Energy Resources and the Role of Mini and Micro Hydro Power in Northern India

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Abstract

This thesis contends that development of mini and micro hydro power (MHP) resources can be both effective and beneficial for the development of Northern India. Fuelwood is the main energy source used in rural areas of the Indian Himalayan region. However, the increasing demand for forestry resources has resulted in the decline of the forest cover and caused environmental degradation of the region. In addition, as the rural system is brought into the wider market economy there is need to diversify economic activities in the region, which will further increase demand for energy. A substitute energy source is required to meet the increasing rural requirements. Commercial energy supplies to the remote hill areas have been inadequate and unreliable, therefore there has been growing interest in utilising decentralised renewable energy sources, of which MHP is one of the most mature and flexible.

Much of the data for this study was collected during a year long study trip to India, based at the University of Roorkee in the north of Uttar Pradesh. In this thesis the development of MHP is considered in the wider context of Himalayan rural development planning and the overall energy sector in India. The experience of implementing MHP as a decentralised power source in India is also compared to the achievements in other Asian countries. An assessment has been made of the present infrastructure for MHP development and field research is reported and analysed from MHP projects in the hill region of Uttar Pradesh.

The main aims of the study were to investigate the need for and the viability of MHP in the North of India. It has been concluded that there is a perceived need for an alternative power source in the Himalayan region of India, both to reinforce the rural grid supply and, more significantly, to serve remote, isolated communities. However, the case study projects and supporting examples of MHP in North India indicate clearly that MHP projects have achieved very limited success, and in many incidents have failed completely. It is asserted here that under the present procedures and policies in India MHP projects will never be sustainable or economically viable in the Himalayan region.

Recommendations are made for improving the prospects of success of future MHP projects. These include the need for innovative and standardised design for MHP projects, to reduce project costs and to adapt to the Himalayan conditions. Also, the establishment of a decentralised rural infrastructure for maintaining and repairing MHP projects is essential to sustain development. It is emphasised that there is a requirement to define clearly the role of MHP projects within rural electrification and hill development objectives. Therefore, it is concluded that in order to develop MHP and rural electrification as a tool for achieving wider developmental goals there should be greater co-operation and co-ordination with rural development organisations and local community groups in the Himalayan region. Proposals are put forward in the thesis for the restructuring of the MHP development approach in Northern India, with more focused development objectives.

Declaration of Originality

I hereby declare that this thesis is based on my own research work and has been composed by myself.

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DEDICATION

This work is dedicated to my family with love.

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Abbreviations and Acronyms

AC	alternating current
AHEC	Alternate Hydro Energy Centre
ANERT	Agency for Non-conventional Energy and Rural Technology (Kerala)
ASTRA	Application of Science and Technology to Rural Areas (IISc)
ATDO	Appropriate Technology Development Organisation (Pakistan)
AVR	automatic voltage regulator
BDO	block development officer
BJP	Bharatiya Janata Party
CASE	Commission for Additional Sources of Energy
CEA	Central Electricity Authority
DC	direct current
DNES	Department of Non-conventional Energy Sources
DPR	detailed project report
DST	Department of Science and Technology
ELC	electronic load controller
ESCAP	Economic and Social Commission for Asia and the Pacific
ESMAP	Energy Sector Management Assistance Programme
FAO	Food and Agriculture Organisation (United Nations)
GDP	gross domestic product
GEF	Global Environment Facility
GTZ	Deutsche Gesellschaft fur Technische Zusammenarbeit (Germany)
HESCO	Himalayan Environmental Studies and conservation Organisation
HPSEB	Himachal Pradesh State Electricity Board
IISc	Indian Institute of Science
IRDP	Integrated Rural Development Programme
IREDA	Indian Renewable Energy Development Agency

ITDG	Intermediate Technology Development Group (United Kingdom)
kgOE	kilogrammes of oil equivalent
km	kilometre
kW	kilowatt
LF	load factor
LPG	liquified petroleum gas
MHP	Mini and micro hydro power (sites up to 1 Megawatt)
MoNES	Ministry of Non-conventional Energy Sources
MTOE	million tonnes of oil equivalent
MW	megawatt
NEA	Nepali Electricity Authority
NGO	Non-governmental Organisation
NHPC	National Hydro Power Corporation
NPBD	National Project on Biogas Development
NPIC	National Programme on Improved Chulhas
NRSE	new and renewable sources of energy
NTPC	National Thermal Power Corporation
OPGC	Orissa Power Generating Corporation
PCAT	Pakistan Council for Appropriate Technology
PLF	plant load factor
RE	rural electrification
REC	Rural Electrification Corporation
RETAIN	Rural Energy Technology Assessment and Innovation Network
SC/ST	scheduled caste/scheduled tribe
SEB	State Electricity Board
SILK	Steel Industrials Kerala

SKAT	Swiss Centre for Development Co-operation in Technology and Management (Switzerland)
SPV	solar photovoltaic
SSI	small scale industry
U.P.MHPCorp	Uttar Pradesh Mini hydro Power Corporation
U.P.NEDA	Uttar Pradesh Non-conventional Energy Development Agency
U.P.SEB	Uttar Pradesh State Electricity Board
USAID	U.S. Agency for International Development

Note on Currency

Exchange rate (1992)

30 Indian Rupee (Rs.) = U.S.$1

45 Indian Rupees(Rs.) = U.K. £1

Costs quoted in the text are generally given in the currency used in the original reference.

Referencing Note

All references from written material, except letters, are referenced in the text by the author's last name and the year of publication within square parentheses, eg [Das,1992]. The references are listed at the back of the thesis.

All personal communications, by private meeting or letter, are referred to in the text using the prefix pc and the contact's last name, eg [pc:Bist]. A list of the personal contacts referred to in the text can be found after the reference section.

CHAPTER 1

INTRODUCTION

The thesis presented here is that mini and micro hydro power (MHP) can be both an effective and a beneficial energy source which can be utilised to promote development in North India. To argue this it is required to propose a feasible and effective strategy for designing, implementing and sustaining MHP projects in the Indian Himalayan region; and also to show the extent to which MHP is able to meet the energy needs of the rural people. Implementation of MHP projects is necessarily placed in the context of contemporary Indian development priorities and considered as an integral component of national energy planning. Particular emphasis is placed on the constraints and possibilities of implementation in the Himalayan setting.

In this chapter the rationale behind the study is explained by reviewing the hydro potential in North India, the energy needs of the rural poor and the environmental concerns in the Indian Himalayan region. The research approach is then described and the study objectives presented. The topics introduced here are expanded in later chapters.

1.1. Rationale behind the study

1.1.1. Historical perspective

The idea of the water turbine is not a modern concept. The energy in flowing water has been harnessed for hundreds of years in various parts of the World as motive power for many purposes. Photograph 1.1 shows an example of the primitive "atta chakkis" or water driven flour mills, which are still widely used across the Himalayas.

During the industrial revolution of the late nineteenth century turbine designs evolved and capacities were increased to match the technological advances and growing demand for power. In 1882 in the USA, a water turbine was connected to an electric generator for the first time [Das,1992]. Small hydro power became popular in Europe and the USA at the turn of the century. At this time the British took the technology to the Indian subcontinent to supply power to the colonial tea

Photograph 1.1 "Atta Chakki" - mill stone and wooden turbine

estates and hill stations. The first plant in India was a 130kW unit installed in Darjeeling, commissioned in 1897. By 1902 a larger scale plant of 4200kW had been installed in Mysore. As national and regional electricity grids grew, economies of scale were promoted and small hydro was gradually superseded by what is now termed "conventional" or large hydro power and by large thermal power plants. During the 1960s and 1970s MHP projects continued to be developed in India in an ad hoc manner, most notably in Uttar Pradesh and Arunachal Pradesh, as an initial step towards electrifying selected hill areas.

In the last few decades, with the realisation of the finite nature of fossil fuels and an increased environmental awareness, small scale hydro power is now generally being reconsidered for development as a mature renewable energy technology. In some developed countries, such as the United Kingdom and Denmark, where the electricity grids now give full coverage, small hydro power development is being encouraged by utilities offering private investors higher rates for electricity produced from renewable sources [Goldsmith, 1992]. Some less developed countries are considering small hydro power projects as an option for improving and augmenting supply to remote areas. India has also realised the potential for MHP exploitation across the country and has plans for widespread MHP development.

1.1.2. Indian hydro resources

Water Availability

The monsoon climate in India results in an uneven availability of water throughout the year, with floods during the monsoon rains and drought in some areas during the dry season. Water storage is vitally important under these conditions. During the dry season the Himalayan rivers are fed by snow or glacier melt so that there is natural storage providing perennial flow and therefore artificial means of storage are less essential. Monsoon floods can cause serious land slides on the steep hill slopes, endangering civil works such as roads, irrigation channels and buildings.

Hydro Power Potential of River Basins

In India there is an estimated hydro power potential of over 84000MW (at 60% load factor), of which only around 14% has already been developed [CWC, 1992]. Figure 1.1 shows the hydro potential of the main river basins of India, three of which run from the Himalayan Mountains to the plains - the Indus, the Ganga and the Brahmaputra. This figure indicates the great undeveloped potential in the Himalayan regions, particularly in the Brahmaputra basin in the North East.

MHP Potential

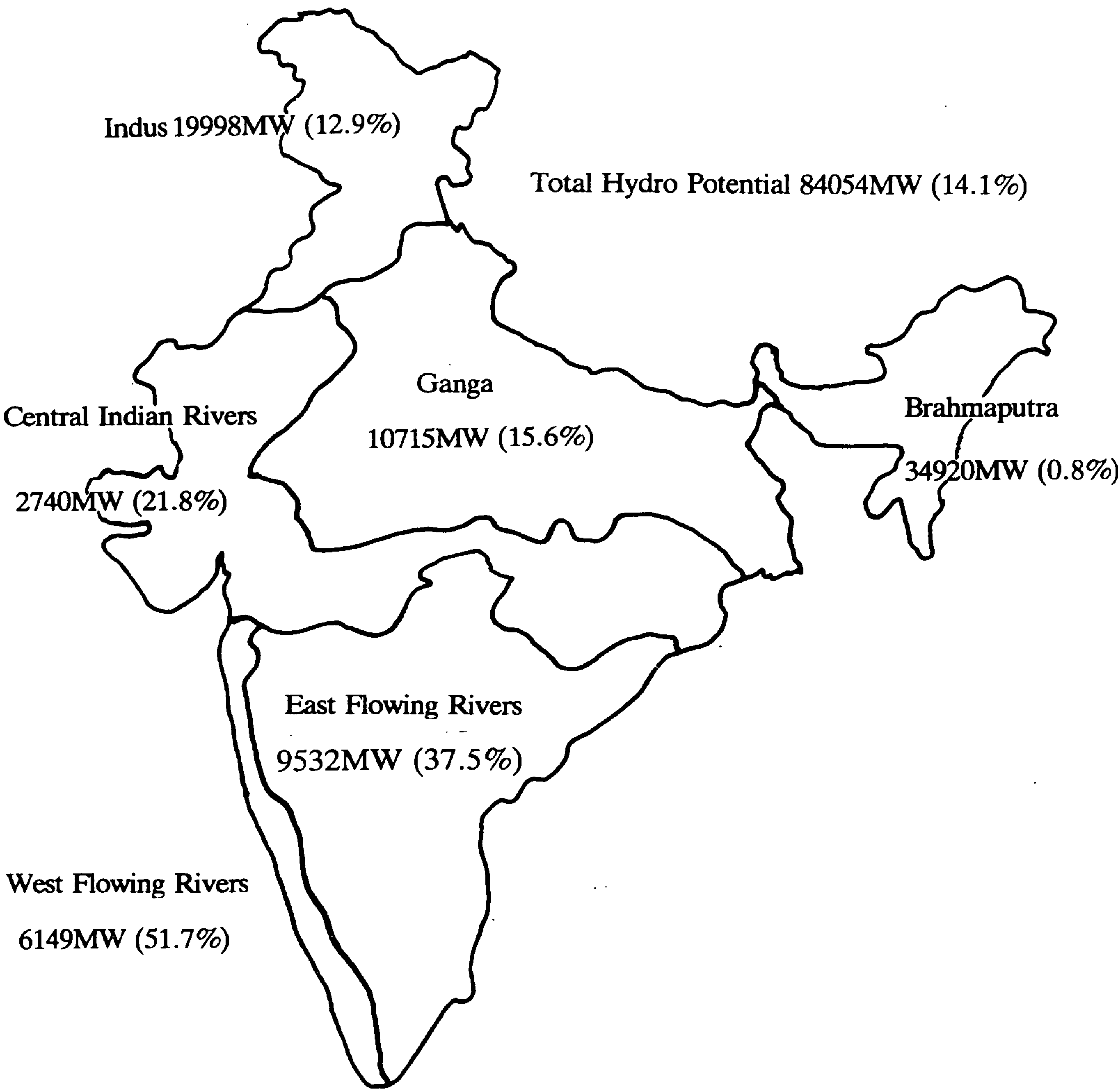
The small hydro potential (for sites up to 5MW) in India is generally quoted as around 5000MW. The Himalayan regions' share is roughly 2000MW. Only about 120 sites of capacity up to 3MW (aggregate capacity of 75MW), are in operation in India. The majority of these schemes are located in Himalayan regions, in particular in the Uttar Pradesh hill districts and Arunachal Pradesh [MoNES, 1992]. Most Himalayan villages are located next to fast moving streams for access to drinking water and irrigation [Sharma, 1991]. In the steep Himalayan hills there are many water falls with potential for development of medium or high head MHP which could provide a valuable source of power to the villages. The Indian government has already identified possible MHP project sites in the Himalayan region with a combined exploitable capacity of 150MW [MoNES, 1992].

1.1.3. Rural energy needs

Figure 1.2 shows the Himalayan states of India and the bordering Himalayan countries. To the South lies the vast Indian Deccan plain. The Himalayan mountains of India are home to over 43 million people [Sharma, 1991], most of whom live by subsistence farming. To provide basic needs for the rapidly growing population in the fragile Himalayan environment requires careful and effective use of local resources.

This section introduces the problems faced by the people living in the Himalayan Region of India, and in particular the dilemma of access to energy resources. Many of the issues raised here are elaborated in chapters 3 and 4.

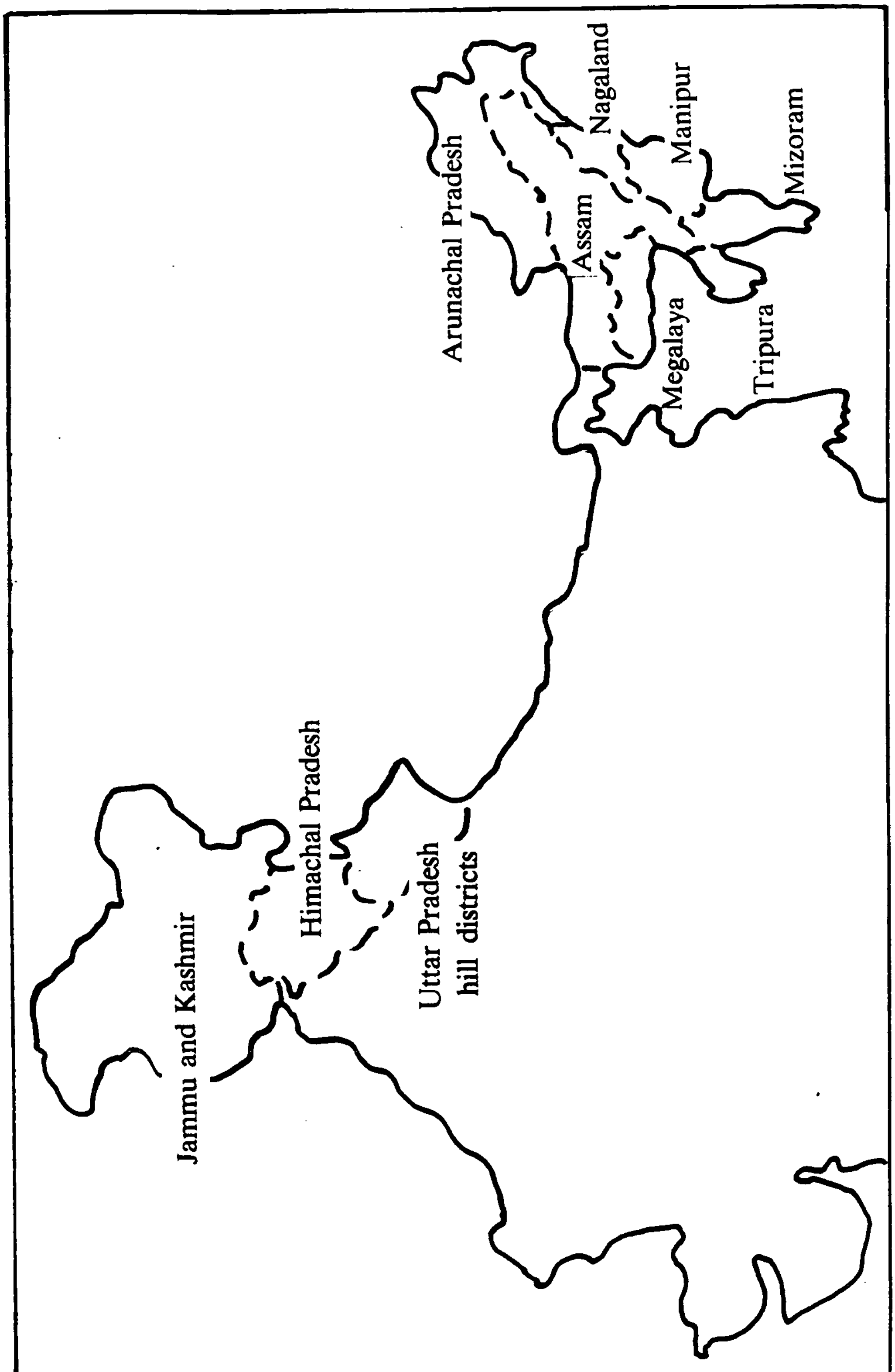
Figure 1.1 Hydro Power Potential of India's Main River Basin



Number in brackets indicates the percentage of hydro potential developed.

Source: Government of India Central Water Commission, "Water Resources and Hydro Power Development in India", New Delhi, 1992.

Figure 1.2 The Himalayan States of India



Socio-economic Conditions of Rural Himalayan People

With the population growth in the Himalayan states significantly higher than the national average, coupled with much un-planned development in the region, pressure on the land and natural resources of the area is constantly increasing. The Indian Eighth Five Year Plan admits that

> *"Poverty in the hills is directly related to shortages of materials for basic subsistence, specially where, under the traditional land and water management systems, the capacity of land to support the population has already been exceeded.*"[GoI, 1992, p.426]

In the Uttar Pradesh hill districts around 77% of the employment and 61% of income is from the agricultural sector [Pande, 1987]. Manufacturing contributes only 4.5% of employment and 3.7% of income [Papola, 1984]. Non-agricultural income is generally from services, labouring, small businesses [Shah, 1983] and money sent from relatives living on the plains. A greater problem than un-employment in the hills is that of under-employment, which stands at between 40% and 50% [Khanka, 1983; Papola, 1984]. As a result, out-migration of young men to the plains is very common. The combined effects of the poverty, inefficient utilisation of resources, rural-urban migration and under-employment in rural hill areas indicates the need for modernisation and alternative employment opportunities in the Indian Himalayan region.

Unfortunately, it is difficult to apply modern farming techniques in most Himalayan regions. Farms are mostly small and fragmented, the terrain is un-suited to cultivation by modern machinery, and lift irrigation can only be of use in areas near to rivers and where there is a small elevation between fields [Sharma, 1991]. It may be possible to diversify the agricultural sector, for example to horticulture and fruit growing [Papola]. In fact Himachal Pradesh has become famous in recent years for apple growing.

Establishing mineral mining and small decentralised industries are seen as other options for development, and the expansion of the tourist trade and related infrastructural developments will bring increased employment and economic opportunities. However, these activities can have adverse environmental impact and will put further pressure on already strained local resources. Careful planning of development will be required [Dhar, 1991b; Papola, 1984]. Development in the hills will inevitably result in an increased demand for energy so that energy planning in the hills will have to take account of demand.

Energy Utilisation Patterns

In the hill areas, fuelwood collected by hand, mainly by women and children, contributes up to 99% of household fuel consumption. This contrasts with energy usage in some areas on the Indian plains where the fuelwood share is only around 36% and dung cake is the main fuel source. The domestic sector accounts for one half the total energy consumption in India as a whole, but for 90% of consumption in hilly areas [TERI, 1991]. A breakdown of domestic end use of fuel in villages in two hill districts of Uttar Pradesh is given in fig 1.3, taken from an energy study of selected villages in the Garhwal region.

Figure 1.3 Breakdown of domestic fuel use in two Himalayan Districts

Domestic Fuel Use	Pauri District	Chamoli District
Cooking/Water Heating	91-97%	88-94%
Space Heating	1-5%	5-11%
Lighting	1-4%	0-1%

Source: TERI, 1991

Kerosene is predominantly used for lighting, the level of consumption of which increases with household income. In areas where access to fuelwood is poor or in villages near to towns, kerosene is occasionally also used for cooking [TERI,1991]. When electricity is made available it is usually preferred for lighting in households who can afford to take connection. For many, though, electricity is not an economically viable option. At the end of the Seventh Five Year Plan period 81% of villages in India were electrified, but only about 27% of households were connected [GoI,1992]. The level of rural electrification (RE) in many Himalayan states is far less than this, especially in the most remote regions.

Energy for agriculture, industry and transport in the hills is almost totally animated, that is by human or animal power [Pande, 1987]. The human drudgery of activities such as carrying fodder and water, preparing and harvesting crops and processing agricultural produce is a common feature of daily life.

Fuel Supply options

With the reduction in forest cover in the Himalayas and the resultant repercussions on the environment (considered in the next section), alternative fuel supply options have to be assessed. Use of more efficient cooking stoves will help reduce the overall amount of fuelwood required per household and new plantations will augment supply. However, substitution or supplementing of traditional with commercial fuel will inevitably be required to reduce the pressure on forest resources as the rural population rises [Khoshoo, 1987; TERI, 1991].

Currently reliability of supply and access to kerosene, cooking gas, coal and electricity in the remote areas is very poor [Dhar, 1991a, 1987]. Transportation of commercial fuels to remote parts of hill areas can be costly and difficult. Cooking gas (LPG) is only a realistic option for villages near to towns or at the road side. Electricity supplies to remote areas are prone to voltage fluctuations and power cuts due to the over extension of transmission line and insufficient power capacity to meet peak demand. Where decentralised diesel generators are in use, the fuel supply problems remain. Even if adequate supplies of commercial fuels are available, the high price of fuels can be a deterrent to wide spread substitution of traditional fuels. Fuelwood is effectively free of charge, therefore incentives will be required to encourage conversion to commercial fuels.

An alternative solution is the use of renewable sources of energy, which are exploitable at decentralised locations, with little or no environmental impact. New and renewable sources of energy (NRSEs)†, including biomass, wind power, solar power and mini-and micro-hydro power, are abundant throughout the Himalayan region. Recently, as a result of the pressures and constraints on other fuel sources, greater emphasis has been placed on utilising these resources [GoI, 1992]. Renewable energy options are discussed in detail in chapter 4. Of the NRSE technologies, small scale hydro power has the longest history of utilisation in the Himalayas and mini hydro technology is at a mature stage. As such MHP would appear to be one of the most viable alternative energy sources for development in the hills in the immediate future.

† New and renewable sources of energy cover the range of "alternative" energy sources under the auspices of the Indian Department of Non-conventional Energy Sources, as described in the DNES Annual Report 1991/92. This includes biogas, wind, solar, photo-voltaic and mini-hydro (up to 3MW). The acronym NRSE is used as an adjective in some cases, such as "NRSE technologies" meaning technologies used to exploit NRSEs.

1.1.4. Environmental factors

As the youngest mountain range in the World, the Himalayas have a continually evolving and vulnerable environment [Ives, 1985; Dhar, 1991a]. Human activities - settlement, agriculture, roads, mining, industry, tourism - are becoming increasingly wide spread in the hills, putting greater pressures on the resources of the region. A balance must be struck between ecological stability and human development needs.

However, continued overuse of resources has resulted in substantial degradation of forest cover throughout the Himalayan region. In the past three decades over one million hectares of forest have been lost in the Himalayan region [Dhar, 1991a, p.113]. As well as increased fuel requirements of the growing subsistence based population, there is a need for increased agricultural land to meet food requirements. This has led to the clearing of steeper slopes and marginal lands for cropping and animal grazing [Ives, 1985]. In addition, commercial tree felling continues, both legally and illicitly, for industrial purposes and to make way for infrastructural developments such as road building [GoI,1992]. Even in the orchard growing areas of Himachal Pradesh, cutting of trees to make packaging for fruit produce is causing serious environmental problems [Melkania, 1987].

The resultant effects of deforestation on the Himalayan environment includes exposure of soil and increased water run-off. Consequently, flooding and land slides are more common, there is an upset in the natural ground water patterns, and there is increased soil erosion and silting of streams [Dhar, 1991a; Pande, 1987]. A subsequent effect occurs on the environment of the plain areas which depend on the run-off of the three main Himalayan river basins [Pande, 1987].

The National Forest Policy, written over four decades ago, states that 2/3 of the Himalayan region should be covered by forest. Four states claimed to have achieved this: Arunachal Pradesh, Uttar Pradesh, Mizoram and Jammu and Kashmir. Other states are well below this level. Many designated "forest" areas in reality have very poor tree covering, so that the figures may be deceptive. The Uttar Pradesh Eighth Five Year Plan admits that, though recorded forest area is over 2/3 of the hill district land area, actual forest cover is only about 41% [Dhar, 1991b]. Uttar Pradesh has banned green felling of trees above 1000m altitude.

At a global level, the World Commission Energy 2000 report on energy planning for sustainable development states:

> *"Sustainable development is dependent upon the implementation of energy strategies which incorporate environmental needs while at the same time provide social change and economic growth"* [FAO, 1990, p.35]

This is echoed in the Indian Eighth Five Year Plan document, which calls for:

> *"socio-economic development of the hills and the people living there in harmony with ecological development"* [GoI, 1992, p.427].

One aim of the Indian Special Hill Development Programme in the Eighth Plan is to develop the use of NRSEs and non-wood based energy sources.

To summarise, with the rapidly growing population heightening pressures on the fragile resources of the Himalayas, there is a need for an alternative and environmentally benign energy strategy to meet the ever-increasing energy requirements of the rural people.

1.2. Approach to research

1.2.1. Research ideology

An assertion of this study is that MHP is being developed as part of the process of socio-economic development of the rural Himalayan region. Therefore, factors other than the purely technical must be analysed in order to design and implement sustainable MHP projects. A holistic or "multi-disciplinary" view must be taken, considering:

- Technical options
- Economic constraints
- Socio-cultural conditions
- Environmental factors, and

- Institutional framework.

This accords with findings of recent studies into utilisation of NRSEs in less developed countries. The RETAIN programme for disseminating rural energy technologies in of developing countries identified "nine key issues" which must be considered for projects to be successful, as shown in figure 1.4. This thesis considers each of these issues for the case of MHP in North India, with particular emphasis on the first four points.

Figure 1.4 Key issues for consideration in the dissemination of rural energy technologies
a) The role of market and state b) Diffusion strategies and the role of (user) participation c) The performance of the technology d) Understanding user needs e) The political economy f) Financial returns to the user g) The macro policy environment h) System overhead costs, scale, and the provision of complimentary inputs i) Monitoring and feedback

Source: Barnett, 1990

The chief of the Environmental Policy Division of the World Bank dismisses NRSEs as "more expensive options" for power production, only to be considered once "less costly options", such as natural gas based generation, energy conservation measures and conventional energy resource development, are exhausted. He states that developing countries cannot extend past "near term economic development goals" when considering environmental preservation and for longer term requirements will have depend on the developed nations for technological innovations and knowledge bases [Munasinghe, 1992]. This thesis challenges these views as they disregard the immediacy of rural energy needs, and ignore the diverse technical capabilities of the more industrially advanced developing countries such as India.

In more practical terms, Munasinghe, in another article, underlines the administerial and infrastructural limitations of many developing countries which affecting the dissemination of RE, including: lack of adequately trained human resources; weak analytical tools and policy instruments; and market distortion due to subsidies and externalities covering the true opportunity cost [Munasinghe, 1990]. As India extends its programme for MHP, this thesis assesses the country's present organisational and infrastructural framework for MHP development, and recommends ways in which to establish a more effective developmental setting.

It must be emphasised that electrification is not the unique answer to rural energy problems, but should be seen as an integral part of the overall rural energy programme in order to produce an optimal rural energy system [Flavin, 1986]. The location specific nature of energy needs and resources means that no single solution can solve the diversity of problems of rural energy supply. MHP must be investigated as one of several alternative "solutions" to the various energy supply problems in the Himalayas. Its appropriateness must be considered in comparison and in conjunction with these alternatives.

1.2.2. Research in India

The author spent one year of the study (1992) in India collecting up to date and area specific data. The research in India provided first hand experience of MHP development in the country and allowed access to expert knowledge, literature and project records available only in India. During this period the author was based at the University of Roorkee in Uttar Pradesh. The Indian component of the study was divided into three main parts:

- a survey of available literature, research reports, and relevant government publications;
- visits to organisations and individuals involved with various aspects of MHP, RE and NRSE development in India; and
- field trips to MHP sites.

Literature Study

The literature survey was a continuation of the survey carried out in the United Kingdom during the previous year. A considerable amount of time had to be dedicated to developing a diversity of contacts in order to acquire the relevant literature, much of which was only available from Indian sources. Most of the information gathered related to MHP development in the country, to the Indian energy sector, to indigenous progress in the field of renewable energies or to Indian development policy.

Office Visits

A list of people and organisations visited in India is given in Appendix A. Visits were made to key contributors to MHP development in India. Four types of office were visited:

- Government offices, at national, state and district level
- Academic and research institutes
- Turbine manufacturers, and
- Non-governmental organisations (NGOs).

Methods of obtaining data included formal interviews, informal discussions, visits to test sites or shop floors and searches through relevant files. A wide range of experiences and opinions were gathered from individuals, as well as reports and documentation of previous projects carried out by the various organisations. In addition, contact with policy makers at various governmental levels allowed the author to assemble an overview of policy for MHP development.

MHP Site Visits

Appendix B gives details of the MHP sites visited in India. The main geographical focus of the field study was in the hill districts of Uttar Pradesh, and most of the empirical data is taken from the eleven sites visited extensively in this region. The Uttar Pradesh hills have the most prolific and varied MHP development programme in India. Over recent years the attitude towards MHP has altered considerably in India, particularly since MHP development was placed in the control of the Department for Non-conventional Energy Resources in 1989. The five Uttar Pradesh State Electricity Board (U.P.SEB) sites visited were chosen as a district study representative of the SEB MHP projects. The six Uttar Pradesh Non-conventional Energy Development Agency (U.P.NEDA) sites were chosen as prototypes of the new approach to micro hydro power, as community based projects. Two sites were visited in the hills of South India to make a comparison with similar projects recently developed in Uttar Pradesh. Also five low head sites on the canal system of the Indian plains were visited as part of the wider study of the Indian energy sector and the MHP research programmes.

For each of the study projects, data was collected from the on site record books and through interviews with project engineers and plant operators. A standardised proforma (shown in appendix C) was completed at most of the sites and site design features were taken from the site detailed project reports (DPRs). At the micro hydro projects visited in Uttar Pradesh interviews were also held with the leaders of villages supplied with electricity from the plant. It was found that a formal questionnaire could not be used effectively in the villages, as availability of data varied from village to village, and therefore a standardised assessment of responses could not be formulated. Instead guided discussion was used to extract the maximum information relevant to each village.

1.2.3. Problems encountered during research

While working in a developing country, many difficulties arise which would not be present in a Western setting. The experiences during the study period in India gave a valuable insight into the infrastructural limitations forced on development projects there. For example, communications are both unreliable and slow. The telephone network and the postal system are erratic, and receipt of, or replies to, letters not always guaranteed. The country's excessive bureaucracy can hinder tasks which would be considered straight forward in the United Kingdom. A particular problem was road transportation, which is slow and often hazardous. Travel in the Himalayan region involves negotiating treacherous roads which are prone to landslides and flooding in the monsoon season. This meant that journeys to the field or to New Delhi from the study base at Roorkee were both arduous and time consuming.

Information held in records is often incomplete and may be difficult to locate between the multitude of agencies or departments involved with development work. Computerisation of information systems is in its infancy in India, and is unlikely to develop greatly in the near future.

Fortunately, language was not a barrier as English is commonly spoken in government offices and academic institutes and an interpreter was available for site visits.

1.3. Study objectives and thesis organisation

Below are listed the main objectives of the study and an explanation of how these objectives are dealt with and presented in the subsequent chapters.

Chapter 2. Review of the body of knowledge on MHP in Developing Countries

Chapter 2 describes MHP technology, its major components and the technological options for development in rural areas. This includes an examination of the concept of "technology level". The chapter then goes on to discuss the main issues involved in setting up sustainable MHP projects in remote regions of developing countries, elucidated by the experiences of MHP, rural electrification and renewable energy development around the World, and particularly in Asia.

Chapter 3. Appraisal of the Indian setting for MHP development

Many different characteristics of the country - geographical, climatic, socio-cultural, political, economic and developmental - will have a direct bearing on the successful implementation of MHP projects. Chapter 3 considers the relevant features affecting such development, first in India and then more specifically in the Himalayan States of India.

Chapter 4. Assessment of the Indian energy sector, putting MHP into context

Chapter 4 describes the energy sector in India, including traditional fuels, commercial fuels, the power sector, and renewable energies, so that MHP is put into the context of Indian energy planning priorities. The infrastructural setting for MHP development is described, including the administrative structure, policies affecting MHP, available financing options and technical and manufacturing capabilities.

Chapter 5. Assessment of the actual achievements with MHP in the Indian Himalayas from field experience

Chapter 5 is predominantly based on the author's field work undertaken at MHP sites in the hill districts of Uttar Pradesh. It also draws on reports from research organisations and records of the project implementing bodies. An assessment is made of technical performance, economic viability and socio-economic impact of individual projects.

Chapter 6. Discussion of the future for MHP in the Himalayan states of India

The discussion in chapter 6 considers the future for MHP in the Himalayan region of India. It discusses the role MHP can play in the future energy scenario and considers the technical progress which will be needed to achieve this. The problems posed by the Himalayan setting are analysed and the possible means of over coming them are proposed. The environmental and socio-economic benefits of MHP are further discussed, in particular how these can be enhanced. Finally there is a analysis of the MHP policies and how they can promote MHP development.

Chapter 7. Conclusions and recommendations for future MHP development in the Indian Himalayas

Based on the discussion as outlined above, chapter 7 presents the conclusions and recommendations for future MHP development in the Himalayan regions of India as an option for improving and augmenting supply to remote areas.

CHAPTER 2

MINI/MICRO HYDRO POWER FOR RURAL AREAS

Before considering the Indian experience of MHP it is useful to review the body of knowledge which has built up from experience of MHP development across the World, and in particular at the application of MHP in rural areas of developing countries. Though there are country specific variations, there are also common findings which can guide decision making for future MHP programmes in India.

This chapter sets MHP within the rural development context by discussing the decisions to be made in project implementation. There is a description of MHP technology and an assessment of the decisions which must be taken when designing projects for the rural setting. The different reasons for developing MHP in rural areas are considered, as are the links between MHP development and wider rural development. The latter part of the chapter discusses the economic performance of the power plants and the variables which affect their viability, including the problem of sustaining MHP projects through appropriate planning and management. Finally, examples are given of MHP development in selected Asian countries.

Each of the aspects of MHP project development discussed here are closely inter-related, and often one aspect cannot be fully considered without an understanding of the others. For example, the choice of technology will depend greatly on both the economic expectations of the project and the desired end uses of the plant. Conversely, the technical choices made and the resultant end uses will directly affect the economic viability of a scheme. These will ultimately have bearing on the sustainability of the projects, though issues of management and planning also contribute to the success of project implementation.

