shown in Figure 6.4.

The penstock constitutes a major expense in the total MHP budget. It is therefore worthwhile optimising the penstock design to minimise both lifetime running costs and initial purchase costs. To ensure low maintenance costs, care should be taken to place the penstock anchors and supports on stable slopes and on a firm foundation.

There should be no danger of erosion/landslides from storm runoff on the slopes, and there should be safe access for repair and maintenance jobs (such as repainting).

Figure 6.4: Components of the Penstock Assembly. Penstocks should be laid in such a way as to prevent airlocks forming inside them. These airlocks act as obstructions in the penstock and cause a pressure drop across them. If the danger of airlocks exists, because the ground rises and the penstock cannot be cut in, an air bleed valve should be fitted as shown. Similarly, water drain valves may be needed. The use of valves should be avoided since, after some years, they can become unreliable.



The following materials are commonly used for the penstocks of MHP schemes, depending upon the design pressure, importance of friction losses, weight and transportation facilities, soil type, weather, corrosion, etc.

Mild steel
Unplasticised polyvinyl chloride (uPVC)
High-density polyethylene (HDPE)
Medium-density polyethylene (MDPE)

The penstock can be above ground or buried; the latter provides greater protection to the penstock but complicates maintenance. In larger schemes a tunnel can also be used.

6.1.6: *Powerhouse*

The powerhouse is where the electro-mechanical components (generator, control equipment, and turbine) are located. It provides shelter for this equipment and for the operators. It should be dry, clean, and well ventilated and should have sufficient free space to allow maintenance and repair work to be carried out inside the powerhouse. The space requirements will be much greater if agro-processing is also to be carried out within the powerhouse

6.1.7: *Tailrace*

After leaving the turbine, having given up its energy to the turbine/generator set, the water returns to the river via the tailrace. This is usually a channel similar in construction to the headrace. This water can also be used for irrigation purposes in certain locations.

6.2: MMHP Turbines

A turbine converts energy in the form of falling water into rotating shaft power. The selection of a suitable turbine for any particular MMHP site depends on the site characteristics; the dominant factors being the available head and the power required. Selection also depends on the speed at which it is desired to run the generator or other devices powered by the turbine. Other considerations, such as whether or not the turbine will be expected to produce power under part-flow conditions, also play an important role in the selection. All turbines have distinct power-speed and efficiency-speed characteristics. For a particular head, they will tend to run most efficiently at a particular speed and require a particular flow rate. A turbine's correct design speed depends upon the power rating (size), the site head, and its type.

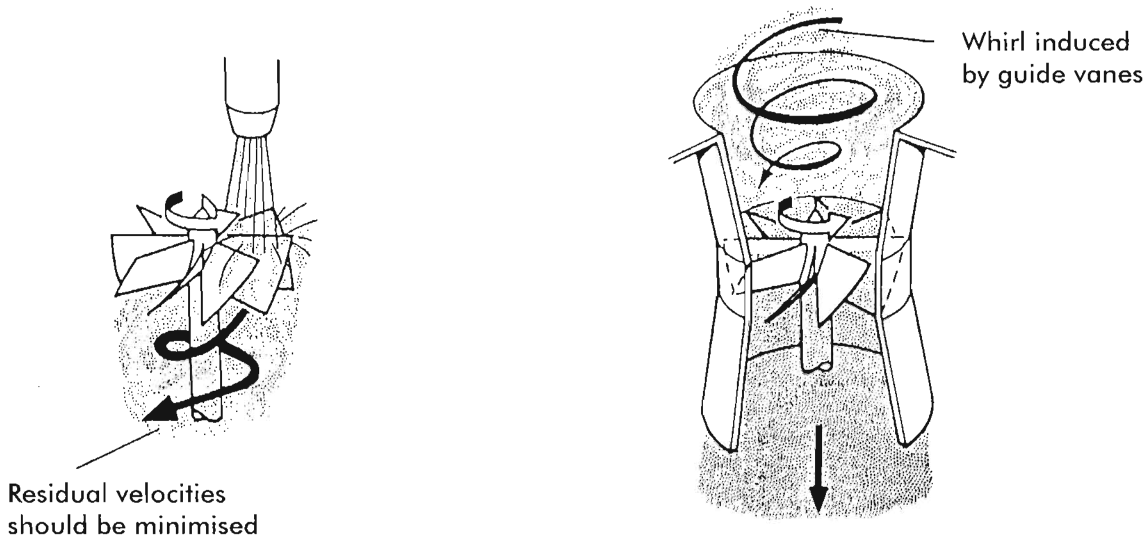
Often, the device that is driven by the turbine, e.g., an electrical generator, needs to be rotated at a speed greater than the optimum speed of a typical turbine. This leads to a need for speed increasing gears, or pulleys and belts, linking the turbine to the generator. In order to reduce costs and difficulties, it is preferable to minimise the speed-up ratio between the turbine and the generator.

Within the micro-hydropower range, we can crudely classify turbines as high, medium, or low-head machines, as shown in Table 6.2. The operating principle also divides the turbines into two groups; impulse or reaction.

Table 6.2 : Groups of Impulse and Reaction Turbines

Turbine Group	Pressure Head		
	High	**Medium**	**Low**
Impulse	Pelton Turgo Multi-jet Pelton	Cross-flow (Mitchell/Banki) Turgo Multi-jet Pelton	
Reaction		Francis Pump-as-turbine (PAT)	Propeller Kaplan

Figure 6.5: Operating Principles of Turbines



a Impulse **b** Reaction

In the case of an impulse turbine (Fig. 6.5a), pressure energy is first converted in a nozzle into the kinetic energy of a high-speed jet of water, which is then converted to rotational energy by runner blades that deflect the water and change its momentum. An impulse turbine needs a casing only to control splashing and give protection against accidents. Usually impulse turbines are cheaper than reaction turbines, because no specialist pressure casing and no carefully engineered clearances are needed.

In the case of a reaction turbine, the runner is fully immersed in water and is enclosed in a pressure casing (Fig. 6.5b). The runner blades are profiled so that pressure differences across them impose lift forces that cause the runner to rotate. The runner and the casing are carefully engineered so that the clearance between them is minimised.

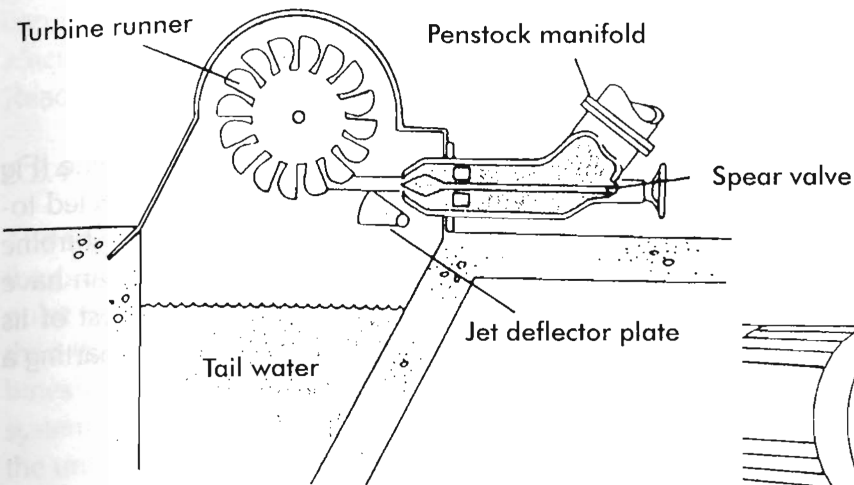
6.2.1: Pelton Turbines

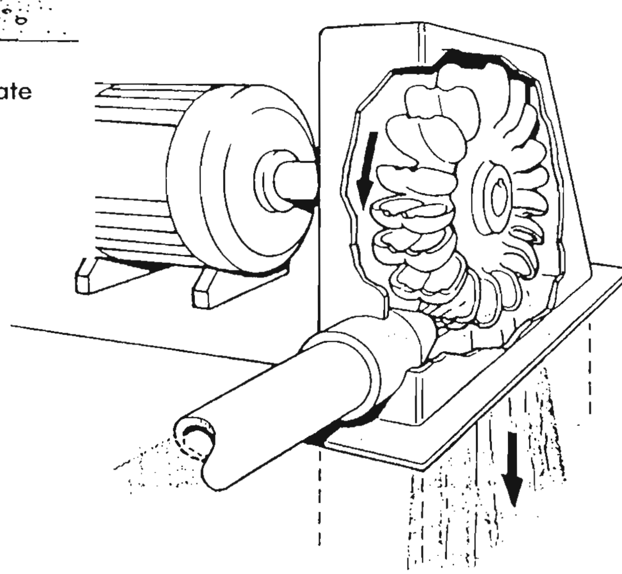
A Pelton turbine has one or more nozzles discharging jets of water which strike a series of buckets mounted on the periphery of a circular disc (Fig 6.6). In large hydropower installations, Pelton turbines are normally only considered for gross heads above 150 metres. For MHP applications, however, Pelton turbines can be used at much lower heads. For instance, a small diameter Pelton rotating at high speed can be used to produce one kW on a head of less than 20 metres.

Seasonal variations of flow over the course of a year can be handled in two ways. In the case of a single jet Pelton, it is possible to divide the yearly flow variation with two, three, or more parts and make a nozzle for each flow. The turbine operator can then fit the appropriate nozzle for each season. It requires some skill to judge when to change the nozzle and which one to fit.

If a multi-jet turbine has shut-off valves fitted on each of its jets, it can be run at different flow rates by simply altering the number of jets impinging on the runner.

Figure 6.6: The Single-Jet Pelton Wheel. Spear valves are not essential components. They can be replaced by various nozzle sizes, or a variable number of jets.





6.2.2: Turgo Turbines

The Turgo turbine is an impulse type similar to a Pelton turbine (Fig. 6.7). However, the jet is designed to strike the plane of the runner at an angle (typically 20°). In this turbine, water enters the runner through one side and exits through the other. As a consequence, the flow that a Turgo runner can accept is not limited by spent water interfering with the incoming jet (as is the case with Pelton turbines). Hence, a Turgo turbine can have a smaller diameter runner than a Pelton for an equivalent amount of power, and it runs at a higher rpm. Like the Pelton, the Turgo is efficient over a wide range of speeds and needs no seals with glands around the shaft. It also shares the general characteristics of impulse turbines listed for the Pelton.

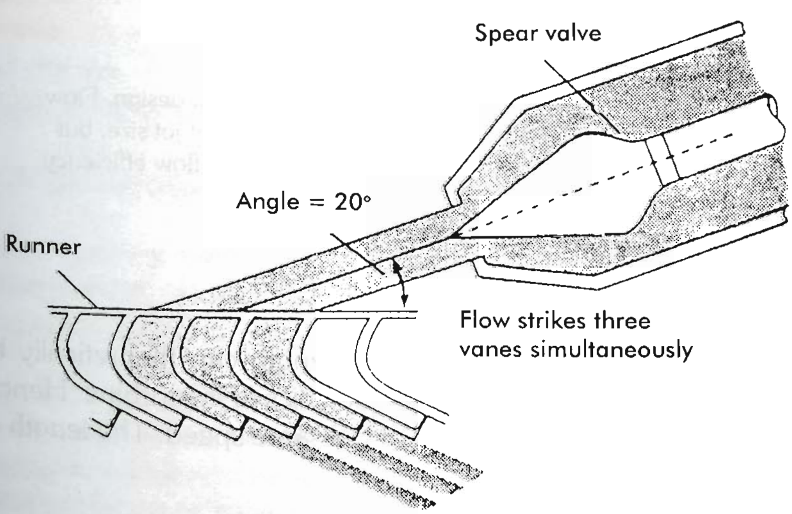


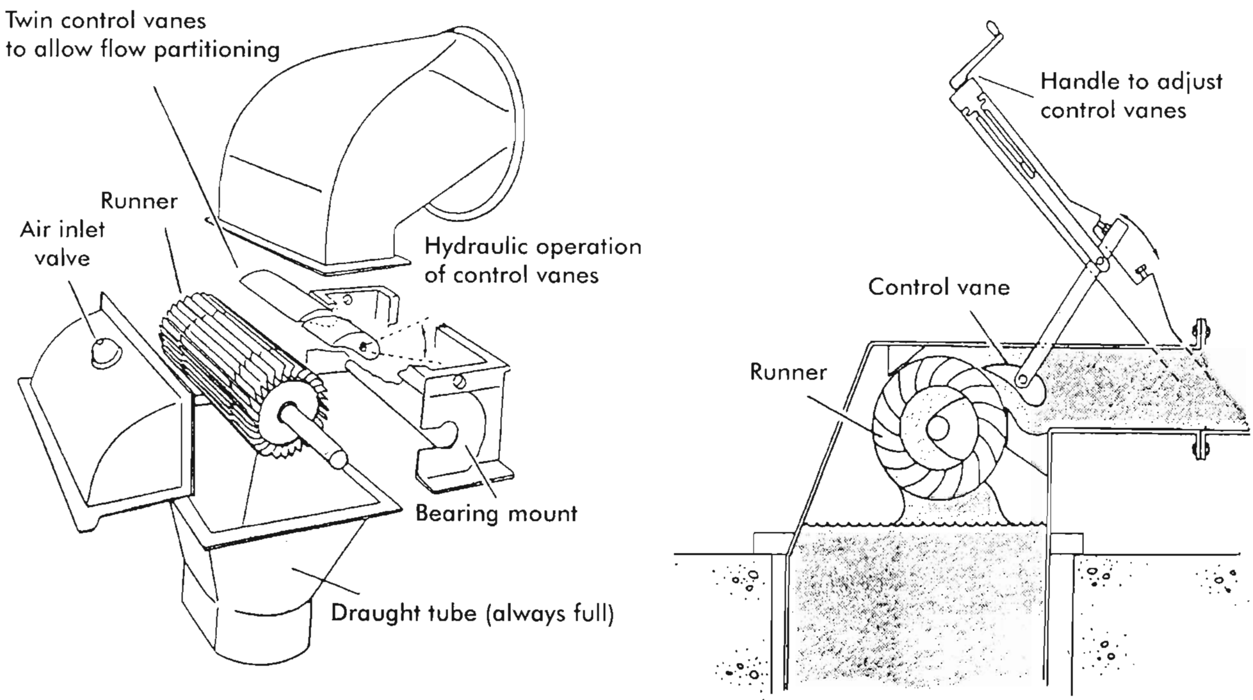
Figure 6.7: The Turgo Turbine. Although this is a compact turbine, the blade shape is complex and less suitable than the Pelton for local manufacture.

The Turgo does have certain disadvantages. Firstly, it is more difficult to fabricate than a Pelton, since the buckets (or vanes) are complex in shape, overlapping, and more fragile than Pelton buckets. Secondly, the Turgo experiences a substantial axial load on its runner which must be met by providing a suitable bearing on the end of the shaft.

6.2.3: Crossflow Turbines

Crossflows are also called Banki, Mitchell, or Ossberger turbines. A crossflow turbine (Fig 6.8) is comprised of a drum-shaped runner consisting of two parallel discs connected together near their rims by a series of curved blades. The runner shaft of a crossflow turbine is horizontal to the ground in all cases (unlike Pelton and Turgo turbines which can have horizontal or vertical orientation). The water strikes the blades and imparts most of its kinetic energy. It then passes through the runner and strikes the blades on exit, imparting a smaller amount of energy before leaving the turbine.