2.1. MHP technology

Small scale hydro projects are commonly classified in two ways: first by their installed capacity; and secondly by the change in water level utilised to produce power, that is, the site head. These have direct bearing on site design.

2.1.1. Classification by installed capacity

The definition of small, mini and micro hydro power varies slightly from country to country. In India the generally accepted classification is

Small Hydro	-	up to 15MW (unit size up to 5MW)
Mini Hydro	-	101kW to 2000kW
Micro Hydro	-	up to 100kW

However, the Indian Department of Energy has designated sites up to 3MW under the heading of "non-conventional energy sources".

In this thesis mini hydro will refer, unless otherwise stated, to projects between 100kW and 1000kW. Micro hydro is defined as up to 100kW. The reason for limiting the range of mini hydro to 1MW is to concentrate specifically on the lower end of the power generating spectrum and the applications of mini and micro hydro power in remote areas where power demand at load centres is low.

More recently a new classification of "pico" hydro has been defined as plants under 30kW, based on village scale hydro projects [Harvey, 1993]. Also in some countries, notably China and Vietnam, "family" hydro schemes of between 50W and 1kW are in common use [Green, 1993].

Almost all MHP schemes are run-of-the-river type. This means that they depend on a constant flow of water, with minimal use of water storage. Often a decision has to be made whether to design the project for the lowest flow of the river or canal and therefore have constant output all year, or to design for a higher capacity, utilising the full capacity at high flow periods, but operating on part capacity the rest of the year. For isolated schemes capacity is usually decided by which design best fits the projected demand profile. For grid connected schemes the capacity is decided by balancing the over all plant cost with the annual revenue thereby achieving optimal economic performance from the project.

2.1.2. Classification by head range

The site gross head is the height between the water level at the forebay and the water level at the tailrace (forebay and tailrace are defined later). Net head is the gross head minus the "head losses" in the penstock. A guide to classification of MHP in terms of head range is

Ultra-low head - up to 3 metres

Low Head - 3 metres to 30 metres

Medium/high head - above 30 metres

Figure 2.1 [Fraenkel,1992] shows the general layout of a low or ultra-low head MHP site. This type of site is most commonly found on canal drops on irrigation works. Photographs 2.1 and 2.2 show two examples of ultra-low head sites on the canal networks which irrigate the plains of India. On canal drop sites much of the civil works are already in place, with only the powerhouse and by-pass channel the major additions. However, due to the relatively large flows involved, electro-mechanical equipment and the powerhouse will be large and costly, on a cost per kW basis.

Medium and high head sites are usually located in hilly areas. Figure 2.2 [Hislop,1992] shows the main features of such MHP sites and Photographs 2.3 and 2.4 show example of MHP sites in Indian hill areas. High heads and lower flows mean that less costly impulse or crossflow turbines can be used, though civil works often including lengthy power channels and penstocks.

This thesis is primarily concerned with medium and high head sites in hilly regions, though lower head sites are discussed in chapter 4 as a recent introduction to the Indian energy sector.

2.1.3. Components of a MHP plant

It is important to view the design of MHP in a different manner to conventional hydro power in order to produce a simplified and cost effective scheme, as opposed to designing a scaled down replica of large hydro projects. The reasons for this are dealt with later in the chapter. Publications which address the problems of MHP

Figure 2.1 Low Head Mini/Micro Hydro Site

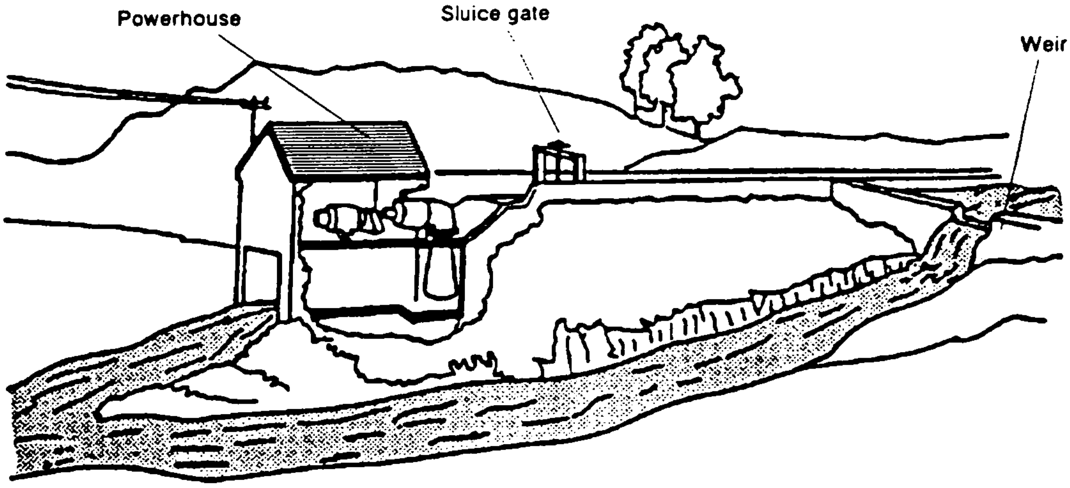
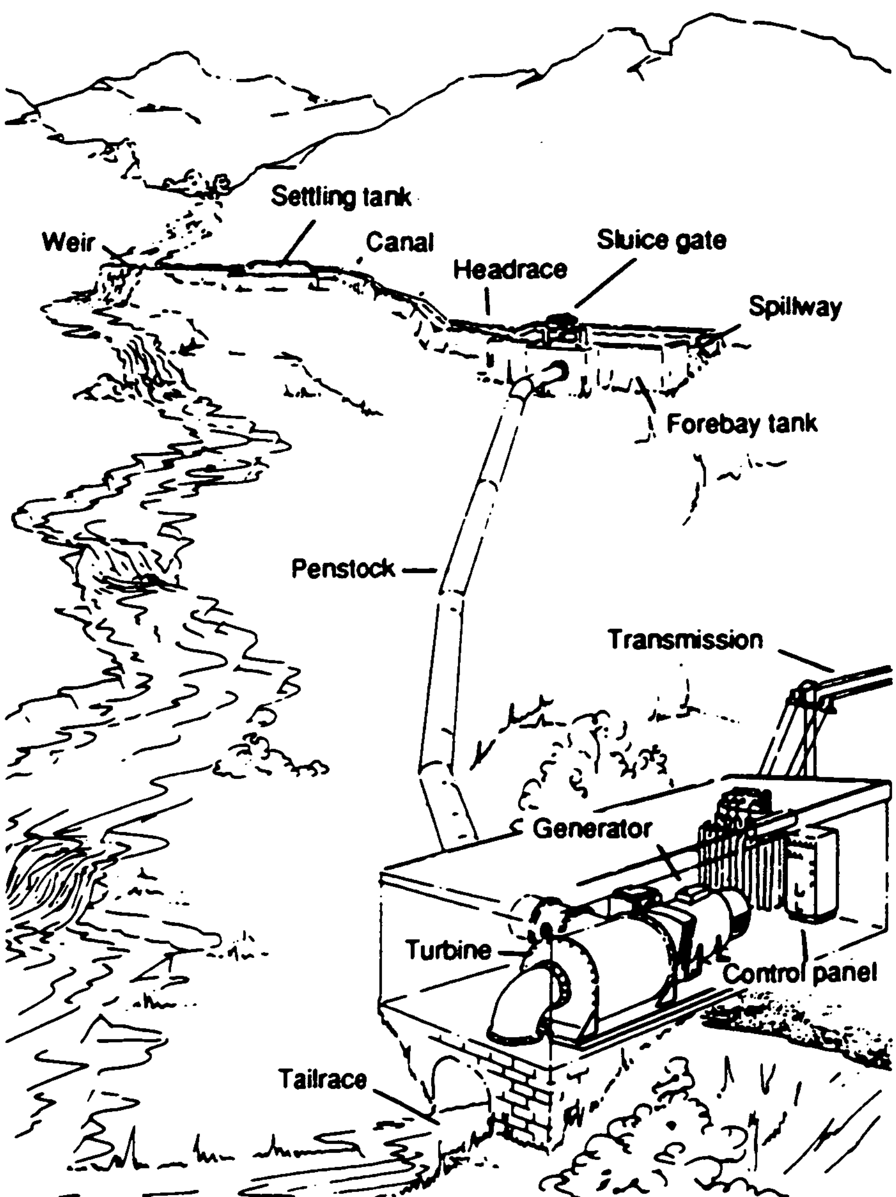
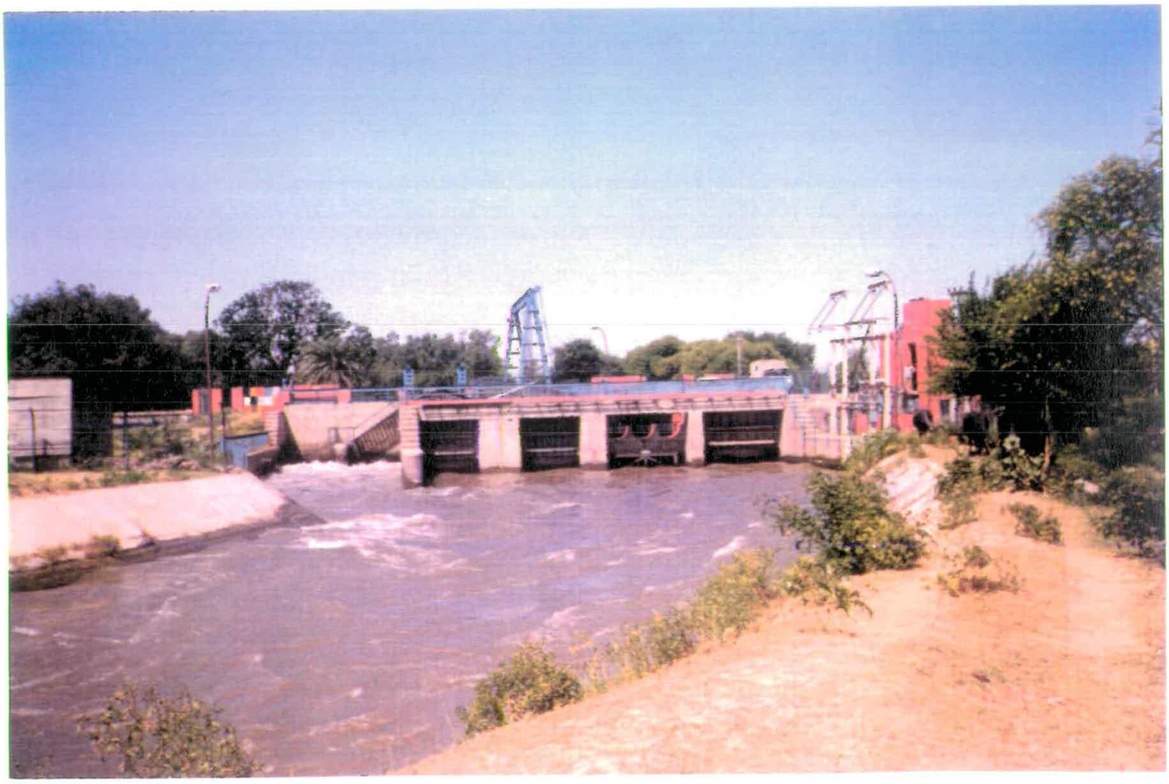


Figure 2.2 High or Medium Head Mini/Micro Hydro Site



Photograph 2.1 Keragodu ultra-low head micro hydro project (Karnataka)

Photograph 2.2 Kakroi ultra-low head mini hydro project (Haryana)



Photograph 2.3 Pookot medium head micro hydro project (Kerala)

Photograph 2.4 Badrinath medium head micro hydro project (Uttar Pradesh)

design include [Wallace, 1990; Inversin, 1986; Fraenkel, 1992; Monition, 1984].

Civil Works

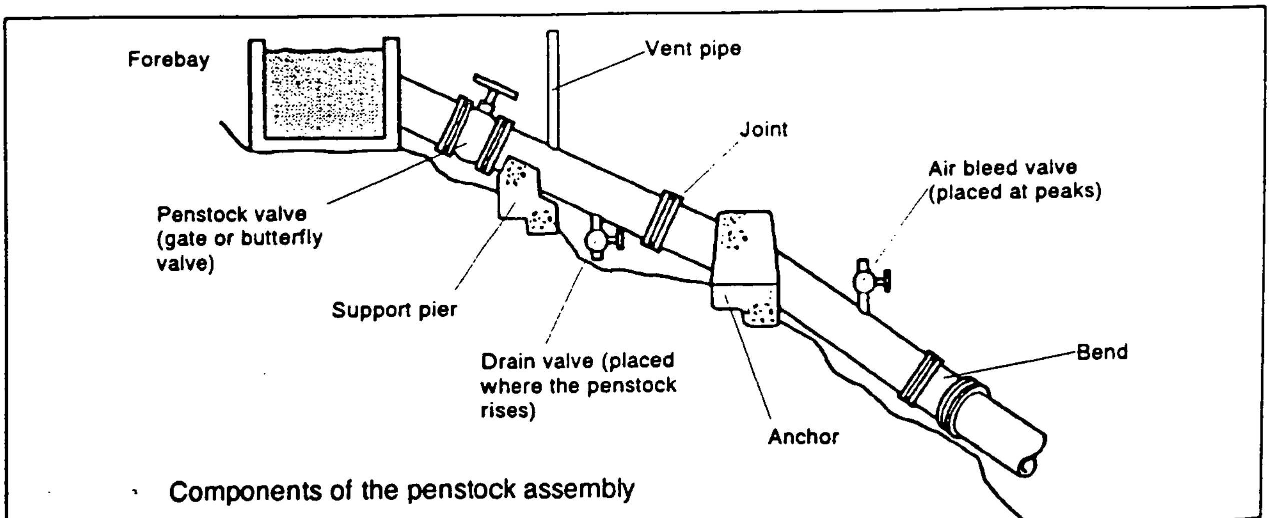
The main components of MHP plants, as shown on figures 2.1 and 2.2, are briefly described below.

A **diversion weir** is a barrier built across the stream or canal with the purpose of directing sufficient water towards the **intake** of the hydro scheme. The intake is usually covered with a trash rack to remove large water borne material before it enters the power canal. A **settling basin** (or de-silting chamber) is often positioned just after the intake, and is dimensioned so as to reduce the flow velocity in the basin sufficiently to allow suspended particles in the flowing water to deposit at the bottom of the chamber. The chamber should have a flush mechanism to allow any build up of deposited materials to be removed periodically. Settling basins are most important in heavily silt laden streams, to prevent erosion of the channel, penstock and turbine.

Most commonly the water is conducted from the intake to the forebay through either an open or covered **power channel** (or headrace), though occasionally a low pressure pipe may be used. Head loss along the channel should be minimal. The **forebay** is the chamber which connects the power channel to the penstock. In some cases, where the power channel is short, the forebay and desilting chamber may be combined. **Spillways** divert the water back to the stream in the case of a flood or when the valve to the turbine has been closed. Spillways are usually found at the forebay, but may also be located at the desilting tank or at a section of the power channel.

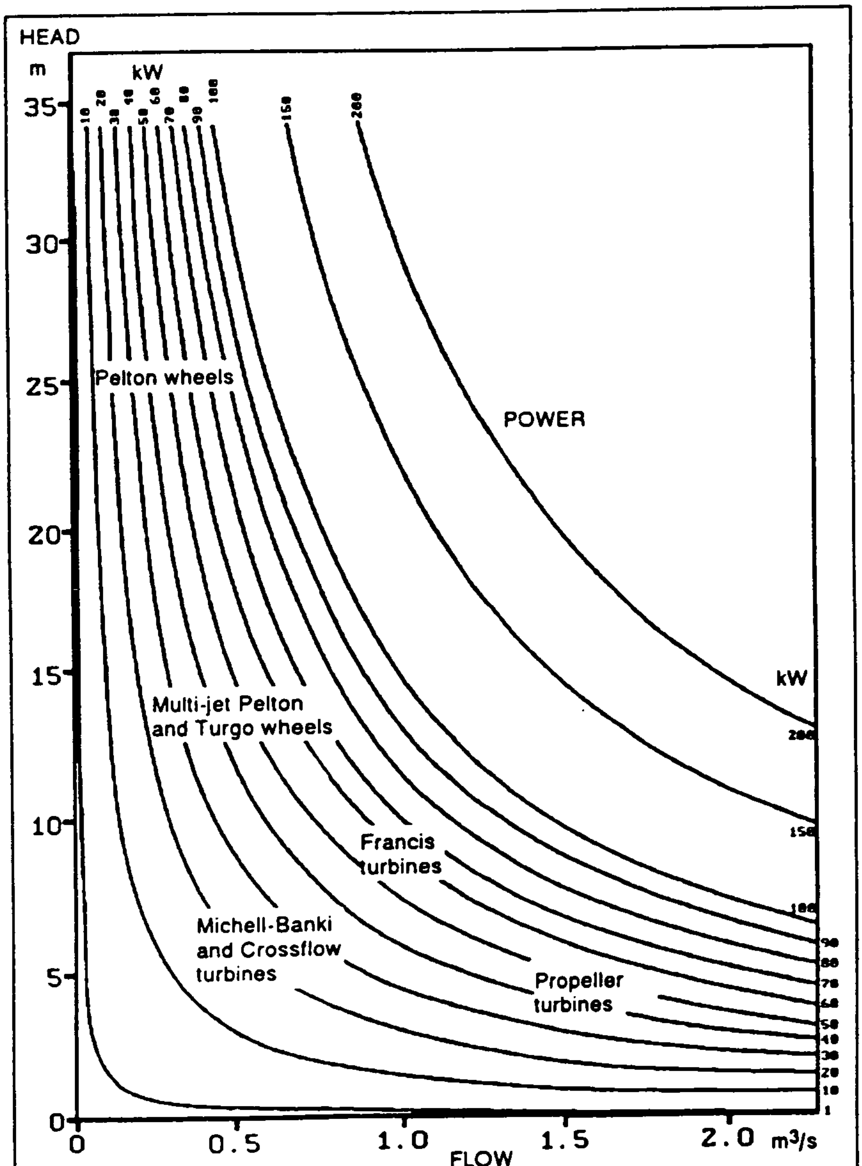
The water is taken under pressure from the forebay to the turbine by a **penstock** pipe. Figure 2.3 shows the features which a penstock may require, in particular at a high or medium head site. The penstock should be designed to ensure minimum possible pressure loss along the length of the pipe. Friction losses in the pipe are greatly reduced by increasing pipe diameter, but this must be balanced against the increase in the cost of the pipe. In general, the head loss due to friction in the pipe should be less than 10% of static head. The penstock must be able to withstand the surge of pressure in the pipe when the penstock valves, or the turbine guide vanes in a reaction machine, are closed rapidly. Pipe materials and wall thickness must be chosen with this in mind, though for larger power stations with long

Figure 2.3 Penstock Features



Components of the penstock assembly

Figure 2.4 Utilisation Range of Various Turbines



Curves indicating the flow rate and head for a range of power outputs, assuming an overall efficiency of 70%.

penstocks a surge tank will reduce the pressure build up. Air bleed valves will let out air and help avoid cavitation at bends in the pipe. An air vent is required if the penstock is to be closed at the intake and drained.

The **powerhouse** must give the generator, switchgear and ancillary equipment protection from the elements, including rain, temperature extremes and insects or vermin. Care should be taken to locate the powerhouse to avoid possible damage by flooding and landslides. Water leaving the turbine re-enters the stream through the **tailrace**. On low head schemes, with reaction or crossflow turbines, some water pressure is retained between the turbine and the tailwater through a draft tube. On higher head schemes, using impulse turbines, the water is virtually at atmospheric pressure as it exits the turbine and enters the tailrace.

The decisions to be made when designing MHP projects in remote locations must consider the appropriate materials, site location and configuration of components, with the cost and maintainability of the schemes as prime concerns. It must be noted that transportation of conventional materials and skilled labour to the site may add significantly to construction costs and subsequent repair costs, therefore alternative solutions are worth considering at the project planning stage. Often it is most appropriate to use local materials or to construct temporary or semi-permanent structures which are maintained by the local people. For example it is possible at some sites to use temporary weirs, which wash away during the flood season and are reconstructed every dry season. It is common to use the natural features of the stream to create an effective diversion and intake. Similarly, natural pondage in the stream may be sufficient to act as a de-silting mechanism and where the ground is non-porous it may be possible to use un-lined power channels.

In general, it is more acceptable to use a non-conventional approach to the civil works on the smaller mini hydro and micro hydro sites, as the technical and economic risks involved are less.

Mechanical Components

There are two classifications of **turbine**: impulse and reaction. In general reaction turbines are best suited for lower head plants and impulse for higher heads. The utilisation range of each type of turbine based on head and flow rate is shown in figure 2.4 for sites up to 200kW.

Reaction turbines are completely submerged in the water flow and the pressure exerts force directly onto the runner blades. Examples of reaction turbines are **Francis**, **propeller** and **Kaplan** turbines. The Francis and propeller turbines are pictured in figure 2.5. There are various configurations for propeller type turbines, depending on the positioning of the turbine relative to the generator, including tubular, S-type and bulb type configurations. With bulb type turbines the generator is inside a bulb which is submerged in the water flow either up-stream or down-stream of the turbine. Kaplan and Francis turbines will often feature guide vanes to guide the water through the turbine to give greatest efficiency. The guide vanes are adjustable to vary flow rate as the load varies. In the case of the sophisticated kaplan turbine the runner blades are also adjustable.

With impulse turbines the pressure is first converted through a nozzle into kinetic energy which is then imparted to the runner. Examples of impulse turbines are the **pelton** wheel and the **turgo** turbine, shown on figure 2.6. Multi-jet peltons or turgos have more than one nozzle directing water at the runner, so that a larger flow can act on a small runner. A multi-jet in effect gives the turbine a higher specific speed (see below) and hence increases the range of application of the turbine runner.

Crossflow turbines (see figure 2.6c) are sometimes referred to as "mixed flow" turbines. Though often used as impulse machines, they can also act as reaction turbines if a draft tube is used. Simple fabrication methods for the crossflow turbine and its wide head range of application has made it a popular choice for micro hydro projects in several developing countries†. The crossflow has a lower efficiency than other turbines; the most sophisticated crossflows have efficiency of about 85%, but the more simple designs have efficiencies of only about 65%.

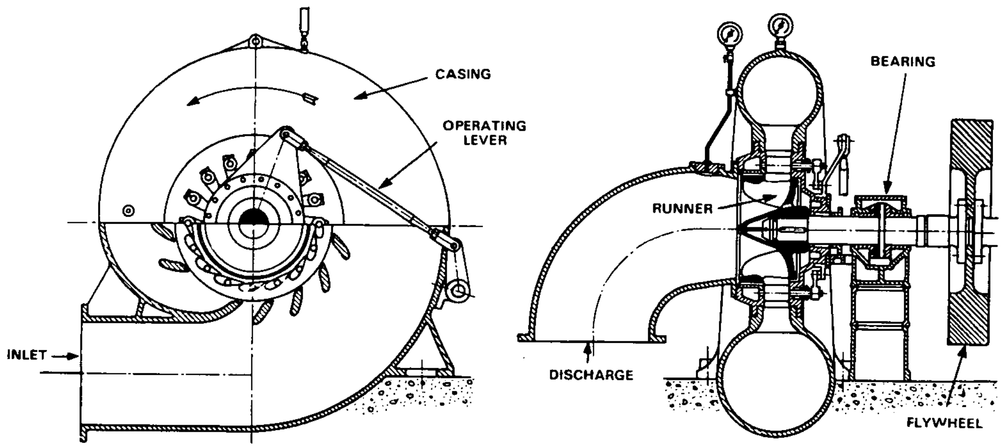
It is important to select a turbine which in the given operating conditions will run at a high enough shaft speed, usually not less than three times slower than the required generator speed - that is, with a maximum gearing ratio of around 3:1. Each turbine has a specific speed, which is used to select the appropriate turbine:

$$n\,1\times\frac{P^{0.5}}{H^{1.25}}=Ns$$

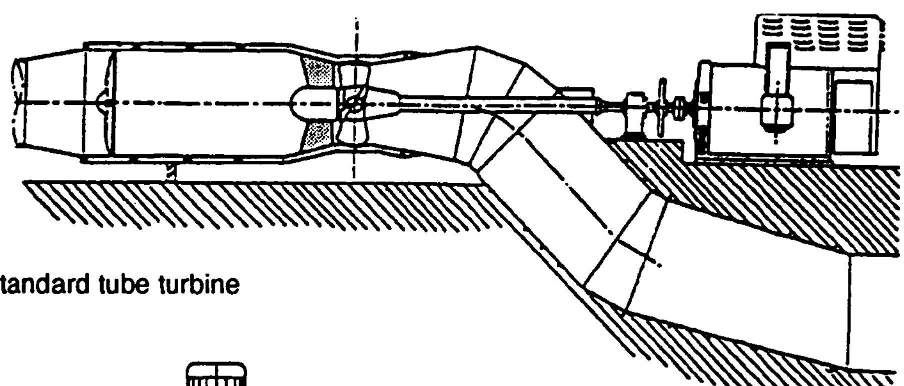
† Locally built crossflow turbines are being used for micro hydro projects in rural areas of Nepal, Pakistan, Thailand, Peru and other developing countries but, surprisingly, not in China, which has by far the greatest number of micro hydro projects [Arter, 1992].

Figure 2.5 Reaction Turbines

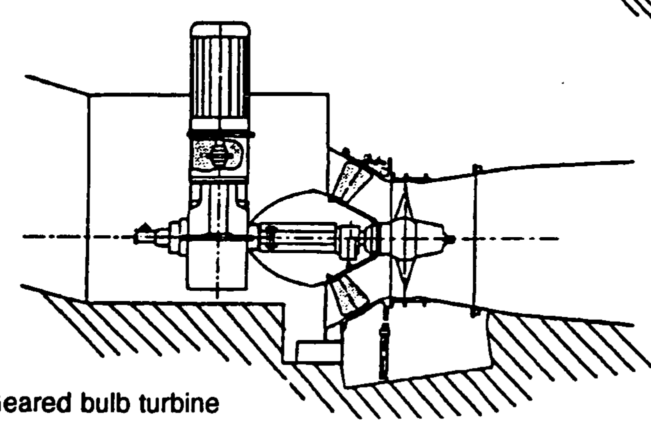
a) Francis Turbine



b) Propeller Turbine



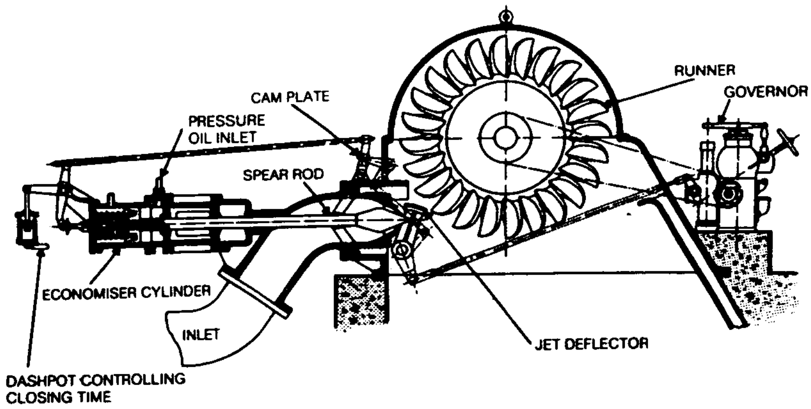
Standard tube turbine



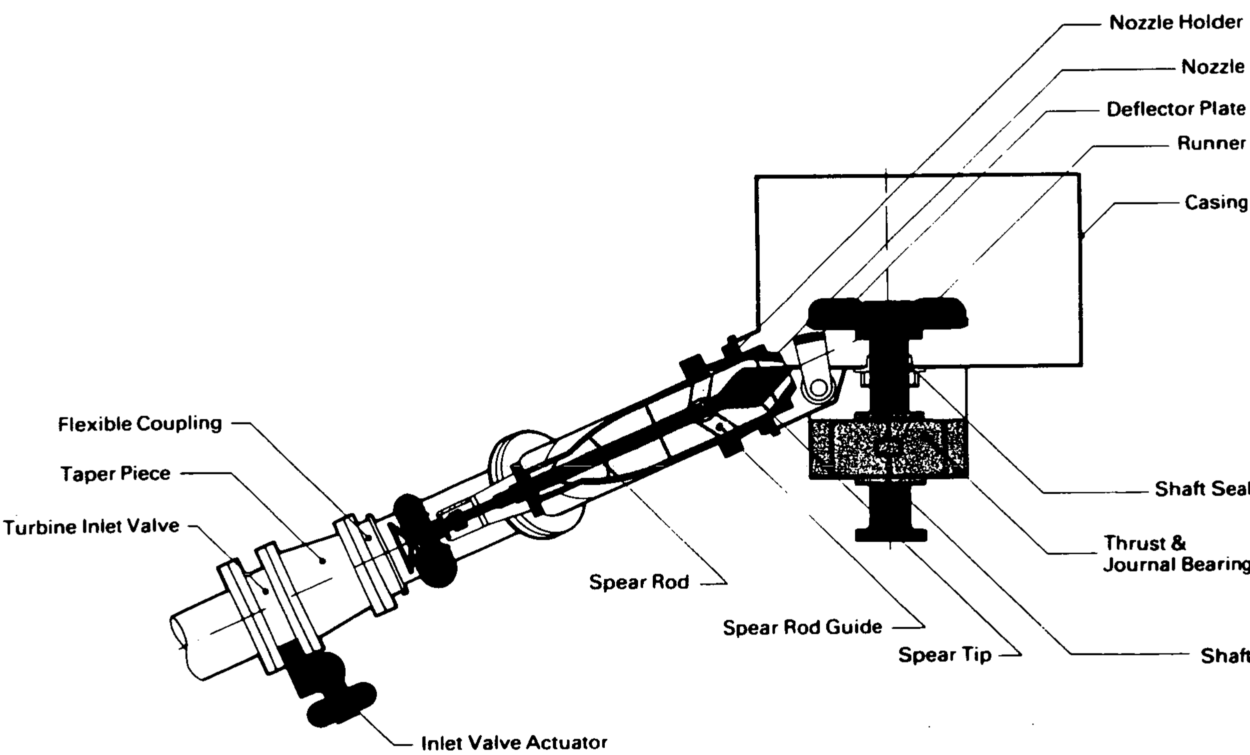
Geared bulb turbine

Figure 2.6 Impulse Turbines

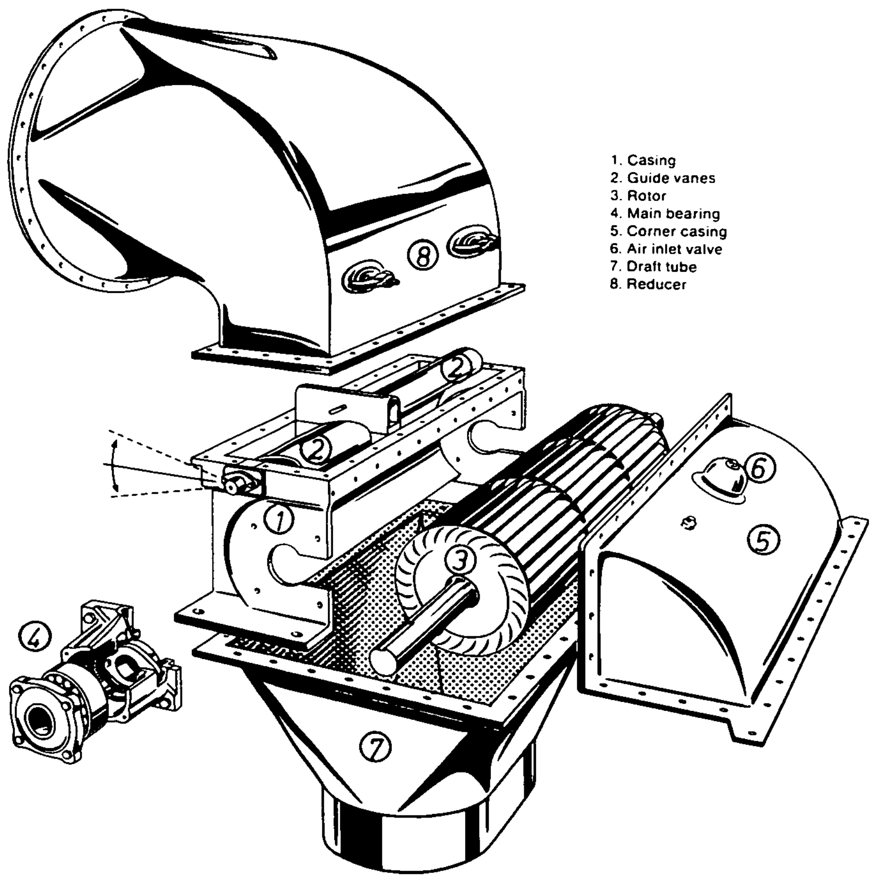
a) Pelton Turbine



b) Turgo-impulse Turbine



c) Crossflow Turbine



n1 - turbine shaft speed

P - power output

H - nett site head

Ns - specific speed

If the site head and power output are known, then it is possible to calculate the specific speed from the required turbine speed. Figure 2.7 gives a guide to the typical range of specific speeds for the various turbine types. For the same head and flow reaction turbines will operate at a higher speed, since the whole runner periphery is supplied with the same amount of water. Impulse turbines admit the water to the runner at one or more points as jets and the turbine "buckets" receiving the water have to be mounted on a relatively large diameter, so that their speed of rotation on a given head will be lower. However, impulse turbines and their associated civil works are less costly and less complex. For lower power sites, particularly where efficiency may be less important than the scheme cost, it may be beneficial in continuing to select impulse turbines for lower head applications [Wallace,1990].

Figure 2.7 Turbine specific speeds

Turbine Type	Specific Speed Range
Pelton 1-jet	15 - 28
Pelton 2-jet	21 - 40
Pelton 3-jet	26 - 49
Pelton 4-jet	30 - 56
Turgo 1-jet	48 - 72
Turgo 2-jet	68 - 101
Crossflow	66 - 162
Francis Low speed	71 -335
Francis High speed	109 - 504
Kaplan	340 - 759
Propeller	348 - 780
Bulb	617 - 1250

Source: Wallace, 1990

A **governor** is the most common speed control system used. This is the mechanism which controls the speed of the turbine to maintain the required electrical frequency from the generator. The governor varies the water flow rate entering the turbine runner so that the turbine/generator speed is kept constant as the electrical loading changes. The water flow rate is altered either by opening and closing a valve in the nozzle, by altering the direction of the water jet to or from the runner using a deflector plate (impulse turbines only), or by moving the guide vanes (reaction turbines only). Originally governors were entirely mechanical, driven by a fly-ball mechanism connected directly or indirectly to the turbine shaft. The governor directly adjusted the position of valve, deflector or guide vanes. It is now common for governors to include hydraulic servo-amplifiers, and to obtain speed signals from generator shafts, either electrically from tachogenerators or electronically from shaft sensors.

Micro hydro units have been increasingly using an electronic load controlling device in place of a governor. A constant load is maintained on the turbine and generator, and the **electronic load controller** (ELC) is used to increase and decrease a dummy or ballast load to compensate for the change in the power demand by the consumer. The ballast is often a water heater, which has several heating units which are switched in and out as required to maintain a constant load on the generator as consumer loads vary. ELCs are less expensive and simpler to maintain than governors, but they are limited to application in the micro hydro range because of limitations on ballast load.

With MHP it is common to have direct coupling between the turbine and generator, though gears or belt drives may be used where the turbine speed is low, such as when pelton, turgo or crossflow turbines are used on lower heads.