Figure 6.8: The Crossflow Turbine



a. A sophisticated crossflow which achieves efficiencies of up to 80 per cent through use of flow partitioning and suction pressure maintained by an air inlet valve

b. A simpler but highly successful design. Flow can be controlled by change of jet size, but with less improvement of low flow efficiency

Because of the symmetry of a crossflow turbine, the runner length can theoretically be increased to any value without changing the hydraulic characteristics of the turbine. Hence, doubling runner length merely doubles the power output at the same speed. The length of the runner is limited by the strength of the runner.

The crossflow turbine has three major attractions. Firstly, it is a design suitable for a wide range of heads and power rating. Secondly, it lends itself easily to simple fabrication techniques, a feature that is of interest in developing countries. The runner blades, for instance, can be fabricated by cutting a pipe lengthwise in strips. They also have a fairly horizontal efficiency curve at part-loads; although the overall efficiency is a little less than the Pelton or Reaction type turbines.

6.2.4: Reaction Turbines

The reaction turbines considered here are the Francis and the propeller. A special case of the propeller turbine is the Kaplan. In general, reaction turbines will rotate faster than impulse types, given the same head and flow conditions. The propeller will rotate even faster than the Francis. These high speeds have the very important implication that reaction turbines can often be directly coupled to an alternator without any speed-increasing drive system. Significant cost savings are made in eliminating the drive so that maintenance of the units becomes much simpler.

On the whole, reaction turbines need more sophisticated fabrication than impulse types, because they involve the use of larger, more intricately and precisely profiled blades. The extra expense involved is offset by greater efficiency and decreased cost if the turbine can be directly coupled to the generator without the need for a gearbox or pulleys and belts.

Fabrication constraints make these turbines less attractive to manufacture and use in the developing countries. Nevertheless, research is being undertaken to develop propeller machines that are simple to construct.

Figure 6.9 illustrates the Francis turbine. The runner blades are profiled in a complex manner, and the casing is scrolled to distribute water around the entire perimeter of the runner. In operation, water enters around the periphery of the runner, passes through the guide vanes and runner blades before exiting axially from the centre of the runner. The water imparts most of its 'pressure' energy to the runner and leaves the turbine via a draught tube.

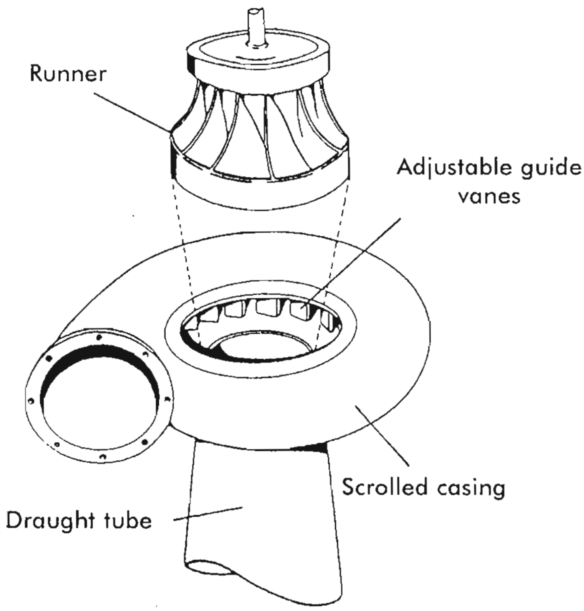
The basic propeller turbine consists of a propeller, similar to a ship's propeller, fitted inside a continuation of the penstock tube; its shaft taken out where the tube changes direction. Water flow is regulated by the use of swivelling gates ('wicket gates') just upstream of the propeller. The part flow efficiency characteristic tends to be poor. This kind of propeller turbine is known as a 'fixed-blade axial flow' turbine, since the geometry of the blade does not change. The Kaplan turbine is the same as a propeller turbine except that the pitch or angle of the blades can be changed.

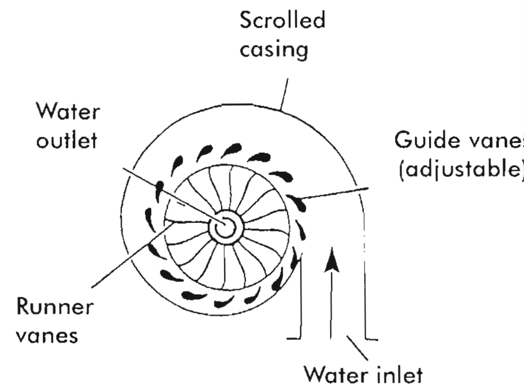
6.3: Governing

Governors are used to control the speed of turbines. Some governing or control of the turbine speed is often required to ensure proper operation of the mechanical or electrical end-use machinery.

Electrical equipment is designed to operate at a specific voltage and frequency. Operation at frequencies and voltages other than the design values can cause serious damage. For example, an electric motor will run hot if the frequency is too low or may burn out rather than start if the voltage is too low. Some control of generator speed is therefore needed. As

Figure 6.9: The Francis Turbine. The complex blades, scroll casing shape, and the need for close tolerance cause this to be an expensive turbine. Guide vanes are rotated to change flow by a linkage mechanism.





the speed of the generator is determined by the turbine, the speed of the turbine must be regulated (kept constant).

6.3.1: Types of Governors

The approaches to governing may be classified in two categories: Mechanical & Electronic Load Controllers.

Mechanical Governors

A mechanical governor controls the turbine speed (hence the generator speed) by varying the flow of water to the turbine. It has a speed sensing device that sends a signal via high pressure oil that in turn controls valves or vanes that vary the flow of water to the turbine. Mechanical governors are complex, requiring quite a high level of skill to adjust and operate them. They should be designed to suit each system, including the penstock. Manufacturing requirements are quite sophisticated. Their main advantage is that only the required amount of water is used, making them very suitable for storage hydropower schemes.

Electronic Load Controllers (ELCs)

Load controllers were developed as a more robust and cheaper alternative to mechanical governors for MHP plants. The turbine/generator set runs at full power all the time. The power is consumed by various loads connected to the system which vary as they are connected or removed. This variable excess power is diverted to ballast heaters. By keeping a constant load on the generator, the output voltage and frequency are controlled. These ballast heaters can either be air or water heaters. In the case of water heaters, the hot water heated by this waste energy can sometimes be used.

This system is suitable for run-of-the-river type schemes where using the full flow is no problem. They are not so suitable for storage or reservoir systems. The load controller is simple to operate and maintain. Faulty components can be replaced and sent away for repairs, as they are light and compact.

Electronic load controllers are much cheaper than mechanical governors for micro- schemes. The ratio may be as high as 1:10 in favour of electronic load controllers.

6.4: Generators

6.4.1: DC - Generators

Low voltage, low power (12 V and 24 V at up to 2kW) direct current (dc) generators and associated low voltage equipment (lights, radios, televisions, motors, storage batteries, and so on) are readily and cheaply available for use in cars and trucks. The costs become comparatively high for larger-sized generators. It is, therefore, sensible to consider use of a low voltage, low power dc MHP system in the following circumstances.

- Where a small scheme (less than 2kW) is being considered and all the loads are very close to the generator, e.g., within 50 metres. Beyond this distance transmission losses are high.
- Where a battery-charging scheme is being considered, the MHP powered dc generator can be used to charge small batteries for customers who take them home to feed suitable small loads, e.g., radios and low wattage lights.

6.4.2: AC-generators

Except for the above-mentioned specialised cases, alternating current (ac) generators are used. There are two types of ac generator suitable for use in an MHP electricity supply scheme. These are synchronous generators (or 'alternators') and induction generators. Induction generators (in which an induction motor is used as a generator) are less common but are being used increasingly in smaller schemes. Their advantages are that they are easily and cheaply available, simply constructed and repaired, reliable, rugged, require little maintenance, and can withstand 100 per cent overspeed.

Induction generators are easily used when they are connected to an existing supply system (grid) and have been used in this way for many years. When used in a stand-alone application, such as an isolated MHP scheme, they need to be fitted with excitation capacitors. They can then be used to power single, fixed resistive loads, for instance a complete set of village lights, either all switched on, or all switched off. If fitted additionally with a voltage regulation system (or 'controller'), they can be used as all purpose ac supply generators.

This type of stand-alone, self-excited induction generator is now being used increasingly in schemes of less than 50kW in size, as a result of the development, since 1985, of an inexpensive voltage and frequency controller; the induction generator controller (IGC).

In synchronous generators, the frequency generated is directly related to the shaft speed. Induction generators are known as asynchronous generators because the frequency generated, though dependent on shaft speed, is not directly proportional to it and changes slightly with load changes. Both types of generators may have the same stator (outer stationary part of the generator) design but they use quite different rotors.

6.4.3: Voltage Regulation

The output voltage of a simple synchronous generator falls very rapidly, as the load current it supplies increases. It is essential that the output voltage remains the same for all loads. An 'automatic voltage regulator' (AVR) controls the output voltage. For synchronous generators (up to 50 kVA), this is usually an electronic unit built into the machine. Older machines may have electro-mechanical AVRs.

The induction generator has poor voltage regulation. Even when driven at constant speed, its output voltage drops rapidly with increasing load. The voltage is much more dependent on the speed with which it is driven than the synchronous generator. The water turbine-driven induction generator can, however, be used to operate multiple fixed resistive loads, such as village lights, with only the addition of capacitors, if some voltage variation and de-excitation problems can be tolerated for the sake of very low costs. The development, in recent years, of a simple IGC, has overcome these problems and made the stand-alone induction generator an increasingly attractive proposition for MHP schemes. It combines the functions of both a load controller and an automatic voltage regulator.

6.4.4: Non-conventional Approaches to Load Control

If high-quality electrical supply is required for sensitive equipment, then one of the automatic controllers listed above must be used. However, where the quality of supply is not so critical, some compromise in performance may be justified, particularly with very small plants (less than 10kW). To achieve lower costs, technically less sophisticated approaches to controlling load and speed are possible.

In rural areas, electricity is a new commodity and loads build up gradually. Non-conventional approaches permit access to electricity with less cost and reduced sophistication. The simplest method of ensuring constant frequency and voltage is to have no switches in the circuit. Power is switched on by opening the valve to the turbine sufficiently wide to attain the nominal frequency and/or voltage. Closing the valve when power is no longer required switches off the electricity. In this approach, neither switches nor power outlets should be included in the system. Frequency may be accurate to only $\pm$ 10 per cent, but modern automatic voltage regulators permit good voltage stability.

One variation of this approach permits more than one constant load to be used. A two-way switch can be used so that switching off one load (e.g., lighting), when it is no longer needed, switches on a second load of similar magnitude (e.g., a water heater). In this manner, a constant load is maintained on the generator despite the use of several loads. Each switch must only control a few per cent of the load. There are numerous variations of this approach.

With the manual control approach, an operator is required to maintain a relatively constant frequency manually. This can be done by adjusting either the flow of water to the turbine, or the total load imposed on the generator.

It is not necessary for the operator to make adjustments continually during the operation of the plant. Small deviations from nominal frequencies and voltages have no adverse effect on the plant or the load.

6.5: Indigenous Design and Manufacture of MMHP Plants

6.5.1: Manufacturing MMHP Equipment in Developing Countries

One of the biggest advantages of micro-hydropower over alternative non-conventional sources of energy is that it lends itself to indigenous manufacture. Very rudimentary workshops can produce equipment of reasonable quality to serve millions of rural people, as is the case throughout the world today. This cannot be said to be true for Solar PV, or Wind.

In Nepal, the crossflow turbine alone provides milling services for oil expelling and rice hulling for close to 10 per cent of the population. It is clear that if the only crossflow turbines available on the market today were those from the Ossberger company in Germany, very few of the two million people served today would have access to water power. Nepal is also fortunate that it has traditional craftsmen who have introduced innovations on traditional water power technologies to produce products such as the Multi Purpose Power Unit (MPPU), the 'improved *ghatta*', and the 'Peltric' set (a small Pelton turbine directly mounted on the shaft of an induction generator). The major advantages of having indigenously designed and manufactured plants are briefly discussed below.

Low Cost

Turbines and other MMHP equipment (for schemes of up to 300kW) are being manufactured in a number of developing countries; and at very low cost. MHP plants, for example, in the micro- and mini-range, are being manufactured in these countries at rates of US$ 300 to 2,000 per kW. The costs in industrialised countries are much higher.

The lower costs of turbines manufactured in the developing countries may well be offset by lower life, less efficiency, and higher maintenance costs. However, for many investors in developing countries, the high prevailing interest rates will mean that schemes are only viable if they can be built at very low construction costs.

Access to Repair and Maintenance

An equally important advantage of manufacturing MMHP equipment locally is access to repair and maintenance. It is reported that the 36 isolated, small hydropower schemes of the Nepal Electricity Authority have equipment from 30 different countries! This makes it extremely expensive and difficult to keep spares and to find workshops that can reliably repair the equipment. The absence of repair facilities can result in extended periods of breakdown. This leads to loss in confidence on the part of entrepreneurs to invest in industries that could improve the load factor of the plant.

A not uncommon problem is trying to trace the international manufacturer of equipment some years after commissioning the powerplant and finding that the industry has closed down, been taken over by another, or has discontinued the particular line of production.

There are, however, a number of limitations to indigenous manufacturing also. These are detailed in the following passages.

Poor Performance of Equipment

In many developing countries, the small workshops which manufacture MMHP equipment are not used to rigorous standards of accuracy and quality. In some cases, this leads to bad workmanship, though this is not usually the case. In many cases, however, even with high quality work, it has been found that the equipment does not actually produce the amount of rated power. The problem stems from over-optimistic assumptions and there not being a regulatory mechanism to verify that the power quoted is actually produced; for example, a penalty to enforce compliance.

Lower Life of Equipment

In order to keep costs low, it is usual for manufacturers to manufacture MHP equipment for a life of between 10 and 15 years. This is not necessarily a problem, as the examples below demonstrate.

As the raw materials for the equipment are usually imported, manufacturers in developing countries are not able to guarantee the longevity of their products even when their own work has been of a high quality. There are examples, in Nepal, in which an adequately sized shaft of a turbine has broken in two to the dismay of both the turbine manufacturer and the customer, and through no fault of the manufacturer.

6.5.2: Trade-offs between Low Cost, Long Life and Reliability

There is clearly a trade-off involved between the low cost of equipment and installations on the one hand, and reliability in performance and long life on the other. The discussion below attempts to use some examples to demonstrate how proper weightage can be given to the competing concerns.

Three examples are taken to illustrate the point.

Example A A high cost site using imported equipment with high quality civil works costing US$ 4,000 per kW installed and distributed. It has relatively low maintenance costs and achieves very high reliability and plant factor.

Example B A medium cost installation using locally manufactured, good quality equipment to the greatest extent possible has semi-permanent civil works and costs US$ 1,400 per kW. It has higher maintenance costs but maintains a high plant factor.

Example C A low cost installation that, using locally-manufactured equipment, uses temporary civil structures and costs as little as US$ 500 per kW. The scheme has fairly high maintenance costs, and relatively low reliability. The scheme will mainly be used for lighting; the low plant factor of 20 per cent results from the absence of a load controller, failure to limit the power used by the consumer, and very limited investment in engineering design for optimal matching between the various components of the installation.

These examples are based on real sites existing in Nepal and Pakistan. Assumptions have been made on the plant factor, operator costs, and maintenance costs but represent, as far as possible, the situation as it exists in the field.