Electrical Components

There are two types of generator, induction and synchronous. **Induction generators** are less expensive and more robust than the **synchronous generators**, but induction generators require external excitation to magnetise the stator and set the generator voltage and frequency. This is generally done through connection to a well established electricity grid. Recent research has produced an economical excitation and control system using charged capacitor banks for induction generators up to about 30kW to enable them to operate in isolation [Brazil, 1990]. For economic and technical reasons capacitor excitation systems are seldom used with larger induction generators.

A MHP plant operating in isolation from the grid will use a synchronous generator in almost all cases. For ease of maintenance, synchronous generators are best to be of brushless type, which either derive their excitation from shaft mounted permanent magnet or auxiliary windings in the stator. Synchronous generators require automatic voltage regulators (AVRs) to control the generated voltage.

In many rural electrification grids in developing countries connected synchronous generators are installed to reinforce the grid by stabilising voltage and frequency. However, there is danger with relatively small generators that wide variation in grid voltage or frequency, as is common on very weak rural grids, will cause the generator protection to operate and trip the generator. Appropriate design and setting of voltage and frequency protection may minimise this.

The level of electrical protection will increase with the size of the scheme and complexity of the distribution system. At least minimum safety standards must be maintained on even the most small and basic schemes. The minimum protection of the MHP scheme should include safeguards against: overload; short circuit; earth leakage; over/under voltage; over/under frequency; and mechanical over speed.

The sophistication of the electricity **distribution network** of a MHP will vary according to the size of the plant and the end use of the power. The distribution for a very small and rudimentary micro hydro scheme may be through single phase 240 volt lines supplying directly to near by consumers. A larger mini hydro plant located several kilometres from the users will require a series of transformers and 11kV or 33kV three phase transmission lines, which are connect to the village 415 volt distribution network. High voltage transmission systems are more costly, but the transmission losses are far lower, which is important if the power is to be transmitted over long distances. For rural electrification, the transmission and distribution lines are usually above ground as this is less expensive and easier to install than buried cables.

2.1.4. Technology level

For MHP projects to be successful in rural areas the first requirement is that the technology should work [Barnett, 1990]. The implications in this seemingly obvious statement are that the technology should a) be sustainable or maintainable within the local rural setting, and b) be able to meet actual rural energy needs. This will require the correct choice of *level of technology* as well as its appropriate application.

The level of technology relates primarily to its sophistication and performance. There are three broad categories for level of technology - conventional, intermediate and appropriate - each of which must be dealt with in different manner [Wallace, 1990]. The decision on technology level will depend on balancing the technical skills available in the rural setting, the available financing for the project and the required plant performance.

Conventional technology uses the most modern designs and manufacturing techniques. The equipment will be high specification, precision built for best possible performance, using top quality, long lasting materials. Construction and maintenance will require specially trained and skilled personnel. Large, medium and small scale hydro power plants are conventionally built to maximise efficiency, to obtain maximum power output.

Intermediate technology uses less complex but well proven designs. The plant efficiency will be sacrificed, so that manufacturing can be done in a general engineering workshop, using less costly materials and with less emphasis on precision and finishing. This approach will substantially reduce costs and utilise more widely available skills and locally available materials. Mini and micro hydro power may incorporate aspects of intermediate technology in order to reduce costs in the absence of an economy of scale.

Appropriate technology is that which is suited to circumstances in remote parts of developing countries where technical skills are lacking and the economy is poor. Designs are simplified to suit the primitive workshop facilities and to utilise local materials and skills. The technology will emphasise functionality rather than performance. Some micro hydro projects, to a degree, can be classed as appropriate technology. The simplest micro hydro design, used exclusively for direct mechanical power, may be constructed almost totally in the rural area using appropriate techniques. If the turbine speed is sufficiently high, a simple alternator may be added to this to generate small quantities of power.

Two other terms frequently used in regard to MHP design are rationalisation and standardisation. Rationalisation refers to designing for simplified operation and maintenance procedures to allow lower-skilled personnel to take over daily running of a site. Standardisation of design into modular units, reproducible on a large scale, may not make optimal use of the given site potential since the design is not specific to that site, but standardisation will substantially reduce overhead engineering and manufacturing costs.

2.2. Reasons and objectives for using mini/micro hydro

2.2.1. Rural electrification

Chullakesa generalises the state of R.E. in developing countries as follows:

> *"Broadly speaking, African countries are in the early phase of main demand centres. Asian countries are in the middle stage of bringing the grid supply to small demand centres, and Latin American countries are concluding the final phase of rural electrification."* [Chullakesa, 1990, p.398]

Many Asian countries are at a stage where it may be possible to optimise development of MHP potential - both grid connected and isolated - as a decentralised source of power and as a means of strengthening and augmenting rural power supplies.

Grid Connected MHP

Electrification of developing countries frequently begins at separate urban or industrial load centres, followed by the intermediate stages of interconnection of the individual generating plants and load centres to form grids. Rural electrification is generally considered to be a matter of expanding this grid network to connect increasing numbers of villages. Ultimately such extensions result in the grid becoming weak, as in India where rural electricity supplies are characterised by voltage and frequency fluctuations, load shedding at peak hours and large power losses, often over 30%. Connecting MHP projects at the remote ends of rural grid feeders can improve the quality and reliability of supplies to rural load centres.

The ESCAP seminar on social and economic impact of rural electrification recommended that "*small hydro power plants and small thermal plants should be connected to rural grids as an effective way to improve stability of power supply to* *rural areas.*" [UN,1990, p.54]

MHP in Isolation

For several reasons it may be difficult to connect some villages to the main grid network. This may be due to great distances or excessive cost involved in extending the grid lines to a particularly remote area. Alternatively, the terrain which the lines would have to cross may be too hazardous or the villages to be electrified may be surrounded by forests which cannot be cut because of environmental regulations. It is in these circumstances that MHP can be of most benefit, where adequate water sources are available. Often such areas will already be using small diesel generators, with the diesel being transported at great cost: in some parts of North East India diesel is air lifted to remote areas. MHP may ultimately be a more viable option.

Isolated schemes must also be planned with the co-operation and co-ordination of the rural electrification grid utility. Too often independent MHP sites have become neglected as a lower priority power source when the grid is eventually extended into the local area [ITDG, 1990]. Interconnection of isolated MHP plants into small localised grids may be worthwhile considering in order to boost reliability of supply, as is common practice in China.

For political reasons, such as India's aim to electrify every village by the year 2000, many rural electrification programmes promote RE as a target in itself [Flavin, 1986]. It must be remembered that R E projects are not simply an "electrical delivery service" [Ragunathan,1989], but is in fact a "means to an end" [NCAER, 1987]. That end is the enhancement of rural development and the living standards of rural people.

2.2.2. MHP and rural development

The Chinese have the most extensive programme of MHP in the World. From the Chinese experience, the socio-economic impact of MHP and other R.E projects are claimed to be [Zhu, 1990]:

- Promotion of local industry

- Increase of income of rural people

- Enhancement of agricultural modernisation
- Mitigation of rural-urban migration
- Mitigation of deforestation
- Improvement of lifestyle of rural people
- More job opportunities for rural people
- Sense of rural ownership
- Development of tourist potential
- Less environmental impact

The end-use of power in R E in China is said to be 80% for productive purposes and only 20% for household sector, as a secondary benefit. The "lifestyle" benefits may include removal of physical drudgery in agricultural processes, extension of working or leisure hours, access to television and improved educational and clinic facilities [Khurana, 1990]. If in fact the Chinese RE programmes achieve all these benefits to the rural communities, they are an exceptional case. In most developing countries the domestic sector, mainly domestic lighting, is the dominant electrical load in rural areas.

The evidence indicates that benefits, other than of improved household lighting, do not occur automatically as a result of R E alone. Many studies have concluded that R E must be accompanied by a wider rural development programme for it to achieve its potential impact [Ragunathan,1989; U.N., 1990; Hurst, 1990; Ramani, 1992]. A barrier to this can be the "sectorial" approach to rural development taken by many governments, where targets of the various development sectors (energy, industry, agriculture, social services, etc.) are not integrated [FAO, 1990].

With often less than 20% of households in electrified villages taking an electrical connection, R E can result in an accentuation of inequalities in rural areas. Commonly it is only the wealthy or influential members of the community who benefit [Cecelski, 1990; WB, 1990]. This imbalance must be addressed when formulating R E programmes for effective rural development.

Without more wide spread and productive use of electricity in rural areas, load density of RE extensions or load factors of an isolated power station will be extremely low and RE will remain highly un-economical.

2.3. Economics of MHP

The viability of MHP projects is normally predominantly judged on economic performance - capital cost, running costs and revenue. In the simplest terms viability of a MHP project can be determined by the payback period. The simple payback period is calculated by:

$$Payback = \frac{capitalcost}{annual\,(revenue - runningcosts)}$$

Though this is a very rough indicator, it does allow a quick evaluation of whether the project will ever be successful. The capital cost of a project must be minimised and annual running costs must avoid un-necessary outlay, as discussed in sections 2.3.1 and 2.2.2. The revenue of is related directly to the plant load factor, which reflects the amount of energy sold annually. As discussed in section 2.2.3, the development and planning of load are equally important for economic viability as the reduction of project expenditure.

When selecting a rural power source, MHP is usually compared to the other feasible alternatives, such as grid extension, small diesel generation or other renewable energy sources. This comparison should consider the overall economic objectives of power supply to the rural area, which may include:

- Economic viability for the developer
- Affordability for the user
- Encouragement of productive power end uses, such as rural industry or agriculture
- Benefit to the poorest in the community, as well as the better off
- Encouragement of environmental conservation

2.3.1. Capital cost

The most prominent economic features of MHP projects are high initial capital cost per kW installed capacity and relatively low annual running costs [Fritz, 1983]. Unfortunately, the high initial outlay often deters planners from considering MHP, when in the long term it may be a more viable option.

The capital cost of MHP is very site specific, with topographical and hydrological characteristics significant factors. Two generalisations can, however, be made about the unit capital cost of MHP (capital cost per kilowatt installed capacity). Firstly, due to economies of scale, capital cost per kW is inversely proportional to the the plant capacity. For example, comparison of India's conventional and non-conventional power generating projects quote a cost range for large hydro schemes to be between 10,000 to 30,000 Rupees/kW, but for micro hydro plants between 35,000 to 50,000 Rupees/kW [UPNEDA, 1992]. Secondly, higher head sites tend to have a lower unit cost than low head sites [Wallace, 1990], due to the relatively lower complexity of the turbine and civil works for higher head sites. A typical example (only indicative) of cost break down of capital outlay for mini hydro sites is shown in figure 2.8.

Figure 2.8 Typical Capital Cost Breakdown of MHP Plants (1000kW)

Head	Low		High	
	%	£	%	£
Civil Works	40	960	35	420
Penstock	10	240	35	420
Turbine	20	480	15	180
Electrical	15	360	15	120
Engineering	15	360	15	180
Installed Unit Cost		2400		1200

Source: Wallace, 1990

Choice of technology level will also have a major influence on capital cost. Micro hydro plants built by conventional means can cost over £2000/kW but projects using appropriate technology methods can cost less than £1000/kW, as projects in North Pakistan and Nepal have shown [NRECA, 1981; Varma, 1990]. Non-conventionally built micro hydro sites in Nepal have been demonstrated to cost one quarter the price of conventionally built projects [Bell, 1992].

The economic and technical risks involved in using lower efficiency non-conventional machinery on a 1MW mini-hydro power plant will be far greater than for a 10kW improved water mill with generator attachment. However, even mini hydro projects can utilise locally available materials, skills and labour for construction.

Building up indigenous manufacturing capabilities for electro-mechanical equipment is frequently advocated by developers [MoNES, 1992; Edwards, 1992; Santos, 1992] as a key element in reducing plant capital cost, as import charges and transport costs are avoided. In addition this ultimately reduces dependence on costly foreign technical assistance. Developing a standardised range of MHP equipment, suited to the country's own demand, can significantly reduce overhead costs for engineering. Production of a standard range of equipment should reduce manufacturing costs in comparison to fabricating site specific, tailor made units.

2.3.2. Annual cost

Annual running costs include

Fixed-charges:

- Fixed taxes
- Interest on loan and capital repayments
- Insurance (if any)

Running-charges:

- Operation and maintenance costs
- Spare parts and repair costs
- Staff wages
- Administration costs
- Water charges and rates (if any)

As there are no fuel costs, the running costs of a MHP plant should be minimal. However, there are two contributing factors which may increase annual costs above acceptable levels, both of which are common features of the MHP sites discussed in chapter 5. The first is over staffing of a plant. Though labour in developing countries is cheap, wages constitute a large portion of annual expenditure on a MHP plant. Staff numbers should be minimised, but without putting reliable running of the plant at risk. The other factor is repeated breakdown of the machinery or damage to civil works. The reasons for breakdown may be due to poor design and construction or because of neglected maintenance. Plants requiring frequent repair work not only add to the annual operation and maintenance budget, but also reduce incoming revenue to the plant due to stoppages in power production.

2.3.3. Influence of load factor

> *"It cannot be stressed too much that load planning is the key to truly productive and economic isolated hydro electric projects."* [Henwood, 1982, p188]

The load factor of a power generating plant is the ratio of energy actually consumed to the energy available if power were consumed continually at peak levels. This expresses the extent to which the power station is utilised in comparison to the total potential energy available. Load factor has direct bearing on the incoming revenue from energy sales, and hence the profitability of the plant. Grid connected MHP does not have the same loading problems as isolated plants, as the grid will normally absorb the power produced. For isolated plants load factor will depend on the type of load connected. In rural areas of developing countries the main load type is domestic lighting. This means that the load demand is concentrated only over a few hours in the evenings. MHP plants with predominantly domestic load connected will have a load factor of less than 25%.

It is therefore essential to develop day time load in order to increase the utilisation of the plant and improve its economic viability. Day loads can be for agricultural or industrial purposes, or for non-lighting domestic uses. In parts of China communities are encouraged to use off-peak power (daytime) from hydro for cooking, which has the additional advantage of reducing fuel wood consumption [Cecelski, 1992]. Unfortunately, it is usually difficult to replace fuelwood by commercial energy, as fuelwood is obtained at virtually no financial cost to the rural user [FAO, 1990, p.8]. Factors affecting the growth of load in rural areas are: the tariff rate; availability of other energy forms (fuelwood, kerosene, etc.); cost of alternative energy sources; and the familiarity of the user with other energy sources and their reluctance to accept the change to electricity.

Load planning is important to avoid overloading of the system at peak times, which will result in load shedding and reduce the users' confidence in the MHP power supply. Examples of such over loading are discussed in chapter 5.

2.3.4. Financing MHP projects

In financial terms RE is rarely profitable for the developer [UN 1990]. Frequently RE is heavily subsidised by industrial and urban users. The main reasons for this are the dispersed nature of rural load centres, limited scope for productive power uses in rural areas and slow up-take of electricity connections due to low spending power of most rural people.

Because of the initial capital intensity of MHP development, it will inevitably require financial assistance. In particular, isolated or privately developed MHP, which does not have the financial backing of a large utility, will require support to ensure financial security. Financial assistance can be in the form of

- "soft" or low interest loans
- capital subsidy
- tariff subsidy

The type of assistance required will depend on the objectives for developing the MHP project. A project which will supply an extremely remote location where access to fuel is severely limited may require a part or full capital subsidy, as will projects with a high experimental input. Grid connected sites may require a soft loan with an extended repayment period so that the high initial cost can be paid over a realistic time period.

MHP projects are often seen by financial institutions as high risk ventures and therefore not secure investments. Loans which are made available are usually on a short term basis only. This is unsuitable for investment in MHP development which pays back over a relatively long period due to the initially high capital cost [Hurst, 1990; Edwards, 1992]. The MHP technology must be proved to be a viable investment, to both national financial institutes and local creditors, so as to encourage the provision of financing suited to MHP development, as in the examples below.

Since micro hydro power has proved itself as a development aid in Nepal, the Nepali Agricultural Development Bank now offers subsidies of up to 75% for communities or individuals to develop MHP in remote areas, and also provides soft loans, with a longer payback period [Edwards, 1992]. Experiences in Nepal and Pakistan have been that in the initial stages of their micro-hydro technology programmes for rural communities high subsidies were required for demonstration projects. However, when other villages saw the benefits of MHP, they were more willing to pay a greater percentage of the costs to develop their own MHP project, so that subsidies could be reduced [ATDO, 1983; Shrestha, 1989]. In China the government subsidises 1/4 to 1/3 of MHP cost and the Bank of Agriculture and the People's Bank of China offer low interest loans [UN,1982].

A financing trap which many developing countries get caught in is that of "tied-aid" from the developed World [Bell, 1992]. Such aid requires that equipment and expertise be supplied from the donor country. Common end results of this kind of development are that the equipment supplied is not suited to the needs of the recipients or that the recipient country does not have the capability to maintain the equipment, and so becomes dependent on the donor country for repairs and spare parts. Bell describes how U.S., Chinese and Japanese MHP equipment had been given to Nepal in this way. In this case the "aid" has also taken business from the local manufacturing industry. An extreme example of tied-aid is the waste recycling unit discussed in section 4.2.2.

Tariff subsidies and appropriate energy pricing policies are generally used to encourage a specific type of electricity end-user, such as agricultural users, small industries, the poorest sections of society or for cooking to replace fuel wood consumption. For example, in Sri Lanka there is a complex tariff system in operation, which is designed to encourage electricity utilisation by various sectors of the rural economy. Also, at Nepali micro hydro power projects the monthly tariff rate is set not by the energy consumed but by the power capacity available to the household, which is limited by a current limiting device. Reduced tariffs to encourage rural industries or cooking with electricity are seen to consolidate load and improve economic viability of projects, as well as benefiting economic or environmental development. It has been shown also that subsidies or soft loans for the relatively high initial household connection charge can substantially increase the number of subscribers among poorer sections of a community, who would otherwise have difficulty in paying a standard relatively high connection fee [Cecelski, 1992; UPDESCO,1980].

2.4. Establishing and sustaining mini/micro hydro projects

For MHP to be sustainable it is important to form an effective strategy for development. This section introduces some of the choices to be made in forming this strategy.

2.4.1. Site selection

In many developing countries lack of hydrological data, and in particular the seasonal flow variations, makes choice of suitable MHP sites difficult [Santos, 1992]. This can result additionally in poor design specifications based on assumed flow patterns, such as insufficient flow diversion during dry season or inadequate precautions against flood. Hydrological surveying of potential sites and knowledge of flow variation is critically important in the site selection process.

Ideally, grid connected sites should be strategically placed in areas where grid supply is poor in order to boost the over all supply reliability. For isolated sites greater care must be taken to select priority sites for development, ideally aiming to match hydro power availability with the actual power demands of the remote area. Preferably there should be a potential for developing productive uses of power [Hurst, 1990]. To optimise the power delivery system, MHP sites should not be selected to compete with grid extension or other alternative power sources, but instead to complement or supplement them whereever appropriate.

2.4.2. Ownership and management

Ownership and management of a MHP project can either be:

- Centralised, by an electricity utility or renewable development agency, or
- Decentralised, by a community co-operative or private entrepreneur

Many factors - including the political, economic and cultural environments - will determine the most appropriate form of ownership and management for projects in a particular country. In terms of financing and required administrations skills, as projects become smaller it becomes more feasible and necessary to decentralise control.

Mini-hydro is often given low priority status by electricity utilities who also have responsibility for large conventional power projects. Neglect of MHP projects by state electricity boards in India, including diversion of funds from small to large hydro projects [Sharma,1987], prompted the government to provide incentives for MHP development, such as soft loans and subsidies. Agencies for NRSEs have now taken over MHP development in some states.

Cultural and political factors influence the success of decentralised schemes. For example, rural electricity co-operatives were successful in parts of Indonesia and the Philippines [UN,1990], but failed in other developing countries, such as Thailand, because *"the people were not ready in terms of philosophy and education"* [Challakesa, 1990, p.399]. A study of the Nepali experience of micro-hydro projects concluded that community run schemes tended to be dominated by influential community members, whereas sites privately owned by entrepreneurs with "roots in the community" provided a cheaper and better service [ITDG, 1990]. NGOs have been the main motivating force for micro hydro development in Nepal. China on the other hand has a highly devolved system for MHP project development, and community owned MHP is very common. In China there are also extensive infrastructural services, for technical assistance, financing and research and development, which provide a more centralised support base for MHP development. In Pakistan the ATDO, a government agency, has been at the forefront of micro hydro promotion in the Northern hill areas [ATDO, 1983]. They provide the technical expertise and support but expect the rural communities to take over construction and running of the projects. The success of each of the different approaches would appear to be very much the result of the socially and politically accepted norms of each country.

Despite differences in approach to ownership and management in each country, in general, successful micro hydro projects have been developed with a degree of autonomy, but supported by a central body for technological and administrative guidance and financing.

2.4.3. Participation of the user community

Development from a "grassroots" perspective and a higher level of involvement of rural people in development projects are increasingly being emphasised in development literature and by NGOs working in developing countries [FAO,1990; CAFOD, 1992; Chambers, 1983]. The following quote summarises Flavin's experience with rural electrification schemes in less developed countries:

> *"Studies show that when local people are involved, there is less stealing of electricity, equipment is better maintained, and productive end uses of electricity are likely to develop more rapidly."* [Flavin, 1986]

The Indian Eighth Five Year Plan accepts this concept by stating that for future development programmes

> *"A greater push towards decentralisation and people's participation has become necessary".*

In his study of small scale irrigation projects in developing countries, Smout quotes the advantages of people's participation as:-

> *"- lower cost*
>
> *- greater likelihood of user acceptance of the technology*
>
> *- appropriate and socially accepted design*
>
> *- user care and maintenance of facilities*
>
> *- assumption by users of part if not all the responsibility for operation and maintenance"* [Smout, 1990, p.7].

This concurs with recent trends in approach to technology development in rural areas.

In Thailand, which has electrified 94% of its villages, local contribution and participation has been a major factor in the success of R.E.. As a result of the local involvement, villagers take care of the R.E. system because they feel it belongs to them [UN, 1990]. Similarly, the motto of the highly successful Chinese MHP programme is *"Self-construct, self-manage, self-consume"* [HRC, 1985].

Involvement of user communities in MHP can be in the form of:

- Financial contribution
- Negotiation on site location and design, load development and tariff rates
- Contribution of unskilled labour
- Operation and maintenance
- Administration and revenue collection

There may be resistance to new technology in rural areas due to cultural, economic and educational barriers. Education and demonstrations of technology in rural areas can play a significant role in developing rural people's confidence in new technologies [Raghuvanshi, 1987]. Motivating the people may be done by government agencies, though often NGO or voluntary organisations are more effective at working at the grassroots level. The Indian Eighth Five Year Plan describes voluntary organisations as *"catalytic agents of social change in bringing about a harmonious interaction between technology and social engineering"*.

2.4.4. Monitoring and future planning

One aspect of implementing MHP and many other new technology projects in rural areas which is often neglected is that of monitoring. Either monitoring and feedback from projects is overlooked entirely or it is undertaken half-heartedly. For example, the Indian Rural Electrification Corporation has developed a detailed monitoring process for its projects, but admits that it is under-funded and under-staffed, and therefore inefficient [NCAER, 1987].

Barnett, from his experience of the RETAIN programme for the dissemination of rural energy technology in different parts of the less developed countries, found that if a long term commitment is to be made to developing new technologies in rural areas is to be successful, honest and continuous feedback from projects can be of considerable assistance. Barnett states that for "*Introduction of an unfamiliar technology to people who have low purchasing power*" there is "*no substitution for.... the use of trials which provide honest feedback of the users' reaction to the promoted technology*" [Barnett, 1990, p.547]. The emphasis is on "honest" feedback, as often organisations are reluctant to report on problems [Hurst, 1990].

The FAO "new approach" to planning for sustainable rural energy development is dependent on feedback from the rural areas for developing national and regional energy planning. This approach has evolved out of a five year study by the FAO drawing on the accumulated expert knowledge on rural energy development in the Developing World [FAO, 1990].

Without monitoring and project feedback, recurring problems or deficiencies will persist unchecked in future programme planning. A standardised monitoring procedure for project technology, management, load development, user acceptance and operation and maintenance will help to highlight common flaws or attributes of the projects.

2.4.5. The effect of macro-economic policies

The macro-economic policies of a country are usually out of the control of rural energy project planners. These, none the less, can significantly influence how successful the dissemination of the technology will be. Subsidies on diesel, kerosene or grid supplied electricity can adversely bias the energy market against NRSE sources. Import restrictions or taxes on manufacturing will influence costs of NRSE technologies. Legal factors, such as restrictions on private electricity production or land and water rights as well as, political attitude towards NRSEs, MHP or RE, can appreciably affect development [Edwards, 1992].

Promotion of MHP and NRSE technologies may eventually prompt governments to improve the overall economic climate in their favour. Recent global interest in protecting the environment has gone some way to achieving this, through the Earth Summit in Rio de Janero [UN, 1992], by bringing the environment to the forefront of global politics.

2.5. MHP development in selected Asian countries

The Asian countries discussed below all have extensive experience of implementing MHP projects and some indigenous turbine manufacturing capability. The experiences of MHP are varied and often specific to the country's cultural, economic and political climate. However, each experience adds to the knowledge base of MHP development in rural areas of developing countries.

2.5.1. China

The Chinese have developed an intensive state run MHP programme since the 1950s. Currently there are over 100,000 sites in operation. Initially MHP was installed to supply power for irrigation in rural areas, with domestic lighting as a side benefit. Since then MHP has been used as part of rural industry development programmes. More recently local MHP grids have been formed, some of which have been connected into the county grids. MHP is one of China's major power sources for rural electrification, which is now being enhanced by the "200 pilot counties" programme for expanding MHP development [Zhu, 1990, 1992]. China has a highly developed, decentralised infrastructure for MHP manufacture and maintenance, as well as a devolved ownership and administration structure.

The Chinese achievements in developing MHP illustrates the possibilities for MHP development provided that adequate infrastructure and support facilities are established.

2.5.2. Thailand

Since the late 1970s Thailand has installed over 15 mini-hydro (200kW to 2000kW) schemes and 50 micro-hydro (less than 200kW) schemes. These have mostly been government sponsored and developed by the Department of Energy Affairs. Mini hydro projects are run by the Provincial Electricity Authorities and the Department of Energy Affairs. Equipment up to 100kW is manufactured indigenously, whereas mini-hydro equipment is imported from either China or Europe. Micro hydro schemes in Thailand have so far been relatively costly and therefore private or community development is presently not viewed to be feasible [Green, 1991]. There has been criticism that the main organisations involved in micro hydro development have not been concerned with promoting cost effectiveness [Green, 1993, 1994].

2.5.3. Vietnam

About 400 MHP sites have been installed in Vietnam, which are now being established by the provincial authorities. It is estimated, however, that about half these sites are no longer operating primarily due to lack of funding for maintenance. In addition there are around 3000 family hydro sets (50W to 1kW) in use. The family units can be purchased from the market and installed by the user. Initially much of the MHP equipment was imported, though the Vietnamese have now developed indigenous capabilities for producing Francis, Kaplan, pelton and crossflow turbines. They now also produce in Vietnam family hydro units, which were previously only imported from China.

Lack of adequate funding, in particular for maintenance, had acted as a deterrent to MHP development. It is hoped that the availability of cheaper and more reliable indigenous equipment will encourage MHP development in the future [Green, 1993, 1994]. The Vietnamese experience highlights the need for adequate operation and maintenance to sustain projects after commissioning.

2.5.4. Nepal

NGOs have been at the forefront of micro hydro development in Nepal since the mid-1970s, with financial support from the Agricultural Development Bank (Nepal) since the mid-1980s. NGO built micro hydro uses a non-conventional approach and their cost per kW is about a quarter that of the Nepali Electricity Authority (NEA) plants. Currently about 650 agro-processing MHPs are being used in Nepal, of which about 70 have generator which are used to provide lighting in the evenings [Bell, 1990]. About 23 MHP schemes of between 32kW and 345kW have been constructed by the NEA [Acharya, 1992].

There are a number of local manufacturers and workshops producing micro hydro turbines in Nepal. The crossflow turbine is most common, though pelton wheels and multi purpose power units (MPPU) - an improved version of the traditional Himalayan water wheel - are also produced.

2.5.5. Pakistan

Pakistan has around 109MW of MHP installed [WPDC, 1990]. This has been developed mainly by the Pakistan Water and Power Development Authority

(WAPDA) or the Northern Area Works Organisation (NAWO) [UN, 1982]. In addition, the Pakistan Council for Appropriate Technology (PCAT)† have installed several community run micro hydro units in North Pakistan. These mostly use crossflow turbines, though recently they have also been using centrifugal pumps in reverse mode [Williams, 1991].

Pakistan has turbine manufacturing capabilities and produces micro hydro turbines in local workshops. Generating equipment is often imported from China.

The Nepali and Pakistani projects show that community based schemes can be effective if the users are involved. Low cost methods and locally available materials have also been used where possible, with much success.

2.6. Conclusion

Though the design and implementation of MHP in various countries have fundamental similarities, there are country and region specific variables which have to be accounted for. As well as technical design, the development process has to consider the reasons and needs for MHP development, the economic constraints, administrative and organisational structures for implementation and the possibilities for user involvement. Ultimately, developers *have* to consider how projects can be sustained in the region into which they are to be established for the development to be worthwhile. The next chapter presents the development setting for MHP in India, indicating the opportunities and the constraints for development in the Himalayan region.

† PCAT was previously known as the Appropriate Technology Development Organisation (ATDO).

CHAPTER 3
THE DEVELOPMENT PROFILE OF INDIA AND THE HIMALAYAN REGION

India is the seventh largest country in the World and has the second highest population, with 862.7 million inhabitants at the 1991 census. Consequently, it is a country of great variety, with extremes of geography and climate, and a diversity of people and culture.

The geographical, social and economic conditions into which the MHP development is being established and the political, infrastructural and bureaucratic setting govern and determine how such programmes of development take place. This chapter gives an overview first of the characteristics of India, then those of the Indian Himalayas. The chapter ends with an analysis of the development needs as perceived by ten villages surveyed at three of the micro hydro projects in the Uttar Pradesh hills.

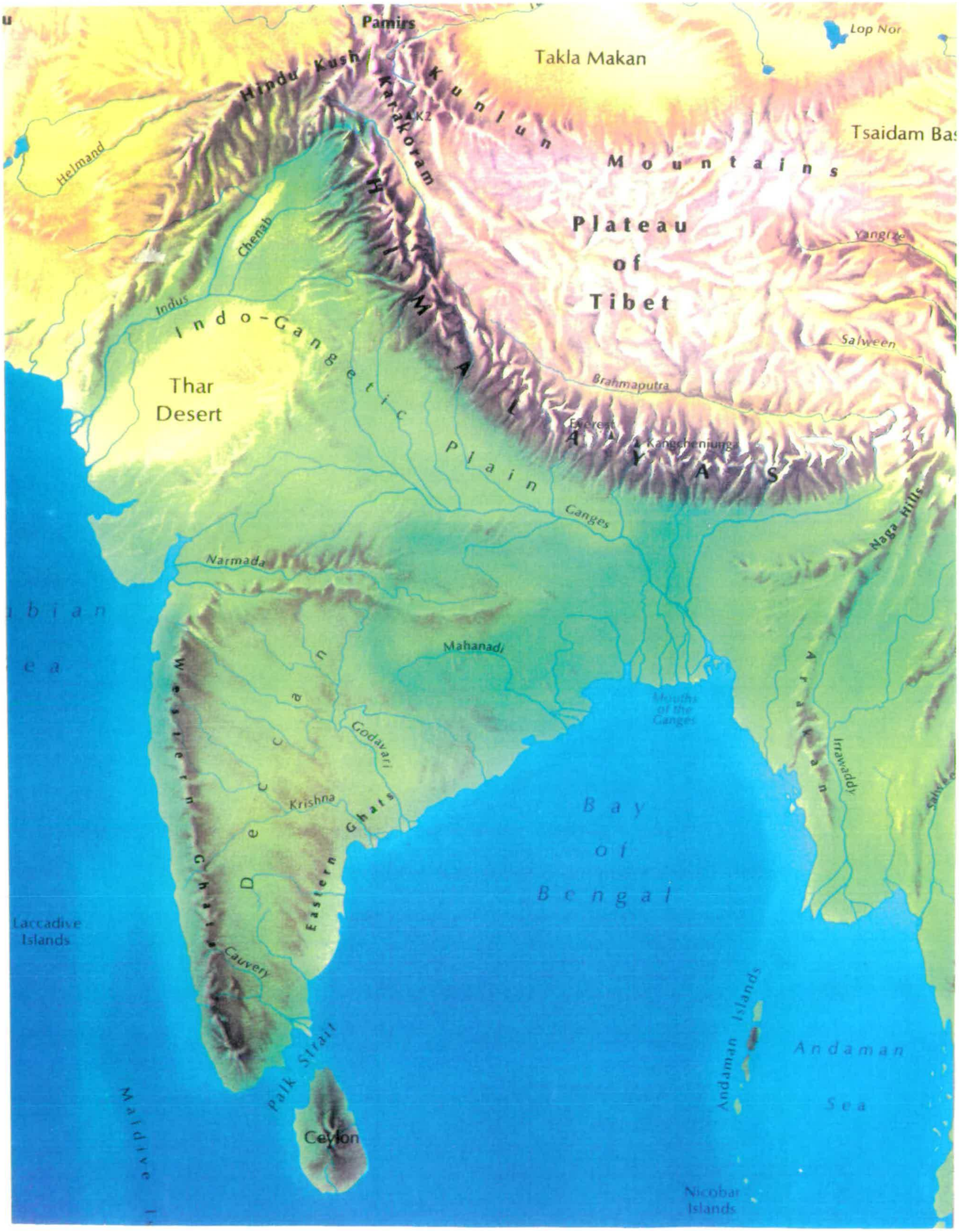
3.1. The Indian context

3.1.1. Geography and climate

India stretches 2000 kilometres in breadth and 2000 kilometres in length. There are six bordering countries: Pakistan; China (Tibet); Bhutan; Nepal; Bangladesh; and Burma. Three bodies of water surround its shores: the Arabian Sea; Indian Ocean; and Bay of Bengal. In area it is one-third the size of the USA, or thirteen times larger than the United Kingdom [Ardley, 1989].

The Indian subcontinent is split into three distinct geographic areas, as shown on the map in figure 3.1. To the south there is the Deccan, or Indian Peninsula, which is a large plateau sloping eastward from the Western Ghat hills. The Indo-Gangetic Plain runs across the top of the Deccan, from Pakistan to the eastern extension of India, in the Naga Hills. The very hot and arid Thar Desert is located in the West of the plain. Finally, the north of the country is dominated by the Himalayan mountain range, with its icy peaks reaching to altitudes over 8,000 metres above sea level [Carpenter, 1979].

Figure 3.1 Geographical Areas of India



The monsoon winds maintain some regularity in the climate across the country, with three identifiable seasons - a cool season, roughly from September to February, a hot season, from March to May, and the rainy season, from June to August.

3.1.2. Population

The population of India has risen at a phenomenal rate over the past century, passing 442.3 million in 1960, and estimated to grow to 1,018 million by the end of the century [UNDP, 1993]. The largest of the Indian states (shown in figure 3.2) is Uttar Pradesh which has a population of 138 million. Uttar Pradesh and Bihar alone account for one quarter of the population, and are also two of the poorest states. Two small states, Punjab and Haryana have the highest per capita income. The small North Eastern states are largely marginalised by the rest of India and are somewhat backward in terms of development.

According to United Nations human development index statistics, India is placed 134th out of 173 countries world wide in terms of development. The average life expectancy at birth is 59 years. Adult literacy is only 48.2%, though there are large disparities across the country as Kerala, Tamil Nadu and West Bengal claim almost 100% literacy. The numbers living in absolute poverty† are 423 million, half the population - 51% of people in rural areas and 40% of urban dwellers [UNDP, 1993]. The Indian government has been forced to admit that "*population growth negates whatever gains the nation has been able to achieve*" [GoI, 1992, vol.1]. This is highlighted by the numbers of highly educated but under-employed† † "elite" and also the even greater numbers of under-educated and under-employed poor.

Although 73% of the population are living in rural areas, there has been a huge trend towards urbanisation in all parts of the country. Calcutta has grown to be the most densely populated city in the world, with 88,000 people per square kilometre (the next most dense city outside India is Cairo with 29,000 people per square kilometre). A large portion of city dwellers live in Bustees, that is shanty towns or slums, and have migrated from the countryside in search of work. Those who migrate to the cities are predominantly young males in search of employment to

† The poverty line is defined as that income level below which a minimum nutritionally adequate diet plus essential non-food requirements are not affordable.

† † Under-employment refers to partial employment or employment on work requiring less skill than the worker has.

Figure 3.2 The Indian States

earn money to send to their families in the villages, leaving a high proportion of females in the rural areas.

There are over 1000 local languages spoken in India, though only 16 are officially recognised, with Hindi and English used for most official purposes. Hinduism is the dominant religion (practised by 80% of the population), though there are many Muslims (10%), Sikhs, Christians and Buddhists also across the country, causing religious tensions and occasionally conflicts is some regions [Ardley, 1989].

The Hindus are separated into four castes; the upper caste, Brahmins, traditionally hold the senior positions in Indian society, followed by the middle caste, the Vaisaya, and lower caste, the Sudra, and then the outcaste, the Harijan or scheduled caste, who are predominantly landless or in menial labour. Scheduled castes make up almost 16% of the population. In addition almost 8% of the Indian peoples are tribal (adivasi), who hold similar status to the harijans [GoI, 1992, vol.2]. Attempts have been made in recent years to promote the status of the scheduled castes and scheduled tribals (SC/ST) by reserving set quotas of government posts and university places for these peoples, and other development programmes and positive discrimination directed at the SC/ST. There have, however, been protests, occasionally violent, against these measures from other sectors of Indian society who view them as reducing benefits to their own kind.

3.1.3. Political structure

The Indian sub-continent was partitioned in 1947, when India gained independence from the United Kingdom and became known as the largest democracy in the world. Britain had previously ruled India for over 200 years. The Indian union is comprised of 26 states and 6 union territories; the states are shown on the map in figure 3.2. Each state is further broken down into several districts for local administrative purposes.

Indian Government

Each state has its own legislative assembly to run local state affairs including health and education. The Indian National Parliament has an upper house, Rajya Sabha, whose members are mostly elected by state assemblies, and lower house, Lok Sabha, which is voted into place by universal suffrage. The President is the head of the country, with executive powers over the union, including charge of the army.

The government is led by the Prime Minister, who is selected by the majority party in the lower house [Hiro, 1978].

Since independence, the Congress party has dominated the Indian parliament, holding power for all but about five years. The Congress party, until recently led by the family of the first Indian Prime Minister Nehru, has a socialist bias and, though India takes a neutral stance, previously had strong ties with the USSR [Housego, 1991]. Over the last few years there has been some political turmoil, with three successive changes in Prime Minister. The Congress party presently holds minority leadership of the country, though there is a strong Hindu Nationalist upsurge led by the Bharatiya Janata Party (BJP) party which currently hold power in the largest state of Uttar Pradesh [Nicoll, 1991]. In certain states, such as West Bengal and Kerala, there is a strong Communist influence.

At a local village level, much of the every day administration is run by the Panchayati Raj system. This is a form of self governing for the welfare and development of the villages, based on a three tier system at village, committee (40 to 50 Panchayats) and district level [Hiro, 1978]. The influence of the Panchayats varies from state to state, and there has been general criticism that they have been dominated by the village elites [Dhingra,1983]. For development purposes, groups of about 100 villages have been designated into blocks, each co-ordinated by a block development officer - discussed further in section 3.5.

The Public Sector

The administration of the government is run by an old-style civil service, well known for its inefficiencies and over staffing. The World Bank estimated that the Indian public sector is over staffed by between 235,000 and 300,000 employees [Housego, 1991], with others estimating about 40% over staffing. There are many complaints about the constraints of the strict and bureaucratic hierarchy within the public sector. The public sector has control of the railways, the power system, telecommunications, coal, steel and state and central industries, most of which are currently loss-making. The inefficiencies of the public sector are compounded by wide spread corruption and mis-appropriation of funds [Housego, 1991]. However, the Indian people have come to be entirely dependent on the government and public sector for many of their basic and developmental needs [Thimmaiah, 1985].

Indian Planning Policy

The Indian government has placed a great deal of importance on its series of Five Year Plans. The Eighth Plan started in 1992: figure 3.3 gives the dates of the successive five year plans and intermittent annual plans.

Figure 3.3 Indian Planning Periods

Plan Period	Date
First	1951-56
Second	1956-61
Third	1961-66
Annual Plans	1966-69
Fourth	1969-74
Fifth	1974-79
Sixth	1980-85
Seventh	1985-90
Annual Plans	1990-92
Eighth	1992-97

The Five Year Plans have mapped out the pattern of the changing development strategy and goals since independence. Each plan lays out the government aims for a five year period, and monitors the progress over the previous plan period, though the Seventh Plan also set targets for a longer term, until the year 2000. The plans intend to develop the country at a realistic rate, with the purpose of achieving a stable and independent economy. The objectives for the energy sector in the Eighth Plan are discussed in detail in the next chapter. The main restriction of the planning process has been financial, both in access to finance and control over how money is utilised. The Eighth Plan admits that the country's poverty alleviation programmes are "*Beset with substantial leakages*" [GoI, 1992, vol.1].

Political and Economic Change

India has, over the past forty years, been a protectionist country with a "*doctrine of self-reliance and central planning*" [Housego, 1991]. However, in 1991, Prime Minister Narasimha Rao introduced political and economic reforms aimed a "*stabilising the economy and deregulating trade and Industry*" [Sharma, 1991b].

The reforms have emphasised the opening up and liberalisation of trade, including increased privatisation, application of fewer regulations on industry, fewer restrictions on import/export and increased foreign investment. The Indian government has been under huge financial pressures, with a trade deficit of over US$70 billion on which it has been close to defaulting payment. This has forced India into dropping its highly independent stance; for the first time in 1992 overseas companies were be allowed over 50% equity in Indian industry [Sharma, 1991]. The reasons stated for "permitting" foreign investment were said to be to "bring better technology, expand production and increase exports" [Housego, 1991]. None-the-less, in his foreword to the Eighth Five Year Plan, Rao stated

> *"The market can be expected to bring about an "equilibrium" between "demand" - backed by purchasing power - and "supply", but it will not be able to ensure a balance between "need" and "supply".* [GoI, 1992, vol.1]

Thereby, India has stopped short of complete transition to free market economy, despite pressure from the IMF to go further with the reforms. India has recognised the necessity of protecting the needs of the poor, such as by subsidising fertiliser for marginal farmers and power supplies for irrigation pumping. However, it is inevitable that widening the influence of the private sector will have considerable impact on the traditionally public sector industries. The impact of private investment on the power sector, and the influence particularly on the dissemination of NRSEs and MHP technologies in India are considered in chapters 4 and 6.

3.1.4. Economy

Although India is one of the ten most industrialised countries in the world, it is also classed as one of the poorest, with a gross national product per capita in 1990 of US$360, which is compared with others in figure 3.4 [UNDP, 1993].

Figure 3.4 Gross National Product per capita in US$	
India	360
Ethiopia	120
USA	21,810
UK	16,080
World Average	4010
Developing Counties Average	810

Source: UNDP, 1993

The poverty gap in India is the most serious problem facing the country. The World Bank reported in 1990 that

> *"In parts of India.....growing landlessness and disproportionately little access to irrigation, electricity and social services have perpetuated concentrations of deepest poverty and accentuated income and irrigation disparities."* [WB, 1990]

The Indian government recognised this problem in its Seventh Five Year Plan, stating the main objectives of the plan to be the removal of poverty, ignorance and disease, and the modernisation of society using science and technology. Unfortunately, this aim is unlikely to be fulfilled since the population is increasing at a rate of 2.5% per annum, against the increase in employment of only 2.2% per annum. [GoI, 1992]

The changing balance of the three economic sectors - agriculture, industry and service - has been towards a growth in the service sector, with 27% of the labour force and 40% of the national income coming from this sector, as shown in figure 3.5.

Figure 3.5 Sectoral distribution of Income and Labour in India

Sector	% of Labour Force		Income as % of GDP
	1965	1990	1990
Agriculture	73%	62%	31%
Industry	12%	11%	29%
Service	15%	27%	40%

Source UNDP, 1993

Exports from India account for only 6% of its GDP, and imports amount to 8% of GDP, indicating a large deficit on income to the country. The average import and export figures for developing countries are 19% and 21% of national GDP respectively [UNDP, 1993]. Although a vast agricultural country, India has a strong industrial base, especially in heavy industry [Schneider, 1988], as highlighted in Figure 3.6 which shows the main products and exports of India and the major import requirements. It is noted that India uses about 25% of its export earnings for servicing its external debt and about 30% on petroleum imports.

Figure 3.6 Production, import and export in India (1990)	
Agriculture	Rice,sugar cane, cotton, jute, tea
Industry	Steel, cloth, cement, fertiliser
Mining	Coal, bauxite, copper and iron ore
Exports	Gems and jewellery(US$2.98 billion)/ textiles(US$1.37 billion), engineering goods(US$1.6 billion)/ tea(US$0.41 billion)
Imports	Petroleum(US$2.94 billion)/ capital goods inc. electrical machinery(US$3.65 billion)/ food and edible oils(US$1.23 billion)/ gems(US$1.98 billion)/ iron ore (US$1.21 billion)

Source: FEER, 1991

The Asia year book identifies two restrictions for economic expansion in India, the first being the environmental devastation which has so far accompanied much of the economic growth in the country, and secondly, claimed to be the single biggest constraint, is the acute imbalance between demand for energy (especially petroleum) and lack of reliable energy and power supply [FEER, 1991]. Chapter 4 discusses the energy and power shortages in relation to the demand and the environmental impact of the expanding energy sector.

Agriculture

The main source of employment in the rural areas is agriculture. Programmes have been run since the 1960s to modernise agricultural methods by introducing mechanisation, large scale irrigation and "miracle" high yield seeds. This has commonly been known as the "green revolution". The dissemination of electric tubewell pumps for lifting ground water for irrigation has been a motivating feature of the rural electrification programme. Benefits from the green revolution have generally only affected the small wealthier states such as Punjab and Haryana, whereas the poorer states such as Uttar Pradesh, Bihar and the North Eastern states have been left behind [Vepa, 1988]. The Himalayan state of Himachal Pradesh has greatly increased its economic output in recent years through developing fruit growing, in particular growing apples. Usually it is only the wealthier land owners who can afford to adopt the new techniques. The majority of India's farms remain marginal, most less than one hectare, using primitive, traditional farming techniques. Two thirds of India's arable land remains un-irrigated. Overall, though, the food production in India has increased greatly, so that it is almost self-sufficient in most food stuffs, despite the huge increase in the population it has to feed [Thimmaiah, 1985].

Land reforms were introduced in the 1960s, in particular "ceiling" laws on land to limit the size of farms, and therefore redistribute the land more fairly. Unfortunately ceiling laws have been difficult to enforce and are frequently abused. Despite the introduction of the green revolution, land ceiling and improved tenancy laws to restrict absentee landlords, between 1961 and 1971 the numbers of landless rose by 81% [Hiro, 1978].

The attempts by the Indian government to improve the living standards of the small farmers are often negated by the economic strength of the larger land owners. The subsidies on power supply for the rural sector, for example, have primarily aided farmers with larger land areas, who can afford to adopt modern farm techniques and pumped irrigation, and therefore increase productivity. Subsistence farmers cannot take advantage of power supply, as their minimal income is insufficient to take an electrical connection. Therefore, inequalities in the rural areas are further emphasised. The implications of this for the success of MHP development projects are considered in ch6.

Industry

Over the last century, industry in India has increased rapidly, with major products including steel, cloth and fertiliser. In its Seventh Plan India claimed to be the

> *"leading Third World exporter of industrial know-how, technical consultancy, and turn-key industry projects"* [GoI, 1985]

In addition, India has a large mining industry, extracting both coal and metal ores. Mining is mainly found in the states on the Indian plains, but there are mineral resources in most hill states also. Minerals found in the hill states include limestone, copper and dolomite. Geographical and environmental constraints restrict mining practice in hill areas. The author visited an area of Dehradun district in Uttar Pradesh where limestone mining had resulted in widespread deforestation. Efforts are now being made at great cost to reforest the area.

Small and village industries have been recognised as particularly important since independence. Small scale industry (SSI) - defined as industries with investment of less than Rs3.5 million - now accounts for 80% of employment in industry and 50% of industrial production [Vepa, 1988]. These have been particularly encouraged as they are often based in rural and semi-urban areas. With 70% of the population living in rural areas, and the population as a whole growing rapidly, there is a rapidly increasing need to provide employment and income for the rural communities.

In 1985/86, 886 products were "reserved" for production by the SSIs only. Uttar Pradesh has set up a separate Department of Village and Small Industries and that state alone now has over 100,000 SSI units, second only to West Bengal. It has been found that SSIs have been most successful in more developed states and in regions with a well developed infrastructure. The Small Industry Development Programme was set up to encourage SSI and financing is provided through the National Bank of Agriculture and Rural Development [Vepa, 1988]. However, there is still great difficulty in obtaining credit for SSIs, as there is no separate financing system for SSI and they generally lack collateral backing. The most successful SSIs have been set up by small contractors and manufacturers of sophisticated items run by wealthier entrepreneurs, rather than agro-based or rural based industries [Mehta, 1984].

As well as encouraging the dissemination of tubewells for pumping ground water for irrigation, RE programmes have attempted to promote rural industry by extending connections for setting up SSIs. These industries have not materialised as expected. The prime reason for this is claimed to be the poor availability of power in the rural areas [GoI, 1992, vol.2]. The Eighth Plan states that rural industries are to be specifically promoted in conjunction with RE in order to provide employment and increase the incomes of rural communities. Improvements in rural power supply must be given priority if this aim is to be achieved.

3.1.5. Rural development strategy

The first priority of the Indian rural development strategy has been to provide the basic necessities for life - water, food, clothing, housing, livelihood. After this there are three areas of development needs: social welfare, including health and education; infrastructure, such as roads and communications; and productivity in the three economic sectors, agriculture, industry and services.

Since independence the Indian government has introduced a number of programmes and schemes aimed at combatting poverty and developing the rural areas. These started in 1948 with 64 "pilot project" villages for development. This was expanded in 1949 with the "Grow More Food Campaign" and the start of the land reform policies. The first of the five year plans saw the start of the National Extension Service, which set up the block system, with block development officers and block staff employed for "extension" to the villages with the aim of all round development of the block. The results at the end of the first three plan periods indicated only partial achievement of the original goals [Tewari, 1988].

In the fourth plan period twenty programmes were set up aimed at target groups, in particular for "extremely backward areas" such as drought-prone, tribal, hill and industrially backward areas. The "Minimum Needs" programme was introduced in the fifth plan period, including Indira Gandhi's "20-point programme", which highlighted the twenty aspects required for development, including education, health, water supply, nutrition, roads and rural electrification. [Mehta, 1984]

In 1976 the "Integrated Rural Development Programme" (IRDP) was initiated with the aim of "*optimum utilisation of local resources*" [Mehta, 1984] and the "*eradication of backwardness, ignorance and poverty*"[Dhingra, 1983]. IRDP was designed to develop target groups in each block, usually the poorest such as SC/ST, rural artisans and marginal farmers, to bring their living standard above the poverty line. The Panchayati system has been a key instrument of this programme. The IRDP has been described as a "*bold experiment in positive discrimination*" [Maheshwari, 1985].

However, there have been numerous criticisms of the government development strategies. It has been found that, despite attempts to target the poor, it is frequently the wealthier and influential people in the villages who gain most from any programme. This has been due to the "top-down" approach which has evolved, where development is imposed from higher authorities to the villagers through the strict hierarchy. Problems have resulted from lack of interest and motivation of block development officers (BDO) and district development officers, who have no desire to stay in remote rural posts, but would prefer the benefits of a position in an urban area [GoI, 1992; Maheswari, 1985]. Such problems were identified by village leaders in the village surveys discussed at the end of this chapter. BDOs are known to exaggerate the benefits gained and also to hide failures, therefore there is no effective monitoring of progress. It is generally the case that there is a lack of basic centrally held information on the villages.

A highly significant factor in the inefficiency of development in India has been the lack of co-operation and co-ordination of the various programmes for development [Singh, 1987], which are run by a proliferation of agencies and government departments [Maheshwari, 1985]. The Ministry for Rural Development runs the special programmes for rural development, but by no means is in charge of all rural development. For example, the Ministry for Home Affairs administers the welfare of the ST/SC, the Ministry of Education is in charge of rural education programmes, the Ministry of Transport builds rural road networks and the Ministry of Energy is in charge of rural electrification development. The Eighth Five Year Plan has realised this and introduced the concept of an "umbrella" for co-ordinating policy formulation and implementation, bringing the various departments/agencies involved in rural development together.

Recently it has been realised that the rural people must be involved in the formation and implementation of rural development programmes. Local involvement has been effective in different parts of India by a variety of means. For example, grassroots organisations and trades unions have been effective in Kerala, co-operatives are common in Gujarat (the most famous being the Amul milk co-operative which provides much of the country's dairy products) and a more capitalistic, intensive farm approach has been taken in Punjab. Women's organisations, such as the Himalayan environmental movement Chipko, have a long tradition throughout India, though they rarely have sufficient authority to operate independently [Thimmaiah, 1985]. The government has identified Panchayats and voluntary organisations as being instrumental in encouraging such development strategy [GoI, 1992 vol.1]. However, the present bureaucratic structure of government does not allow for decentralisation of decision making as there is a strict hierarchy of administrative power within the public sector. It remains to be seen how effective decentralisation of development organisation will be in India and what role the non-government organisations will play. This issue is discussed with respect to MHP development in chapter 6.

3.2. The Himalayan context

3.2.1. Geography and climate

The Indian Himalayan region has a total geographical area of 0.53 million square kilometres, representing about 16.7% of the Indian land area. The region can be split into three mountain ranges:

Greater Himalaya - average altitude 6100 metres

Lesser Himalaya - 2600 to 4600 metres

Outer Himalaya - 1000 to 1300 metres [Bahadur, 1985].

Below this level is found the sub-Himalayan zone or lower foothills. In general the height of the Himalayas increases from west to east and from south to north [Dewan, 1987].

There are four agricultural zones of the Himalayan region. The low hills, at less than 1000 metres altitude, have a tropical to sub-temperate climate and a combination of rolling hills and deep, fertile valleys. The mid-hills, at between 1000 and 1500 metres, with a sub-tropical to temperate climate, consist mainly of steeper slopes and has agriculture which depends on rain water. The high hills, between 1500 to 2000 metres in altitude, have a temperate climate which is suitable for fruit growing, and again the agriculture is dependent on rain water. Finally, the very high hills, ranging from 2500 to 8000 metres in altitude, with a cooler climate, have very restricted agricultural potential. Above this range the land is perpetually snow bound, and many lower hills are snow bound in the winter months, only allowing for mono-cropping. [Sharma, 1991]

Apart from the extremes of temperature in the region, the rainfall also has extremes, with a wet:dry season ratio of surface water flow of around 1000:1 not uncommon, causing flooding and landslides. Most parts of the Himalayas receive around 70% of the annual rainfall during the monsoon [Das, 1981]. The rainfall in the North East and the foothills is higher than the greater Himalayan ranges of the West, with most of Jammu and Kashmir receiving low levels of rainfall [Dhar, 1992b].

The Himalayan ecology is fragile. The young geology of the mountains means that they are easily eroded, and there is a naturally high silt content in streams, which increases when the soil is exposed due to deforestation and other human interference. Chapters 5 and 6 contain clear examples of how the Himalayan geography and climate have had direct impact on MHP projects and the environmental constraints imposed on such developments in the Himalayan region.

3.2.2. Population

The Himalayan population is approximately 16.7% of the nation. In all of India the population increase between 1911 and 1981 was 272%; in some North Eastern states the increase was 400% [SHERPA, 1991]. The population increase in the Himalayan region has generally been higher than in the rest of the country. There has also been an increasing migration of people, and in particular young men, from the Himalayas to the plains, and from poorer to wealthier Himalayan districts. For example, out-migration from the remote Almora and Pithoragarh districts of Uttar Pradesh has been high, compared to high levels of in-migration to the more developed Nainital district [Khanka, 1984]. The out migration of educated and trained people is draining the human resources of the region.

There are many differences between the Western and Eastern Himalayan regions, not only in climate, topography and vegetation, but also in the ethnic origin of the peoples. There is a higher proportion of tribal peoples in the North East, many of whom keep their traditional life style. Arunachal Pradesh, Megalaya, Nagaland and Mizoram are dominantly made up of tribal peoples. The difference in culture may be partly attributed to the relatively higher exposure of the Western Himalayan communities to the outside cultures. The numbers of scheduled castes are greatest in Himachal Pradesh and Uttar Pradesh, where they make up about 25% and 16% of the communities, respectively [Dhar, 1992b].

3.2.3. Infrastructure

The location of the Himalayan states, on the borders with neighbouring countries, makes them highly politically and strategically important. None the less, transport and communications within the region are extremely poor. Railways are limited to connections between the plains and main hill towns. Some North Eastern states have no rail connection at all. Transport depends on the road network. Road travel in the Himalayas can be hazardous, especially in the rainy season when floods and landslides are common. Many villages in the hills have no road connection and can only be approached on foot: for example, in Uttar Pradesh hill districts only 21% of villages may be reached by a durable permanent road, and 34% are more than five kilometers from a road. In Himachal Pradesh 44% of villages are road connected. Road development is mostly done in an ad hoc manner, which until recently has had little regard for the environmental impact of construction. Transportation and communication is vital for economic development of the region, but must not unnecessarily disrupt the ecological balance.

Similarly, postal service, telephones, printed media, radio and television have a limited coverage in the Himalayan region, mainly because of the high cost of such communications, the difficulties of the terrain and low consumer density [Dhar, 1992b].

Social services, such as education and health, appear to be satisfactory in many of the hill states, but the coverage of such facilities is poorly distributed. It is the village communities in the most remote, off the road locations which have least access to services. The cost of establishing and maintaining services in such remote areas is prohibitively high. Access to potable water varies from region to region. Himachal Pradesh has almost complete coverage, whereas in Jammu and Kashmir and Uttar Pradesh coverage is widespread in more developed districts but low in less developed districts. The overall provision of water supply in Uttar Pradesh is 91%, with highest levels in Nainital and Uttar Kashi [Dhar, 1992b].

3.2.4. Hill economy

Though agriculture is by far the greatest source of livelihood for the Himalayan people, the Himalayan habitat is not suited to intensive, modern farm methods, except on the lower hill and valleys. The agricultural land base of the hill regions is very limited. In the Uttar Pradesh hills only about 13% of the land area is cultivated, compared with 58% across the state. Only 29% of the cultivated area is irrigated [Papola, 1984]. Lift irrigation, by electric pumps or hydrams, is limited by the topography of the land and also by the lack of support for maintenance and the high cost of the equipment [Jura, 1991]. The electric tube well programme, at the forefront of rural electrification in other states, has hardly affected the

Himalayan region. However, the advantages of irrigation would tremendously aid the hill agriculture if utilised wherever feasible. Figure 3.7 shows the huge difference in crop production using lift irrigation. The use of chemical fertilisers is also limited, again with use in the lower hill being the greatest. In the Almora district of Uttar Pradesh only 4 kilogrammes of fertiliser is used per hectare of land, in Pithoragarh 2 kilogrammes and in Nainital 97 kilogrammes are used [Khanka, 1984], indicating the poor quality of farming in the more remote districts.

Figure 3.7 Productivity of hill crops under rain fed and irrigated situations (quintals per hectare*) in Almora District

Crop	Rainfed	Fully Irrigated
Wheat	18.0	42.5
Paddy	15.5	47.4
Oil Seed	6.7	14.2
Soya	18.0	22.5
French Bean	64.6	90.4
Tomato	25.6	60.5

* quintal = 50.8kg
Source: Sharma, 1991

With the limitations of hill agriculture, it is vital to develop alternative means of income for the expanding hill communities. For example, horticulture has brought increased prosperity to Himachal Pradesh in recent years. The state government has had a key role in the development of apple growing, through a German collaboration [Melkania, 1987]. This, along with the development of tourism and trekking in the state, has tremendously improved the overall standard of development in Himachal Pradesh, unlike in most other Himalayan regions. The hinderance to the fruit growing potential of the Himalayas as a whole include poor transportation, scarcity of packaging material and poor storage and marketing facilities. Environmental has also been a major concern.

Industries in the Himalayan region are highly concentrated in town areas. In the Uttar Pradesh hill districts, the main industrial areas are in Dehradun and Nainital, both of which have substantial areas of plains. Similarly, in the North East, only Assam has significant industrial development as several of its districts are on the plains. In Himachal Pradesh and Jammu and Kashmir industry is centred on the state capital. In addition, there are a small number of cottage crafts and rural artisans operating in the villages. The fruit processing industry has a high potential in many rural hill areas.

If the infrastructure for rural industry is developed further, there may be opportunity to develop a number of new small industrial, agro-industry and craft work enterprises in the hills. If development of this kind is to be sustainable in the Himalayan region, infrastructural development must include development of environmentally benign energy sources, as alternatives to fuelwood and diesel. Industries which have been identified as having potential for development in association with the use of off peak (daytime) power from MHP plants in rural hill areas are mostly agro-based, forest based (carpentry and saw mills) or cloth and garment making [DST, 1991; DESCO, 1990]. For such industries to be successful there must be co-ordination with other development agencies, for training and finance, which presently is lacking.

The service sector in the hills consists almost totally of government posts [Khanka, 1984].

3.2.5. Hill development

Human activities have far reaching effects on the hill regions, so great care must be taken in the planning of development projects. There are several constraints for developing business and industry in the remote Himalayan districts. A study of one block in the Pithoragarh district of Uttar Pradesh identified the constraints to be [UPDESCO, 1990]:

a) difficulty in accessing finance and credit;

b) poor marketing facilities, for raw materials and finished goods;

c) lack of technical guidance and training;

d) very poor infrastructure;

e) lack of initiative and aptitude for entrepreneurial activities; and

f) poor co-ordination between development schemes, agencies and institutions.

The lack of economic development specifically of the Himalayan region, can, however, be attributed primarily to the geo-physical features of the region - poor soil quality and soil erosion, extreme climate, highly un-even topography and limited access, and restrictions arising from the fragile environment [SHERPA,1991] - which will hinder any development efforts.

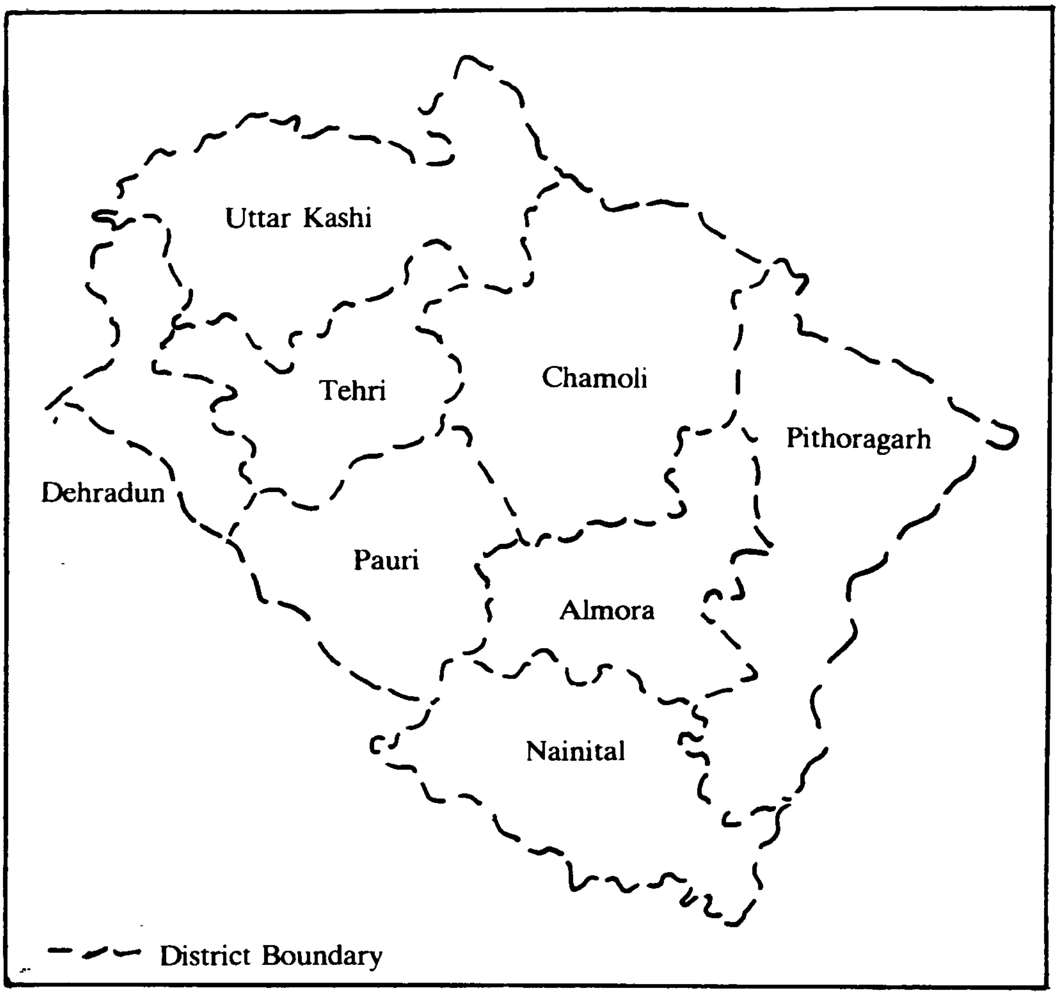
Poverty in the hills is the result of poor access to the basic needs for subsistence, inadequate social services and the limited opportunity for economic development. The Eighth Plan has targeted the development of the hill economy, moving from the previous focus on infrastructural development. The plan claims that its aims are to harmonise socio-economic growth, infrastructural development and protection of the ecology in the hills [GoI, 1992, vol.2]. Raising the cash income of the people in the rural hill areas has become increasingly vital, as hill communities are further integrated into the market system and the limitations of the local resources increase the dependence on the outside regions. For example, the provision of electricity or other alternative fuels to reduce the utilisation of fuelwood will not have effect until the buying capacity of the hill people is sufficient to pay for these commercial fuels [Purohit, 1981].

3.3. Development requirements - results of village surveys

Figure 3.8 shows a map of the Uttar Pradesh hill districts. All ten villages surveyed are in the lower hill districts, three at the Ramgad MHP project on a tourist route in Nainital district, four at the road side Dior MHP project in Pauri and three at the Bilkot MHP project in an interior region of the Pauri district. The Bilkot and Dior villages are located in the Corbet National Wildlife Park. Figure 3.9 gives details of the villages. It is noted that most of the larger settlements are "Gram Sabhan", that is a group of closely located smaller villages who are led by one "Gram Pradhan", or head man.

The surveys are used here as illustration of some of the development problems of the Himalayan villages in the Uttar Pradesh hill district. The survey provides examples of the needs and limitations of specific villages, reinforcing and confirming the preceding analysis of Himalayan life.

Figure 3.8 The Uttar Pradesh Hill Districts



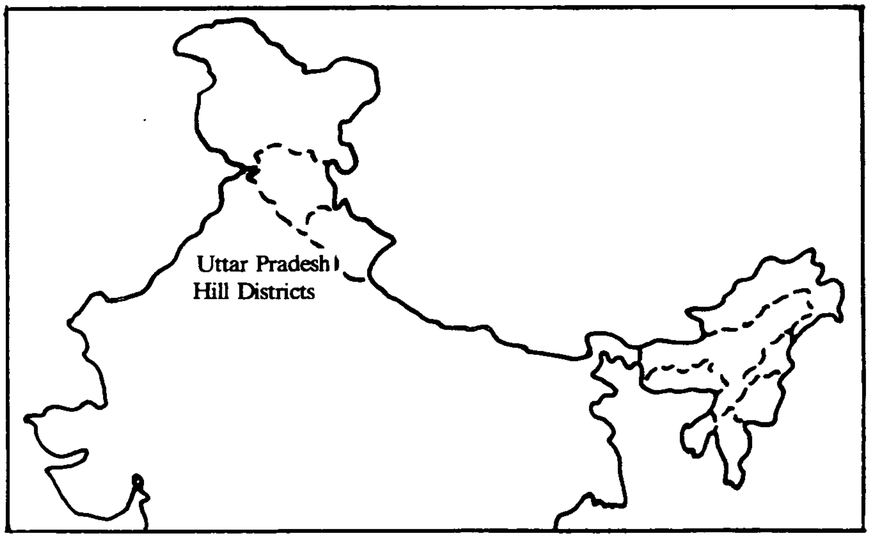


Figure 3.9 Village details

Name	District	Distance from Road (km)	No. of Households Total	No. of Households Scheduled	Total Population
Ramgad Project					
Kapulta	Nainital	Roadside	85	2	720
Garjuli	Nainital	6	95	40	n.a.
Bargal	Nainital	Roadside	80	15	500
Dior Project					
Khadrasi	Pauri	3	200	30	950
Kanda	Pauri	Roadside	95	2	400
Kartiya	Pauri	Roadside	200	100	500
Dior	Pauri	Roadside	19	15	90
Bilkot Project					
Umta	Pauri	8	200	80	1000
Bilkot	Pauri	5	155	7	n.a.
Chillaon	Pauri	8	200	50	1200

n.a. - not available

Amenities and services

Social services in the villages are some what erratic. Education of the children is viewed as a high priority. Two of the villages do not have primary schools, and there is great concern from the Umta villagers about sending primary aged children 4 kilometres across hilly terrain to the nearest school. Secondary schooling is available near to all the Ramgad villages, but not at the Bilkot or Dior villages where children have to walk at least five kilometres to school.

Medical facilities are, again, most accessible at the Ramgad villages, where there is a hospital six kilometres away. The only medical facilities available at Dior are at clinic at Khadrasi, usually without a doctor available. At Bilkot the only facility is a private clinic, with no doctor, five kilometres from the villages. Most of the villages have piped water, though four villages, two of the Dior villages, one at Ramgad and one Bilkot, have to take water from a stream.

Post offices were located in or near to all the villages, but banking facilities were totally inaccessible at the Dior and Bilkot villages. The bank nearest the Ramgad villages was at a distance of 6 kilometres. Shop facilities are minimal in the villages, with only one small store in some villages for commodities such as sugar, tea and batteries. One village in the Bargal Gram Sabha is a market town, so it is unusual in that it has small hotels, shops and restaurants.

Occupation and Income

The main occupation in all of the villages is farming. At Ramgad, which is located at a lower altitude and in a valley, there is a predominance of market farming of vegetables (peas, tomatoes, sweet peppers, etc) for cash crop sales. Fields at Ramgad villages are all irrigated by gravity fed channels. The average farm size is very small at about one hectare, but the annual income from farming can be as high as Rs20,000 (US$570). Productivity at the more interior village of Garjuli is less than the other, road side, villages. The average income at Garjuli is only about Rs6,000 (US$170). It is noted that Garjuli has a higher proportion of the poorer section of scheduled caste households. At Bargal there are about twenty-five people working in commercial business (shops and restaurants). In other villages there are no commercial activities other than a few flour mills. Generally, the villages at the Ramgad project have a relatively high income when compared to other Himalayan villages, due to their lower altitude, quality of farmland, accessible location and relatively better developed infrastructure.

At Bilkot and Dior the economic situation is very different. The Bilkot and Dior villagers have larger farms, at about three to five hectares. These are at higher altitude and, particularly at Bilkot, on poorer terrain. The main crops are wheat, paddy and a few vegetables, which produce only sufficient for village subsistence needs - less if the crops are damaged by wild animals which inhabit the national park.