Example A

Size of plant:	400kW
Cost per kW:	US$ 4,000
Lifetime of plant:	40 years
Annual opert cost:	NRs 600,000
Annual maint cost:	1% of capital
Plant factor:	55%
Reliability:	98%

Example B

Size of plant:	50kW
Cost per kW:	US$ 1,400
Lifetime of plant:	15 years
Annual opert cost:	NRs 80,000
Annual maint cost:	2% of capital
Plant factor:	55%
Reliability:	95%

Example C

Size of plant:	100kW
Cost per kW:	US$ 500
Lifetime of plant:	15 years
Annual opert cost:	NRs 80,000
Annual maint cost:	3% of capital
Plant factor:	20%
Reliability:	85%

6.5.3: Putting a Cost to Trade-offs

Completing installations at a low cost per kW is important; however, it is the cost per kWh of energy produced and used by consumers that gives us the best indication of the cost-effectiveness of an MHP investment. Assuming the same rates of financing, for the cost per kWh to be low, the following conditions must prevail.

1) Installation costs per kW are low.
2) Energy use is high.
3) Operation and maintenance costs are low.
4) Breakdown of the equipment is infrequent.
5) The life of the equipment is long.

By producing clear costing for the above parameters, the cost of energy produced by a power plant can be provided by using the following procedure.

1) Annual Equivalent Installed Cost

The following annuity equation provides a simple way of converting the initial cost of installing a scheme into an annual cost. We can say that the initial outlay or capital cost is equivalent to a fixed sum outlay (A) each year for the life of the plant.

where,

A = annuity (fixed yearly outlay),
C = capital cost,
r = annual discount rate (fraction), and
n = predicted plant life (years).

2) Annual Cost of Operation

This includes the salary of the staff to keep the plant operating, to collect tariffs, and perform repairs. This will also involve any training the operators need to receive over the course of the year.

3) Annual Costs of Repair and Maintenance

Maintenance costs need to be taken into account for parts' replacement, civil works' repairs, and the input of outside specialists.

4) Total Annual Cost

The total annual cost is the sum of 1, 2, and 3 above.

5) Annual Energy Delivered to Consumers

The number of kilowatt hours of energy generated and, after deducting losses, delivered to the houses of the consumers, needs to be estimated.

6) The Cost of Energy Delivered

The cost of energy delivered is then computed by dividing the total annual cost by the annual energy delivered.

This procedure was followed for examples A, B, and C above in order to compute the resulting cost per kWh of energy produced.

Costs	Example A	Example B	Example C
Annual equivalent installed cost	Rs 6,000,800	Rs 384,300	Rs 274,500
Annual cost of operation	Rs 600,000	Rs 80,000	Rs 80,000
Annual cost of repair and maintenance	Rs 800,000	Rs 70,000	Rs 75,000
Total annual cost	Rs 7,400,800	Rs 534,300	Rs 429,500
Annual energy delivered	1,794,223kWh	217,412kWh	141,474kWh
	Rs 4.12	**Rs 2.46**	**Rs 3.04**

Methodology of Calculation

- In calculating the annual equivalent installed cost, a real discount rate of seven per cent was used. This is arrived at by deducting from the prevailing interest rate of 16.5 per cent (the market discount rate) an estimated inflation of nine per cent using the equation $1 + r = (1 + m)/(1 + f)$.

  These and other equations are discussed in more detail in the following Chapter (7).

- The total annual energy delivered is arrived at by multiplying the theoretical annual potential of the plant by the plant factor and then deducting five per cent losses in distribution from the powerhouse to the consumers.

6.5.4: Conclusions

These figures show that the medium initial-cost installation (example B) has the lowest cost per kWh (energy). The low-cost installation has the next lowest energy cost, while the high cost imported equipment installation has the most expensive energy. A significant influencing factor for the medium-cost installation is the good plant factor (that is assumed to be 55%). Variations in plant factor can alter the cost of energy quite significantly. The plant factor is affected by many factors other than equipment quality, e.g., types of loads and tarrif structure.

These figures do, however, suggest that good quality, locally-manufactured equipment with semi-permanent or permanent civil works will produce the lowest cost energy. If, on the other hand, the same plant factor was used (say 55%) in all three cases, while allowing for variation in the reliability, the following costs per kWh would be applicable; indicating that Example C would be the most cost effective option.

Example A	Rs 4.12/kWh
Example B	Rs 2.46/kWh
Example C	Rs 1.10/kWh

Chapter 7
Costing and Financial Analysis

7.1 Costing of MMHP Schemes

As discussed in Chapter 4, some studies are carried out prior to deciding or approving a project proposal for installation of any kind, including the MMHP plants. In all such cases (e.g., prefeasibility or feasibility studies), cost estimates are included with a varying level of accuracy. Initially, e.g., during a prefeasibility study, rough estimates of cost are made, while, at a later stage, they should become more accurate. These cost estimates are also used to make economic/financial analyses to assess the viability of the plant, to compare and choose the best possible alternatives for different components, e.g., the head race and the allied civil works. The estimates are also used for comparing MHP with other alternatives such as photovoltaics, grid extension, or diesel-generator sets. Therefore, making such cost estimates is an important part and basis of decision-making and planning processes.

In some cases, it is also possible to redesign the same option in order to reduce the adverse environmental effects without severely affecting the other aspects, especially the costs. Similarly, some components may be changed/redesigned to create an optimum balance between the reliability aspects and the costs.

Financial analysis should also include accounting of the environmental, or even health, issues. It is usually not easy to put accurate monetary values on various environmental, social, or health aspects. For example, how to place a monetory value on better lighting from an electricity bulb compared to that from a kerosene lamp. Such difficulties would, no doubt, be encountered in almost all other cases. Therefore, an easier method would be to give quantified weightage to such a benefit or adverse effect separately from the financial analysis and make the decision, taking into account the results of the financial analysis as well as cumulative weightage of socio-environmental aspects. This procedure has been explained in Section 7.4. But, wherever possible, rigourous and accurate financial analysis should be undertaken so that 'apples are compared with apples'.

7.1.1: *Cost Approximation at Different Stages*

Cost estimation for a hydropower plant, in general, is described below for various stages of decision-making.

<u>Stage 1: Prefeasibility Study</u>

The cost estimate during this first stage is likely to be a crude one, accounting for major items such as civil works, electro-mechanical equipment, labour, transportation, and so on. The estimate would also reflect unusual construction problems, such as accessibility, climatic conditions, etc, affecting construction time or method; while altitude may affect the efficiency of equipment and manpower, availability of labour and supplies, equipment repair facilities, and location and quality of construction materials.

Stage 2: Feasibility Study

Detailed construction schedule and construction cost estimates should be made based on the main construction and equipment items and miscellaneous costs. The cost of the main civil works is based on computed volumes and unit prices adapted to the actual location. Miscellaneous costs cover all the costs not included in the main items. These will be defined as percentages of the main items.

The cost of the permanent equipment will be obtained, based on preliminary equipment descriptions and performance specifications, from approved manufacturers and suppliers.

Construction cost elements include general costs and infrastructure, civil works, equipment (manufacture, transport, and erection), taxes and import duties, engineering fees and supervision costs, administrative and legal costs, insurance, land acquisition, rights of way, resettlement, surveys and investigations, and interest during construction (for financial evaluation).

At this stage, construction schedules and procedures should also be prepared, and this might affect the costs and vice versa. For example, some equipment might be air-lifted rather than manually transported to save time; air lifting would increase the costs but saving time can reduce them in many ways.

Both construction schedules and cost estimates should be expanded to include all work and costs involved in the investigation, planning, design, purchasing (tendering), and construction.

Annual operation, maintenance, and replacement costs can be estimated from experience with similar projects in the area. Otherwise, a percentage figure of the construction cost is used, two to three per cent is an accepted figure.

An example of cost estimates for a hypothetical 60 kW scheme, itemising capital and running costs, is presented in Table 7.1.

7.2 : Methodology of Financial Analysis

7.2.1: Theoretical Concepts

An MMHP scheme is expensive and risky because all the investment is made in the beginning, without being sure about the performance and the extent of returns. Some kind of analyses/calculations are necessary to determine whether the scheme will yield financially viable results.

The financial viability of a project is judged on the basis of the cost-benefit analysis. From the private entrepreneur's stand point, a project is regarded as viable if the benefits quantified as financial returns are higher than the costs.

It is also useful to distinguish between 'economic analysis/evaluation' and 'financial analysis/evaluation'. Financial analysis is usually based on cost-benefit analysis; accounting only for the monetary benefits against the investment costs based on market prices. An economic analysis also attempts to quantify social and other such intangible benefits and includes them in the cost-benefit analysis. Admittedly, this is not an easy or accurate task. However, some aspects and methodologies are discussed in the next section.

Table 7.1 Itemised Capital and Running Costs for a 60 kW scheme

Capital costs	Cost ($)	Proportion of total cost	Contribution to benefits
1. *Planning/design* Engineering, energy survey, hydrology study, site survey, pre-feasibility report, feasibility report, supervision fees, commissioning fees, training, manuals	4,000	3%	High
2. *Management and finance* Institution formation, funding procurement, legal & insurance, training for management	2,000	1%	High
3. *Penstock*	37,000	27%	Medium
4. *Other civil works* Weir & intake, canal, powerhouse, site preparation/access roads, others	35,000	25%	Medium
5. *Electro-mechanical* Turbine, generator, switchgear, other	36,000	26%	Medium
6. *Distribution of electricity* Transmission lines, distribution lines, domestic connections	12,000	9%	High
7. *Appliances*	3,000	2%	
8. *Contingency*	10,000	7%	
Total capital costs	139,000	100%	
Running costs			
1. *Fixed annual (O&M) costs* Labour wages (O&M staff) Management committee (O&M) Specialist overhaul, maintenance, others	2,000/year	6%	High
2. *Variable running costs* O&M staff recruitment, initial O&M training, 5-yearly O&M training refresher, spare parts, tools, materials, specialist advice, replacement, equipment, others	Allow 1,000/year	3%	High
3. *Contingency*	Allow 1,000/year	3%	
Estimated total yearly running costs (O&M)	4,000	12%	High
Capital cost expressed as an annual cost (C_{an}) [See equation (8)]	28,000/year	88%	
Total annual cost $= C_{an} + (O\&M)$ $= 28000 + 4000$	32,000	100%	
Plant factor	0.4		Very high

$$\text{Unit energy cost} = \frac{C_{an} + (O + M)}{P_{ins} \times 8{,}760 \times PF} = \frac{28{,}000 + 4{,}000}{60 \times 8{,}760 \times 0.4} = 0.15\$.\text{kWh}$$

$$\text{Cost per kW installed} = \frac{139{,}000}{60} = 2{,}300\$ / \text{kW}$$

Some indicators of financial analysis and viability of schemes and basic financial concepts are described below.

Discount Rate

The economic life of an MMHP is generally assumed to be in the range of 10 to 30 years. The costs as well as benefits incurred in different years of the MMHP plant's life need to be reduced to the price of a particular year so that these can be compared. For example, $ 100 spent in year-1 is not equal to $100 earned in year-2, since $100 earned in year-1 would have yielded ($ 100 + x) in year-2 because of the opportunity cost of capital, which explains the interest paid by the banks for the deposited capital. Therefore, $ 100 in year-2 is less than $ 100 in year-1. The value in $ 100 of year-2 in year-1 can be found by multiplying the earnings in year-2 by a factor known as the discount factor. Mathematically,

Value of $ 100 earned in
year-2 reduced to year-1 $(B^1{}_2)$ = Earnings of year – 2(B_2) x Discount factor (DF)

$$\text{or,} \quad B^1{}_2 = B_2 \times DF \quad --- (1)$$

in a non-inflationary economy, the discount factor is known as the real discount factor DF_r
In this case:

$$B^1{}_2 = B_2 \times DF_r$$

where, $$DF_r = \frac{1}{(1+r)}, --- (2)$$ and

r = real discount rate.

Equation (1) and (2) can be combined in the following general form:

$$PV = \frac{FV}{(1+r)^n} \quad -------(3)$$

Where, PV → present value of an expected future return / value

FV → future value, and

n → number of years (between future and present value).

For example, if a $ 100 was earned in year-11 and the annual real discount rate was 0.12 per annum, then the value of this future earning reduced to year-1 may be determined as follows:

$$PV = \frac{FV}{(1+r)^{10}} = \frac{100}{(1+0.12)^{10}} = \$32.2.$$

In other words, if a $100 was expected to be earned during the 11th year, its value at present is only $ 32.3.

Inflation is another reason why the value of a particular sum of money decreases in future. The relationship between present and future values of a sum in an inflationary situation can be expressed by the following formula without accounting for the opportunity cost[8] of capital.

$$PV = \frac{FV}{(1+f)^n} \quad \text{-------(4)}$$

where, $f \rightarrow$ inflation rate for the relevant period (year, month, etc), and
$n \rightarrow$ number of periods separating the periods under consideration.

In real life both the opportunity costs of capital and inflation are to be taken care of while discounting. Such a discount rate is known as the market discount rate (m) or actual yearly rate of return, which may be equivalent to the prevalent market interest rate or actual yearly rate of return on an investment. The market discount rate is reflected in the lending interest rates of the banks.

The following relationship exists between the real and market discount rates.

$$r = \frac{1+m}{1+f} \quad \text{-----------(5)}$$

or, approximately $r = m - f$ ----------(5a).

Choosing an appropriate discount rate is very important for the financial analysis which reflects the real yearly return after deducting the inflation rate. A real discount rate of eight to 12 per cent is recommended for the developing countries.

The Annuity Equation

Equal income or expenditure over a long time (over a number of periods) is called annuity (A). The present value of annuity and vice versa may be found using the following annuity equation:

$$PV = A.\frac{(1+r)^n - 1}{r(1+r)^n} = A \text{ x } DF \quad \text{-----(6)}$$

8 The opportunity cost of capital is the earning it can make when invested. For example, if $100 invested in an enterprise yielded $20 in return after one year, the opportunity cost of capital ($100) is $20 provided there is no inflation. If there was inflation and $20 earned after one year equals $10 at the time of investment (assuming 10% inflation), then the opportunity cost of capital was $10. Real discount rate reflects the opportunity cost of capital.

Example: Cash flow analysis and calculation of financial indicators calculate NPV, IRR, B/C and discounted pay-back period for the scheme for which the yearwise revenues and expenditures are given below (in thousand $).

1. Year, n	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
2. Cost (expenditure)	100	15	5	5	5	5	5	7	7	7	37	7	7	
3. Benefit (revenue)	0	28	28	28	30	31	31	31	31	31	25	31	31	
4. Cash Flow	-100	13	23	23	25	26	26	24	24	24	-12	24	24	
5. Discount Factor (for r = 12%)	1	0.893	0.797	0.712	0.636	0.567	0.507	0.452	0.404	0.361	0.322	0.288	0.257	
5a. Discounted Costs	100	13.40	3.99	3.56	3.18	2.84	2.54	3.16	2.83	2.53	11.91	2.02	1.80	153.76
5b. Discounted Benefits	0	25.00	22.32	19.94	19.08	17.58	15.72	14.01	12.52	11.19	8.05	8.93	7.79	182.31
5c. Discounted Cash Flow	-100	11.6	18.38	16.38	15.90	14.74	13.18	10.85	9.69	8.66	-3.86	6.91	6.17	28.55
5d. Discounted Cumulative Cash Flow	-100	-88.4	-70.7	-53.69	-37.79	-23.04	-9.87	0.98	10.67	19.33	15.47	22.38	28.55	NPV=28.55 B/C = 1.19
6. Discount Factor (for r=15%)	1	0.870	0.756	0.658	0.572	0.497	0.432	0.376	0.327	0.284	0.247	0.215	0.187	
6a. Discounted Costs	100	13.05	3.78	3.29	2.86	2.49	2.16	2.63	2.29	1.99	9.14	1.51	1.31	146.5
6b. Discounted Benefits	0	24.36	21.17	18.42	17.16	15.41	13.39	11.66	10.14	8.80	6.18	6.67	5.80	159.16
6c. Discounted Cash Flow	-100	11.31	17.39	15.13	14.30	12.92	10.90	9.03	7.85	6.81	-2.96	5.16	4.49	
6d. Discounted Cumulative Cash Flow	-100	-88.69	-71.30	-56.17	-41.87	-28.95	-18.05	-9.02	-1.17	5.64	2.68	7.84	12.23	NPV =12.23 B/C = 1.09
7. Discount Factor (for r= 18%)	1	0.848	0.718	0.609	0.516	0.437	0.370	0.314	0.266	0.226	0.191	0.162	0.137	
7a. Discounted Costs	100	12.72	3.59	3.05	2.58	2.19	1.85	2.20	1.86	1.58	7.07	1.13	0.96	140.78
7b. Discounted Benefits	0	23.74	20.10	17.05	15.48	13.55	11.47	9.73	8.25	7.01	4.78	5.02	4.25	140.43
7c. Discounted Cash Flow	-100	11.02	16.51	14.00	12.90	11.36	9.62	7.53	6.39	5.43	-2.79	3.89	3.29	
7d. Discounted Cumulative Cash Flow	-100	-88.98	-72.47	-58.47	-45.57	-34.21	-24.59	-17.05	-10.67	-5.24	-7.53	-3.64	-0.35	NPV= -0.35 B/C = 0.998
8. Discount Factor (for r=17.9%)	1	0.848	0.719	0.610	0.518	0.439	0.372	0.316	0.268	0.227	0.193	0.163	0.139	
8a. Discounted Costs	100	12.72	3.60	3.05	2.59	2.20	1.86	2.21	1.88	1.59	7.14	1.14	0.97	140.95
8b. Discounted Benefits	0	23.74	20.13	17.08	15.54	13.61	11.53	9.80	8.31	7.04	4.83	5.05	4.31	140.97
8c. Discounted Cash Flow	-100	11.02	16.53	14.03	12.95	11.41	9.67	7.59	6.43	5.45	-2.31	3.91	3.34	
8d. Discounted Cumulative Cash Flow	-100	-88.98	-72.45	-58.42	-45.47	-34.06	-24.39	-16.80	-10.37	-4.92	-7.23	-3.32	0.02	NPV= 0.02 B/C = 1.00

where, $DF = \dfrac{(1+r)^n - 1}{r(1+r)^n}$ - - - - - (7).

DF is known as the discount factor based on the discount rate.

For example, if an investment of $ 100,000 was made for an MMHP plant in year-1, and it yielded a constant net income of $ 6,000 from year-2 to year-20, the viability of this MMHP could be established easily using the annuity equation as follows (assuming r= 0.10)

$$PV = 6,000 \text{ x } \frac{(1+0.1)^{19} - 1}{0.1(1+0.1)^{19}} = \frac{5.12 \text{ x } 6,000}{0.612} = 8.36 \text{ x } 6,000 = \$50,159$$

or, alternatively

$$A = \frac{PV.r(1+r)^n}{(1+r)^n - 1} \text{ - - - - - (8)}$$

$$= \frac{100,000 \text{ x } 0.612}{5.12} = \$11,963$$

The above example shows the financial non-viability of this plant, because the present value of the expected returns over the lifetime of the project is less than the capital investment.

In the above example, the discount factor for conversion of annuity into the present value equals 8.36. Discount factors are calculated by using equation (7), or they can be found in the discount factor tables given in many books dealing with financial analysis. Equation (8) can also be used to calculate the annuitised Capital Cost C_{an} (C_{an} = A) over the lifetime of the plant representing the Capital Cost.

7.2.2: Unit Energy Costs and Returns

The unit energy cost of MMHP can be calculated by using the following formula:

$$\frac{\text{Unit energy cost}}{\text{(say \$ / kWh)}} = \frac{\text{Total annual cost}}{\text{energy usefully consumed per year}}$$

$$= \frac{C_{an} + (O+M)_{an}}{P_{ins} \text{ x } 8,760 \text{ x } PF} \text{ - - - - - - (9)}$$

where,

C_{an} (or A) $\rightarrow$ annual repayments for invested capital in \$ they can be calculated usin g the annuity equation,

$(O \& M)_{an}$ $\rightarrow$ annual operation and maint enance cos t, which is assumed to be cons tan t at this stage,

P_{ins} $\rightarrow$ installed capacity in kW and plant factor.

PF — PF is defined as the ratio of total actual energy produced by a plant in a year to its max imum energy production capacity

Mathematically,

$$PF = \frac{\text{Annual Energy Output}}{8{,}760 \times P_{ins}}$$

7.2.2: Unit Energy Costs and Returns

The unit energy cost of MMHP can be calculated by using the following formula:

An example of a unit energy cost calculation is presented below.

Example

Plant Capacity	=	20 kW
Plant Cost (c)	=	\$40,000
Annual O & M Cost	=	3% of the capital cost
Expected Life	=	10 years,
Real Discount Rate, r	=	10% / annum
Plant Factor	=	25% or 0.25

Annuitised Capital Cost (C_{an}) (or Annuity (A)

$$= PV\frac{r(1+r)^n}{(1+r)^n - 1}$$

$$= \frac{C \times r(1+r)^n}{(1+r)^n - 1}$$

$$= \frac{40{,}000 \times 0.1(1+0.1)^{10}}{(1+0.1)^{10} - 1}$$

$$= \$6{,}510$$

Total Amount Cost

$$= C_{an} + \text{Annual O\&M Cost}$$

$$= C_{an} + 0.03 \times 40{,}000 \text{ (3\% of capital cost)}$$

$$= 6{,}510 + 1{,}200$$

$$= \$7{,}710$$

Unit Cost

$$= \frac{\text{Total Annual Cost}}{\text{Installed Capacity} \times 8{,}760 \times PF}$$

$$= \frac{7{,}710}{20 \times 8{,}740 \times 0.25} = \$0.176 / kWh$$

Net Present Value

The Net Present Value (NPV) is the sum of the discounted net benefits (revenues) throughout the project period. A project is regarded as financially viable if the NPV is greater than 0.

Mathematically,

$$NPV = \sum_{i=o}^{n} \frac{B_i - C_i}{(1+r)^i} \text{ - - - - - - - - -(10)}$$

where,

B_i, C_i → benefit and cost of year i

i → time interval under consideration, and

n → life of the project in terms of the intervals (say years)

In the above formula, the project begins with a 0 interval, which is the construction period of the project. This convention is adapted to start the life of the project from the first interval.

Alternatively, and more simply, the NPV at a given real discount rate (r) can be calculated from the following equation:

$$NPV_{(r=---\%)} = PV - C \text{ - - - - - - - - - - -(11)}$$

where,

C is capital cost and the PV can be calculated from equation (6).

The following example illustrates the use of NPV as an indicator of the financial viability of a project.

Capital cost, $120,000; expected life, 15 years; expected yearly net income, $12,000; real discount rate, 12 per cent.

$$PV = A\frac{(1+r)^n - 1}{r(1+)^n} = \$12{,}000\,\frac{(1+.12)^{15} - 1}{0.12\,(1+.12)^{15}} = \$81{,}600$$

$$\therefore \quad NPV_{(r=12\%)} = PV - C = \$81{,}600 - \$\,120{,}000 = -\ \$38{,}400$$

The -ve sign shows that the present value of all the future net incomes is less than the present investment. Therefore, the project is not viable at the given discount rate and the expected life.

Internal Rate of Return

The Internal Rate of Return (IRR) is the discount rate at which the project's NPV is zero. The determination of IRR is an iterative process and hence time consuming for manual calculations. The procedure for calculating IRR is demonstrated in cash flow analysis, given in the Example on p86.

In most situations, it is generally asked what would be an acceptable rate of return estimated before implementation for commercial MMHP projects. As a very simplistic 'rule of thumb', an IRR of 12 per cent or higher would justify the investment on a project, and eight per cent or less would not; the values in between are a grey area.

Benefit-Cost Ratio

Benefit-Cost Ratio (B/C) is the ratio of discounted total benefit (income) to the discounted total cost. A project is financially viable if B/C is greater than one.

Mathematically,

$$B/C = \frac{\sum_{i=o}^{n} B_i}{\sum_{i=o}^{n} C_i} \text{ - - - - - - - - - - (12)}$$

B/C has also been calculated in the following example (p90). Its value is 1.19 at a discount rate of 12 per cent. Thus the project is viable.

Pay-back Period

The time period (usually in years) within which the simple or discounted capital investment is completely recovered is called the pay-back period. It is an important indicator for private investors because they will be interested not only in a high IRR but also in a short pay-back period.

'Simple pay-back period' does not take into account the time value of money; i.e., the money is not discounted and can be calculated by using equation 13. It is usually not used for long-term projects such as MHP. The 'discounted pay-back period' takes into account the change of money value with time.

$$\text{Simple payback period (yrs)} = \frac{\text{Total capital cost}}{\text{Annual revenue} - \text{Annual expenditure}} \text{ - - - - - - - - (13).}$$

Discounted pay-back period 'n' can be calculated from the following equation, when capital cost, annuity and discount rate are known. Various values of 'n' can be assumed until the two sides are numerically equal. Alternatively, it can be calculated through cash flow analysis, as demonstrated in the following example. This is the only method in which the net incomes are not constant over the years. When the investment is paid back, the sign of discounted cumulative cash flow changes from '-' to '+'. Thus, the discounted pay-back period is seven years in the example for r = 12 per cent.

$$C/A = \frac{(1+r)^n - 1}{r(1r)^n} \text{ - - - - - - - - - - -(14).}$$

'n' in the above equation is the pay-back period.

Steps for Iterative Cash Flow Analysis

Step 1. Calculate the B/C and NPV at a real discount rate considered to be suitable; say 12 per cent in this case. The B/C ratio of over one and NPV greater than zero indicate the viability of the scheme at a given value of 'r' (Lines 5-5d).

Step 2: IRR is the discount rate at which the NPV is zero. At r = 12 per cent, the NPV is greater than zero. Therefore, the IRR is greater than 12 per cent. The B/C ratio of 1.19 indicates that the IRR is not near to 12 per cent. Assume r = 15 per cent as a second guess; but that the NPV is still positive. Therefore, a higher r needs to be tried. Note that when r was raised by 3 per cent the B/C ratio dropped by 0.10. The B/C ratio needs to be further reduced by 0.09, therefore r may be raised by a further 3 per cent.

Step 3: Assume r = 18 per cent as a third guess. Here, the NPV is nearly zero but -ve. Thus, for practical purposes the IRR may be taken as 18 per cent. However, for a better understanding of the iterative process more steps may be introduced in this example.

Step 4: At r = 18 per cent the NPV is negative. Therefore the IRR is somewhat lower than 18 per cent, but quite close to 18 per cent as the B/C ratio of 0.998 indicates. Make a fourth guess of r=17.9 per cent. The NPV in this case is 0.02, which is close to zero and +ve. Therefore, the IRR is very slightly above 17.9 per cent but less than 18 per cent.

Results: The NPV is -ve at r=18 per cent and +ve at r=17.9 per cent. Therefore, the value of the IRR can be taken as 17.9 per cent.

Also, B/C = 1.0 at r=17.9 per cent

The pay-back period at r=12 per cent is about 7 years (when discounted the cumulative cash flow becomes +ve)

at r=15 per cent, it is about 9 years

at r=18 per cent, it is more than 12 years.

<u>Explanatory Notes for Cash Flow Analysis</u>

1. *The capital cost of the project is $100,000. All investment is supposed to be made in year-0, which is the construction year. The life of the project is assumed to be 12 years. It is critical to properly assess the plant life.*
2. *The analysis has been made at constant prices, that is without consideration of price escalation. When all cost and benefit components are subject to the same inflation rate, inflation need not be considered. Operation and maintenance costs that spread throughout the project life are variable. The costs at year-1 are high because of training and initial management costs. These costs have been assumed to increase from year-9, due to wear and tear of equipment. The high costs in year- 10 are due to refurbishment of some capital equipment.*
3. *Benefits (revenues) shown in row 3 are income from energy sales. The energy sales have been assumed constant in the first three years, then they rise slightly and stabilise from year-5. The low revenue in year 10 is due to plant refurbishment works.*
4. *Cash Flow = Benefits - Costs.*
5. *Discount Factor* $= \dfrac{1}{(1+r)^n}$
6. *Discounted Costs = Discount Factor x Cost (for each year separately)*
7. *Discounted Benefits = Discount Factor x Benefits*
8. *Discounted Cash Flow = Discount Factor x Cash Flow.*
9. *(Discounted Cumulative Cash Flow)*$_{12}$ = *(Discounted Cumulative Cash Flow)*$_{12\text{-}1}$ + *(Discounted Cash Flow)*$_{12}$.
10. *Positive NPV, IRR higher than discount rate and B/C ratio greater than one indicate the financial viability of the MHP. The pay-back period of seven years is a little high.*
11. *If subsidies are available, the costs used for calculations should be exclusive of these.*
12. *One might attempt more calcuations, e.g., for r=17.91 per cent. However, for practical purposes this is not necessary.*

7.3: Selection of Analysis Method

MMHP plants are long-life projects with varying revenues and expenditures (benefits and costs) each year. These variations are mainly associated with time taken for load growth, heavy expenditure during the construction period, and replacement of equipment. It is important to note that the treatment of benefits and costs of MMHP as constant annuities could become a risky over-simplification. A feasibility study for MMHP requires a fully-fledged cash flow analysis, which essentially is an effort to consider actual benefits and costs on an annual basis.

More accurate expenditure in and revenue from an MMHP can be predicted using the following guidelines.

a. Depending upon the size of the MMHP and the socioeconomic conditions of the locality, it could take three years or more for full use of the plant's capacity. Judgement of load growth should be made by comparing the locality under consideration with other similar localities where MMHPs have been installed earlier. The feasibility of the MMHP is greatly influenced by this load growth. Therefore, it is advisable to be conservative in estimating the load growth.

b. MMHP technology is relatively new. There is still no well-established MMHP expenditure pattern, especially for repairs and parts' replacement. Expenditure seems to be influenced by the type and make of the equipment, management capability of the owner, and remoteness of the site. Therefore, it is advisable that expenditure patterns of similar MMHPs be studied in order to estimate expenditure for the MMHP under consideration.

At the prefeasibility study stage, whenever possible, it is desirable to use cash flow analysis. This is especially true if the purpose of these studies is to check the financial viability of a particular project and not the ranking of a number of candidate projects. This is what a private entrepreneur normally does.

When the assessment of yearwise benefits and costs is yet to be made, the annuity method may be used for financial analysis. The annuity method assumes the annual benefit and costs to be constant. Therefore, judgement of the financial strength of the project can be carried out simply by assessing the financial performance for one year. The indicator very often used for this purpose is the unit cost of energy produced. The unit cost gives a general impression about the financial standing of the project as well as helping to rank the candidate projects.

7.4: Accounting for Social and Environmental Factors

Financial analysis is designed to make judgements about the viability of an MMHP purely from the market stand point, commonly called financial viability. A private investor might be interested in the financial analysis only but not the public investor or the society; because financial analysis might not take social costs and benefits fully into account. For example, the market price of many commodities might not reflect the real price due to government subsidies and taxes. The wages also may not reflect the real wages due to these price distortions. When the financial analysis is conducted, by using not the distorted market prices but the real values to the society, the analysis is called economic analysis. Government or public agencies are expected to make judgements on the projects on the basis of economic analysis.