Dior village has one hydram for pumping irrigation water and Kanda has two hydrams which have been broken for four years. At the other villages there is an understanding that pumped irrigation is not feasible due to the terrain, so crops have gravity and rain fed irrigation only. There were frequent complaints that irrigation works were damaged, and it is assumed that it is the responsibility of the irrigation department to repair any faults.

Those who farm for subsistence have to supplement their income by other means.

This usually requires the men to labour for the government on irrigation and road works, for one to three months in the year depending on work availability. The labourers earn about Rs25 per day, which is less than one U.S. dollar. Frequently money was sent to village households from relatives who had gone to a town to find waged employment. Another important source of cash income for the hill communities is from pensions of ex-army servicemen, as was found at the slightly more wealthy village of Khadrasi.

Development Priorities

None of the villages has a development organisation working in the village, though the Gram Pradans will meet regularly to discuss village needs. In some villages the block development officer had visited to discuss development of village infrastructure, but there is general discontent with the block development system and its staff, and a feeling that some BDOs are corrupt.

The perceived development needs were generally improved road and village access, school facilities, irrigation supply and better drinking water supply. Two villages viewed a bridge as important; in Kartiya village a girl had been drowned while wading the stream. The Bilkot and Dior villages requested protection from the wild animals in the national park, as they are not allowed to kill the animals but animals had killed some villagers and destroyed crops. The villagers were happy to receive electricity, if they were able to afford it, but this was not generally a priority. The villagers views on electrification and MHP are discussed further in chapter 5.

3.4. Conclusion

Development efforts in India are frequently undermined by the rapid growth in population and are restricted by the bureaucratic structures of the organisations implementing the development programmes. Recently, there has been an increasing understanding of the need to involve local communities and NGOs directly in the development process, so as to initiate programmes at the grassroots level.

The Himalayan region has specific characteristics of terrain, infrastructure and economy which require special attention. The development priorities of the

Himalayan communities are often focussed on basic necessities of subsistence. However, as the agricultural base of the Himalayan region is being exploited to the extremes of the ecological limits, there is need for diversification of activities, without adverse environmental implications.

Increasing energy needs for daily life as well as for economic activities will put further strain on local resources and increase demand for commercial fuels. The next chapter considers the patterns of energy supply and demand in India. The role of and development potential for NRSEs and particularly MHP are considered within this context, assessing the extent to which they can be utilised to meet rural energy needs.

CHAPTER 4
THE INDIAN ENERGY SECTOR

Although in India there has been a steady increase in the consumption of every type of energy resource, there has been a change in precedence between the various energy resources within the Indian economy. Energy supplies in India as a whole, both in the commercial and non-commercial sectors, have increased from 82.7 million tonnes of oil equivalent (MTOE) in 1950/51 to 291MTOE in 1990/91. In rural areas non-commercial energy sources still account for over 90% of energy used, whereas the share of non-commercial energy has decreased in the over all national energy consumption from 74% to 41% [GOI, 1992, vol.2], indicating rapid growth of the urban and industrial sectors over the the last four decades. India has the largest coal resources in South Asia and also holds reserves of oil and natural gas, though oil remains the country's largest imported commodity. The power sector is increasingly vital for industrial and economic growth, though utilities are struggling to expand installed capacity to match the growing demand from all economic sectors, including the rural sector. While currently their impact on energy supply has been marginal, renewable energies have been recognised in the medium and long term energy planning of the country.

This chapter examines the structure of the Indian energy sector, looking at non-commercial, commercial and renewable sources. The country's energy policies and future planning are assessed in parallel with the demand characteristics and environmental considerations which can no longer be ignored in energy planning. In the latter part of the chapter the changing nature of the power sector is analysed, the possible role of NRSEs is assessed, and, in particular, the infrastructural setting and future opportunities for MHP development are considered.

4.1. Non-commercial energy sources

Non-commercial or traditional energy sources are those, such as human and animal power, fuelwood, dung and agricultural waste, which are freely available to the user. The rural and urban poor in India, as in all developing countries, depend on non-commercial energy sources to meet daily requirements. Financial constraints and poor accessibility of commercial alternatives perpetuate the dependence of the poor on traditional energies for domestic, agricultural, industrial and transport needs. This section describes the pattern of use of non-commercial fuels in India.

The burning of fuelwood alone accounts for 65% of non-commercial energy consumed in the country [GOI, 1992, vol.2]. Unfortunately this is burned mainly on stoves or open fires with energy efficiency of under 15%. The growth in demand for wood has greatly exceeded the production rate, so that there is continuing deforestation of large areas of the country resulting in a gradual decline in fuelwood availability. The national coverage of adequately forested land is only about 11%, instead of the national requirement for one third forest cover (two thirds in the Hill regions) to supply fuelwood, timber, fodder and industrial needs [GOI, 1992, vol.1]. Use of this supposedly renewable source of energy is the result of unplanned and uncontrolled activity. There is concern that its use will have to be better managed, for example through the dissemination of improved efficiency cooking stoves (improved chulhas†), by greater effort to reforest vast areas of denuded forest land, and through substitution by other energy sources. A secondary effect of fuelwood scarcity has been an increasing commercial value being placed on fuelwood, especially for urban use but also in some rural areas.

For rural energy supply, fuelwood is supplemented by cow dung and other forms of agricultural waste. The use of various fuels depends on a number of factors, including fuel availability and traditional practice. For example, dung is used less in hill regions for four main reasons: cattle are generally not stall fed, therefore collection problems arise; problems of low temperature affect the drying of the dung and burning efficiency; there are religious restrictions; and dung is primarily used as a fertiliser [Sharma, 1987b]. Household income is another important factor in the pattern of fuel use; as incomes increase there is a trend towards commercial fuels and to acquire improved efficiency wood stoves. Fuel consumption patterns also change with increase in altitude, as fuelwood is often the only fuel source adequately available in significant quantity at higher levels. An example of fuel use variations in one area of the Tehri Gharwal district of the Uttar Pradesh hills at "low", "medium" and "high" altitude is given in figure 4.1. It has also been estimated that, on average, energy consumption in the hills is 30% greater than on the plains. Figure 4.2 shows the large variation in patterns of non-commercial fuel consumption between the various agro-climatic regions of India according to the results taken as part of the Integrated Rural Energy Programme during the seventh planning period. This programme makes studies of the rural energy consumption at a decentralised, village level to aid rural energy planning. The table indicates the huge dependence of the Himalayan people on fuelwood resources, but the lesser

† "Chulha" is the Indian name for the traditional wood burning cooking stove.

use of agricultural waste and cow dung compared to the more southern climatic zones.

Figure 4.1 Average annual fuel consumption pattern at different altitudes

Fuel	High	Medium	Low
	Altitudes (percentage of total consumption)		
Wood	95.38	92.26	90.02
Kerosene	4.62	7.17	9.61
Electricity	-	0.09	0.17
Dung	-	0.48	-
Coal	-	-	-
Gas	-	-	-

Source: Sharma, 1987b, p.56

Figure 4.2 Average per capita use of Non-commercial fuels in various agro-climatic zones

Agro-climatic zone	Firewood (kg)	Crop residue (kg)	Cow dung (kg)
Western Himalayan Region	710.450	52.41	79.131
Eastern Himalayan Zone	621.419	-	-
Middle Gangetic Plain	274.568	238.401	182.325
Upper Gangetic Plain	129.991	127.308	156.008
Trans-Gangetic Plains	136.173	321.762	238.924
Eastern Plateaus & Hills	582.193	-	-
Western Plateaus & Hills	288.212	139.461	172.068
Southern Plateaus & Hills	225.485	108.305	69.208
East Coast Plain & Hills	218.308	30.422	47.031
West Coast Plain & Ghats	469.464	76.009	-
Gujarat Plains & Hills	336.400	111.104	79.952
Western Dry Regions	393.913	11.17	156.942

Source: GOI, 1992, vol.2, p.53

Animate power, that is power from humans and animals, is by far the most widely used form of motive power, primarily for transportation but also for cottage industry and agricultural purposes, including ploughing and crop processing [Pande, 1987]. Donkeys, ponies, bullocks, elephants and, in desert states, camel are used for transportation of larger loads, but human power (mostly women) is frequently used for smaller loads and to cross difficult terrain, such as the slopes of the Himalayan hills. The majority of farms in India are under 0.5 hectare, therefore are too small for mechanised cultivation, and animate power prevails.

4.2. Commercial energy sources

Despite the dependence of the majority of the population on traditional fuels for their daily requirements, commercial fuels have become the dominant source of energy in India, primarily due to the growth in the industrial and urban sectors.

India's per capita final commercial energy consumption is one sixth that of the world average at just over 200 kilogrammes of oil equivalent (kgOE), as shown in figure 4.3. The energy consumption varies within the country ranging from 515kgOE in Punjab, which is a more industrialised state and has been most affected by the agricultural revolution, to 35kgOE in the isolated and less developed North Eastern state of Tripura. The per capita consumption in Uttar Pradesh is on average 87kgOE, though there is a disparity between the less developed hill regions and the more modernised plain areas [Khanna, 1992]. Rural areas, which account for three quarters of the population, consume only about one fifth of the total commercial energy used in the country.

Figure 4.3 Per Capita Commercial Energy Consumption in Selected Countries

Country	Per capita energy consumption (in kgOE)
India	208
Canada	9156
China	500
USA	7265
Australia	4821
UK	3805

Source: Subudhi, 1992

Overall commercial energy consumption has increased since 1953/54 from 19.76 million tonnes oil equivalent (MTOE) to 101.5 MTOE at the beginning of Eighth Five Year Plan. The percentage share of the different commercial fuel types is shown in figure 4.4. The figures given for coal, oil and gas are those used for primary energy consumption only, and exclude the quantities of coal, oil and gas used for power generation or used for non-energy purposes. This shows a reduction in the dominance of coal, which was once the mainstay fuel for India's transport and industry, and an increase in the proportion of oil and electricity consumption. India is almost self-reliant in all forms of energy extraction except oil, the import of which accounts for around 30% of India's export earnings (foreign exchange reserves). The country still has a current energy shortage, expressed as the imbalance between supply and demand, estimated at 7.9%, peaking at an annual average of 16.7% in July 1991 [GOI, 1992b].

Figure 4.4 Percentage Share of Different Fuels in Commercial Energy Consumption

	1953-54	1960-61	1970-71	1980-81	1990-91
Coal	79.6	74.1	59.1	52.6	39.0
Oil & Gas	17.1	20.9	31.3	35.7	43.4
Electricity	3.3	5.0	9.6	11.7	17.6

Source: GOI, 1992, vol.2, p.162.

Industry is the main consumer of commercial energy, accounting for 78% of coal consumption and 62% of electricity consumption. Transport and domestic sectors are the greatest consumers of oil, using 56% and 29% respectively [Khanna, 1992]. The balance of energy consumption between the various sectors has also changed slightly, as shown in figure 4.5, with a marked decrease in the share of the transport sector, but increases in the industrial, domestic and most notably the agricultural sectors. The increase in commercial energy consumption in the agricultural sector is primarily due to the increased use of electric and diesel tubewells for pumping groundwater for irrigation.

The Indian Eighth Plan emphasises the need to meet the growing demand for energy across the country. There is particular concern about the trend towards greater use of petroleum products. The plan stresses the importance of energy efficiency, conservation and demand management with the aim to reduce the

Figure 4.5 Percentage Share in Final Energy Consumption by different Sectors

Sector	Percentage share in consumption 1953-54	1960-61	1970-71	1980-81	1990-91
Industry	39.8	40.7	51.6	57.0	50.4
Transport	46.2	44.9	29.4	23.5	24.5
Domestic	9.9	10.6	14.3	12.3	13.8
Agriculture	1.7	1.8	3.8	6.1	9.0
Other	2.4	2.0	0.9	1.1	2.3

Source: GOI, 1992, vol.2, p.162.

energy consumption of the different economic sectors. Effective inter-fuel substitution is a long term priority, aiming to move towards less costly and more sustainable forms of energy. Energy pricing has been identified as a tool for adjusting supply and demand to meet the targets set in energy policy planning. There has been caution over subsidies on kerosene, electricity and LPG, except to target specific socio-economic groups. An issue raised in the plan is the need to move towards maximising the use of renewable energies by low income groups in both rural and urban areas [GOI, 1992, vol.1].

The Indian production and utilisation of the three fossil fuels - coal, oil and natural gas - are described below. The power sector is described in section 4.3. Renewable energies are discussed in section 4.4 and MHP in section 4.5.

4.2.1. Coal

India has large deposits of coal which are unevenly distributed across the country. The largest reserves are in West Bengal, Bihar, Madhya Pradesh and Andhra Pradesh. The total Indian coal reserve is estimated at 196 billion tonnes - 40 billion tonnes greater than estimated at the start of the of the seventh planning period due to new discoveries, including reserves in Orissa. Whereas some other states have hydro resources to compensate for poor access to coal, a few states, such as Rajastan and Tamil Nadu, have poor energy resource bases and have been required to pay the high price of transporting fuel from resource rich regions. Lignite deposits have been found in the otherwise coal poor states of Tamil Nadu, Rajastan and Gujarat, and moves are being made by the state governments to develop power generation using lignite [GOI, 1992].

Coal is the main source of primary commercial energy in India, for direct industrial use and also as the main fuel for thermal power production. The major industrial uses of coal are for the production of iron and steel, cement, bricks and textiles.

There is an annual shortage of coal each year of over 10% due to failure to reach production targets, inadequate rail transport systems and also due to the low quality of the coal. The quality of Indian coal is generally very poor, with a very high ash content [DeLima, 1981]. The steel industry has been forced to import large quantities of high quality coking coal due to shortages in supply from within India.

To reduce the difficulties and cost of coal transportation, there has been a trend since the fifth planning period to build large thermal power stations at the pit heads, using long transmission lines to the load centres. The pit-head power stations now contribute 25% of thermal power produced, but are accompanied by environmental problems such as large scale land degradation, population displacement and pollution of land, air and water [GOI, 1992, vol.2]. Coal burning is the largest single cause of air pollution in India [Khanna, 1992].

The Indian government has had exclusive right to set up new establishments for coal mining since 1948 [Henderson, 1975], and the coal industry was fully nationalised in the early 1970s. Many of the mines are over a hundred years old and still use old fashioned "pick and shovel" extraction techniques [DeLima, 1981], and many older sites have caused severe land degradation. However, the environmental impact of new mining projects is now seriously considered before they are approved for new development, as is the welfare and safety of mine workers.

4.2.2. Oil and gas

Of the estimated 20.31 billion tonnes of petroleum and gas resources in India only 5.32 billion tonnes have been proven, divided as 61% off-shore and 39% on land. Half the estimated reserves are believed to be natural gas [GOI, 1992, vol.2]. Crude oil production increased three-fold during the sixth planning period, but stagnated during the Seventh Plan with only marginal increase. It is predicted that the domestic production will only be sufficient to supply half the demand for oil in India by the end of the century [GOI, 1985] and that, according to a Central Electricity Authority report on long term power planning, the Indian domestic oil reserves will only last 20 years at present rate of usage [CEA, 1987]. Further oil exploration is a policy priority of the five year plans.

The increase in the use of oil and petroleum products - 6.9% per annum during the seventh planning period - has been largely due to the relatively low cost and high availability of the fuel to the consumer. Kerosene is sold at subsidised rates for lighting and cooking, and is frequently the most accessible and least costly option for domestic use. Consumption of motor spirits and diesel has increased rapidly with the increased use of motor vehicles and the trend toward road instead of rail transportation . Similarly there has been a rise in the number of diesel pump sets used in the agricultural sector. With little prospect of increasing the domestic production of oil to match the present growth trend, controlling the oil demand is viewed as vitally important. This is to be achieved by increasing the efficiency of oil usage, through conservation measures and by substitution of oil with coal, natural gas, electricity and other energy sources [GOI, 1992, vol.2]. The Petroleum Conservation Research Association, set up by the Ministry for Petroleum and Natural Gas, has been at the forefront of promoting general awareness of the need to reduce consumption and conserve the remaining reserves of oil.

So far the use of natural gas as an alternative fuel has been limited by constraints on supply. The Indian infrastructure for utilising natural gas is in its early stages of development, though there are high hopes that gas may eventually substitute for many petroleum imports. However, India has a long way to go to achieve this goal while there remain situations such as the large scale burning of gas reserves off the Bombay shore line. This has happened since 1978 due to bureaucratic disputes as to how the gas should be distributed between energy production, petrochemicals and fertiliser industries [Piramal,1991]. It is thought that the opportunity cost of using natural gas for fertiliser production may be far higher than for electricity production, which will result in conflicting priorities for its utilisation [Ranganathan, 1993].

4.3. The power sector

There are five planning regions for power in India as shown in the map in figure 4.6.

At independence in 1947, the total installed electrical capacity in India was 1362MW. The total installed electrical capacity in India at the start of the Eighth Plan was 69,810MW, compared to the capacity in the United Kingdom of about 70,000MW, for a population one sixteenth that of India. The Indian installed capacity breaks down as follows:

Thermal (including gas based)	48,825MW
Hydro	19,168MW
Nuclear	1,785MW
Wind	32MW

Although the Seventh Plan almost achieved its target by adding 21,401MW to the power capacity during the plan period, only about 70% of the target hydro addition was commissioned. Rapid development of gas fired plants made up for this deficit [GOI, 1992, vol.2]. The targeted addition in the Eighth Plan is 30,538MW, against the estimated required increase of 35,155MW to meet the growing demand. The target addition assumes that almost 3,000MW of capacity will be developed in the private sector. The country's peak power supply is already significantly in deficit (see section 4.3.2) [Suri, 1989]. The main constraint in the development of the power sector is lack of funding [CEA, 1987].

There are frequently large delays in construction of all types of power projects. The reasons given for this are

a) delays in obtaining environmental clearance,

b) protracted procedures for acquisition of land,

c) delays in supplying of equipment, and

Figure 4.6 Electricity Planning Zones in India

d) inadequate financing of the projects.

Delays in project completion also mean increases in project cost. The Eighth Plan document is very critical of the organisation and management structure of the power sector, implying that this is another reason for the poor performance of the power industry. There is over staffing within the industry, coupled with generally poor training of staff (see section 4.3.1).

The Indian power system incurs huge losses averaging at 23% of the power transmitted, with some rural networks losing over 40% of power. Losses in developed countries are generally between 7 and 9%, and China claims only 8% losses [Ambarani,1986]. The large line losses are attributed to the low level of investment in the transmission and distribution system plus the over extension of low voltage rural and urban network facilities. This also accounts partly for the poor quality of supply to many areas, with voltage and frequency fluctuations and power cuts. The rural networks often have high inductive loads caused by the numerous electrified water pumps plus the hugely over-extended lines, an example of which is a 33kV grid extension of over 150km in length in the Chamoli hills [pc:Bist]. Through a combination of renovation and modernisation of existing plants and increased investment in transmission and distribution, it is aimed to reduce the losses to 15% by the end of the century. This does not, however, account for the huge losses incurred through theft, with pilferring of about 25 billion units annually [Piramal, 1991], often by corrupt electricity board employees making private deals with industrial users.

In general the state electricity authorities practice "breakdown maintenance" rather than "preventative or protective maintenance" [Sah]. This means that system reliability is often low and consumers are dissatisfied by the service. The shortage and poor quality of the power supply has had an extremely adverse affect on industry, which is severely constrained by the non-availability of a reliable electrical supply. The state of the power industry is viewed as an infrastructural "bottle neck" for economic development [Pirmal, 1991], as an un-reliable power supply will deter new industries which depend on power supply.

The main objectives for the power sector in the Eighth Plan include the reduction of system losses by at least 7%, therefore increasing the useful power available. Expansion of the installed capacity is to give priority to hydro power projects to meet the peak demand and improve the over all power availability. To do this, the plan recommends the reduction of the gestation period for hydro plant development through better control over project management and financing, and also greater exploitation of the resources of the North Eastern states. Other fuels which are promoted in the policy proposals are natural gas and nuclear power. Other general issues in power development which are highlighted in the plan are conservation, improved efficiency of generation and the role of renewable energies [GOI, 1992, vol.1]. The plan document includes only one short paragraph on the environmental aspects of the power sector, saying that this is a "*subject of public debate*".

Industry is the greatest consumer of electricity in India accounting for about 62% of consumption, with 12 major industries, in particular textiles, iron and steel, fertiliser, chemicals and cement, consuming two-thirds of this. 17% of power consumption is for agriculture, with domestic and other uses accounting for the remainder. The main agricultural use is for water pumping, with a big increase in the agricultural consumption in Haryana, Punjab, Rajastan and the Uttar Pradesh plains. 30% of electricity consumption in the Northern region is by the agricultural sector, but only 4% in the East and 2.4% in the North East, where the modern agricultural techniques have had least impact. The low industrial and agricultural loads in the North East region is indicated by the low average load factor of the power system, as shown in figure 4.7. The highest load factor is in the Western region which has a high industrial load. [CEA,1987]

Figure 4.7 Regional Average Load Factors

Region	Average Load Factor
Northern	61.1
Western	74.5
Southern	66.3
Eastern	66.3
North Eastern	51.3
Total	66.9

Source: CEA, 1987

4.3.1. Power authorities

Although the Electricity Supply Act, which established the State Electricity Boards (SEBs) and the Central Electricity Authority (CEA), was written in 1948, it was not until 1956 that an Industrial Policy Resolution was passed to reserve generation and transmission of power for the public sector only. The role of the CEA was originally as a policy maker and the SEBs were seen as power project developers. However, in 1975, two centralised organisations were set up to establish a number of power projects under central control. These are the National Thermal Power Corporation (NTPC) and the National Hydro Power Corporation (NHPC). In addition, the central sector has undertaken part responsibility for the transmission system. Distribution has remained totally in the state sector[Sah]. In 1976 the Department of Atomic Energy was established to develop the Indian nuclear power facilities under central control. Until recently, private power development has been limited to captive power generation supplying directly to industry plus a limited number of licensed private utilities who supply power to the urban areas, most notably three large companies who supply to the grid for Calcutta, Bombay and Ahmedabad [CEA,1987]. Since 1992 there has been a change in power policy, so that the private sector and foreign companies are being positively encouraged to invest in the power sector, as discussed in section 4.3.6.

The share of the centrally controlled generating capacity in the overall system total has increased in recent years, from 16% in 1985 to 26.1% in 1991/92, with the greatest increase in plants installed by the NTPC. Of the planned increase in capacity, 32% is planned in the central sector [GOI, 1992, vol.2]. The reasons for the increase in central participation has been to balance the effect of the un-even distribution of energy resources between the states and also to supplement the SEB development to keep up with demand [Sah]. The private sector has been encouraged primarily because the Indian Government does not have sufficient funds to develop adequate capacity to meet the growing demands. The 17 SEBs still control 63% of power production [Pirmal, 1991].

Nearly all the SEBs are in financial debt, estimated at a total of Rs.64.72 billion at the end of the Seventh Plan and expected to rise to Rs.1600 billion by 1993/94 [Financial Express, 1991]. This is attributed mainly to huge subsidies given to the agricultural sector. In all states farmers pay rates far lower than urban rates [Pirmal, 1991]. It is now generally considered that the state governments should compensate the SEBs for the losses incurred by the enforcement of the reduced agricultural tariff.

The Power Sector has gradually taken on a complex nature, comprising of SEBs, multi-state organisations for projects such as inter-state hydro projects, central government organisations and companies, Government of India Departments such as the Department of Atomic Energy and now an increasing private sector involvement.

4.3.2. Hydro/thermal mix

It is claimed that India could supply all the peak power demand with the present installed capacity if there was a higher hydro/thermal installed capacity ratio [Naidu, 1990]. It is general practice to use thermal power as the base load power supply and vary the hydro generation to meet peak demands. Hydro power allows greater flexibility in achieving peak power over the base power because, unlike thermal plants, the output of a hydro power plant can be varied rapidly and can start up to full power within minutes. Over recent years in India the share of hydro capacity has fallen below the required level to meet the peaking demand, putting greater pressure on the thermal plants. Because of the inflexibility of the power system and the greater cost of thermal power production over power produced by large hydro plants, the peak power deficit has increased and there has been a rise in the cost of electricity production [CEA,1987]

The share of hydro power in the Indian total installed capacity has fallen from 34% in 1985 to 29% in 1990, and again to 27.8% in 1991/92 [GOI, 1992, vol.2]. Even in the state of Uttar Pradesh, which has a huge hydro power resource, the contribution of thermal power has steadily risen in the state power mix [Shastri, 1992]. The target hydro/thermal mix is 40% hydro and 60% thermal by the end of the century.

The reason for the slow development of the hydro power resources are, firstly, the high capital cost of constructing hydro power plants compared to thermal and, secondly, the very long gestation time involved in construction. Construction of civil works is mainly by manual labour and frequently can take over ten years to complete. Poor project financing and cost over runs further hinder construction. Despite the high fuel cost for thermal generation, the plants are far less capital cost intensive and much more rapid to construct. Modern gas fired plants are particularly popular for this reason.

For improved over all power system flexibility and management in India, efficient development of hydro power resources is a key issue.

4.3.3. Large hydro power projects

India has an extensive experience of hydro power development, with a wide range and variety of power projects, including storage schemes, run of the river schemes, canal drop schemes and pumped storage schemes. Some projects are multi-purpose, that is they are also used for irrigation purposes or drinking water supply. The head range of the projects varies from over 1000 metres to under 2 metres. The civil works vary in size and complexity including: a total of over 500 kilometres of tunnelling for hydro schemes across the country; a wide range of dam types including the 260.5 metre high rock fill dam being constructed at Terhi; and power houses both above and below ground [CWC,1992]. The equipment is nearly all indigenously manufactured, with the largest single unit produced being 250MW. The Francis turbine is the most common turbine used, with 207 units (10,150MW) installed, followed by the pelton turbine with 117 units (4,280MW) and the Kaplan turbine with 91 units (2,293MW) installed. Other equipment used on Indian schemes include low head bulb and tubular type turbines and 13 reversible pumps (1,172MW) [Singh, 1990].

The Himalayan region holds most potential for large scale hydro development in its lower hills, due to its greater accessibility than the Greater Himalayan region and the abundance of potential run of river schemes. The North Eastern Region is very attractive for development, except that its isolated location would require extremely long transmission lines to the load centres. The Indo-Gangetic plains hold no potential for large hydro development, but the hills of the Indian peninsula are very favourable, though there would be a requirement for large water storage facilities due to the seasonal nature of the rainfall [CEA, 1987].

In India water resources assume a highly political dimension, which is obvious at every level of organisation. International water agreements have been formed, and often disputed, with Pakistan, Nepal and Bangladesh. Inter-state water rights can be highly sensitive: during the author's study period in India, riots broke out in Karnataka state over a water agreement with Tamil Nadu. Two huge multi-purpose projects which are at the centre of considerable international controversy are the Narmada river basin project, including the Sardar Sarvor Dam, and the

Terhi Dam project.

The Narmada project is a massive development in the river basin of the Narmada River, between the states of Maharashtra and Gujarat. It is envisaged that it will consist of 30 major dams, 135 medium dams and 3000 minor dams, submerging thousands of hectares of land and displacing around 200,000 people. The project should eventually generate 1450MW of power and irrigate over 200 million hectares of land. Originally the World Bank had pledged to donate a large portion of the approximately $1.7 billion construction cost, and Japanese aid was given to finance the Japanese turbines [Guardian, 1991]. However, due to overwhelming opposition from the international community against the potential environmental and human rights violations that could result if the project was to go ahead, the World Bank has withdrawn from the project. It has been claimed in an independent study that insufficient resources are available to rehabilitate the ousted people and that there was never a full environmental impact study carried out on the project. The environmental study was to take place concurrently with construction [Urja,1992b]. The Indian government has been left with the dilemma that they are now committed to the project (the Sardar Sarvor dam is in an advanced stage of construction), but have restricted financing and increasing opposition from many sources.

The Terhi dam in the Uttar Pradesh hills will be 260.5 metres high, one of the highest dams in the World. The generation plant is to have an installed peak power capacity of 2400MW, with pumped storage facilities, and in addition the dam will supply irrigation water to the plain areas and drinking water for Delhi. It is to be built at a cost of US$2 billion, and will displace over 80,000 people. Again there have been objections to the scale of the project, with added concern over the possibility of failure due to an earthquake. There are differing opinions as to the size of earthquake possible in the unstable hill district, with the Terhi dam engineers claiming the largest seismic action possible in the area to be 7.2 on the Richter scale but the environmentalists claiming that the large body of water held by the dam could induce a larger quake of over 8 on the Richter scale [New Scientist, 1991]. The project was to be completed during the Eighth Plan, but is far from reaching this goal because of inadequate funding from both state and central governments [Urja, April 1992c].

Because of the problems encountered with huge hydro power developments, including environmental objections, long gestation periods and escalating costs, the

Indian Government has announced that for the Eighth Plan period new hydro projects will be limited to 100MW capacity [WPDC,1992].

Conservationists often cite widespread use of small scale hydro as the alternative to the huge projects, but in fact this is not the case. Small scale projects have a different purpose to those of large scale hydro. Small scale projects serve the rural needs in the local surrounding area, whereas the large scale projects are designed to serve urban needs for power and drinking water and also to supply irrigation water for large scale, modern farming.

A new approach must be taken to supply power and water requirements for the social and economic development of India, for example, through hydro development based on medium scale projects backed up by small scale projects to develop the decentralised, rural sector.

4.3.4. Nuclear power

The Indian National Power Plan 1985 - 2000 claims that

> *"the nuclear fuel resources of India are substantially larger than the coal and hydro resources and are of special significance in meeting the long term energy needs."* [CEA, 1987]

The first nuclear power station in India was of American design and commissioned in 1969, and the following two plants were Canadian built during the 1970s. It was not until the 1980s that India established its own capabilities for developing nuclear power stations [Kati,1990]. However, the Indian reactor design has been plagued by technical problems, delays in implementation and cost over runs. The plants have rarely exceeded 50% of their rated capacity. The target of having 10,000MW installed by the year 2000 has been cut to 6,050MW, though it is predicted that even this target will not be reached [Greenpeace, 1992].

The focus of future nuclear energy development in India is to be on safety and self-reliance, with emphasis on reducing time and cost over runs on project construction. Research and development is to focus on developing fast breeder technology [GOI, 1992, vol.2].

It is an irony that, globally, less than 10% of the energy research and development budget (1979 to 1990) was spent on renewable energy, but 60% was spent on nuclear energy [Greenpeace, 1992]. Similarly, in India the outlay on the Nuclear Power Corporation over the Eighth Plan is expected to be Rs.42.61 billion, but the DNES will receive only one fifth this amount.

4.3.5. Rural electrification

Rural Electrification (RE) in India was almost non-existent at the time of independence in 1947, but has grown to the extent that 81% of villages were supplied with electricity by 1990. Figure 4.8 shows the scale of advance in RE over the first four decades since independence. RE in India is most commonly defined in terms of the percentage of villages with electricity, figure 4.9 shows the rural electrification figures for each state up to February 1991. It can be seen that it is generally the very large, less wealthy states, such as Uttar Pradesh, Orissa and Bihar, which are well below the average coverage of rural electrification for the whole of India. In addition, most of the remote North Eastern states have very low rates of electrification, excluding Assam, which is the most modernised and developed state in that region.

Figure 4.8 Growth in Rural Electrification in India

	Independence (1947)	1988
Indian Population	337 million	800 million
Installed capacity	19,00MW	54,287MW
Villages Electrified	1 500	440 000
Pump sets	6 500	7.4 million

Source: Khavana, 1990

The definition of an electrified village in India is a village with "*one service connection provided within its revenue boundary*" [Economic Express, 1991]. Not even one household need be connected for a village to be counted electrified. The percentage of rural households with electricity is quoted as only 27% [GOI, 1992, vol.2]. Of the budget allocated for power development in the Eighth Plan period, only 5% has been allocated to the development and upkeep of RE.

One of the motivating factors for rural electrification in the 1960s and 1970s was the Green Revolution, which introduced the use of modern farming techniques

Figure 4.9 Rural Electrification in the Indian States (1991)			
State	Number of Villages	Number of Villages Electrified	Percentage Villages Electrified
Northern Region			
Haryana	6745	6745	100%
Himachal Pradesh	16807	16761	100%
Jammu and Kashmir	6477	6109	94.5%
Punjab	12342	12342	100%
Rajastan	34968	26320	75.3%
Uttar Pradesh	112566	80617	71.6%
TOTAL	189905	148894	78.4%
Western Region			
Goa	386	377	100%
Gujarat	18114	17892	100%
Madhya Pradesh	71359	61176	85.1%
Maharashtra	39354	39106	100%
TOTAL	129213	118551	91.7%
Southern Region			
Andhra Pradesh	27379	27358	100%
Karnataka	27028	26483	100%
Kerala	1219	1219	100%
Tamil Nadu	15831	15814	100%
TOTAL	71457	70891	100%
Eastern Region			
Bihar	67546	46270	68.5%
Orissa	46553	30299	65.1%
Sikkim	440	378	84.8%
West Bengal	38024	26853	70.6%
TOTAL	152563	103800	68.0%
North Eastern Region			
Arunachal Pradesh	3257	1374	42.2%
Assam	21995	21010	95.5%
Manipur	2035	1292	63.5%
Meghalaya	4902	2206	45.0%
Mizoram	721	407	56.4%
Nagaland	1112	1099	98.8%
Tripura	4727	2734	57.8%
TOTAL	38749	30122	77.7%

Source: Economic Times, 1991, p.14

requiring modern irrigation methods. As a result there has been a widespread programme of electrifying irrigation pumps for lifting ground water. This has become one of the main focusses of the RE programme. There are now over 8 million electrified pumpsets across India. The electrification of pumpsets has had an overall positive economic impact on rural areas. There has been a change in cropping patterns and increased use in high yield seeds, which require a greater amount of irrigation [Ranganathan, 1989]. This can be seen extensively over states such as Punjab, which has benefited greatly from the green revolution. However, the electrified pumpsets mainly benefit the wealthier farmers, who have been able to adopt modern farming methods. Due to the poor availability of power in rural areas, diesel back up pumps are prevalent in many areas. There have been very few pumpsets installed in the Himalayan region, as in most areas the terrain is not suited to water pumping and farming techniques are frequently still primitive. As a result the hill regions have received least economic gain from the RE programme [UPDESCO, 1980; NCEAR, 1987].

The Rural Electrification Corporations (REC), at both central and state level, were set up in 1969 to plan and finance the RE development by the SEBs around the country. In nearly all cases RE is far from viable in financial terms [ESCAP, 1990], which puts huge strain on the SEB resources, so that they are often reluctant to undertake RE projects [Sah]. Reasons for the poor return from investment in RE are:

- the low load density and large investment required in line extension;
- the low rural tariff; and
- the low load factor in rural areas.

Load factor may be low even in more developed states such as the Punjab, where the agricultural load varies by a ratio of 1 to 3.5 between January and August [Meunier, 1990]. Investment in transmission and distribution has been low, so that RE targets of connecting increasing numbers of villages and pumpsets have been achieved often without adequate transmission and sub-transmission systems [Shishoo,1992]. One option being employed during the Eighth Plan is the use of decentralised, non-conventional generation methods. It is envisaged that 10,000 of the planned 50,000 villages to be connected are to be electrified by non-conventional means [GOI, 1992].

Initially, the principal reason for investing in RE was to aid development and therefore improve the incomes and living conditions of the rural poor [UPDESCO, 1980]. It was assumed that the benefits would "trickle down" to the poorest in the communities. In India it has been shown that the impact of RE is greatest in villages which already possess greater economic advantages, such as more developed infrastructure and access to markets. A study by USAID found that 76% of electrified rural households had experienced lifestyle changes since connection, though this had only affected the wealthier members of the community who were able to afford electrification [Khuvana,1990]. In this respect, electrification has accentuated the inequalities between the rural wealthy and the rural poor.