Virtually all the environmental problems being faced by developed countries are also found in the developing countries; although the scale and extent of damage might be different. If industrial pollution is more pervasive in the industrialised countries, soil erosion and deforestation are more acute problems in the developing countries. Therefore, it is necessary that both, the developed as well as the developing countries, make efforts to address these difficult problems and collaborate with each other.

Thus, the environmental consequences of various energy supply and usage options must also be appraised and accounted for while selecting one for a given area or application. The same is also true for the social consequences (benefits as well as damage).

MMHP can have intangible social and environmental benefits such as stimulation of the rural economy, substitution of fuelwood, etc. Likewise, it can result in environmental damage, such as erosion, along the canal and tailrace. Monetary evaluation of benefits and costs in such cases is not easy. But there are cases for which these could be accounted for. For example, the damage caused by seepage along the canal can be abated through engineering solutions, for which costs could be estimated. It is important that the negative consequences of MMHP, if any, should be identified and the abatement costs related to them should be accounted for as far as practicable. Obviously, the negative effects of fuel systems, such as petroleum products, are far more serious than those of the MHP on the environment and sometimes even on health. Therefore, the potential costs of such effects have to be taken into consideration also.

7.5: Selection of an Appropriate Option

At present, in Nepal, private utility MHP is being promoted not as one of the competing sources of electrical energy but as the sole source. Therefore, the MHP being appraised is, generally, not compared with other sources. Likewise, a particular MHP is not compared with other MHPs that can be built elsewhere as investment alternatives, because the MHP is still a completely local enterprise with local entrepreneurship designed to provide electricity to a particular locality. Therefore, so far, the project selection implies the assessment of financial viability of a particular MHP rather than the selection of a best MHP project for investment within a large area/region/district.

7.5.1: Appraisal of a Single Option

While appraising a single option project, any of the financial indicators can be used to judge the viability of the option. However, the IRR has some advantage over others, because of its being easily understood by investors, and because it directly shows the per unit (period) yield from capital. In addition, the IRR of a project helps to facilitate a decision about the feasibility of the project through direct comparison with the prevailing interest rates.

Power projects being long-life projects, it is important not only to know the ultimate profit from the project but also the pay-back period. Therefore, it is recommended that the IRR and discounted pay-back periods be used as tools for measuring the financial viability of single option projects.

7.5.2: Comparative Evaluation of Options

Comparative evaluation of options is carried out to find a project or a set of projects yielding the best financial rewards. When the available projects are ranked as per the benefit-cost ratio, net present value, and internal rate of return, the preferences shown by these parameters might differ. Furthermore, the ranking for a particular financial indicator might differ for different interest/discount rates. Therefore, the choice of a particular indicator for project selection should be made only after considering the context of selection. The following guidelines for project selection could be used.

(a) Select an appropriate real discount rate. The real discount rate should be based on the real interest rate applicable for the projects being considered.

(b) Consider meeting the following criteria for ranking projects:

B/C > 1, NPV > 0, IRR > Discount Rate.

(c) If there is no resource constraint to project funding, or, in other words, if the available funds are sufficient to fund any of the alternatives, then the alternative yielding the largest NPV should be selected.

(d) When the availability of capital is relatively small, compared to the availability of projects, it is most desirable to develop those projects that have the highest benefit-cost ratio first.

(e) The net present value indicator is to be preferred to the internal rate of return for ranking mutually exclusive projects.

(f) In the case of independent projects, selecting projects in order of their benefit-cost ratio, until the available funds are exhausted, should be preferred to selecting projects on the basis of their net present values. However, when a large amount of money remains unused while adapting this method, the combination of projects yielding the maximum NPV should be chosen.

Chapter 8 Execution, Supervision and Commissioning

8.1: Background

Traditionally, MHP projects in Nepal were implemented by three main players working together: i.e., the entrepreneur, the manufacturer, and the bank. The entrepreneur was responsible for the project management and civil works, the bank provided the necessary loan, and the manufacturer supplied and installed the equipment. This system has continued with add-on as well as stand-alone electrification plants. As plant size and sophistication have increased, it has become more difficult for entrepreneurs and manufacturers to carry out the work in the same way as with the mills.

The system that has evolved in Nepal for the implementation of turbine mills has turned out to be inadequate for implementation of electrification schemes, especially the larger ones (>25 kW). As manufacturers are not set up to provide the extensive design and supervision required for larger projects, the number of projects they are able to implement is severely limited.

Private sector MMHP plants in Pakistan are promoted mainly by the Pakistan Council of Appropriate Technology (PCAT) and the Aga Khan Rural Support Programme (AKRSP). The PCAT is a government organisation and the AKRSP is an NGO. They provide financial and technical support to communities wanting to install an MMHP plant. Technical support is provided for survey, design, and installation. Most of the equipment is manufactured locally under the supervision of the PCAT/AKRSP.

Pakistan has evolved a system in which a separate agency is responsible for survey, design, and installation. This system allows for more specialisation, which could improve the quality and volume of work.

8.2: Schedules and Methodology of Execution

8.2.1: Equipment Manufacture/Procurement

Once the detailed design of the MMHP project is completed by the consultant/ manufacturer, the equipment required must be procured. The current practice in Nepal is to buy all the equipment from the manufacturer. In the case of turbine mills, the survey, design, procurement, site supervision, and installation are carried out by the manufacturer. In some instances, the milling machinery for an MMHP plant has been purchased separately from neighbouring countries by the entrepreneur, because, as a cottage industry, the turbine mill is eligible for low customs' duties. However, this is a time and energy consuming process and entrepreneurs have generally left it to the manufacturers to supply all the hardware for the MMHP plant.

With electrification schemes, the tendency for 'one stop buying' has increased, because of the technological complexity and the need for all the components to be compatible with each other. Only a few of the simple but bulky items (transmission wires and insulators) are sometimes purchased separately.

There are advantages to the customer in buying all the equipment from one place, as it simplifies the process and saves time and effort. However, it could increase the project cost.

8.2.2: Organisation of Recipient's Contribution

For most community-owned MMHP plants, there is some element of recipient contribution to the project. This could be in cash and/or kind. When it is contribution in kind it is in the form of local labour and materials.

When organising project construction, it is important to keep in mind the peak agricultural season when labour will be in great demand. Failure to plan for this will result in project delay.

There must also be a clear agreement among the recipients about the labour contributions; who is to provide how much and who is responsible for organising the work? The responsibility for organising the labour contribution should lie with the community and not with the manufacturer or implementing agency.

The responsibilities of the various parties involved in the MMHP project must be clearly understood by all involved, otherwise delays and increased costs will be incurred.

8.2.3: Agreements between the Parties Involved

There must be a written agreement between the different parties involved in the MMHP project before work begins. The relationships and the agreements between the different parties are given in Figure 8.1. When the manufacturer/installer takes on the role of the consultant/promoter (as with turbine mills in Nepal), the agreements will be between the manufacturer and the community/entrepreneur.

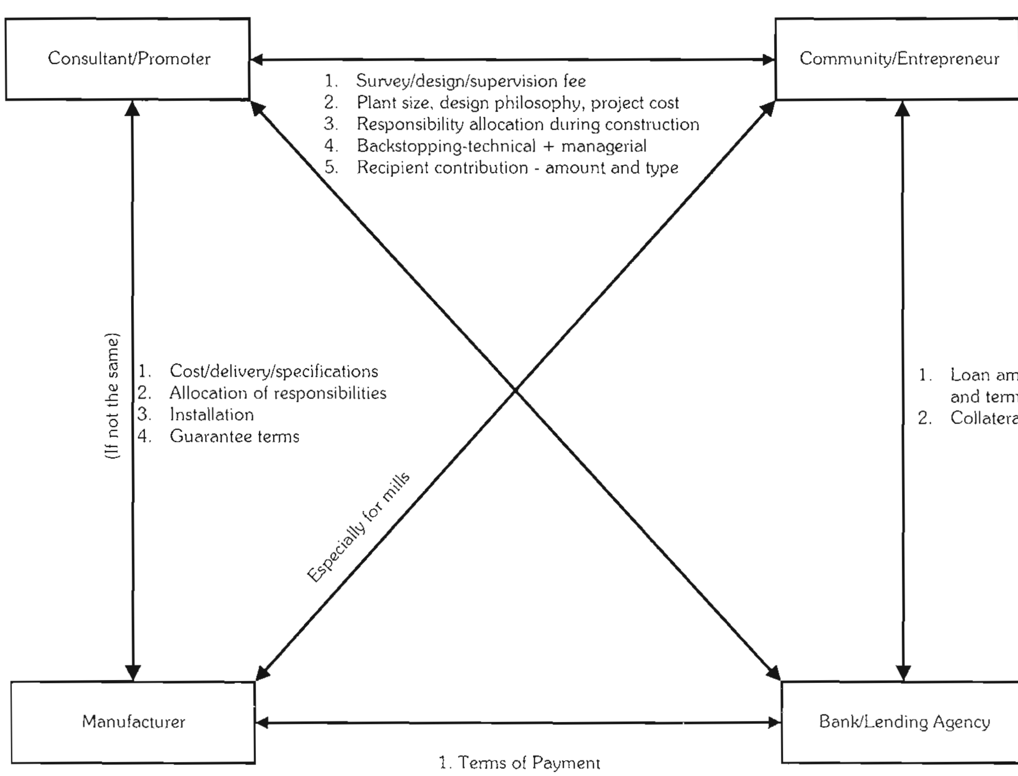


Figure 8.1 Agreements between Various Parties Involved in Building an MMHP Plant

8.3: Site Construction, Management and Supervision

Different countries in the region have evolved different systems for supervision and management. In Pakistan, the implementing institution supervises the work and manages the project. In Nepal, this is carried out by the entrepreneur and the manufacturer. For peltrics, the entrepreneur does all the site work and management himself; for turbine mills, some of the work, such as foundations and forebay tanks, is supervised by the manufacturer and the rest by the entrepreneur; for bigger electrical schemes, the electrical portion is supervised by the manufacturer as well.

8.3.1: Civil Works and Powerhouse

Supervision of the civil works and powerhouse is best carried out by a qualified supervisor on the site, especially if the work involves a fair amount of cement and concrete work. In cases in which the canal required for the MMHP plant is similar to the ones that are already being constructed for irrigation, this work can be left to the local people.

8.3.2: Inspection and Testing

The equipment made and supplied by the manufacturer must be inspected and tested before it leaves for the site. This should be undertaken by the manufacturer and supervised by the entrepreneur or his consultant. The following tests/inspections are recommended.

Penstock	– Pressure test of up to at least 1.5 times the design pressure; painting, other corrosion protection adequately carried out. Numbering markings carried out, as required.
Turbine	– Unobstructed movement of the runner, guide vanes. Balancing of the runner. Painting, corrosion protection.
Other mechanical parts	– Construction integrity, corrosion protection
Generator, control equipment	– These must be shop assembled and run to see if the control system works as designed.
PTCs, MCBs, current cut-outs	– These must all be tested to see that they function properly before despatch.

8.3.3: Transmission and Distribution System

This area requires careful supervision, especially in terms of safety.

Poles	– Buried to appropriate depth. If wooden poles are used, it must be ensured that they are of the right species and size for the purpose. Painting, treatment carried out appropriately .
Transmission wire	– Properly strung out. Connection to insulators sound.
Lightning arrestors	– Connected properly, earthing completed.
Distribution	– Proper connection between service wire and transmission cable. Properly connected cut-out devices. Wiring up to standard. Earthing carried out properly.

8.3.4: Transport

The transport of equipment and materials must be organised so that it arrives at the site not long before it is required. There, it must be stored properly so that it is not damaged or stolen. Components and parts, such as controllers, generators, turbine shafts, and electric meters, which might easily be damaged, must be protected or packed well enough to prevent damage.

Transport of materials for an MMHP plant in remote areas could involve the following modes of transport.

- By road vehicles
- Carried by porters or animals
- By air

When the equipment has to be carried by porters or pack animals, it is important to design the packing properly so that it is easily carried. If costs permit, it is worthwhile considering transporting bulky but sensitive equipment, such as generators, by air.

Involvement of the recipient (individual or community) is an important aspect of project implementation. Portering the equipment to the site from the roadhead is usually the responsibility of the recipients. However, they might need advice and supervision for this.

8.3.5: Equipment Installation

Different systems have been developed in different countries of the region for equipment installation. In Nepal, this is normally carried out by the manufacturer. In Pakistan, another implementing agency handles installation.

Installation Procedure

- Ensure that all the necessary materials, tools, and personnel are available.
- Mark out the position of the various equipment according to the design.
- Concrete in the parts that are to be embedded
- Wire up electrical connections and other work that does not require the concrete to have set.
- Install the machinery on the foundation when the concrete has set

8.4: Commissioning and Testing

The commissioning and testing procedures for an MMHP plant are an important part of the implementation process. They provide a system for checking that all the components of the MMHP plant function as designed and as specified by the supplier. The commissioning and testing procedures also provide a record of the operational status of the plant at start-up, and this is useful for future reference.

The commissioning and testing procedures, the methods for working out whether the equipment meets the performance standards stipulated in the contract, and the action to be taken in the case of under-performance must be agreed upon beforehand. In the case of under-performance, the penalties to be paid, the remedial work to be carried out, and so on must also be agreed upon at the time the contract is signed, otherwise it could lead to unnecessary disputes.

8.4.1: *Commissioning Procedures*

The commissioning procedure can begin after all the work has been completed and checked. The commissioning report must have a list of all the items to be checked or tested. Alongside the items, their condition, whether this condition is satisfactory, or whether it needs to be rectified must be mentioned. Likewise the test results and the data obtained (e.g., efficiency) must be noted, along with the conclusion concerning whether or not this meets the specifications.

Items to be included in the list are as follow.

Civil	– Intake, canal, desilting/flushing system, overflow, gates/stoplogs, trash rack, penstock supports/anchors
Mechanical	– Turbine, baseframe, penstock, valves, governor/controller
Electrical	– Generator, load controller, control and protection panel, ballast load
Distribution	– Poles, wire/insulator, lightning arrestors, service connections, cut-outs.

8.4.2: *Commissioning Tests*

The machines should first be checked with no load. The speed is increased at 10 per cent intervals until the rated speed is reached. At every stage, it is checked for unusual sounds, vibrations, and behaviour.

Starting at the rated speed and no load, the load on the machines is increased in steps of 10 per cent until full load is reached. At every load interval, the system is allowed to reach a steady state and readings are taken.

Readings to be taken, at different outputs

Flow (if possible), turbine speed, bearing temperature, alternator temperature at different points, governor oil temperature, alternator voltage and current on all phases, exciter voltage and current, power factor, voltage drop across transmission line.

Efficiency tests are quite difficult to carry out on small plants and peltrics. However, electrical power is measured to ensure that the specified output is achieved. For larger plants and where the dry season flow is critical, efficiency tests are more appropriate.

Tests to be carried out

Over-voltage, over-current, over-speed, vibration, efficiency, governor/controller response, generator insulation test, transmission line 'megger test'.

8.4.3: *Rectifying Problems*

During the commissioning tests, it is possible that there will be problems with the functioning of the plant for various reasons. The nature of the problem must be determined during commissioning as one of the following.

- **Serious :** stop work until the problem is rectified
- **Ordinary :** commissioning work can continue and the problem be rectified later at a more convenient time.

- **Minor :** can be rectified immediately or not significant enough to stop commissioning.

If there is a major rectification to be carried out, the responsibility for the work, its completion, and commissioning date must be agreed upon between the concerned parties.

8.4.4: Certification

In Nepal, the procedures and methods for carrying out the commissioning and testing are not well developed. In the case of mill turbines, the general practice is for the manufacturer to operate the turbine and the mill machinery for a day and then hand it over to the client. The client then signs a statement saying that the turbine and mill machinery are performing satisfactorily. The manufacturer then presents this statement as proof to the bank that the work has been completed and requests the remaining payments. In electrification projects, the requirement is that the manufacturer demonstrates that the design power output has been achieved.

In larger electrification projects, such as those in Siklis or Salleri, the commissioning procedures are more elaborate and involve measurement of turbine efficiency, operation of the control and protection system, and so on. This is largely because these projects are backed by institutions that have the technical expertise and resources to demand and get such tests done.

A system of testing and certification that is acceptable to all sides is needed. This would establish performance standards and make it possible to compare the relative performances of different manufacturers, which in turn would be an incentive to the manufacturers to continue to improve their products.

The main parties affected are the manufacturers, the lending institutions, the consultants/promoters, and the recipient communities/entrepreneurs. A new organisation, or an existing one, which is independent of the affected parties and has the technical capability to carry out the work, is a desirable institutional need. Such a separate body will need to be financed; and, ideally, the various parties involved will pay for its services.

8.4.5: Training

Training is an important but often neglected aspect of MMHP. In Nepal, most of the training given to MMHP plant owners/operators is 'on-the-job' training. In turbine mills, the installer demonstrates to the owner how the turbine and milling machinery works once the installation is complete. Similarly, for electrification schemes, the manufacturer demonstrates how the plant operates and points out the safety aspects in running the plant before handing over to the customer. The areas in which training is required are discussed in more detail in Chapter 13.

Chapter 9
Management, Operation and Maintenance

9.1: Background

Regardless of who has ownership of an MMHP plant, what is important is that it is kept optimally operational and that the tariff rates are affordable to consumers. It is not necessary for the owner and the manager of the MMHP plant to be the same. In cases of entrepreneur-owned MMHP plants, it is normally the entrepreneur himself who manages the plant. In community-owned plants, attempts to manage the MMHP plant directly by the committee have not generally been successful. A more manageable system is to contract the management out to an entrepreneur or a professional/suitable manager.

Management, operation, and maintenance (MOM) of MMHP plants, especially in the informally-managed sector, have been weak links in the use of MMHP plants to meet the energy needs of rural areas. The management has largely been *ad hoc*, unsystematic, and inadequate. This has led to the following problems.

- Waste of resources: bank loans, subsidies, entrepreneur's/community's time, effort, and money
- Inconvenience and hardship to users: could mean going back to manual processing or travelling further to another mill. In cases where electricity is supplied, it means going back to inferior quality kerosene or resinous wood lighting. In some cases, the bulbs or wiring are damaged.
- A bad name for the technology

Many difficulties of this nature have been reported, and they are largely due to the lack of skill and knowledge on the part of the MMHP plant managers/operators. External intervention and support can improve the situation and lead to better managed and run MMHP plants. The main areas in which improvements can be made are given below.

- Training in management, operation, maintenance, and repair
- Monitoring, assessment, feedback, and improvement
- Technical support and backstopping, viz., stocking of spare parts, technical advice, and information regarding maintenance and repairs

9.2: Various Aspects of Management

In addition to the technical aspects of running an MMHP plant, there are managerial aspects that are just as important for successful operation, as described below.

Load management. Managing the load properly increases the revenue from the MMHP plant, maximises its use, and could lead to lower energy costs for the consumer. The energy produced, and hence the load factor of the MMHP plant, is an easily measured quantity (for electricity). Finding new and useful ways to use the power available and to increase the consumption of the available energy by the existing customers should be a major goal of the MMHP plant management.

At the start of operations, the plant factor of the MMHP plant will be low. Sustained effort is required to increase electricity sales to earn extra revenue for the MMHP plant, thus improving its finances. As there is no 'fuel' cost there is little extra cost in selling as much power as the MMHP can generate. New and imaginative ways of selling energy need to be developed.

For MMHP-operated agro-processing, careful load management can reduce costs and provide improved services. For example, in the slack season, users can be requested to come only at designated times so that the machines run continuously for a few hours rather than having to stop and start as customers arrive. This also makes more efficient use of the operator's time rather than it being wasted in waiting for customers.

Accounting/book-keeping. This is an important but often neglected aspect of MMHP. In Nepal, many of the turbine mills have had difficulties with financial management of the plant due to, among other reasons, lack of proper book-keeping. This has led to mismanagement of the MMHP plant's income, failure to pay back bank loans, and inability to carry out essential repairs due to lack of funds.

Accounts of services provided need to be kept (e.g., grain milled, oil expelled, etc), income, and expenditure. This will assist in financial planning, making loan repayment schedules, and working out how much profit the MMHP plant is making.

Public/customer relations. Good public and customer relations are essential for running an MMHP plant well, especially a privately-owned scheme. An MMHP plant providing electricity is a natural monopoly and a bad public image could lead to non-payment, refusal to take up connections, sabotage, etc. In cases where plants have been erected with partial government subsidies, failure to have good public relations could lead to resentment on the part of consumers; in such cases the public may believe that the entrepreneur is profiteering, taking undue advantage of his monopoly situation, misusing public funds, etc. These views might appear to be irrational, but good public relations will assist greatly in allaying suspicions and getting cooperation from customers.

Elements of good public relations are reliable and prompt service at fair prices and good behaviour. Careful attention to the customers' needs would also be helpful in this respect.

Expansion/improvements. As the load and usage grow and as the equipment and structures begin to wear, investments will have to be made to keep them in good working condition and sometimes even to replace them. This will also need to be planned for and money needs to be set aside for such work.

Reliability of supply. As the consumption of electricity increases and people get used to using electricity, it becomes more and more important to have a reliable supply of electricity from the MMHP plant. Consumers will become less tolerant to interruptions in the supply as they become habituated to and dependent upon a regular electricity supply. Supply reliability is important both in public relations' terms and in terms of income for the MMHP. There have been reports that the consumers were reluctant to pay the bills, because the electricity supply was poor quality or unreliable.

Revenue collection problems. An MMHP plant with low downtime, reasonably priced rates, a reliable supply, and good public relations should have few problems in revenue collection. Labour services in lieu of cash payment of bills is one possibility of getting around the problem of lack of cash resulting in non-payment. This has advantages for the MMHP owner as well in that he has available labour resources in case of emergencies, or at times of labour shortage.

Training/improving management and operating skills. This is an area that has received very little attention, even though its importance is accepted by all. Operators and managers need to be trained properly on different aspects of MMHP such as operation, maintenance, accounting, end uses, how to increase electricity sales, public relations, technology advances, etc. Training should be scheduled in such a way that there is least inconvenience to customers.

Planning for maintenance shutdowns. There should be as few unscheduled shutdowns of the MMHP plant as possible. This requires careful management and planning. Customers should be informed in advance of the shutdown and the period should be chosen so as to cause the least inconvenience to users. The role of planned, preventive maintenance is crucial in reducing downtime as a result of breakdown of machinery. Operators and managers need to be trained in this concept. Replacing equipment and components before they cease to function reduces downtime to a minimum.

Salaries and payment to employees. Salaries made to operators and other employees should be adequate and in line with the going rate for similar work. Inadequate salaries could lead to a high turnover in operators, and this will affect plant operations badly. Employment and payment terms should be clearly understood and accepted by both sides.

9.3: Operation

In operating an MMHP plant, there should be a set of routine procedures for starting, stopping, and load connecting for operators to follow. Weekly, monthly, six-monthly, or annual maintenance schedules must be part of the O&M manual. Standard responses to normal operation and maintenance problems should also be spelled out in the O&M manual. There should be a minimum of situations in which the operators (or the manager) do not know the correct response to a problem. The O&M manual need not necessarily be in book form. For small plants, wall charts with pictures and diagrammes showing the various steps and procedures would be adequate.

9.3.1: Log Book

It is also essential for all MMHP plants to maintain a log book. A correctly filled out log book makes it possible to check how the plant is operating, to analyse problems, and to schedule shutdowns at the least inconvenient time for consumers. Having to fill out a log book and to record all the actions taken or not taken ensure that the required work gets done.

The log book should contain at least the following information. Time, date, voltage, power used by consumers (for ELC), any unusual event, any special action taken in case of breakdown or malfunction, temperatures of machines, and operator's signature.

9.3.2: Safety

The powerhouse should be well lit, clean, and free of clutter. Unauthorised persons should not be permitted to enter the powerhouse. Moving parts, such as belts, pulleys, and fly-wheels, should have guards around them so that they are not easily touched.

The operators must not wear loose clothes and jewellery or have loose long hair that might get caught in the machinery.

9.3.3: Sensing Signs of Malfunction

While operating the machines, operators must always remain alert to any unusual sounds, temperature rises, and other indications of possible malfunction. An early response to malfunctioning could save the plant from more severe damage and, consequently, great expense.

9.3.4: Adopting a Suitable Operating Procedure

The powerhouse equipment is operated according to a procedure given by the manufacturer, and this procedure should be followed by the operators. Routine actions, such as starting, stopping, connecting the load, normal shutdown, and emergency shutdown, should follow set procedures. These procedures need to be practised and followed by the operators.

9.4: Maintenance

9.4.1: Regular Maintenance

MMHP plants that are well maintained have very few or no unplanned shutdowns. The maintenance schedule should be organised so that it causes the least inconvenience to consumers. Good maintenance practices by properly trained and skilled operators reduce downtimes and the need for repairs.

9.4.2: Repair and Maintenance Manuals

All MMHP plants should have an O&M manual also, which can be referred to when needed, containing information on repair and maintenance. The repair and maintenance section must have procedures for dismantling and assembly of the equipment, how to identify components for replacement or repair, and special handling procedures, if any. Provision of the manual should be part of the supply contract with the manufacturer. The manual should have the following information.

Spare parts. List of spare parts with their names, specifications, and where they are available. Recommendations on which spares to keep in stock.
Daily, monthly, and annual maintenance. List of work that is to be carried out at different time intervals and the format for recording the same.
Records to be kept/powerhouse log. List of readings and observations to record and the format.
Trouble shooting guide. The O&M manual must have a trouble shooting guide which deals with common faults, their diagnosis, recommended actions to be taken, and instructions on where and how repair personnel can be contacted.

9.4.3: Regular Maintenance Inspection

A sample portion of a maintenance schedule is given in Table 9.1. below.

Table 9.1: An Indicative Maintenance Schedule for MHP Plants

Maintenance Schedule	All year	Drought	Floods
Weir and intake			
1. Check for boulder damage		monthly	daily
2. Check for leaks, undercutting		monthly	daily
Regulating sluice			
1. Check operation	monthly		
2. Grease screw	monthly		
3. Adjust		as needed	as needed
Settling tank			
1. Grease flushing sluice screw	monthly	monthly	daily
2. Drain and clean			
Channel			
1. Inspect for leaks, overflowing		weekly	daily
2. Drain and clean	every 3 months		
3. Clean culverts		monthly	daily
4. General repairs	annually		
Forebay tank			
1. Clean screen	daily		
2. Grease valves	monthly		
3. Drain and clean		monthly	daily
Penstock			
1. Visual check for flange leaks	monthly		
2. Repaint	every two years		
3. Visual corrosion check	yearly		
4. Inspection of supports	6 monthly		

9.5 Spares, Tools and Consumables

The stock of spares, tools, and consumables to be kept by an MMHP plant depends on its access to materials and technicians, the degree of reliability the plant needs to provide, and the amount of money available. If conditions permit, spare parts' stock for five years of operation should be kept; otherwise, at least one set should be kept.

For those spares that are not kept at the plant, information on who supplies them, how much it will cost, and how to acquire them must be easily available (specifications, address of agents/suppliers, etc).

The MMHP plant must keep a full set of hand tools like spanners, screwdrivers, files, hammers, hand drills, etc. The range of tools to be kept should be carried out in consultation with the manufacturer and he should give a quotation for this along with the equipment. The full list should also be included in the manual.

It is not advisable to keep consumables stocked for more than one year's requirement. A system of regular replenishment is preferable to keeping a large stock, as the chances of spoilage, pilferage, and so on increase with the quantity of stock kept.

Chapter 10
Repair of MMHP Plants

10.1: Background

The ability to carry out major repairs of MMHP plants, especially in remote areas, is severely limited because of the lack of workshop facilities, skilled personnel, and transportation problems. This means that when major repairs are required, the MMHP plant has to rely on workshops in a major city like Kathmandu or Butwal; and these are often at a long distance of some days' walk away, leading to plant shutdown for weeks, even months.

In planning for repairs to an MMHP plant, access to suitable workshops and technicians must be kept in mind. Downtime can be reduced while major repairs are carried out by careful planning and execution.

The benefits of low downtime must be compared to the cost of keeping expensive parts which might need workshop repairs, e.g., turbine runners. Given the low incomes in rural areas, it might well be the case that users prefer lower reliability and lower costs to higher reliability and higher costs. Even so, a planned shutdown is preferable to an unplanned breakdown.

The current situation, in which MMHP plants remain inoperative for long periods due to difficulties in getting quick access to repair facilities, wastes the resources that have been invested in MMHP. It also causes undue hardships to users, since MMHPs save a lot of drudgery, and any breakdown in the MMHP plant means that users have to revert to using manual methods for grain processing or to travelling longer distances.

10.2: Some Suggested Initiatives

10.2.1: Strengthening Existing Workshops in Remote Areas

One option is to support workshops that already exist. DCS has extension offices/workshops in Baitadi and Jumla, in Nepal, to service MMHP plants in these areas. Although useful, these workshops are surviving mainly due to the external support they receive. The number of MMHPs and the amount of work they require do not seem to justify setting up workshops on a commercial basis in remote areas at the moment. As the number of plants increases and the consumers begin to demand (and be willing to pay for) more reliable services, setting up such workshops will become commercially viable. The possibility of seeking out and strengthening some existing private facilities or technicians (a smith's shop, a local mechanic) should also be explored for appropriate locations in remote regions.

10.2.2: Establishing New Workshops

Another option is to establish new workshops in areas that have MMHP plants. "*How many MMHP plants are required before a workshop needs to be set up to service them?*"

is a question for which the answer depends on how much money is available, the relative affluence of the recipients, and what level of service they expect from the MMHP plant. These factors, in turn, depend on the broader political question of what the rest of the country is willing to spend to raise the quality of life of people living in poor, remote areas.

The small, extra amounts required to provide facilities for repair and maintenance of the plants should be considered in terms of the investments in MMHP plants as well, rather than on a very narrow 'feasibility' of establishing a workshop.

In establishing a new workshop, it is best to start small and gradually build up as the demand increases. The staff should be recruited locally and given adequate training in preference to bringing in trained people from outside. However, in the beginning, that might be the only option.

10.2.3: Mobile Workshops

Another alternative is to have a 'mobile workshop' to carry out repair and maintenance work. One such mobile workshop has been established recently in Pakistan by a government agency. A van is fitted out with the necessary tools and equipment and a team of technicians travels from plant to plant carrying out repairs. This kind of service facility is suitable only for areas with a good road network and road access to the plants.

10.2.4: Minimum Equipment/Training Required

Equipment

In addition to the normal hand tools expected in a workshop, there should be a welding machine, a bench drill, a hand grinder, and a cutting tool. A lathing machine would not normally be required.

Training

Wherever possible, the technician should be a local. As the workshop would normally be established in an area that already has a number of MMHP plants, there should be people with a background of technical skills and experience. Short courses at regular intervals to improve or learn new skills, combined with on-the-job training, are preferable to extended training periods.