Despite the intention of the REC to develop rural industry connections, the rural industrial load remains low. The poor quality of power supply available in the rural areas is said to be the main reason for this. However, lack of co-ordination with rural industry development programmes has also been a cause of the slow uptake of industrial connections in the hills. For rural industry to develop further in India there is considerable need for complementary development of infrastructure, such as roads, training and financial credit [Flavin,1986]. This is discussed further in Chapter 6.

4.3.6. Policy changes and privatisation

Until the last few years, the power sector in India has been tightly controlled and regulated by the public sector, with only a very limited private participation through licence or in the generation of captive power for use by industry. This amounted to less than 1,000MW capacity [GOI, 1992b]. Similarly, there have been strict controls on foreign investment in the country, with India preferring to remain self-sufficient to the greatest extent possible. However, due to a shortage of public financing, India has now been forced to open the power sector to private investment and is encouraging foreign investment of up to 100% equity in power generation projects.

Although, up to the end of 1992, there had been 40 offers of private investment in power generation from both Indian and foreign firms, no funds had yet been committed [Ranganathan, 1993]. Many interested parties were primarily concerned about improving the power supply to their own factories, rather than in the development of the power sector for the public or rural interests [Piramal, 1991]. It is thought that the private sector has not found the incentives offered by the government to be sufficient for participation in power generation [Financial Express, 1991]. Also, the private sector will only be allowed to sell energy to the SEBs, and not directly to the public [Ranganathan, 1993]. There will be no private transmission or distribution. This will mean that the SEBs will have the monopoly on power pricing, and therefore market forces and competition, normally associated with privatisation, will not be allowed to prevail.

There are two worries over the move towards privatised power generation in India, as in other developing countries. Firstly, there are fears about the impact on the environment if the privatised companies are not made accountable for emissions from their power plants [Munasinghe, 1992]. Secondly, the Indian private companies do not have sufficient finance to build projects bigger than 500MW, which could reduce the cost effectiveness of the power sector by losing the economy of scale [Piramal, 1991]. Foreign investors may, however, be able to construct plants up to 1000MW. It is unlikely that the private sector will invest in hydro power development other than in small scale projects. This is due to the large initial capital expenditure required and also the length of gestation period to construct medium or large hydro power projects [Ranganathan, 1993].

The changes in power policy have consequently widened the scope for private development of MHP, and therefore opened new opportunities for NGO and community development of MHP.

4.4. New and renewable sources of energy

Locally available renewable energy sources are now being considered as possible alternative sources of energy, in particular for poor households and the rural sector. These resources will only be developed if economical and sustainable methods of harnessing the abundant renewable resources can be developed for rural use. This section discusses the potential that various new and renewable sources of energy have to play a role in meeting future energy demands.

The importance of NRSEs in the future energy scenario in India was recognised by the establishment of the Ministry of Non-conventional Energy Sources (MoNES) and subsequently the Department of Non-conventional Energy Sources (DNES) in 1982. The DNES is the central body for formulating policies and programmes for research and development and implementation of NRSE technologies. In addition, nearly all the Indian states have now set up agencies or have allocated a sub-group of one of the state government departments - usually the State Electricity Board or the Department of Science and Technology - for the development of NRSEs. The main NRSE technologies promoted by these agencies are: biogas, improved chulhas, solar thermal, solar photo-voltaic, urban and agricultural waste and MHP.

The Seventh Five Year Plan document stated that one of the country's long term goals as:

> "*to achieve a transition to an economy in which an intensified programme of rural electrification and a viable renewable energy programme together make a significant contribution to meet energy needs in rural areas*" [GOI, 1985]

The Eighth Five Year Plan policy document is very positive about the future for NRSEs stating:

> *"Wind energy has a potential of 20,000MW and mini/micro hydels have potential of 5000MW which needs to be tapped. Other non-conventional sources like solar photovoltaics, ocean energy, MHD (magneto hydro dynamic), geo-thermal energy, etc., can become economically feasible with indigenisation of technology." [GOI, 1992, vol.1, p.36]*

The Eighth Plan proposals for NRSEs give priority to the development of indigenous technologies and their commercial exploitation and promotion. The two general targets for NRSEs in the Eighth Plan are to

- develop between 750 MW and 1000MW of power based on NRSEs such as wind power, MHP, urban/agricultural waste and solar photo-voltaic technologies.

- enlarge and intensify programmes for biogas, improved cooking stoves (chulhas) and low grade solar thermal installation.

However, the funds allocated for NRSE development over the Eighth Plan were a fraction of the amount initially requested by the DNES. The amount allocated for NRSE development over the plan period was Rs.8,570 million, equivalent to slightly over 1% of the funding allocation for the power sector and far from sufficient to put NRSEs on an equal level with the conventional energy development [Urja, 1992].

4.4.1. Financing NRSEs

The principal financial organisation for supporting the development of NRSEs is the Indian Renewable Energy Development Agency (IREDA), established by the DNES in 1987 as a "*specialised, autonomous public undertaking at the central level to translate the policies of the government of India into reality*" [Bakthavatsalam, 1991]. As NRSEs are generally viewed as a risky investment by the commercial banks and the private sector, IREDA has been set up as the enabling financial mechanism to promote NRSEs in India. The agency has two main functions: firstly, to finance NRSE projects; and, secondly, to encourage state agencies, commercial companies and other financial institutions to popularise and commercialise NRSEs and to establish an industrial infrastructure for NRSE technologies.

Resources for IREDA are provided primarily by the Indian Government, but aid has also been given by the Dutch Government, who, after assessing the achievements in India, have been "*highly satisfied*" with the IREDA programmes [DNES, 1992]. Interest has also been shown by the World Bank, the European Community and Japan for future collaborations with IREDA.

IREDA provides loans for NRSE projects at special rates of interest (ranging from 10.3% to 15.0%) with flexible payback terms. It encourages co-financing with other institutes in order to promote commercial financing for NRSEs. Special efforts are made to encourage and assist promoters working in the "*backward/rural section*" of society, including women, scheduled castes/ scheduled tribes, and ex-servicemen [IREDA, 1992]. Additional funding, in the form of subsidies to selected programmes and projects, is provided by the central and state governments.

The government has also allowed special concessions to manufacturers of certain NRSE equipment by de-licensing the equipment for some NRSE technologies and giving sales tax exemptions. The manufacturing concessions do not as yet cover MHP equipment, but is presently under review.

Funding for NRSE projects has recently been negotiated with the newly established Global Environment Facility (GEF), set up as a joint venture of the World Bank, United Nations Development Programme and the United Nations Environment programme. The main purpose of the GEF is to finance projects in developing countries which will reduce the level of greenhouse gas emissions, preserve biological diversity, protect international waters and reduce damage to the ozone layer. The funding provided to India includes US$40 million in grants for photovoltaic demonstration projects, US$80 million loans for wind power development, and a US$7.52 million grant for MHP development in the hill regions. There has been some controversy over the GEF funding, with some developing countries refusing to participate due to the strict regulations accompanying GEF finance, which are said to reflect the priorities of Northern governments rather than those of sustainable development needs for the developing countries. Also NGOs have objected to the lack of non-government and grassroots involvement in the projects funded by GEF [Fraenkel, 1993; Urja, 1992c].

4.4.2. Comparison of NRSEs with conventional power production

Arguments for and against the adoption of NRSEs as major energy sources for power generation are mainly based on economic comparison of the decentralised renewable sources with centralised generation and grid expansion. The comparison is based on projected initial capital costs, running costs and plant revenues. Figures provided by the Uttar Pradesh Non-conventional Energy Development Agency for various power generation projects are presented in figure 4.10.

Under direct comparison, the renewable sources appear least favourable, except when considering gestation period and MHP running costs, which are comparable to some thermal options. However, the costs for centralised power generation do not consider the effects of a long gestation period, of the huge line losses in the rural electrification network or of the cost of construction and upkeep of the transmission and distribution systems.

Considering each of the options in figure 4.10, large hydro is most economical in the long term. However, there is increasing concern over the environmental impact particularly of large multi-purpose plants. The costs given for nuclear power plants hide many of the lifetime costs associated with the nuclear industry, including decommissioning, waste disposal and safety. Coal based power plants, the mainstay of the Indian power sector, are the country's largest polluter, a problem which will have to be faced by energy planners. Current interest in short gestation gas powered plants, has not considered of the finite nature of the Indian gas

Figure 4.10 Comparison of Conventional and Non-conventional Power Generation Projects

Type of Power Station	Installation Cost (RS.)	Gestation Period	Unit Cost of Generation (Rs./kWh)
Hydro Plants (Multi-purpose)	20-30 million/MW	7-10 years	0.35
Hydro Plant (Run of river)	10-20 million/MW	5 years	0.40 at 40% PLF
Coal Based Thermal	15-25 million/MW	4-5 years	0.95 at 48% PLF
Nuclear Thermal	18-20 million/MW	7-10 years	0.45
Gas based Thermal	10-13 million/MW	2-3 years	1.10
Micro Hydro (100kW)	35-50 million/MW	2 years	0.91 at 60% PLF
Wind Farm (100kW)	25 million/MW	2 years	3.06 at 100% PLF
Solar Photo-voltaic (100kW)	315 million/MW	1 year	8.4 at 100% PLF

Note: PLF - Plant Load Factor
Source: U.P.NEDA, 1992.

reserves and the opportunity cost of gas for non-power purposes. Of the NRSEs, solar photo-voltaic power is not an option for large scale power production. However, wind and MHP present an increasingly attractive alternative as equipment costs reduce. The viability of NRSE options are discussed later in this section.

A highly critical report by Reddy, et al, [Reddy, 1989] claims that actual costs used in energy cost analysis are distorted by the energy establishment in India to disadvantage NRSEs and energy conservation measures. The report claims that there is a lack of information available and an absence of a standardised and accurate method of comparison. Also there is no accounting for the environmental impact of the various centralised and decentralised options. Using figures from on going Indian projects, the report compares costs of energy conservation methods, centralised generation schemes and decentralised generation projects. It shows energy conservation measures to be most cost effective over the total project life time. The report also concludes that decentralised renewable energy generation projects are more economical than conventional centralised projects based on thermal or hydro power. This is in direct contradiction to other cost analysis of NRSE systems. There has also been criticism that the high subsidies given to electrification of the agricultural sector distort the true cost of grid supplied electricity to rural areas in comparison to decentralised alternatives [Bhatia, 1988].

There is a need for more accurate cost monitoring and accounting for real project costs. This is an issue which will require considerable unbiased analysis, with emphasis not on arbitrary generalised figures and assumptions, but instead on studies of actual individual projects. Only with this information will it be possible to conclude when and where NRSEs are most suitable.

4.4.3. NRSE options

The NRSE technologies which are being promoted in India are now discussed individually, with MHP discussed in detail in section 4.5. This section describes the progress made in India with each of the NRSE technologies and assesses the technical and economic feasibility of widespread adoption of the technology, in particular suitability for application in the Himalayas. MHP is thus put into context of other NRSE options and their relative suitability for supplying rural energy needs.

Biogas

Biogas is an environmentally clean, cheap and convenient fuel for cooking, lighting and small engines. Through a digestion system (see photographs 4.1 taken at the test centre of ASTRA), animal dung and agricultural waste are converted to methane gas and a slurry residue which can be used as an effective fertiliser. As well as the improved efficiency inherent in burning biogas as opposed to the solid waste (biomass), there is benefit from the improved cooking environment through the elimination of smoke. There are two categories of gasifiers available: either family or community size. Dung from 2 or 3 cattle is sufficient for the daily cooking needs of a family of up to four people [DNES pamphlet], therefore the use of family gasifiers is restricted to the wealthier families only. Poorer households do not have sufficient livestock to run the gasifiers. Projects are currently underway to test the utilisation of human waste in biogasifiers, and wood gasifiers are being investigated for the production of producer gas from trees grown on energy plantations.

Photograph 4.1(a) Family biogasifier

Photograph 4.1(b) Improved family biogasifier designed by ASTRA

Power generation from biogas has also been successful on a small scale. One NGO has installed seven biogenerators, using the lantana weed (which is prolific in the Himalayan region) as the feeder material, to generate 3.5kW. The biogas produced from the lantana replaces a high percentage of the diesel fuel in modified diesel generators. These generators provide lighting for one small village plus electrical power for small scale industrial use, such as spice grinding or for leaf plate moulds † [pc: HESCO].

Larger scale generation projects have had varied success, with the main short comings of such projects being: technical problems and poor maintenance; poor dung supply; and lack of public participation (which is essential for the collection and supply of dung). Similar problems have been found with community biogas projects. Another concern is that biogas takes "free" traditional fuels such as dung onto the commercial market. Careful consideration is necessary as to how this transition is made, especially the effect on the poorer, more vulnerable sectors of the community.

There are several problems with the application of biogasifiers in the Himalayan region. The major limitation is due to low temperature, causing the performance of biogasifiers to decrease greatly. Figure 4.11 shows the temperature/production relationship across the Indian states, with the Northern and hill states yielding the least gas per tonne of dung, most notably in Jammu and Kashmir [SHERPA, p143].

Other problems encountered trying to apply biogasifiers in the hill region have been the difficulty of dung collection due to outdoor cattle grazing and the higher cost of the gasifiers due to the higher cost of transporting the equipment. There has been some success with biogasifiers installed in the lower foothills, and added incentives are being provided for development in the hill areas, such as greater subsidies [DNES, 1992].

The National Project on Biogas Development (NPBD) was started in 1981/82 to promote family type biogas plants and to encourage the replacement of diesel with biogas in "dual fuel engines". This also encourages research and development into improving the methane production of gasifiers and the utilisation of other

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† Leaf plate moulds are heated moulds which dry leaves in the shape of bowls. Leaf plates are commonly used in India as disposable plates for functions.

Figure 4.11 Biogas production rate from cattle dung in different states of India

State Name	Monthly temperature Min. (deg. C)	Max. (deg. C)	Biogas Production (m3/tonne dung)
Andhra Pradesh	22.8	33.7	75.0
Assam	16.8	20.4	64.0
Bihar	17.0	31.7	68.0
Gujarat	20.7	34.2	66.3
Haryana	13.5	34.2	66.3
Himachal Pradesh	10.7	28.7	52.3
Jammu and Kashmir	3.2	21.0	23.2
Karnataka	21.9	29.4	69.0
Kerala	26.6	28.8	74.0
Madhya Pradesh	17.7	33.3	67.2
Nagaland	16.8	29.4	64.0
Orissa	20.8	31.3	72.8
Punjab	13.5	43.2	66.3
Rajastan	15.8	33.7	69.6
Tamil Nadu	24.7	31.6	77.3
Uttar Pradesh	15.1	32.9	61.1
Delhi	13.5	34.2	66.3

Source: Darmora, 1987, p.143

agricultural waste such as leafy biomass, crop residue, banana stems, and others. In the first decade of NPBD, 148,000 families have benefited. Lack of finance is the main restriction to further dissemination of gasifiers [Kaul, 1991].

Improved Chulhas (cooking stoves)

By improving the efficiency of the traditional cooking stove it is possible to save vast quantities of scarce fuelwood (photograph 4.2 shows one design from ASTRA), a fuel which should be renewable if not over exploited. The improved chulhas are designed to optimise the heat transfer to the cooking pot with minimum energy loss in the cooking process. Generally traditional chulhas are between 5% and 10% efficient, whereas the improved stoves are 20% to 25% efficient, with some experimental models achieving 40% efficiency [pc:ASTRA].

Photograph 4.2 Improved "chulha" (wood burning stove)

It is important to design the stoves to suit local traditional cooking methods in order for the new chulhas to gain popular acceptance. For this reason the DNES has approved sixty models of chulhas for dissemination as part of the National Programme on Improved Chulhas (NPIC).

The NPIC was introduced in 1983 as part of the government 20-point and minimum needs programmes (discussed in chapter 3). Preferential treatment is given to extension of the programme to the scheduled castes/scheduled tribes, hill areas, areas with severe deforestation, the North Eastern region and the urban slums [DNES, 1992]. The programme has been implemented both through state agencies and voluntary organisations, and in the past decade has provided 10 million families with stoves. There have been some problems with maintenance of the chulhas because of lack of technical knowledge for repair work, which should be solved through training in the rural areas [GOI, 1992, vol.2]. The NPIC is perceived to have been successful in achieving its targets [Kaul, 1991].

Solar Thermal

India has a huge solar power potential, with Indian cities receiving on average a solar energy intensity of 242 watts per square metre, compared to the best radiation intensity found in the USA of 208 watts per square metre [Tyner, 1978].

There are a variety of applications for low grade heat produced through solar thermal energy, such as: cooking; water heating; power plants; space heating; refrigeration; water desalination; and timber kilns for wood seasoning and crop drying.

Research and development is being carried out on each of these applications within India, with emphasis on:

a) new, efficient, durable and low cost materials;

b) new design of equipment for conversion of solar energy to mechanical, electrical and other energy forms; and

c) solar refrigerators, pumps, ponds, storage, greenhouses and power generators [DNES, 1991].

Much of the research is being carried out at the Solar Energy Centre in Haryana.

Solar cookers are one of the main devices promoted by the DNES, though these have been received best in the urban areas with some 250,000 units sold up to 1993 [Barlow, 1993]. It is necessary to present the solar cookers in a different way to rural people. The different cooking technique used with solar cookers is a major deterrent to the adoption of solar cookers in rural areas, though the cost of the cooker is also an important factor even if subsidies are provided. In the Himalayan region cloud cover can be a problem, reducing the time that the cooker can be used, especially in the monsoon season.

Other applications in the domestic, industrial and agricultural sectors are increasingly being used as indigenous technology is being proven effective and economical. However, their use is as yet far from widespread. Two experimental power generation plants have been set up, one of 20kW capacity and one of 50kW, with future intentions of developing a site of several megawatts. Subsidies of between 30% and 50% are available from the government for many solar devices.

Solar Photovoltaic

Widespread adoption of solar photovoltaic (SPV) cells is limited by the high cost of each unit and the requirement for storage batteries for most applications. The aims of the research and development being carried out in India on SPV technology are: cost reduction; development of new materials; and an increase in the efficiency of energy conversion (solar to electrical energy). Indigenous manufacture has been established, producing silicon and also fabricating solar cells [DNES,1991] with units ranging up to 2.5 kW. The Indian manufactured SPV modules are produced to international standard and have been exported around the world.

The applications of SPV are primarily for use in the most remote and inaccessible areas, where conventional power supplies cannot be extended. By 1993 approximately 40,000 SPV systems had been installed in India including: 8,000 street lighting and 5,000 domestic lighting systems; 1,200 water pumps; 25,000 communication systems; and 1,000 small community power systems [Dutt, 1993]. Other feasible applications for SPV are in community televisions, navigational aids and vaccine refrigerators. As with solar cookers, the SPV cells are less effective when there is frequent cloud cover and there are also problems with maintenance particularly where SPV cells are in remote locations.

For very small power applications SPV is becoming increasingly economically attractive, so that Indian companies are now installing several hundred every year [Flavin, 1986]. However, it is unlikely that SPV will make a significant impact on the power sector until improved and more economical technology is available.

Wind Power

One of the NRSEs with the best prospects for widespread application in India is wind energy. The three main applications for wind energy being promoted by the DNES are mechanical water pumps, battery chargers and grid supply generation.

Wind generation in areas isolated from the grid is only possible in connection with battery charging, due to the erratic wind patterns resulting in unsteady power production. Another option, which has not yet been seriously considered in India, is co-generation units of wind/diesel hybrid. These units can be used in isolation from the grid, and have the benefit of reducing diesel fuel requirements in remote locations, although there will remain a degree of dependence on supplies of diesel [Scotney, 1993].

Wind power mapping is being carried out around the country to identify areas of sufficient wind potential. Hill and mountain areas have been found to be very favourable for wind energy applications.

Research and development into wind power in India has focussed on the development of indigenous technologies, as the programme had previously been depended on foreign imports. There are now 20 manufacturers of wind pumps in India [Barlow, 1993]. Up to 1992, 2756 wind water pumps had been installed, 97 small wind powered battery chargers were in operation around the country, and seven 10kW battery chargers had been installed in the far North and in Gujarat [DNES, 1992]. The main problems with the units have been associated with operation and maintenance [GOI, 1992, vol.2]. An improved infrastructure for this will have to be developed for future expansion of the wind programme.

Wind generation for grid connection has been progressing, with an installed capacity of 38.3MW, comprising of over 250 individual units. The largest wind farm in India, and also in Asia, is located in Gujarat, with a capacity of 10MW. This project was established in collaboration with the Danish government. Currently the Indian company BHEL is developing wind generation units of 55kW and 200kW capacity for indigenous manufacture. The maximum load factor attained by any Indian project was 53% at a 6MW wind farm in Tamil Nadu [DNES, 1992].

The lifetime cost of wind generation projects are generally slightly higher than other conventional power projects, though the DNES claim it is comparable to "new thermal power projects located away from mining areas". It is thought that the costs involved will decrease as indigenous technologies are further developed and improved.

Energy from Waste Recycling

Progress is being made in the country's efforts to generate energy from agricultural, industrial and urban waste, by both direct incineration and by the production of methane gas. These projects require large scale waste recovery, in contrast to the small scale biogas projects. There have been research projects around the country, of varied size and using different forms of waste, including methane from land fills, sewage, sugar cane waste, kitchen waste and waste from fruit and vegetable production.

A project which is classed as a failure due to "tied aid" (see section 2.3.4) is a municipal waste project near to New Delhi. Denmark donated a complete municipal waste incinerator/generator system to India with the prerequisite that all equipment must be imported from the donor country. The unit has never produced power since commissioning. The reason for this is that the waste from New Delhi, which is sorted and scavenged by the city's poor people, has a far lower energy content than waste from cities in developed countries. The New Delhi waste had never been properly tested. This system is now a liability and embarrassment to the Indian government instead of being an asset [pc:DNES].

Other NRSE Programmes

Other NRSE research programmes being undertaken in India include studies of:

- Human and animal energy (animated power)
- Magneto hydro dynamic power (MHD)

- Hydrogen energy
- Chemical sources of energy
- Alternative fuels for transport
- Ocean energy (wave energy)
- Geothermal energy

Other than the improved use of animated power through higher efficiency devices (carts, hand looms, etc.), none of these energy sources will be of use in the near future in India, as research is in its very early stages. However, as fossil fuel resources deplete, optimum development of every possible alternative will be required. As research and development progresses in the medium to long term, some of these resources may become viable options.

One programme which the DNES is presently expanding is Urjagram, aimed at "*introducing decentralised energy supply options in villages, and to bring about energy self-sufficiency by harnessing locally available energy resources*" [DNES, 1991] The programme surveys village energy needs and resources, and plans to meet local needs through utilisation of the locally available renewable sources of energy. By the end of 1991, 1385 villages had been surveyed with 564 surveys under way and a further 153 pilot villages have been identified with the aim to achieve energy self-sufficiency in the villages [DNES, 1992].

4.5. Mini/micro hydro power development

MHP is a well established and mature technology which could potentially supply the energy needs of many isolated communities, but it is important to recognise that its application must differ in almost every respect from that of conventional large hydro power and even in many respects from small hydro. In India MHP is included in the NRSE category as an environmentally neutral, self sustaining energy source which requires a new and radically different approach for successful and economical development.

It has been recommended that small, mini and micro hydro power plants installed in the Uttar Pradesh hills will be required to "*obtain local immediate benefit so that* *they act as fillers in the gaps made by large gestation schemes"* [Nigam, 1989]. Similarly, a report by the Indian Commission for Additional Sources of Energy (CASE) in 1990, when they decided to recommend MHP as a priority of the DNES, stated the advantages of small scale hydro are that they:-

> *"a. can be harnessed to reduce total dependence on larger projects without in the process intensifying non-replenishable resource use;*
>
> *b. can bring generation nearer to the consumption centres thus decreasing transmission and distribution losses and increasing a sense of local participation;*
>
> *c. generally have short gestation periods."* [CASE, 1990]

The three positive characteristics of MHP which are identified by the Indian planners are its decentralised nature, environmental neutrality and speed of construction. These are features which the power sector, and RE in particular, view as highly advantageous at the present time. However, MHP has not as yet made a significant impact in India, though recent progress and changes in approach to MHP envisage widespread development in the coming years.

This section describes the present status of MHP in India, including the changes and opportunities.

4.5.1. MHP development potential

The small hydro power potential in India is frequently conservatively estimated at 5000MW, of which 40% is located in the Himalayan hills and the other 60% is to be found on the Southern plains. As shown in figure 4.12 [DNES, 1992b], the majority of India's 75MW installed capacity is in the Himalayan region, with some of the North Eastern states generating most of their power by small hydro power and MHP. Although the majority of new sites under construction are also in the hills, there is a marked increase in development in many of the other states, with many of these sites on canal drops on the irrigation network. The potential for MHP at irrigation canal drops in Karnataka state alone has been estimated at 350MW [pc:Soundranayagam].

Figure 4.12 Distribution of Small Hydro Power Installations of up to 3MW

State name	Projects Installed Number	Projects Installed Capacity(MW)	Projects Under Construction Number	Projects Under Construction Capacity(MW)
Northern Region				
Haryana	1	0.20	1	0.1
Himachal Pradesh	13	9.17	4	10.30
Jammu & Kashmir	5	2.31	5	5.40
Punjab	4	3.30	-	-
Rajasthan	2	0.57	5	5.56
Uttar Pradesh	30	9.77	30	27.80
TOTAL	53	24.75	40	43.60
Western Region				
Gujarat	-	-	1	2
Madhya Pradesh	2	1.20	7	9.05
Maharashtra	3	3.58	5	8.20
Goa	-	-	2	2.90
TOTAL	5	4.78	15	22.15
Southern Region				
Andhra Pradesh	4	3.01	4	5.00
Karnataka	1	0.40	3	1.39
Kerala	2	0.02	4	10.00
Tamil Nadu	-	-	3	4.75
TOTAL	7	3.43	14	21.14
Eastern Region				
Bihar	-	-	1	1.00
Orissa	-	-	7	5.08
Sikkim	6	6.90	3	2.60
West Bengal	5	7.46	1	1.20
TOTAL	11	14.36	12	12.03
North Eastern Region				
Arunachal Pradesh	25	15.16	19	18.40
Assam	1	2.00	-	-
Manipur	4	2.60	4	3.90
Meghalaya	1	1.51	-	-
Mizoram	5	2.40	5	4.82
Nagaland	4	2.82	6	6.10
Tripura	2	1.01	-	-
TOTAL	42	27.50	34	33.22
All India TOTAL	120	75.36	117	125.55

Low Head Sites - Canal Drops

There are numerous potential low head and ultra low head MHP sites located on the canal drops along the irrigation network on the plains of India. The REC identified over 1000 possible site locations in the mid-1980s [ESMAP, 1991]. Although at canal sites the civil works are usually available with only limited modifications required, there have been problems encountered with power house development on irrigation canals. For example, the Orissa power generating Corporation (OPGC) have experienced severe difficulties during construction of two power houses due to the water table rising and flooding into the excavations and causing bank subsidence. This has resulted in construction time delays and escalations of as much as 40% on the civil costs [pc:OPGC].

Because the turbines and generators can become relatively large at lower heads, with a high unit costs (cost/kW), it is widely thought that ultra low head schemes and low head micro hydro power schemes are infeasible and uneconomical, though there have been recent moves to develop these resources. Test models of ultra low head micro hydro projects at Kakroi in Karnataka and Keragodu in Haryana were visited by the author. There is hydrological potential for widespread development of such projects on the canal network, though the economic viability of the projects are still in question.

One disadvantage of irrigation canal sites is that the canals are frequently only used for eight or nine months in the year, so there is only flow available for power generation during that time. Also, flow is highly dependent on the amount of rainfall during the monsoon, which can be unreliable [pc: Das(c)]. This seasonality will require prior planning and load management. At grid connected projects this will be less of a problem, though there will be lost revenue when the canals are out of service. At isolated projects a back-up energy supply will be required during the dry period.

Medium and High Head Sites - Hill sites

The Government of India has given priority to remote hill sites, especially in those regions into which the grid is unlikely to extend and diesel generators are presently the only source of power. In addition it is the plan to develop mini-hydro plants for grid connection in the hill areas of Uttar Pradesh and other Himalayan states in locations where the grid supply is weakest.

For a given output power, higher head sites imply lower flows and impulse or crossflow turbines can be selected, which ought to offer reduced unit costs (cost/kW). At higher head sites there are different problems associated with civil works due to the nature of the geology and climate in the Himalayan region. The long power channels and penstock pipes are prone to frequent damage due to flooding and landslides, particularly during the monsoon period, and silt erosion is common if adequate precautions are not taken. Correct siting of the powerhouse to minimise these problem is critical. Problems with extreme temperature and remoteness of some hill sites frequently hinders site construction and implementation. For example the construction of the Ghagria site, at 4150 metres above mean sea level, had problems with: extreme cold and wetness causing concrete to dry very slowly; difficulty with welding the penstock; a short working period of only five months; and disinterest from skilled labour to work in such conditions. In addition the remoteness of the project made transportation of large parts of machinery to the site very difficult [Goel, 1992].

In the Himalayas the lean flow period of a high hill site is not in the dry pre-monsoon period, during which time snow and glacier melt is available, but in the Winter months when the stream freezes over. The resulting reduction in generating capacity during Winter frequently coincides with the population leaving the higher regions, so has less impact than may be expected.

4.5.2. Institutional structure for MHP

Figure 4.13 shows the hierarchy of government departments involved with MHP in India and also the other participants in MHP development - namely NGOs, the private sector, research and development institutes and manufacturers. Since independence MHP has been developed in the government sector, with only a few privately owned sites commissioned to supply captive power to industry. This section considers the function of the various government departments in MHP development. The promotion of MHP in the private sector is discussed in section 4.5.3 and manufacturing and research activities for MHP are examined in section 4.5.4. The possibilities of the involvement of NGOs are considered in later chapters.

The original MHP sites were built by the private sector, but were almost all run down or taken over by the **State Electricity Boards** in the post independence period. Information available from the various states on the development of MHP,

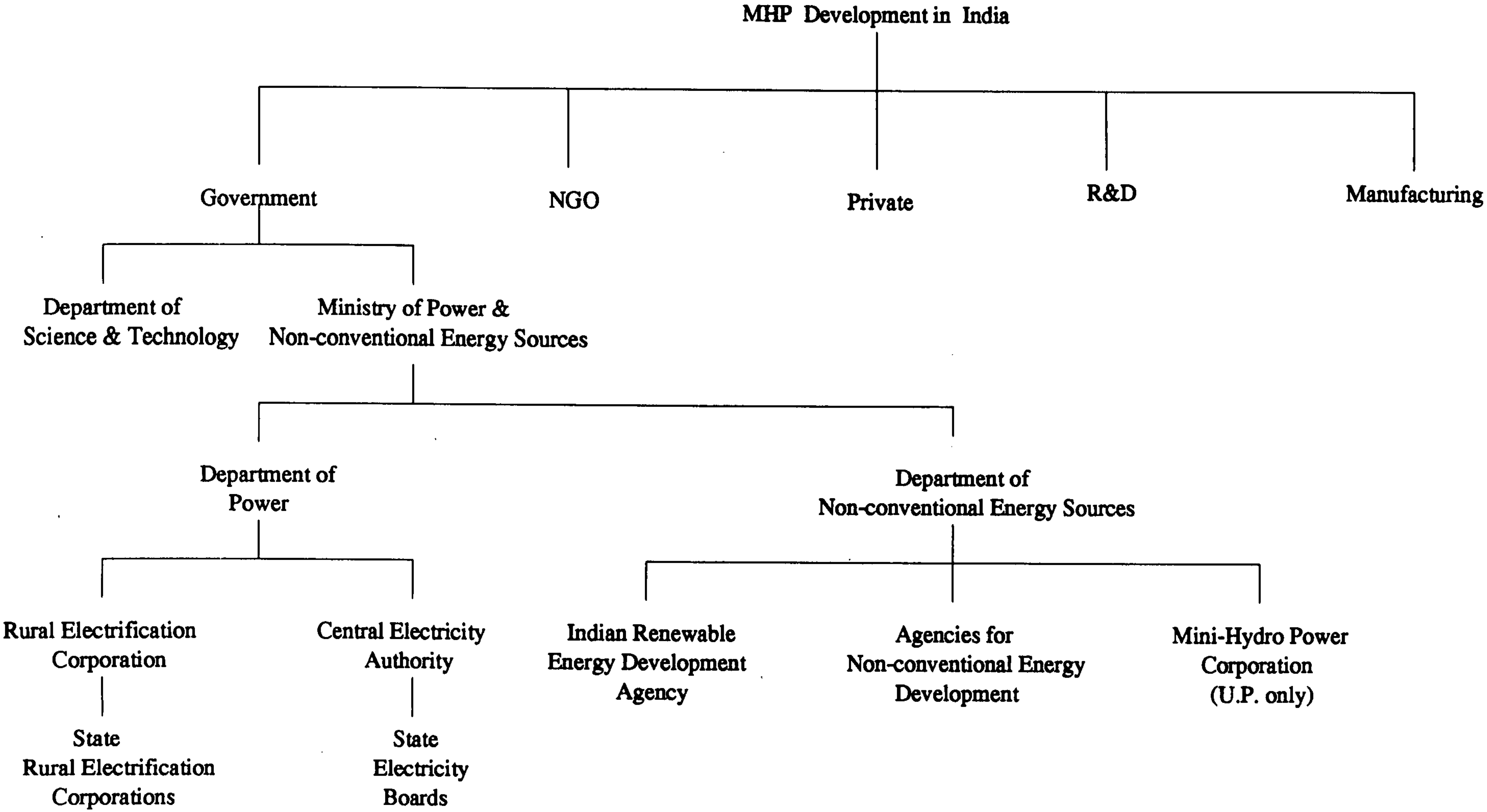

Figure 4.13 The Institutional Hierarchy for MHP Development in India

provided through the DNES, is incomplete. It is therefore difficult to describe accurately the progress of MHP over the past three decades. What can be deduced from the statistics collected by the DNES is that MHP has primarily been developed by the State Electricity Boards in the Himalayan region in a sporadic manner since the 1960s. Since the mid-1980s there has been increased interest in MHP by several other states, in particular on canal drop sites. Examples include Punjab, which has installed plants with combined capacity of 3.3MW since 1986, and Maharashtra, which has installed a total capacity of 3.57MW since 1985 [DNES, 1992, unpublished].

In 1992 the **Central Electricity Authority** stipulated that only projects with a capital cost of over Rs.250 million would have to be assessed by the CEA for clearance to develop. As such MHP development is now the responsibility of state government alone, with only environmental clearance required from the central Ministry of Environment.

The **Rural Electrification Corporation** was first allowed to develop small generation projects in 1990, with the aim of improving rural power supply. The corporation is undertaking six pilot mini hydro power schemes, three of which had been completed by 1991 [REC, 1991].

The **Department of Non-conventional Energy Sources** took over the role of promoting hydro power of up to 3MW capacity in 1989 because it was considered that, despite the large hydrological potential and Indian capabilities to develop MHP, there had been very little progress and MHP had to some extent been neglected by the SEBs. In order to promote the development of MHP it was decided that it should be classed as an NRSE to distinguish it from conventional technologies, and that incentives should be given through the DNES.

The DNES is presently at the centre of negotiations to develop policies, obtain funding, establish research and promote MHP across the country [MoNES, 1992]. The DNES will provide direct subsidies to certain types of MHP projects, but its main source of financing for MHP is through the **Indian Renewable Energy Development Agency.** Financing for MHP is discussed further in section 4.5.3. There have been proposals to extend the maximum capacity of projects under the DNES to up to 25MW, though it is thought by many that projects outside the mini-hydro range are not legitimately in the NRSE category.