Chapter 11
Economic Returns and End Uses of MMHP Plants

11.1: Background and Objectives

One of the most serious discrepancies in private MMHP plants has been the very low levels of plant capacity use, resulting in quite low plant factors and incomes. This is in spite of the fact that private plants are reported to be performing better than government-managed plants. The latter, reportedly, are only earning around 20-30 per cent of the recurring expenditure.

For some formal private plants in Nepal, plant factors higher than 40 per cent have been reported. Data are not available for the plant factors of informal private MHP plants in Nepal or Pakistan. However, the range is most likely to be from ten to 30 per cent, as demonstrated in the following examples. An isolated MHP plant generating electricity for about four hours per day, at 80 per cent capacity, for 90 per cent of the days, would result in a power factor of 12 per cent. Similarly, an agro-processing MHP plant using 60 per cent of the rated power on average and operating for 10 hours during the day, for 90 per cent of the days, would have a power factor of 22.5 per cent. Both the above working timings would be considered typical, given the circumstances of mountainous rural areas.

Adequate net incomes or profits are necessary for private MMHP plants, whether they are community-based service systems or commercial enterprises owned by entrepreneurs. Otherwise, the programmes are unlikely to be sustainable and would not be supported in the long run by the owners/beneficiaries or promoters/financiers. Even the supposedly non-profit making plants need net savings to cater for unforseen repairs, upgrading of equipment, expenditure on additional distribution lines, repayment of loans and interest, etc. It is, therefore, important to plan for significant net incomes from the MMHP plants. It is not easy to suggest an indicative figure or range for the net incomes, because of so many different factors affecting different locations, especially economic conditions. However, for a commercial MHP plant, 20 per cent would be the minimum expected return on investment, whereas for a community-owned plant, it may be somewhat lower.

The current situation is that isolated electricity-generating plants are not earning any significant income, many in fact are earning less than the expenditure. However, since they are providing a useful service, i.e., electricity for lighting, they are still coveted, especially in Pakistan. The situation regarding agro-processing units, with or without add-on electricity generators, mostly prevalent in Nepal, is more complex. There are many plants that have been reported to be making adequate money for their owners/investors. However, serious problems have also been cited such as loan non-repayment, plants having been closed down, and so on. The installation rate has also drastically declined. It has also been suggested that people in general were not too keen about installing additional agro-processing plants. Of course, there can be many reasons for this apathy, in addition to the lack of adequate income. Therefore, special efforts are needed to promote the idea of MHP plants to have adequate incomes, in order to ensure public demand as well as sustainability.

11.2 Increasing Capacity Utilisation

The most effective solution to increasing the economic returns from MMHP plants is to increase capacity utilisation. The energy that the plant is capable of producing, but which it is not producing and using, is simply wasted. This is especially true for run-of-the-river type MMHP plants which do not have water storage capacities.

Capacity utilisation can be enhanced in two ways. The first is to increase the existing system of use, e.g., by increasing the sale of electricity to additional houses, shops, hotels, etc, especially during off-peak hours. Similarly, for agro-processing units, the amount of business can be increased through ingenious management techniques, better customer relations, and more dependable services. The key to enhancement in this way is competent management of the plant in all respects. The method needed is proper load management, whereby a number of load units could be connected to the prime-mover to optimise the load and get more work done in a short time period.

Some novel tariff systems have also been tried out in Nepal to promote more uniform use of electricity for longer hours, especially during off-peak hours. The simplest form of tariff is to charge consumers on the basis of the level of power connected to them; e.g., NRs 50/month charged for a 50W connection; NRs 100/month charged for a 100W connection, and so on. The rates could vary for larger power levels. The consumer, then, has the liberty to use this power for as long as it is available. In some cases, more complex tariff systems have been employed, having additional components, including an initial connection fee; an energy-based component, and different rates for domestic, commercial, and industrial connections. Power cut-off devices have been used for such connections to prevent people from drawing power in excess of their allocation. Many such current limiting/cut-off devices are available in the market; some of them cost as little as NRs 250 (US$ 5). In some cases, compound meters have also been used to register the energy consumed in two locations: one for a lower power consumption (say 100W), thus qualifying for a lower tariff, and the second registering energy consumed at higher rates, resulting in higher tariffs; which could be up to three times higher than the former. A typical complex tariff system, which is currently being used by the Salleri Chialsa Plant in Nepal, is reproduced in Table 11.1.

Table 11.1: Tariff System for the Salleri Chialsa Plant (1993)

Level	Connection Fee (NRs)*	Admissible Power (kW)		Fixed Rate (Rs/mth)	Exempted (kWh)	Further (kWh)	Price Per Unit (Rs/mth)	Further (kWh)	Price Per Unit (Rs/mth)
1 Domestic	250	0.1 max		50	all	--	--	--	--
2 Domestic	500	0.5 max		200	all	--	--	--	--
3 Domestic	1000	2.0 max		210	55	65	3	all	1.25
4/1 Service	1500	4.0 max		350	70	90	3	all	1.25
4/2 Service	1500	8.0 max		700	75	95	3	all	1.25
		off peak	**peak**						
5/1 Industries	1500	>10.0	0.1	220	50	all	0.9	--	--
5/2 Industries	1500	>10.0	0.5	300	75	all	0.9	--	--
5/3 Industries	1500	>10.0	2.0	500	120	all	0.9	--	--

* This amount is automatically transformed into company shares

Table 11.2: Compatibility of Some End Uses with Electricity

End Use	Advantages	Drawbacks
1. Cooking, domestic heating	- clean operation - no health hazards - biomass saving	- low voltage devices take longer to cook - very expensive - cooking clashes with peak load
2. Lift irrigation	- clean and appropriate	- expensive - irrigation time same as low water availability
3. Rural industries • paper making • timber processing • agro-produce drying (tobacco, cardamom) • ice-cream making • village workshop (welding, drilling, grinding) • noodle making • bakery • commercial ironing • milk chilling	- utilisation/value-adding of local raw materials - electricity and motive power useable - local employment generation and economic growth	- expensive - limited power capacity and seasonal fluctuations - unreliable supply
4. Battery charging	- extended outreach of electricity	- high investment - problematic transportation
5. Business (tourist lodges, eateries, shops)	- improved atmosphere - enhanced business - utilisation for cooking/heating	- limited power capacity - some contribution to peak load - unreliable supply

11.3: Diversification of End Uses

Many different end uses can be identified and developed to increase the power use from a given plant, especially during the off-peak period, e.g., during the day time. Applications such as agro-processing and wood-working (sawing, turning, planing, etc) are already being practised, either directly coupled to the turbine shaft or, to a lesser extent, through electricity supply. A number of other end uses have also been identified and attempted. Obviously, the end uses that can bring about economic returns are preferable to other non-economic ones such as cooking. Some of these end uses are described in Table 11.2, along with their positive aspects and limitations.

11.4: Other Inputs and Prerequisites

It has become increasingly clear that the advent of electricity alone does not automatically bring about economic benefits to a community. Other considerable inputs are also needed to promote industrial or income-generating activities in a given area. Some localities, such as roadside bazaars or tourist routes, might well require less motivation and inputs to use electricity for commercial activities, such as a refrigerators for beverages, ice-cream making, commercial ironing, etc; but, for other areas, it could be more difficult to adopt other end uses. Adoption of end uses also depends considerably upon the economic status of the people in a given area. The village of Barpak described earlier, for example, is not located on a main road or tourist route. Still, the majority of the community is fairly well off and can afford electricity and host other industrial activities. This points to an unfortunate fact that the poorest of the communities usually do not benefit significantly from such programmes. Here again, in order to ensure that the poor also benefit, at least from electricity for lighting, more inputs are needed, especially additional funding and wisely-developed support methodologies. Funding is needed for awareness-raising/motivation campaigns; for providing loans and subsidies to promote newer devices such as low wattage cooking equipment, equipment for noodle/breadmaking, etc; and also for R & D, field testing, and so on.

11.4.1: Research and Development

It is obvious that only good products and equipment will be successfully promoted and accepted/adopted by the target group. In many cases, a product has to be modified to fit/ suit the local situation. Experience has shown, unfortunately, that technical aspects of product development are not adequately looked after. R & D efforts need to be undertaken within the country to develop or adapt a product. For this purpose, adequate institutional development/strengthening is also necessary.

11.4.2: Tariff Systems

Novel tariff systems have played a significant role in increasing use of plants for longer hours of the day. The tariff systems can be improved further to suit other situations and conditions. The obvious conclusion here is that fixed energy (kWh) based tariffs are not suitable for MHP plants. In designing tariffs, two important aspects must also be kept in mind; i.e., adequate net incomes from the plants and capacity of the people to pay.

11.4.3: Reliability of Supply

This aspect has also been discussed in detail elsewhere in this document. It is necessary to reiterate here that the quality and reliability of electricity supplies from private MHP plants are not adequate at present. To some extent, the same is also true for agro-processing units directly coupled to MHP turbines in Nepal. It is necessary to improve the performance and reliability of these plants through improvement of equipment and installation practices, training of managers and operators, and enhancing economic returns. Adequate emoluments for operators are also a necessary ingredient for successful operation of the plants, so that they have a worthwhile stake in the well-being of the plant.

11.4.4: Customer Relations

Customer relations can be variously defined as good behaviour as well as speedy, reliable, and fair service to customers. This applies to both electricity consumers and clients for agro-processing services. If the service is unreliable and/or the behaviour to customers not good, they will seek other alternatives. It has also been reported, in Nepal, that consumers have not paid electricity bills because supplies were unreliable or of poor quality.

11.4.5: Backstopping and Training

Many cases of deficiency in terms of management have been reported in Nepal. Therefore, a visit from a professional of an implementing agency to monitor the performance of the plant and to provide some advice regarding various management aspects could be a big help to owner-managers. Simultaneously, suitable training programmes for managers and operators would contribute significantly towards improved operations and economic returns.

11.4.6: Repair Facilities

One of the serious problems faced by plant owners is the lack of repair facilities in the vicinity of their plants. They sometimes have to travel for days to reach the original manufacturer to get something repaired; and he may not be sympathetic enough to get the repairs done speedily, since repairs are not big business. One suggestion has been to help establish/strengthen repair workshops in appropriate locations to cater for the needs of these plants and to train local technicians from such workshops in repair practices. Alternatively, manufacturers could set up a service station in such locations to help the owners organise repairs. Generally speaking, the cost/benefit calculations for such establishments, based on financial considerations alone, may not be so favourable. Nevertheless, the need is clearly there, and such workshops will almost certainly lead to sustainability of MHP in remote areas.

Chapter 12
Monitoring, Evaluation and Backstopping

12.1: Introduction

Monitoring is the process of determining the status of certain indicators related to a project after a certain time interval, e.g., quarterly or semi-annually, over a given total time period (e.g., first two years). Decision-makers at various levels need to know the status of a project in order to make speedy and appropriate decisions; monitoring project performances provides them with the necessary data to do so. Monitoring involves assessing the delivery of inputs, intended outputs, and generation of desired effects.

Evaluation means assessing the real situation of a project in question at a given time. It is usually more thorough than monitoring and covers all important aspects of project performance. Evaluation is undertaken some time after project completion; allowing adequate time to sort out the usual post-commissioning problems and to achieve a level of stability. A team of experts is usually engaged from outside the implementing department; although, it may be constituted from a sister organisation of a larger system. The team is usually given a set of objectives and terms of reference for such an evaluation. The main goal is to prepare a set of conclusions and recommendations for the decision-makers who, in turn, can introduce corrective measures in due course.

Backstopping is the process of providing technical, financial, and managerial support to the management of a project. Private technical consultants or other specialist agencies might be in the best position to provide such support in the form of analysis, advice, training, and on-the-job assistance. Financial institutions might also provide financial backstopping. The main objective is to assist managers and operators to improve their capabilities and to enhance their performances, especially on a long-term basis. Backstopping is especially important for projects such as MMHP plants, since the capability levels of managers and operators are usually quite low, and they need such assistance.

12.2: Important Aspects of Monitoring

12.2.1: Technical Aspects

The monitoring process attempts to determine some indicators for the plant such as power output and sale at a given time, as well as total energy generated during a year or other suitable period. This should enable the monitoring team to estimate the daily power factor. It would also be useful to determine the maximum power that the plant is capable of producing without serious noise or vibrations. If the management has kept daily records of operation and power production, yearly power factors can also be worked out. In the case of MHP plants mechanically powering some units such as grinders, hullers, and sawmills, an estimate of peak power as well as cumulative power used during the day can be made. The maximum power that can be produced without serious problems can be determined by connecting different units at the same time. The yearly power factor can also be estimated from the available data. Noting down the voltage, the current, and revolutions per minute is always useful in more ways than one.

An appraisal of the plant performance and related problems can be carried out by checking whether the plant has been well maintained; whether any part is malfunctioning; whether the connecting belts are in proper shape; whether there is any leakage, vibrations, noise coming from any part; and whether the premises are well kept, clean, adequately lighted, and safe. The safety aspect should be given special attention. Some idea of past performance problems can be obtained from the log book (if one is being kept) or from discussions with the managers and operators regarding past breakdowns and stoppages, the components involved, reasons, extent of repairs, improvements introduced, and so on. The length of shutdowns and the various reasons should also be noted and analysed. The main goal should be to find out whether the plant has been performing as a good plant should; or whether there are technical problems and the reasons thereof (equipment quality, installation, inherent/local problems, operation/management capability, etc).

Some capability assessment of the manager and operators is also desirable. They could be asked, for example, about their knowledge regarding functioning of various components, training they have undergone, and the books/records they have been keeping. The level of interest of the owners/managers in the overall well-being of the plant could also be assessed through appropriate questions; for example, what can be done to improve the performance and returns? Another good indication would be the extent to which efforts had been made during a breakdown to bring the plant back into operation, as well as the state of maintenance of the civil works, a relatively uncomplicated job.

12.2.2: Financial Aspects

The primary financial aspect to be ascertained is whether a plant has been earning adequate income to meet its operational costs. Any plant that does not meet this primary requirement cannot be considered viable and would most probably be closed down in due course and not earn a good name for the technology. However, this is also not a sufficient condition. The plant should at least earn enough to cover its routine maintenance/repair costs and save an amount for the future and/or a profit for the entrepreneur/investor. Assessment of the income might not be easy, since it is the usual tendency of owners to understate the revenues. The monitoring team, therefore, needs to be careful about asking questions regarding the overall income of the plants and assessing the answers. It would also be useful if the monitoring team could make on-the-spot assessments of the agro-processing business, for example. However, this would depend upon the time available. In some cases, the income could be from more than one end use; e.g., electricity for domestic lighting, electricity for industry, and agro-processing within the premises. Intelligent queries to more than one source (e.g., the owner/manager, operator, and perhaps even customers) can provide reasonably accurate information in this respect.

Similar information should be gathered concerning the yearly expenditure, including staff salaries, loan repayments, regular maintenance, periodic maintenance, and other consumables such as stationery/postage, lubricating oil, some tools and spares, travel, etc. In addition, a certain percentage of capital costs (2-3%) should also be set aside from the income for major repairs for unforseen breakdowns.

The net income of the plant can then be assessed and analysed to determine whether it was adequate for this given type of plant. A fairly low net income from community-owned MHP plants might be acceptable, whereas entrepreneur-owned plants would be expected to make significant profits.

12.2.3: Social Aspects

It is usually useful to learn about the social status of an MHP plant and the services that it provides to the community. Some reporting from consumers could be helpful in this respect. For example, consumers might report that some level of cheating is going on during agro-processing, or that the behaviour of the manager/operators is not appropriate, and so on. In the case of electricity-only plants, the enquiries should reveal whether supplies are reliable and of good quality. If the consumers are not happy with the quality of the services being provided, then they might not have goodwill towards the plant, they might take their business elsewhere, or they might end up causing damage, e.g., to the power channel, even inadvertently. Therefore, social acceptance and the goodwill of the people from surrounding communities are also necessary for success of MHP plants, and these need to be assessed. An informal chat with the operators might also reveal their feelings about the plant and the management. For example, have they been paid and treated well? have they been reasonably happy? or are they planning to leave their current employment? and so on.

Similar discussions with the owner might also reveal some aspects of the success and satisfaction with the outputs of the plant. For example, had any efforts been made to persuade other people to take more electricity connections? or what were the reasons for people not being able to have electricity connections? Is he/she thinking of doing something in this respect? What efforts is he/she making to overcome some of the problems (e.g., landslides disrupting the water supply)? Is he/she also planning to install other processing equipment (say a sawmill, a rice beater, etc)? Such discussions would indicate the level of happiness and enthusiasm of the owner with the plant.

Enquiries about social conflicts beyond the control of the owner could also produce useful information. For example, conflicts between communities, castes, or even sociopolitical groups might prevent one group or the other from using the services of the plant. Such conflicts could affect the water supply to the plant also.

Monitoring privately-managed plants is very important in order to judge the level of success of a scheme or indeed a project or programme. It is suggested that plants should be monitored at least once but, more appropriately, twice or even more times. One suggestion made during an international meeting was to monitor the plant about three to six months after commissioning for the first time, and later about one year after the first monitoring. Monitoring frequency and overall methodology are not prevalent anywhere in the region, and a final more appropriate system would have to be formulated in due course through experience.

12.3: Evaluation of MHP Plants

Evaluation of MMHP plants installed under a given project/programme can be ordered and directed by sponsoring/financing agencies under stringent terms, in order to provide answers to specific questions related to, e.g., success/failure of the project/programme, impact on the target group, environmental consequences, and so on. Therefore, evaluation is a more thorough and wide-ranging process than monitoring, whereby the target group, people from the surrounding areas, even other agencies, could be asked about various aspects and consequences of the project. A more thorough economic analysis of the impacts/benefits could also be undertaken after quantifying them.

Evaluation would usually involve all the steps described in Section 12.2 concerning monitoring, which could be measured/assessed more thoroughly and accurately. For example, flow and head could be measured to determine the actual power potential against the (maximum) power being generated. Similarly, the cost of energy production could be computed and compared with the tariff being charged. However, more emphasis is usually placed on thorough evaluation of the economic and social impacts, negative as well as positive; cost-benefit analysis; and adequate assessment of the environmental consequences. For example, how much kerosene combustion has been replaced by electric lights? It is not possible, however, to quantify some of the benefits; for example, how can one quantify the benefits of better lighting from electricity rather than from kerosene lamps? The economic benefits, such as the number of micro-enterprises (shops, industries, etc) established, the number of new jobs created, the quantity of additional local produce being marketed, and so on, should also be worked out under the economic benefits. Again, it is not a straightforward task to place a value on the level of reduced drudgery for women who no longer have to process agro-produce manually and, instead, are using MHP-powered mills.

Evaluation is usually a one-time affair and not a regular process. It is also more time-consuming and expensive. Therefore, it may be not so cost effective for the smaller, private MMHP plants in the HKH Region. However, if proper monitoring of such plants is not taking place, then it may be necessary to undertake evaluation of a number of plants at an appropriate time. Evaluation can be more suitable for larger (and more expensive) MMHP projects, since the process itself is also more expensive, and complicated. Also, large manuals on the subject can usually be found. Therefore, further details on this subject are not considered necessary here.

12.4: Backstopping

Backstopping is a fluid subject that is not easy to define or justify purely on economic grounds. In the past, one or more full-time experts were assigned to Nepal to advise and train plant managers and operators in various techniques, tariff designs, billing, and promotion of more connections. In the case of the Salleri Chialsa Plant, a separate project called the 'Salleri Electricity Utilisation Project' (SELUP) was established to increase the use of electricity for other end uses, including cooking. It is generally agreed that a certain minimum level of support for a newly-established plant, especially in remote and inaccessible mountain areas, is very necessary to develop the skills and managerial capacities of the staff adequately. Initially, training on the names, functions, and operations of the different parts, what could go wrong, and how to prevent it would be useful. Additionally, training about assembly/disassembly could be provided, followed by training in various aspects of inspection, maintenance, and book-keeping, along with basic trouble-shooting.

Subsequently, after a few months of operation, another backstopping mission could be sent to see whether the operators and managers were doing a good job or whether they needed further assistance/advice and training. This would be a beneficial input since the managers and operators, by then, would have found out what they could do reasonably well and where they needed further assistance. They, almost certainly, would have a lot of questions by this time, and these could be answered and explained. It would also be necessary to develop a training/backstopping manual for this purpose, mainly for the trainers, covering all aspects, including the social and economic ones.

It would be more cost-effective if the monitoring and backstopping visits were combined to cut the costs, assess the problems, and provide assistance on the spot. However, in order to achieve tangible results in this respect the assisting personnel should be adequately trained, not only in the technical aspects but also in social subjects and public relations. At the same time, the owners have to be made clearly aware about the limitations of such services and their own responsibilities. This would help to curtail excessive expectations or a tendency on the part of recipients to think that everything will be sorted out by the backstopping team.

12.5: Institutional Arrangements

Having prescribed additional workloads and financial expenditure, the important questions that need to be dealt with are who should provide funding? and who should organise and carry out the monitoring and backstopping services? (as mentioned earlier, evaluation may not be necessary for private MHP plants, unless specifically ordered by, e.g., donor/financiers).

Regarding funding, the obvious answer is that it should be set aside by the main agency that funded the project in the first place; e.g., the Water and Energy Commission Secretariat (Nepal) and the Ministry of Science and Technology (Pakistan). With regard to implementation, a specialised government or private agency having adequate expertise in this field would be most appropriate. Usually, the installer/contractors are not in charge of this endeavour; although one of their experts may be included in the team to provide information regarding the various technical details and characteristics of different parts.

Chapter 13
Training Needs Priorities and Methodology

13.1: The Importance and Implications of Training

For any new endeavour, especially concerning the introduction of a new technology to an underdeveloped and remote rural area, training is perhaps the most important intervention. Even for simple devices, such as improved cooking stoves, some level of user training has been found to be quite beneficial for achieving optimal results. In the case of MHP plants, training of various related groups; especially managers/operators, has been cited as an important input for their success. Many past studies and reports in Nepal and Pakistan have also pointed out the need for adequate training programmes for different groups.

Some activities have been undertaken, in this instance for participants from the HKH Region, during the past few years. ITDG, in collaboration with other international/ regional agencies, has organised about half a dozen such training programmes for manufacturers, implementers, engineers, and planners lasting for a month or more in different countries such as Switzerland, Sri Lanka, Nepal, and, more recently, The Philippines. Similar training is also organised by the Hangzhou Regional Centre (Asia and Pacific) for Small Hydropower (HRC-SHP) every year, lasting for two months, in Hangzhou, China. The scope of this programme, however, is mostly for small plants (ranging up to 10MW in capacity).

Training programmes have also been organised for operators and owners in Nepal by the manufacturers, particularly the BYS in Kathmandu and the DCS/BEW in Butwal; these are usually funded by other donor agencies. These training programmes, however, are not held on a regular basis and have certainly not covered the needs of all the plants and their employees. Some training is also provided to operators during the commissioning phase of MHP installation. This is reported to be happening in both Nepal and Pakistan. This training is imparted by the installing agencies (PCAT/AKRSP in Pakistan and manufacturers in Nepal). However, the usual perception is that such training is not adequate. Evaluation has not been attempted so far. Training for managers, installers, surveyors, and so on is not usually available.

There can be no doubt that training for different groups is necessary and must be undertaken regularly through a suitable institutional system. However, the requisite regular funding and institutional arrangements have not materialised as yet. The costs versus benefits' issues have also not been fully examined or appreciated. Let us assume that about 100 MHP plants are to be installed per year in Nepal, costing about Rs 100 million. HMG/Nepal spends around Rs 20 million on subsidies and another 60 million on loans per year (at the prevalent rates). The cost of training for about five surveyors/assessors, five installers, and about 200 managers/operators would be around Rs five million (6.25% of government expenditure). This additional money, coming either from the government system or donors, would be well spent, since it would contribute towards decreasing breakdowns and failure rates and towards increasing economic returns. This, in turn, would not only improve the success and impact of the plants, it would also alleviate the loan non-repayment situation for the lending agency. Thus, this additional expenditure would almost certainly bring greater returns/rewards. Some training programmes might be more cost effective if organised on a regional basis.

13.2: Training Needs

A number of different groups, needing significant levels of training, has been identified through many studies completed in Nepal and Pakistan, including studies sponsored by ICIMOD. These various groups, principally associated with private, informally-managed MHP plants, and their training needs are described below.

a) Decision-makers from government departments or donor organisations, including planners, financiers, energy administrators, etc, need to be made aware and convinced of the usefulness and viability of MMHP for remote, isolated, inaccessible, and scattered populations in mountain areas. They should also be made aware of various options in technology, funding systems, and methodology of implementation, as well as the advantages/limitations thereof.

b) Communities and their leaders should be informed about the benefits and limitations of MMHP installations, plus their responsibilities and actions desired in this respect. Additionally, some basic information should also be provided to consumers regarding other end uses such as cottage industries, irrigation, cooking and heating, and so on.

c) Surveyors and assessors of the potential and available power from a given site should be trained in the techniques of flow and head measurement and location and layout of various civil works and equipment; e.g., intake, power channel, forebay, penstock, powerhouse, turbine, tailrace, and so on. In this respect, surveyors/designers have also to cater for geological constraints, floods, landslides, and other such eventualities.

d) Technical personnel with a strong civil engineering background should be trained in the design, construction, and supervision of civil works.

e) Mechanical engineers from relevant agencies should be trained in design/selection of electrical/mechanical equipment such as penstocks, valves, turbines, governing/ control systems, coupling/transmission, generators, instrumentation, supply panels/switches, etc.

f) Manufacturing personnel need to be trained in appropriate methods for manufacturing various components, as well as quality control and dimensional accuracy.

g) Engineers/technicians should be trained in installation procedures for testing equipment and performance during the commissioning phase. The concerned engineers should also be trained in design and construction of transmission and distribution systems, including transformers if required.

h) Owners/managers should be trained in various aspects of plant operation, including load management; following operational procedures, including speed/frequency maintenance; watching out for signs of malfunction (noise, power loss, vibrations, overheating); book-keeping; organisation and scheduling of maintenance and repairs; public relations; and so on.

i) Operators should be trained in operation and maintenance procedures.

j) Mechanics/technicians (e.g., from nearby workshops) should be trained in various aspects of plant machinery, its functioning, assembly, and so on, so that they can undertake repairs easily. They should also be trained in the appropriate repair procedures.

k) In addition, personnel from appropriate institutions should be trained in assessment of plant performance, economic as well as technical; especially technical performance, including power output, operational problems, etc.

Some training needs are already being met through courses being organised by ITDG and HRC-SHP; i.e., those described in 'c', 'd', and 'e' above. However, most other needs are not being catered to at present. The situation is more serious in Pakistan than in Nepal; but it is far from satisfactory even in Nepal.

13.3: Priority Areas for Training

Some training needs are obviously more crucial than others, and the extent/depth would have to be decided accordingly. Since resources are also usually limited, training needs have to be prioritised in some way. Considering a number of factors, such as the relative necessity and current availability of some training programmes in the HKH Region, indicated in various studies/reports, the following priorities are suggested. The letters in parentheses refer to the groups described in section 13.2 above.

Plant managers (h)

Plant operators (i)

Installers (g)

Surveyors/layout designers (c)

Prospective repair personnel from nearby areas (j)

13.4: Training Methodology and Materials

The first prerequisite for training programmes is the existence of appropriate institutions to undertake organisation of such training programmes on a regular basis and with a desired level of competence and devotion. Such an agency would also have to mobilise assistance, including funding and other inputs. It is not necessary for all the requisite ingredients to be present under one roof (e.g., equipment, instruments, and faculty). Whereas it would be necessary to have most of the hardware available, the faculty could come from the outside, e.g., manufacturers, NGOs, etc.

Some basic equipment and instruments would be needed to train managers, operators, and repair personnel. The plant rig could be a real-life or simulated one to demonstrate how the system works. In addition, sub-assemblies of other components, such as runner and casing, bearing housing, load controller, etc, would be needed. Similarly, some instruments would be needed, e.g., for power measurement, flow measurement, and vibration measurement. The training materials, especially the technical manuals, could be prepared for and provided to the trainees in a simple written form with adequate illustrations and explanations. To some extent, the trainers have also to be trained, at least initially.

The training (of the managers/operators, say) should have two or three components; in a central institution dealing with theory and basics, through visits to some well-run plants and, finally, at a site where a new plant is being installed and commissioned. The last training aspect would be the most crucial. More detailed training programmes have to be prepared by experts in the field.

Bibliography

The following documents have been suggested by the contributors to this document as additional reference material. This list, however, is not complete and only the most important documents have been included. Most of the data presented in Chapter 2 and elsewhere have come from country reports or papers prepared for ICIMOD.

Aitken, J.M.; Cromwell, G.; and Wishart, G., 1991. *Mini- and Micro-hydropower in Nepal*, ICIMOD Occasional Paper No. 16. Kathmandu: ICIMOD.

East Consult, 1990. 'Socio-economic Evaluation of Micro-hydro Schemes on Rural Communities of Nepal'. Prepared for ITDG, Kathmandu, Nepal.

Edwards, A.; Brown, A., 1991. *The Role of International Agencies in Promoting Sustainable Micro- and Mini-Hydro Activity in Developing Countries.* Proceedings of the ESHA Conference, Nice, France: European Small Hydropower Association (ESHA)

Harvey, A.H.; Brown, A.; Hettiarachi, P.; and Inversin A.R., 1993. *'Micro-Hydro Design Manual'*. U.K.: Intermediate Technology Development Group.

Hveding, V., 1992. *Hydropower Development in Norway*. Hydropower Development Series, Vol. I. Norway: Norwegian Institute of Technology (NTH), the University of Trondheim.

ICIMOD, 1994. *Mini- and Micro-hydropower for Mountain Development in the HKH Region: Report of the International Experts' Consultative Meeting.* Kathmandu, Nepal: ICIMOD.

Inversin, A.R., 1994. *New Designs for Rural Electrification: Private-Sector Experiences in Nepal.* U.S.A.: National Rural Electric Supply Cooperative Association.

Junejo, A.A. (Ed), 1995. *The Orientation-cum-Training Programme on Mini- and Micro-Hydropower Development in the HKH Region*. Kathmandu, Nepal: ICIMOD.

Junejo, A.A., 1994. Mini- and Micro-Hydropower Development in the Hindu Kush-Himalayan Region - Status, Prospects and Problems (unpublished). Kathmandu, Nepal: ICIMOD.

Nafziger, D.L., 1994. 'A Synopsis of Domestic-Sector Impacts at the Andhikhola Hydel and Rural Electrification Project and Their Implication for Future Butwal Power Company Rural Electrification Planning'. A Butwal Power Company Report (unpublished), Kathmandu, Nepal.

WECS/UNDP, 1994. *A Study on Improvement of Economic Viability of Micro Hydropower Plants*'. Kathmandu, Nepal: Water and Energy Commission Secretariat.

WECS; 1988: *Report of the Task Force on Rural Electrification Impacts in Nepal* Report No. 4/4/220688/1/1, seq 308. Kathmandu, Nepal: Water and Energy Commission Secretariat.