In some of the states of India the development of MHP, and especially micro hydro projects, has been moved from the SEB to a specially created agency for NRSE development. Uttar Pradesh is unique in having a public corporation specifically for mini hydro power development, the **Uttar Pradesh Mini Hydro Power Corporation** (U.P.MHPCorp). † Micro hydro power is developed in Uttar Pradesh by the **Uttar Pradesh Non-conventional Energy Development Agency** (U.P.NEDA). Both these organisations are discussed in the next chapter.

The **Department of Science and Technology** (DST) has become involved with micro hydro power development through a collaboration with the Indian Institute of Science (IISc) in Bangalore, to develop an Indian design of crossflow turbine. These DST/IISc turbines have been installed in some of the U.P.NEDA projects and in two sites in Kerala, with seven projects planned in the North Eastern region.

4.5.3. Finance for MHP

Funding for MHP has been made available from state resources, REC loans, central financing or the DNES. Now IREDA also provides financing for MHP and encourages co-financing with commercial sector. The extent of financing available for a project depends on the type, location and purpose of the scheme. Funds are available to public, private or co-operative organisations.

The CASE 1990 report recommends that the funding for MHP be allocated as follows:

10% - for repairs and modifications to existing projects;

5% - for development of the traditional water mills (gharats) to make electricity generation possible at village level;

30% - for small hydro projects in decentralised hill locations;

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† The U.P.MHPCorp is also known in India by its Hindi name of the U.P. Laghu Jal Vidyut Nigam.

50% - for small hydro on irrigation works, primarily for grid connection; and

5% - for other areas, including R&D.

Subsidies are available from the DNES on a limited basis. Projects which are grid connected may receive up to 25% subsidy on the cost of civil works and electro-mechanical equipment. Sites which are isolated from the grid may receive up to 50% in subsidies on civil and electro-mechanical costs. Priority is given to sites which have a high research and development component, sites in very remote locations and sites where the local infrastructure is very poor [Kumar, 1992; CASE, 1990]. Some state governments have also provided subsidies for specific MHP developments, such as in Uttar Pradesh where micro hydro is being part-funded through the Hill Development Programme. In addition, soft loans are available through IREDA with 12.5% interest, a three year moratorium period and a ten year repayment period, assuming that the promoter's contribution is 25% of the cost. [Bakthavatsalam, 1992;IREDA, 1992]

The subsidies given by the DNES are based on the original estimated cost of the project in the detailed project report (DPRs)†. The Orissa Power Generating Corporation has had difficulties raising finance for their canal drop projects because of escalating costs due to unforseen problems with the sites, resulting in an increase in cost of 40%. The subsidies given to these sites do not account for the unforseen costs and will leave the projects with a cash short fall [pc:OPGC].

The CASE report also recommends that MHP equipment should benefit from the exemptions and concessions on taxes and duties which are currently available to other NRSE technologies [CASE, 1990]. This has been echoed by turbine manufacturers [Bhutani, 1991]. The DNES estimate that if the same benefits were extended to MHP as to other NRSEs then the equipment cost to the developer could be reduced by at least 25%, hence further increasing the viability of the schemes [Kumar, 1992].

Incentives for preparing detailed project reports (DPRs) have been offered through the DNES to organisations in the public or private sector for sites of capacity up to

† DPRs are reports submitted when applying for project approval and funding. The DRPs outline: the technical design for a proposed MHP project; details of projected site capital cost and economic performance; and the predicted electrical loading patterns.

3MW. The intention of encouraging site investigation and DPR preparation is to produce a "shelf of projects" from which sites can be selected for development on a priority basis and also to assist in the development of standardised equipment by identifying projects with similar head, flow and capacity. In this way it is hoped to reduce over all project costs. The incentives offered are in the form of grants based on the size of the project being investigated plus a travel allowance for site investigation.

The recent encouragement for participation of the private sector in power generation has also included a move to stimulate private investment in MHP and small hydro power. IREDA has been actively encouraging private participation through a combination of direct awareness promotion in the private sector and measures to "streamline" the procedures for private participation [Bakthavatsalam, 1992].

Through its Energy Sector Assistance Programme (ESMAP), the World Bank has made available up to $70 million in loans to the private sector for development of grid connected canal based projects. ESMAP has produced project proposals for 53 schemes in Andra Pradesh, Karnataka, Tamil Nadu, Kerala and Punjab [ESMAP, 1991]. The ESMAP assistance will provide technical support for the investors but will require that "standardised" project designs are adopted, as prescribed in the proposal documents. This is intended to simplify the design of civil and electrical components to minimum complexity and to produce standard turbine designs, hence creating an economy of scale and reducing equipment costs. [MoNES, 1992] It is also expected that the World Bank will provide technical assistance to develop the skills of IREDA, the DNES and the SEBs in administering, promoting and designing canal based mini-hydro projects.

The ESMAP programme has been received with caution by the private sector, who have shown only limited interest. Claims have been made that the cost estimates in the ESMAP report were too low [pc: Nair] and unrealistic, and that the "standard" designs produced are too restricted and inflexible. The interest rate on the loans is relatively high, at 15.5% (0.5% rebate given for timely payment) and there is speculation as to whether there will be sufficient return on investment from the projects. This is compounded by uncertainty about the rates the SEBs will pay for the power supplied by MHP [pc: Das(c)]. However, it is hoped that eventually the programme will add 110MW of power capacity to the private sector.

MHP projects in remote hill areas are to be promoted by the Global Environment Facility (GEF) in collaboration with the DNES through a three year programme entitled *"Optimising Development of Small Hydel Resources of Hilly Regions"* [DNES,1991; MoNES, 1992]. The programme is expected to concentrate on the development of schemes up to 200kW in capacity [pc: DNES], though it is officially to incorporate sites up to 3MW. The emphasis is on reducing the demand for fossil fuels and fuelwood in the hill communities by offering an alternative energy source. The two main aims of the scheme are

- to formulate technical and economic policy guidelines; and

- to adopt advanced, feasible and environmentally superior technologies.

The strategy which is to be followed under the programme involves:

- detailed surveys and preparation of master plans for MHP in three geographically distinct but representative areas, at high, medium and low altitude;
- identification of training needs;
- development of standardised, portable and economical equipment;
- development of pilot projects;
- load development, in particular use of low wattage cookers and heaters, and appropriate industrial and agricultural uses; and
- improving efficiency of traditional water mills

The programme also envisages improving the laboratory, technical and training facilities at the Alternate Hydro Energy Centre (discussed later) and two regional centres in the Western Himalayas and the North East. The involvement of NGOs and community groups in execution, operation and maintenance are said to be a *"special consideration"*, though the programme has been targeted almost exclusively at government institutions. The negotiations with the GEF are in their final stages.

4.5.4. Indigenous technology and manufacturing capabilities

Manufacturing

India has become almost self-sufficient in producing equipment for mini hydro power generation, through import substitution and technology transfer contracts with overseas manufacturers. There are nine manufacturers of mini hydro turbines in India, all of whom have had collaboration with European manufacturing companies, as shown in figure 4.14. Each of the turbine manufacturers produce equipment both for the domestic and the overseas market. Seven of these Indian turbine manufacturers also produce generators and four can develop MHP projects on a turnkey basis. Three other manufacturers, Crompton Greeves, Kirloskar Electric Company and NGEF, produce generators suitable for MHP applications.

Figure 4.14 Indian Manufacturers of Small and Mini Hydro Turbines

Manufacturer	Foreign Collaborator	Turbine Types
Beacon Neyrpic	DUMONT Neyrpic, France	Siphon,Kaplan,Francis,Pelton
BHEL	Neyrpic, France*	S-type,Pelton,Bulb,Kaplan,Francis
Boving Fouress	Boving, UK	Kaplan,Semi-Kaplan,Francis, Pelton
Flovel	Tampella, Finland*	Tubular,Francis,Pelton
Jyoti	Escher-Syss, Switzerland*	Tubular,Kaplan,Francis,Turgo,Pelton
Larsen&Toubro	Voith, Germany	Francis,S-type,Pelton
Punjab PGM	Voest-Alpine, Austria	Tubular,Francis,Pelton
SILK	Koessler, Austria	Kaplan,Francis,Pelton,Crossflow
Triveni Engineering	Esac Energie, France	Kaplan,Bulb,Francis

Note: * Contract now expired.
Source: Kumar, 1992; MoNES, 1992

The oldest of the manufacturers is Jyoti who were established in 1958, with the other eight companies only entering the small turbine market in the past decade. For many years Jyoti worked in collaboration with the British company Gilbert, Gilkes and Gordon, to produce turgo impulse turbines, many of which are installed at MHP sites in Indian Himalayas. Also, until very recently, Jyoti was the only manufacturer and active promoter of the micro hydro range. Under the DST/IISc micro hydro programme, there have been crossflow turbines fabricated by an engineering company in Saharanpur in Uttar Pradesh since 1989, and since 1992 by the public sector manufacturer Steel Industrials Kerala (SILK) in Kerala. Some of the other manufacturers will occasionally produce turbines in the micro range which are based on conventional turbine designs, but the view of one manufacturer was that micro turbines take up too much machine time for their size and are uneconomical for the manufacturer [pc: Bhutani].

One manufacturer complained that the utilities over specify or over elaborate MHP project design, such as by including remote operation, fully electronic control and high material specifications, thereby making MHP uneconomical to build [Bhutani, 1990]. There is growing appreciation by the manufacturers as well as the development agencies that MHP requires simplification and standardisation. The manufacturers' perception is that the high initial capital cost inhibits wider development of MHP, and therefore will reduce the demand for equipment. Simplified, less expensive designs would be more conducive to development on a wider scale.

In addition, at present the indigenous micro hydro equipment is relatively bulky and heavy, unsuited to transportation by porters as required at many hill site [Goel]. This is a concern which the DNES plans to address in the near future by developing modular units whose individual units are of portable size [pc: Singh(b)]. Negotiations have started between the DNES and turbine manufacturers to produce appropriate, standardised and economical turbines for the MHP range which are suited to the Indian requirements, though as yet little progress has been made.

Research

Research is being carried out on various aspects of MHP in India, in particular on turbine design for different applications.

The DST/IISc crossflow research and pilot schemes have had varied success. The turbine, designed and tested at the IISc in Bangalore, has been developed as a low cost, simply fabricated alternative to the costly conventional, high precision turbines produced by conventional manufacturing companies. All sites where the crossflow units have been installed incorporate electronic load controllers to further reduce cost and complexity. The pilot schemes set up in Uttar Pradesh are discussed in the next chapter. These have generally not produced their rated output power, as expected from the lab tests at IISc. Two have been damaged by debris entering the penstock, though this is primarily due to poor debris screening, rather than a fault of the turbine design. Two 10kW projects have been set up in Kerala in a joint venture with the Kerala Agency for Non-conventional Energy and Rural Technology (ANERT) and SILK. The turbines at both projects are functioning very well at rated output. However, the civil works for the schemes are over elaborate and over specified for the size of scheme, for example the Pookot site has a very large and mostly unnecessary surge tank, as shown in photographs 4.3 and 4.4. The project cost of each of the Kerala sites was almost Rs100,000 per kW, which would seem to thwart the purpose of utilising low cost turbines to produce cost effective sites [Site visit to Pookot and Sugandhagiri]. None the less, there is interest in developing new sites under this programme in Uttar Pradesh, Kerala and some North Eastern states [pc: Soundranayagam].

There has been growing interest in the development of ultra low head sites, under 3 metres, due to the abundance of small canal drops in rural India. Two projects have so far been set up as test sites for ultra low head technology. One site, Kakroi, has been established in Haryana, to compare an indigenous unit to an American and an Austrian unit, using propeller turbines in different configurations (S-type, bulb and split flow). Each of the turbines are of 100kW capacity and operate on a 1.5 metre head. The site is grid connected. Unfortunately there have been no results obtained due to a series of mishaps during installation. The shaft of the Austrian unit was seriously damaged due to an error incurred while drilling the flywheel shaft during installation and the power house was flooded while testing the American unit. There are insufficient funds to repair the Austrian unit at present [Site visit to Kakroi].

The second ultra low head site is Keragodu, in Karnataka. This is a 40kW site using a semi-Kaplan turbine on a 2.75 metre head. The turbine has been designed at the IISc by the same group developing the crossflow projects. The current design [Soundranayagam, 1988] is complex, and will require sophisticated maintenance, though it is hoped that the design will be simplified over time so that such projects can be economically duplicated. This project had not been commissioned when visited by the author. [Site visit to Keragodu]

The idea of utilising indigenous standard centrifugal water pumps in reverse mode as turbines was tested at two micro hydro sites in Himachal Pradesh: Jubbal which has one 100kW and two 25kW pumps operating as turbines; and Manali which has two 100kW pumps operating as turbines. Both operate on medium/high heads. The reverse mode pumps have operated well, but the project has drawn the conclusion that, considering the cost and efficiency of the pumps compared with conventional turbines, only pumps under 25kW were more economically viable than conventional turbines. Above 25kW capacity the pumps cost per kilowatt are comparable to standard turbines. [pc: Das(b)]

The Alternate Hydro Energy Centre (AHEC) was set up by the DNES at the University of Roorkee in Uttar Pradesh as its principal research centre for small, mini and micro hydro power. Research carried out by the centre has included the work on pumps as turbines, the Kakroi ultra low head site, improved water mills (gharat) and the development of an indigenous electronic load controller (ELC). The AHEC designed ELC has been used on some of the U.P.NEDA projects. They are also developing a data bank of small hydro power in India, which was in very early stages at the time of the author's visit, only recording the name, capacity and date of commissioning of the sites known to the centre. They also take part in biogas and other energy research programmes. The centre has come under considerable criticism from some researchers in the MHP field for its lack of expertise. It is hoped that the capabilities of the AHEC will be considerably strengthened by the GEF programme.

4.6. Conclusion

Overall, there appears to be a great deal of opportunity for MHP development in India at the present time, but so far there has been a somewhat cautious response. The Government of India's contribution to MHP over the Eighth Plan, as with other NRSEs, is only one third of the amount requested by the DNES, at Rs.1 billion. Private interest in MHP has not as yet materialised as expected.

This chapter has described the policies and infrastructure for MHP development in India. The next chapter examines individual MHP projects in the Indian Himalayas.

CHAPTER 5
FIELD EXPERIENCE OF MINI AND MICRO HYDRO POWER IN NORTH INDIA

To acquire a full understanding of the viability and impact of MHP development it is necessary to evaluate individual projects to establish their merits and failings. Intrinsic reasons for failure must be identified and addressed. Successful schemes must be studied so that the success can be reinforced and replicated at similar sites. In this way a positive approach to project appraisal and refinement may be achieved, and the experience gained may be applied to future projects.

This chapter reports the experiences of MHP development in the Indian Himalayas. Section 5.1 focuses on the MHP programmes in Uttar Pradesh - that is the MHP projects of the U.P.SEB, U.P.MHPCorp and U.P.NEDA - with examples given in particular from the sites visited by the author. There are assessments of

- technical reliability and competence,
- economic viability,
- infrastructure for management and administration, and
- socio-economic impact of the individual sites.

Section 5.2 gives an overview of the status of MHP in other Himalayan states. Finally, conclusions are drawn, highlighting common factors among projects which require immediate attention and which are discussed in chapter 6.

5.1. Uttar Pradesh MHP programmes

Until the mid-1980s MHP projects were developed by the U.P.SEB only. Since then project development has been taken over by two agencies, U.P.NEDA and the specially created U.P. Mini Hydro Power Corporation. Eleven case study sites were visited by the author, five U.P.SEB projects and six U.P.NEDA sites. Case histories of these sites are contained in appendix D, including site technical descriptions, details of technical and economic performance, plant utilisation and project management.

5.1.1. U.P.SEB projects

Background

According to the superintendent engineer for Chamoli District, the U.P.SEB installed MHP sites in the 1960s and 1970s in rural areas of the U.P. hills in order to educate the hill people about the advantages of electricity before the extension of the state grid to the region [pc:Bist]. In recent years, though, for a combination of the economic and environmental reasons discussed in earlier chapters, MHP has been considered as a possible substitute for grid extension to particularly remote areas, or, alternatively, as a method of reinforcing the grid supply.

The U.P.SEB sites which were considered to be operating at the time of the study are listed in Figure 5.1.

Site Running Conditions

U.P.SEB engineers have openly recognised that, for a number of reasons, many of the sites are presently out of commission or can only operate at part capacity. Examples of this are:

- Bageshwar, which is closed due to repairs which are required on the power house and other civil works;
- Champawat, which is closed due to a heavy landslide damaging the power channel;
- Sureingad, which is generating power up to only half capacity (reason not stated); and
- Dharchula, which is closed due to repairs required on the power house and machinery [pc:Rhudra].

The case study sites also show signs of similar problems and neglect, as presented below in the presented on site design and equipment.

Figure 5.1 U.P.SEB Mini and Micro Hydro Power Stations				
Name of Power Station	District	*Installed Capacity* Units (No x kW)	Capacity (kW)	Commissioned in the year
Badrinath	Chamoli	1x30	30	1968
Bageshwar	Almora	1x50	50	1966
Bhatwar	Uttar Kashi	2x25	50	1970
Chamoli	Chamoli	2x200	800	1967
		1x200		1970
		1x200		1987
Champawat	Pithoragarh	2x100	200	1965
Dharchula	Pithoragarh	2x100	200	1977
Gangori	Uttarkashi	3x200	800	1966
		1x200		1987
Genthicheeri	Pauri	2x100	200	1969
Guptakashi	Chamoli	1x100	200	1967
		1x100		1969
Harsil	Uttarkashi	2x100	200	1976
Koti	Uttarkashi	1x100	200	1973
		1x100		1975
Pandukeshwar	Chamoli	1x250	750	na
		1x250		1974/5
		1x250		1981/2
Tilwara	Terhi	2x100	200	1966
Deoprayag	Pauri	2x50	100	1970
Sureingad	Pithoragarh	1x400	800	1986
		1x400		1988
Tapovan	Chamoli	2x400	800	1987
Tharali	Chamoli	1x400	400	1989
Gangotri	Uttarkashi	4x5	20	na

Source: U.P.SEB, 1987/88

(na - not available)

The U.P.SEB plan sites to have a 35 year life span, in compliance with Indian Electricity Act. However, some U.P.SEB sites have already been closed down permanently. Eight stations, all under 30kW and operating in isolated mode, were closed when the peak demand in the area exceeded the installed capacity, in most cases about ten years after plant commissioning. These plants were replaced either by larger MHP plants or grid extension. Two larger plants, one of 100kW and one of 200kW, were also closed down, also after about ten years of operation, when the grid extended to the area. The site's synchronous generators could not be connected to the grid due to the instability and frequent voltage swings of the grid supply; the site were judged to be costly to run isolated from the grid.

The two oldest small hydro power stations run by the U.P.SEB are Galogi (3000kW) and Durgapur (1150kW). Both were constructed at hill stations in the early 1900s and were only taken out of service in recent years because they could not be synchronised into the grid extension which now services their catchment areas. The old power system of the projects is not compatible with the grid.

Site Design and Equipment

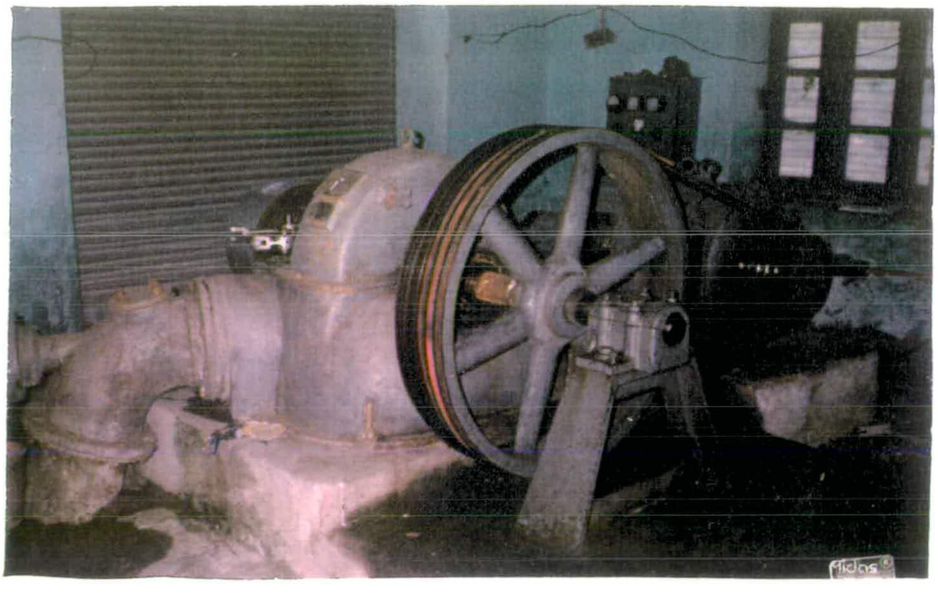
Of the case study sites, in appendix D, all but two of the turbines are turgo impulse turbines manufactured by Jyoti (Photograph 5.1). The two other turbines are a Gilkes turgo from the U.K. at Badrinath and a German pelton turbine, manufactured by Ernstutte Coburg, at Chamoli (Photograph 5.2 and 5.3). The only problems experienced with any of the turbines was caused by silt erosion (Photograph 5.4 and 5.5).

Generating equipment has been supplied from within India. Some of the projects had problems with synchronisation of generators at the power house, for example at Tapovan where only one machine can run at any time because there have been problems synchronising the two machines. The site therefore runs at half capacity. At Chamoli the fourth machine is run on a separate distribution grid because of a fault with the DC supply from the automatic voltage regulator. The problem of synchronisation between machines would appear to be primarily caused by poor training and lack of technical skills of the site engineers, as such problems with synchronisation can be rectified with adjustments to the equipment, only possible where there is the appropriate level of technical competence.

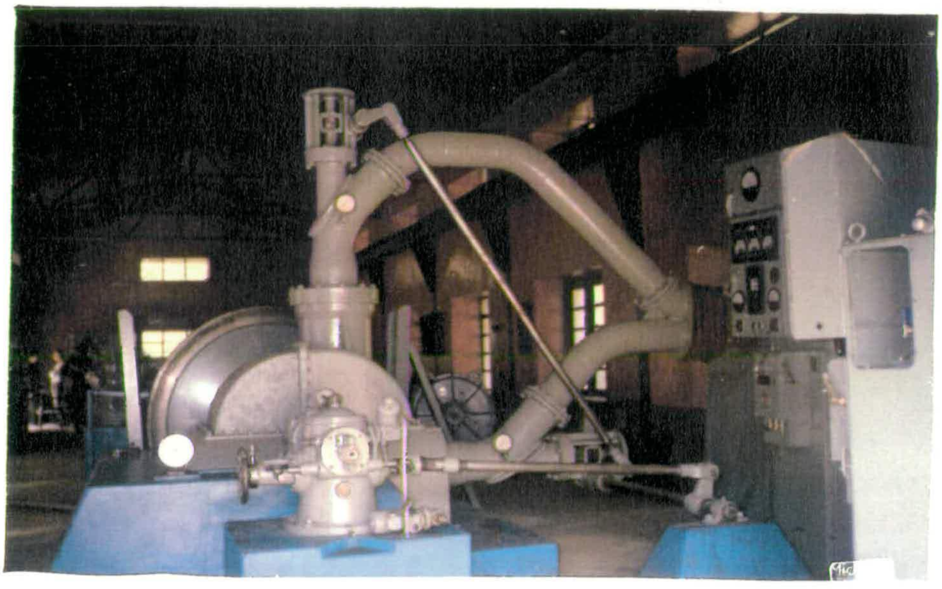
All of the projects studied operate in isolation from the state grid and use synchronous generators. Although the state grid has been extended to each of the sites, the projects cannot be connected to the grid because the grid supply is over extended, very weak and prone to large voltage and frequency swings, which would activate the generator voltage and frequency protection and trip the generator at

Photograph 5.1 Jyoti turgo impulse turbine runner (Chamoli MHP Project)

Photograph 5.2 Gilkes turgo impulse turbine (Badrinath MHP project)

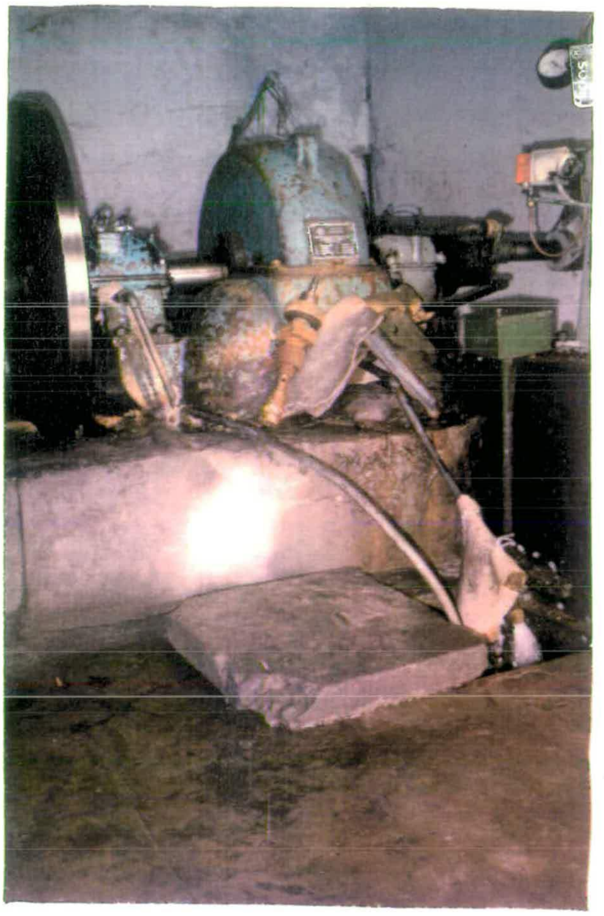


Photograph 5.3 German pelton turbine (Chamoli MHP project)



Photograph 5.4 Silt eroded turgo runner (Pandukeshwar MHP project)

Photograph 5.5 Silt eroded turbine casing (Pandukeshwar MHP project)



the MHP sites.

No major problems were reported with the distribution network, though this would be the responsibility of a separate department of the U.P.SEB.

A common complaint at the sites is over loading and therefore voltage drops at peak evening hours, indicating that some sites have over stretched the generating capacity by connecting too many domestic customers. An example of this is shown by a study of Bageshwar 50kW site where the distribution network has 11kV lines over 30km long and supplies 31 villages [Joshi, 1987]. This is an economic failure which is unable to meet a fraction of the peak demand.

There are cases where project civil works are flawed or have been prone to damage. Most notably of the case study site Tapovan had several defects in power-house design, which resulted in severe cracking of the building itself and a leaking penstock. Three of the sites had concrete power channels over 1km long, which were frequently damaged by landslides, and therefore required costly and time consuming repair work. Desilting mechanisms were inadequate at a few of the sites, though poor maintenance and clearing of the channels also contributed to silt erosion problems.

Project Requirements and Regulations

U.P.SEB sites have had to comply with the same regulations which are generally required for conventional large or small scale hydro, which has led to over specification and over-staffing at most of the sites. This results in high capital cost and excessive annual running costs. There has been little scope for projects to use innovative design or to adopt practices and equipment which improve cost-effectiveness.

At two of the sites, Badrinath and Pandukeshwar, the natural features of the stream are used as an intake. Temporary diversions made of boulders are used in the Summer season, when the flow is at its lowest, to direct the flow to the intake. The temporary weirs wash away during the floods in the rainy season. No other temporary structures are used on any of the sites, and the use of local material or labour is very limited. Construction and subsequent repairs of U.P.SEB sites are undertaken by contractors using labour and materials usually brought in from outside the project area. The sites are therefore forced to rely on external support.

By SEB regulations, staff levels are set at a minimum of four (two operators and two helpers/oilers) and increase with the number and size of machines installed. Staff patterns of the sites visited are given in Figure 5.2. In addition the sites share a junior engineer who acts as supervisor and a mechanic, and have at least one line worker plus helper to service the distribution lines. This level of staffing is maintained even if machines are out of operation awaiting repair as at the Tharali site, though the Chamoli site is not presently staffed as the repair costs are too high for the site to be restored to service in the near future.

5.2 Staffing Patterns at U.P.SEB MHP Stations

Power Station	Operators	Oilers	Total
Chamoli (4x200kW)	4	4	8
Tharali (1x400kW)	4	4	8
Pandukeshwar (3x250kW)	4	4	8
Tapovan (2x400kW)	4	4	8
Badrinath (1x30kW)	3	2	5

The project operation and maintenance staff are U.P.SEB employees, and not necessarily local to the site, or even from the hill districts. Local input to the projects is minimal and, consequently, vested interest of the staff in the project is virtually nil. One engineer claimed that engineers not from the hill districts would purposely neglect remote hill MHP sites in hope that they would be closed and the engineer could transfer back to the plains [pc:Singh]. This view was also held by some of the power station staff at the case study sites, who were disheartened by frequent and extended breakdown periods at the projects.

Because of the relatively high running costs and the small scale of the MHP projects in comparison with the conventional U.P.SEB hydro or thermal power stations, MHP sites are often not given the full priority status, which has led to plant neglect. The schemes in the case studies have all had long down times for repairs due to repair work being delayed. All five sites now have grid connections available within their supply areas, which is able to substitute, if somewhat inadequately, for the MHP power supply. At sites where grid supply is not available greater effort is made to keep sites running as the only means of electricity supply. In these cases temporary measures are used at the sites to keep the plant running until more permanent repairs can be made. For example at

Gangotri and Harsil in Uttar Kashi district the power channels were repaired using local stones until permanent materials could be brought to site [pc:Verma].

Economic Performance

The author's experience of cost accounting by the electricity boards reflects the opinion concerning lack of available information on costs in the power sector in India (discussed in section 4.2.2). Great difficulty was encountered in collecting cost figures for the case study MHP projects of the Uttar Pradesh State Electricity Board. This was due to the poor record keeping at the district offices and because records were held between several departments. This made costs analysis very difficult, though every effort has been made to achieve accuracy.

The capital costs per kW of the three most recent case study projects are given in figure 5.3 (1992 prices). The unit capital cost of the two larger MHP sites shown in figure 5.3 compare favourably with the cost of large hydro schemes, that is within the range of 10,000Rs/kW and 30,000Rs/kW [UPNEDA, 1992]. The smaller site, Therali, shows a significant increase in unit cost, in line with the classical model of economy of scale as discussed in section 2.3.1. This is emphasised again when compared to the cost of U.P.NEDA micro-hydro projects given in section 5.1.3; the micro-hydro projects' cost per kW are more than double that of the mini-hydro sites quoted here.

Figure 5.3 Cost of U.P.SEB projects in 1992 prices

Power Station	Capacity (kW)	Cost per kW (Thousand Rs.)
Tapovan(1989)	2x400	23.09
Pandukeshwar(1975,76)	3x250	21.18
Therali(1987)	1x400	38.93

(Assuming 8% annual inflation rate)

It is unlikely that any of the case study sites will ever become profit making or pay back the initial capital cost. One factor which prevents the sites from running at a profit is the frequency of breakdowns, which requires expenditure for repairs and also reduces revenue when the plant is not running. This is compounded by the limited finance available from U.P.SEB to carry out costly repair work, thus extending the breakdown period or closing the plant entirely, as at Chamoli. The second cause of low profitability is the low load factor at most plants (discussed later) resulting in low plant revenue.

Another factor which increases disappointment in the poor performance of the site is that the detailed project reports of the sites, written when applying for approval for project funding, all under-estimated capital costs and exaggerated the estimated loading patterns. This was done to make the projects appear viable in order to be accepted. Therefore, these problems were over looked at the project planning stage and were never considered until after the projects had been commissioned.

The tariff charged for energy from the U.P.SEB MHP sites is the same as the unit charge for the grid supply. During the author's visit to India the grid tariff in Uttar Pradesh was increased from one rupee per unit to almost two rupees per unit. Households taking connection for the first time have also to pay a lump sum connection fee (the amount depending on the number of socket outlets and lights in the house), which has been shown to be a major economic hurdle to taking up an electrical connection. The option of "Janta" connections for scheduled castes and tribal people (the poorest members of the villages) is available, with a reduced connection charge and monthly flat rate charge for a lighting load only. There is evidence that the U.P.SEB are not encouraging the uptake of Janta connections because they result in financial loss to the board and subject to frequent mis-use of the service, including electricity pilferaging [Joshi, 1987].

The report by Joshi on two MHP projects in Uttar Pradesh suggests that

> *"There is thus a conflict between the obligation of the Government to improve the conditions of the people, especially the weaker sections, and the role played by the electricity board as a commercial organisation."* [Joshi,1987, p.163]

This is a dilemma which has created great problems for the U.P.SEBs, which currently has a large outstanding debt, which is mostly due to its RE programme.

Site Management

All U.P.SEB sites are managed by the electricity board, and are therefore subject to the highly centralised and hierarchical bureaucracy of the government institutions. Decision making, for example on repair work, can often be delayed considerably due to bureaucratic hold ups. The rigid structure of the U.P.SEB, with separate district offices for civil works, electro-mechanical works and distribution, means that information and responsibilities for any site is spread between several offices. To collect data on the sites it was necessary to visit four offices in different towns, often a day's journey apart - in addition to visiting the sites. Much of the data available on the sites was incomplete and inconsistent.

Utilisation

Another common problem at almost all sites is low load factor, normally less than 25% at sites predominantly used for evening lighting with very little daytime load. Examples of calculated average load factors are given in table 5.4. At some sites, such as Chamoli and Pandukeshwar, there have been indications of new loads being developed, including agricultural processing and small industrial loads. The load factors at Chamoli and Therali taken on one randomly chosen fully operational day were both over 40%, indicating a potential for profitable operation. However, because of breakdown and poor reliability, the load factors have generally remained low.

Figure 5.4 Average Plant Load Factors

Power Station	Average L.F (%)
Tapovan	5.28
Therali	12.28
Guptakashi	5.54
Chamoli	19.57
Pandukeshwar	23.63

Note: Load factors have been calculated from 1983/84 or from the plant commissioning date to 1991/92. Load factor is calculated by dividing the actual annual energy generation (in kWh) by the plant capacity (in kW) multiplied by 8760.

Studies which have investigated the perceived benefits of electrification by the households in some of the villages have found that the benefits gained from the projects were mostly related to the improved lighting supply, such as increase in the time for childrens' study and for reading, increase in time spent on spinning and weaving, decorative lighting for festivals and improved household cleanliness and safety. It is noted that there is not much scope for electric water pumping for irrigation in the hills because of the terrain. Also development of commercial activities is limited by the very poor infrastructure in the hills, lack of market in the rural areas and inadequate transportation facilities [Joshi, 1989; UPDESCO, 1980]. It is clear that development of daytime loading requires more than the presence of electricity, but must be accompanied by other infrastructural development.

Future Prospects for Case Study Sites

There are plans to install a 240MW large scale hydro project for grid connection in the Chamoli district. The infrastructure for construction of this site is almost established, including improved road access and bridges to allow transportation of materials and equipment to the site. Temporary power generation for site supply (25kW MHP and 6x400kW diesel) has also been installed. The project construction has, however, been suspended for the present primarily because of financing problems. When this project is finally completed, it should provide a much improved grid supply system, which will put the role of MHP projects in the district into question.

5.1.2. The U.P. Mini Hydro Power Corporation

Though the running of U.P.SEB sites has remained the responsibility of the state electricity board, new development of mini-hydro projects (between 200kW and 3000kW) in Uttar Pradesh state was taken over by the U.P. Mini Hydro Power Corporation in 1985. One reason for establishing the corporation was to give MHP greater priority status than it had under U.P.SEB control. So far only one site has been completed, at Kotabagh (200kW). 23 other sites with total capacity of 30MW are at various stages of construction.

The corporation's plan is that the majority of sites will be grid connected, but that about 15% of installed power capacity will be fed directly to local villages [pc: Krishna]. Preference will be given to larger mini hydro projects, as these are considered to be more profitable. It was viewed that sites under 500kW were not economically viable, even with a 100% capital subsidy. Sites near to the roadside will be given priority on grounds of ease of transport of equipment. Construction of sites is carried out by contractors, and equipment may be purchased from overseas as well as indigenous manufacturers [pc:Pandy].

It is aimed to complete construction of each project within 30 months, but unfortunately the corporation has already had difficulty in achieving this goal. An example of this is at the Chirkils site, which was to be constructed between 1987 and 1989. This site was still not completed at the time of the author's visit to the corporation office in 1992, with the explanation given by a corporation employee was *"poor use of funds"*.

The possibility of the corporation taking over and renovating or upgrading U.P.SEB sites has not been considered, despite plans to develop new sites close to under-utilised SEB projects. For example a new 800kW project is planned for the Tapovan valley, while the U.P.SEB Tapovan site lies in disrepair.

The U.P. Mini Hydro Power Corporation has been set up with the intention of stimulating the growth and viability of mini hydro within the state. It would appear, however, that so far there has been little scope for innovation in project approach or design. The U.P. Mini Hydro Corporation still retains many of the restrictions imposed on the U.P.SEB sites, including design specification and staffing numbers. Project reports of the corporation sites claim that the purpose for MHP installations include fuelwood replacement, industrial use and lift irrigation [U.P.MHPCorp, 1988], but there is no consideration as to how such development in the rural areas will come about. It is too early to evaluate any of the individual schemes, as none has a history of operation.

5.1.3. U.P.NEDA projects

Background

U.P.NEDA was set up in 1983 *"to promote utilisation of renewable sources of energy"*, with *"special attention....paid to programmes relating to energy supply in hilly areas and rural areas"* [DST, 1991]. It is assumed that the provision of electricity will result in the advancement of the isolated rural communities through the use of power for domestic needs, including cooking, agricultural purposes and small industry uses. As the project proposal for ten prospective U.P.NEDA MHP sites claims,

> *"Availability of cheap and reliable electricity supply will transform the socio-economic status of the population and will help prevent large scale deforestation, thus maintaining ecological balance of the area with speedy development".* [U.P.NEDA, 1990]

U.P.NEDA took over micro hydro development in 1989, with projects so far limited to capacities of up to 100kW, though there are plans for developing sites up to 200kW. The aim of the projects is to supply electricity to communities which are isolated from the state electricity supply, with the criterion that the schemes chosen should be located a minimum of 3 kilometres from the grid [pc:Tiagi], though at some of the sites the U.P.SEB grid extended to the project area after construction work had started. Figure 5.5 lists the nine completed U.P.NEDA MHP projects. Six sites were visited during the study, and details of these sites are included in appendix D.

Figure 5.5 U.P.NEDA Micro Hydro Power Stations

Name of Power Station	District	*Installed Capacity* Units	Capacity	Commissioned in the year
Ramgad	Nainital	2x50kW	100kW	1990
Naini	Chamoli	1x50kW	50kW	1991
Khet	Pithoragarh	2x50	100kW	1992
Ghagria	Chamoli	1x50kW	50kW	1992
Dior	Pauri	1x50kW	50kW	1991
Khokta	Dehradun	1x50kW	50kW	1992
Bilkot	Pauri	1x50	50kW	1992
Kempti Falls	Garhwal	1x12kW	12kW	1989
Sahastradhara	Dehradun	1x10kW	10kW	1991

Source: NEDA records, 1992.

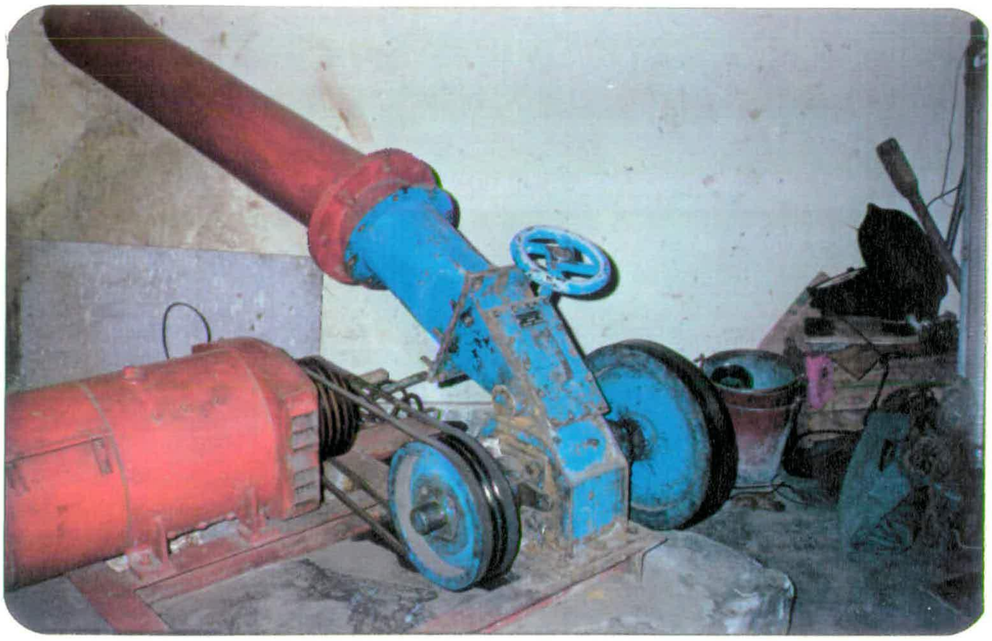
About 40 improved water wheels of 1kW capacity have also been installed throughout the hill districts, which are predominantly used for agricultural processing such as milling and grinding, but can be connected to an alternator to produce power for lighting in the evenings.

The head of U.P.NEDA's MHP section said that the aim of the projects is to *"give happiness to the villages"* [pc:Goel(a)]. That is, the supply of electricity by micro hydro was viewed as a social service, rather than profit orientated. Most of the projects implemented so far by U.P.NEDA have been run as pilot projects, to familiarise U.P.NEDA with MHP and to test new technology. As the sites are viewed as a social service, their capital costs are heavily subsidised by state and central government. U.P.NEDA and the DNES claim that there are hundreds of possible micro hydro sites in the hill districts of Uttar Pradesh. U.P.NEDA plan to carry out further surveys of potential sites.

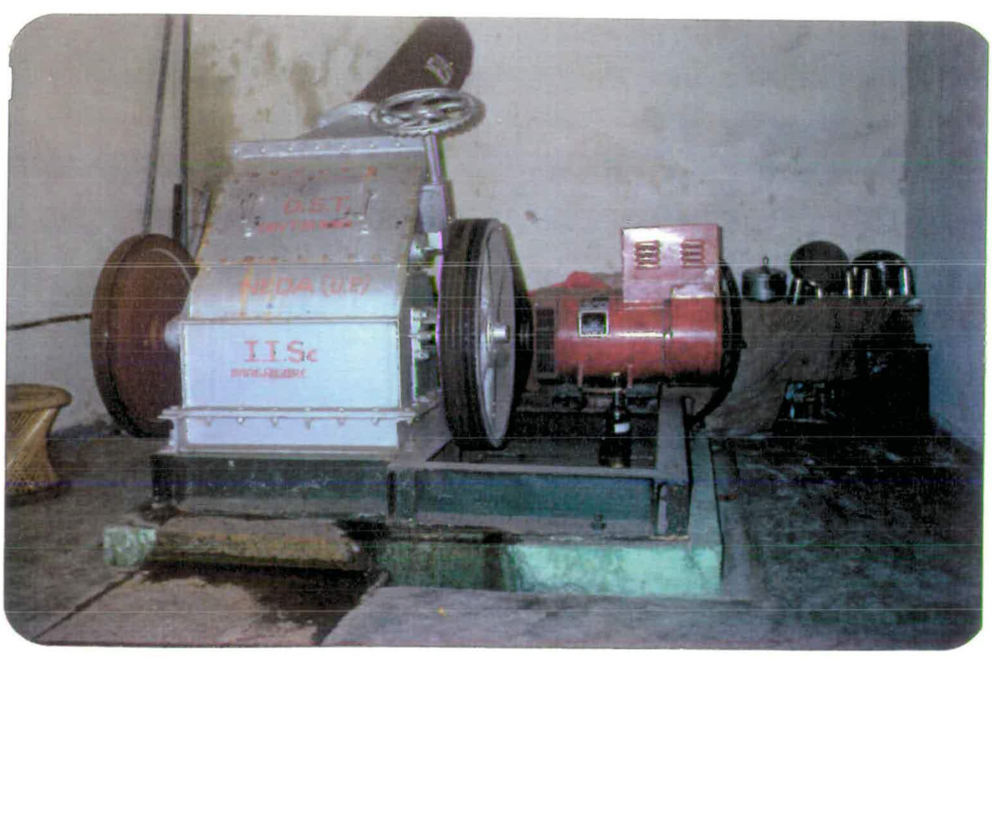
Micro Hydro Equipment and Design

Four of the U.P.NEDA sites, Kempti Falls, Dior, Sahastradhara and Khokta are sponsored by the DST as part of its crossflow turbine development programme, using equipment developed at the Indian Institute of Science in Bangalore and fabricated by a Uttar Pradesh engineering firm (Photographs 5.6, 5.7 and 5.8). These sites were also installed with electronic load controllers of Indian design. Photographs 5.9 and 5.10 show the ballast loads for two of the sites . Ghagria has had a German built crossflow turbine and load controller installed for comparison (this site was only just commissioned before the author left India, so no results of the comparison are yet available). The other sites used conventional turbine designs, either turgo or Francis turbines, usually with mechanical governors, all manufactured by Jyoti turbine manufacturers (Photograph 5.11). A cost comparison of the five 50kW sites is given in figure 5.6. This indicates that the cost of the locally built crossflow is less than 1/3 that of cost of the conventional equipment and 1/5 that of the German imported crossflow. The efficiency of the Indian crossflow turbines has been very low, however, at less than 65%, and reliability of the turbine at some sites has been poor. The Indian crossflow turbines at Dior and Kempti have both been badly damaged by debris which entered the penstock and passed through the turbine. U.P.NEDA has started to work with turbine manufacturers in India to produce a standardised or modularised range of turbines, with the eventual aim of mass producing equipment for schemes of similar head and flow characteristics. For example, a possible consideration has been to produce a standard range of 50kW turbines to suit "typical" head ranges.

Photograph 5.6 Crossflow turbine at Kempti Falls MHP project



Photograph 5.7 Crossflow turbine at Sahastradhara MHP project



Photograph 5.8 Crossflow turbine at Dior MHP project

Photograph 5.9 Sahastradhara MHP project ELC ballast load - water distiller

Photograph 5.10 Bilkot MHP project ELC ballast load - open air bar heaters

Photograph 5.11 Turgo impulse turbine at Ramgad MHP project

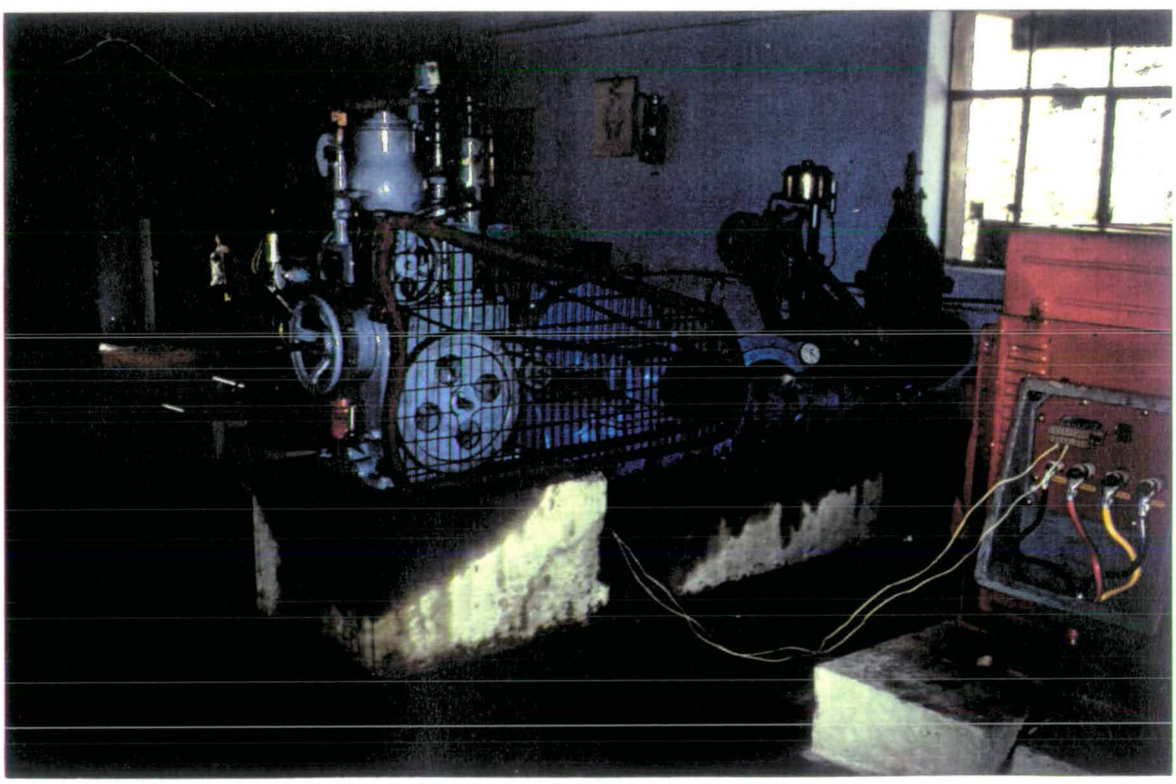


Figure 5.6 Capital Cost of UPNEDA Micro-Hydro Projects				
			Cost in Million Rupees*	
Site	Head	Turbine Type	Total	Electro/Mechanical
Naini (50kW)	95m	Indian Turgo & Governor	3.17	1.30
Bilkot (50kW)	22m	Indian Francis & ELC	3.24	2.06
Ghagaria (50kW) **	40m	German Crossflow & ELC	3.55	2.55
Dior (50kW) **	35m	Indian Crossflow & ELC	2.53	0.453
Khokta (50kW)	35m	Indian Crossflow & ELC	2.15	0.453

* £1 = 45 Indian Rupees; ** Civil works on Ghagaria and Dior built for two units of 50kW;

Source: UPNEDA records.

The opportunity for innovation in civil design has not been taken at most sites, instead conventional materials and skills have been brought from the plains. Structures such as diversion weirs, settling basins and power houses tend to be over sized or over designed for the scale of the project (Photographs 5.12, 5.13 and 5.14). Several problems have been experienced with civil works, such as: severe landslide damage to the power channel at Ramgad (Photograph 5.15); stones getting into the turbine due to the absence of a trashrack at Dior; insufficient water entering the intake in Summer at Bilkot due to poor design of the diversion weir (Photograph 5.16); silting of the diversion at Kempti Falls (Photograph 5.17); and flooding of the Sahastradhara power house when the water level rose higher than predicted.

Project Requirements and Regulations

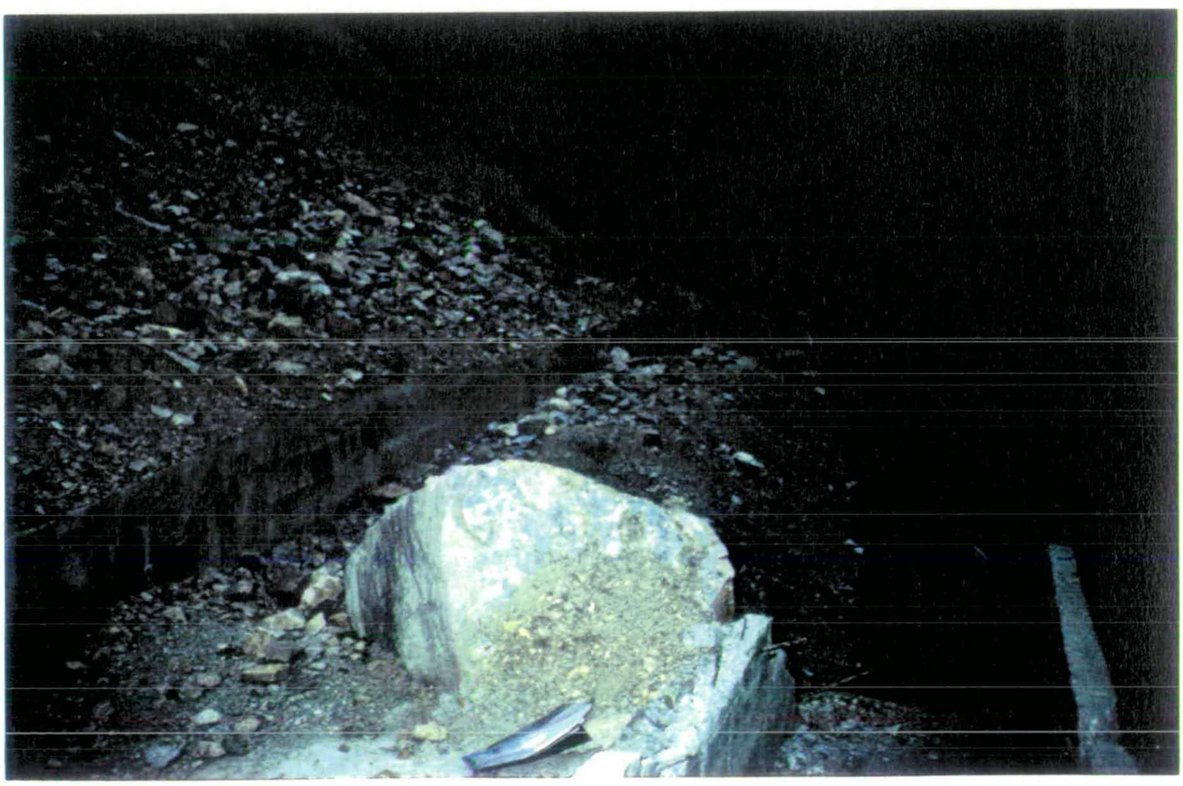
As NRSE projects, U.P.NEDA sites are less regulated than the U.P.SEB sites, so that the use of innovative designs and locally available materials are possible, though not frequently adopted. Standard electricity supply regulations do apply. Staffing requirements are more relaxed. The power houses are run usually by one

Photograph 5.12 Forebay for Sahastradhara 10kW MHP project

Photograph 5.13 Power house for Khokta 50kW project

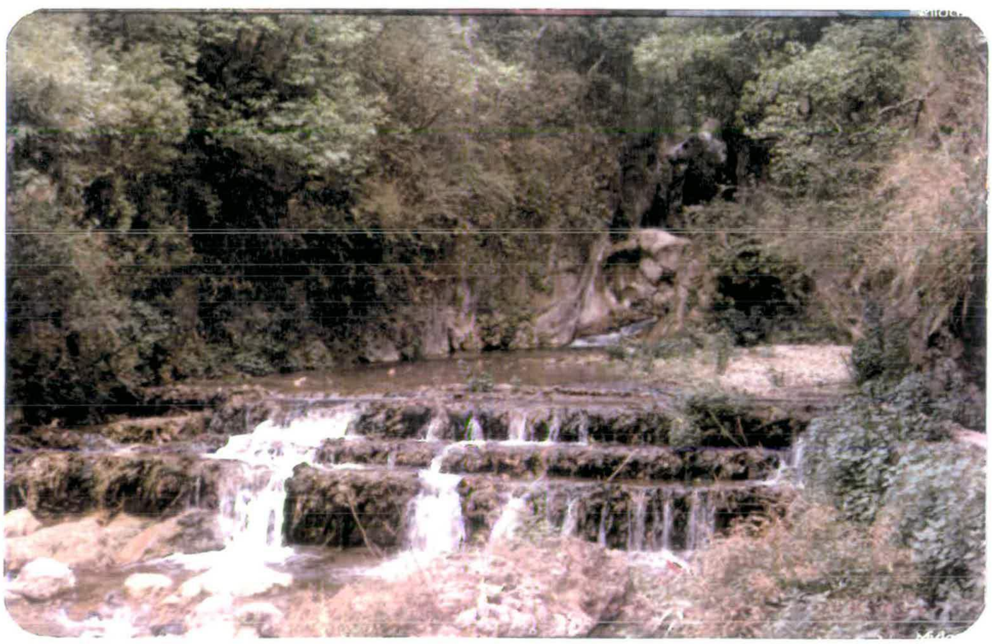
Photograph 5.14 Power channel and forebay for Bilkot 50kW project

Photograph 5.15 Broken power channel at Ramgad MHP project



Photograph 5.16 Diversion at Bilkot MHP project - un-able to divert sufficient flow during the dry period

Photograph 5.17 Silted diversion structure at Kempti Falls MHP project



or two local people. The reason given by one U.P.NEDA engineer for using local staff was the low cost of local labour, and because they were not required to pay local staff when the plant was out of service. At some sites the villagers complained that the power house staff were under-trained and could not cope with more than routine operation and maintenance.

U.P.NEDA has been involved in negotiations with the central government for a policy change in the Electricity Act to allow agencies of their kind to proceed with the development of micro hydro schemes without first getting approval of the CEA. Currently the approval period takes about one year [pc: Goel(a)].

Economic Performance

The economic performance of the U.P.NEDA projects has been very poor. Capital costs and repair costs are extremely high and have been completely subsidised by the Uttar Pradesh state government and the DST. The unit capital cost of the sites range from Rs.42,000 to Rs.70,100 per kW, excluding transmission and distribution lines. At some sites transmission and distribution equipment accounts for up to 50% of the overall project cost. Kempti Falls, Ramgad and Sahastradhara only just collect sufficient revenue to pay the site workers and basic operation and maintenance costs, though the wage of the operator at Kempti Falls had to be cut from 600 Rs per month to 450 Rs. in order to achieve this. The other sites have collected no revenue at all due to the unreliability of power supply.

User Involvement

Construction of the MHP schemes is done by contractors who usually use labourers from outside the local area. Co-operation of the local people with the projects construction has been low, with large compensation sought by locals for disturbance of land or water rights [pc:Das]. The projects are not viewed as belonging to the local people, but a government responsibility. This creates apathy towards the projects, in that the villagers want electricity supplies, but they view it as the government's responsibility to provide and maintain the supply. As the case studies show, when a project breaks down the common response is for a dispute between the local people and U.P.NEDA officials over poor supply reliability, instead of a positive response or initiative from local people to help keep the plant running in the future. The Bilkot project has been closed down because of a dispute of this kind caused primarily by poor communication with the village leaders. Only one positive response was noted during the field study, at Dior, where some of the village people proposed a new site for development of an MHP project on a local canal drop. This project, if implemented, could boost the quality of peak times power supply to the area, which at present the Dior project is incapable of fully supplying.

U.P.NEDA do try to encourage discussion with the local people at all stages of project implementation. Local people are consulted over site location, practicalities of construction, power utilisation, project management and tariff rate. It is aimed that the projects should eventually be be run by local people, with back-up support from U.P.NEDA as required, as has been the case at Kempti Falls and Sahastradhara, and is being arranged at Ramgad and Kapkot. Tariff rates are calculated to cover plant running costs only and at most sites there is a special reduced tariff for scheduled and tribal castes.

Load Development

Load development has not been successful at the U.P.NEDA sites so far. At Kempti falls and Sahastradhara the daytime load is associated with the tourist restaurants. All other sites are operated in the evenings only, with frequent over-loading at Bilkot and Dior requiring load shedding. A report was written from a study of use of off peak (daytime) power for productive purposes. The study focused in particular on the Ramgad project. The report suggested several options for power the use in agriculture and small industry, and outlined the necessary input to implement these options, including finance and training [DST, 1991]. To date, however, Ramgad has no daytime load and little indication of more than one or two flour mills with potential to be electrified. U.P.NEDA is currently working to develop a low wattage cooker which can be used during the daytime in the villages to replace at least part of the fuelwood need in the village.

The engineer in charge of micro hydro at U.P.NEDA has conceded that the MHP programme has not been greatly successful to date. Plans are, however, continuing to improve both design and implementation. The possibility of involving NGO groups with load development at the projects has been met with scepticism, as mis-trust of objectives had been experienced on previous attempts of collaboration with an NGO. There have also been difficulties in co-operating with government industrial development agencies for the promotion of productive uses of power at the sites. [pc:Goel(b)]

Socio-economic Impact on the User Community

Electricity is generally not the first priority for development in the villages served by the micro-hydro projects, where access roads, drinking water supply, schools and security from wild animals are of greater importance. However, in all the villages electricity supply is valued as an improvement in living conditions. Economic reasons were seen as the most common barrier to some households taking an electrical connection, because of connection charge and also the monthly tariff. Household uses for electricity are usually confined to lighting, as other electrical implements can not be afforded by most local people. A few wealthier households had bought televisions and tape-recorders. Though electricity was often viewed as comparable in cost to kerosene for lighting, cooking with electricity was not seen as a viable option. This is because the associated electricity charges would be too high, and fuelwood is still freely available even if the forest resources are reducing.

As the majority of the U.P.NEDA sites have no productive load connected, the economic impact on the communities has been minimal. Only where the site was located in an accessible tourist area has there been a significant impact on commercial activities, by providing power for refrigeration, lighting and fans for restaurants and shops. User participation in the running of the site has been greatest where there have been perceived financial benefits.

Complaints about the electricity supply from the U.P.NEDA micro-hydro schemes were primarily concerned with poor reliability of supply. Some villages had received electricity for less than one quarter of the period since connection. Poor reliability of the electricity power supply from the micro hydro plants was stated as reason for some households not taking an electrical connection. It was debated whether a U.P.SEB connection would be more reliable than the micro-hydro supply.

Future Plans for Micro Hydro Development

Future U.P.NEDA projects include a 100kW crossflow scheme at a high-altitude site at the pilgrimage centre of Kedernath. This will replace a diesel generator supply, which presently requires costly transportation of fuel, especially as the site is eight kilometres from a motorable road. The plant is being constructed so that it can be dismantled and stored in safe keeping during the winter months, when there are no pilgrims at the site, and weather conditions would be a threat to the equipment.

Also there are plans to develop ten sites of between 40kW and 100kW in the Kapkot block of Almora District. The sites will use conventional equipment, with some of the plants interconnected to form localised grids. These schemes are projected to cost between Rs.36,000 and Rs.60,000 per kW installed capacity (1990 prices, excluding transmission and distribution lines).

5.2. Mini/Micro Hydro in other Himalayan states

Although the focus of attention regarding MHP in the Himalayan states is generally directed to Uttar Pradesh as the state with the most prolific development of MHP, the other Himalayan states all have a history of MHP development. As noted earlier, many of the North Eastern states rely almost solely on small hydro for power supply (see figure 5.7). In particular, Arunachal Pradesh must be noted, with 15MW of MHP developed at 25 sites.

The rural electrification figures given in figure 4.12 show Himachal Pradesh to have 100% rural electrification with Jammu and Kashmir very close, therefore electricity supply is, in principle, available to everyone. The statistics are somewhat deceptive, however, hiding the fact that there are many households who cannot afford electrical connection, and there are many tiny communities which are too small and dispersed to be classified as a village. In addition, the statistics do not indicate the quality of supply or the need to augment the power supply, with the peak power deficit in the Northern region of India at about 7% and most likely to increase, [Suri, 1989] and line losses in rural networks at over 20% [Shishoo, 1992]. In essence, the presence of a grid transmission does not remove the need for mini or micro hydro in decentralised locations.

5.2.1. Himachal Pradesh

With a hydro potential conservatively estimated at 20,000MW, the power supply to Himachal Pradesh is almost entirely derived from hydro power [Dhar, 1991b]. The Himachal Pradesh State Electricity Board (HPSEB) in 1989/90 had an installed capacity of 153.57MW, with one plant, Bhaba Power Project, of 120MW and a number of small hydro projects, including nine under 1MW. Of the small projects presently under construction, though, only one is under 1MW. The central government has in addition developed over 3000MW of the large hydro resources, including the 990MW Beas Sutlej project. There are plans for a much larger scheme at Nathpa Jhakhri, which will be over 1500MW and other medium size plants [Dhar, 1991b].

Himachal Pradesh is rare in that, not only can it claim 100% of its villages are electrified, but also that around 80% of the village households have taken an electrical connection. The success of the state rural electrification programme has been attributed to the fact that Himachal Pradesh is a small and well managed state [pc:Anand] which has developed rapidly in recent years.

The experience of MHP in Himachal Pradesh has not been entirely successful, with huge construction time and cost over runs, and general under-utilisation of the installed capacity. As with sites in Uttar Pradesh, it has been found that when project reports are submitted for approval to obtain funding it is common practice to under estimate the costs and exaggerate the benefits. This results in under funding and therefore time delays for construction and repairs. Often funds for allocation to small projects are diverted to larger, higher priority projects, hence accentuating the financing problem [Sharma, 1987]. Some of the Himachal Pradesh sites have experienced problems of flood or landslide damage and silt erosion, and in addition problems of extreme cold weather in the Winter months which freeze the river, reducing the flow and also freezing the turbine equipment. The remoteness of some sites has meant long delays in carrying out repairs [Chauhan, 1983]. The projects are also excessively over staffed, for example the Rongton 2MW project has a compliment of 50 staff - 4 supervisors, 20 operation and maintenance staff, 10 distribution workers, 1 clerical staff and 15 unskilled workers.

None-the-less, the availability of power, along with other infrastructural developments in some areas, has brought substantial benefit to the local people and opened up the tourist market considerably. Benefits are said to include improvement in drinking water supply by using electric pumps. The increase of the tourist industry has, however, been accompanied by social and environmental disruptions, ranging from rubbish dumping to drug trafficking [Chauhan, 1990].

Two experimental sites were installed in Himachal Pradesh to assess the performance of pumps as turbines. Five Indian made pumps were installed as turbines by the AHEC at Manali (2x100kW) and Jubbal (1x100kW and 2x25kW). These sites are grid connected and operating well.

As grid coverage is widespread, the need for MHP is probably least urgent in Himachal Pradesh among the other Himalayan states, though there is a large potential for MHP which should not be ignored in future state electricity planning, especially when environmental impact of other power plant development is considered.

5.2.2. Jammu and Kashmir

Despite the attraction of its natural beauty to tourists, Jammu and Kashmir remains somewhat elusive due to the continuing conflict with Pakistan over land rights. This has severely limited the economic development of the state, which otherwise has few resources. None the less, there is evidence of development in the State, including new MHP projects installed by the Power Development Department of the State Government. The turbine manufacturer Jyoti has on order two Francis turbines for the state, one of 500kW and the other of 350kW capacity. Two large turbine orders, of 2500kW and 3000kW capacity, were under negotiation at the time of the author's visit [pc: Anand]. Jyoti has also been supplying very small "semi-portable" units to the military in Jammu and Kashmir. These units are between 2kW and 40kW, tubular or turgo type turbines with electronic load controllers. In addition, recently one NGO in the Ladakh region (the most under-developed region of the state) was attempting to install community micro hydro units, based on the SKAT crossflow design with reasonable results [pc: Dawa].

The high percentage of rural electrification in Jammu and Kashmir disguises a history of huge transmission and distribution losses, peaking at 51% in 1981 [Dhar, 1992b]. Medium and small scale hydro projects feature significantly in the state's power supply mix, though still only around 2% of the 10,000MW hydro potential has been utilised. There is both need and opportunity for hydro power development of varying scale across the state.

5.2.3. North Eastern States

Accessibility to these states is greatly restricted for both foreigners and Indian nationals. This is primarily due to internal disputes within the states and border conflicts with neighbouring countries. The isolation of the North Eastern region from peninsular India has marginalised these states, which, along with the dominance of the traditional tribal population living in dispersed communities over the difficult terrain, has meant the North East has remained somewhat under developed and economically backward.

Only Assam, which has a large region of plain land, has a significant industrial base. The farming methods used are mainly traditional, with shift cultivation techniques still in practice despite efforts by the government to have it banned. Therefore both industrial and agricultural load is low in most of the states.

There is a great deal of scope for MHP development in the North Eastern states which generally have low population density, with many villages almost completely cut off by the difficult terrain. It is both costly and time consuming to erect and maintain a wide ranging network of transmission and distribution lines due to the geographical conditions. With water supply the most copious resource available to the North East, which has no coal or oil reserves and a limited supply of natural gas, hydro is viewed as the most viable power supply option. There are plans to build huge dams to tap the hydro resources of the North East, such as the 20,000MW Dihang Project or the even more fantastic 40,000MW project at Yarlang Zangbo Jaing, the electricity from these projects is to be entirely exported, over great distance and at high transmission costs, to the industrial areas of the Indian plains. For local utilisation small projects are far more feasible. The installed capacity of the North Eastern states is shown in figure 5.7. Currently, to supplement the poor coverage of electricity supply in the most remote areas there are numerous private diesel generators in operation, estimated to total 100MW, which operate at high cost due to diesel transportation.

5.7 Installed Capacity - North East India					
	Thermal (MW)		Hydro (MW)		
STATE	Coal	Gas/Oil	Major	Small	Total
Arunachal Pradesh	-	-	-	15.0	15.0
Assam	240	272.4	-	2.0	514.4
Manipur	-	-	-	2.8	2.8
Meghalaya	5	-	174	12.71	191.71
Mizoram	-	-	-	2.03	2.01
Nagaland	-	-	-	2.5	2.5
Tripura	-	10	-	16.01	26.0
Central Sector	-	-	255	-	255.00
Industry (Captive)	-	173	-	-	173. 00

Source: Kedia, 1990.

Hydro development in the North East is also limited by a number of difficulties, which include:

- poor hydrological survey data
- delays in obtaining clearance, in particular environmental clearance
- poor load factor (no industrial load)
- poor maintenance
- drastic reduction in water run-off during the dry season in some states, especially Mizoram, Tripura and Manipur [Kedia, 1990].

However, there are plans for further MHP development in the North Eastern states. Boving Fouress turbine manufacturers have orders for a series of sites in Assam. Jyoti is to supply two 500kW turgo impulse machines to Nagaland and a 1000kW turgo impulse turbine to Mizoram. Foreign manufacturers have also been consulted for various MHP projects in the North Eastern states. There is interest in the DST crossflow turbines, with six sites, one of capacity 100kW and five of 50kW, already under construction in Arunachal Pradesh and another 50kW project in a remote part of Mizoram, to which the components had to be air lifted.

The North Eastern states have a poor reputation for maintenance of MHP projects. There are reports of a site in Mizoram with two Francis machines where the generators had not been synchronised simply due to bureaucratic complications holding up approval for the work. Another site appeared far older and more abused than expected for its age due to poor maintenance and there being no spares or maintenance budget [pc:Wallace]. In another case, in Meghalaya, two 15kW sites were started in 1986, but neglected when the government officer in charge of the sites was changed. When the site was inspected in 1992 it was found that the power channel was completely over grown with vegetation and the turbine was so rusted that it would have to be replaced. There was no documentation at the sites, so that the details of design and operation were not clear [Soudranayagam, 1992].

It would appear that hydro power development in the North East will have to be matched by management and infrastructural improvements for implementing and maintaining sites.

5.3. Conclusions

MHP projects and programmes in the Himalayan states have been restricted by technical, financial, bureaucratic and socio-economic constraints. The projects have never attained the results predicted in the original project proposals. Achievements so far have been limited, with very poor economic performance and very low technical reliability at many sites, and the socio-economic impact often confined to provision of domestic lighting.

The consequences of, reasons for and solutions to these problems and constraints are discussed in the next chapter.

CHAPTER 6
DISCUSSION OF MHP IN NORTH INDIA

From the previous chapter it might be concluded that MHP has not been a success in the Indian Himalayan region. The case studies describe a series of breakdowns, failures in management, poor loading patterns and economic failure. It would therefore seem a logical assumption that there is little prospect of MHP contributing significantly to hill development. However, there is substantial evidence that the failure has been predominantly in project planning and in the approach and attitude taken towards the development of MHP, and not in the failure of the technology itself. Individual problems and their possible solutions are discussed further in this chapter, which concludes by addressing collective problems as symptoms of a flawed development approach.

6.1. MHP and the energy sector

The MHP programmes in the Indian Himalayas have consistently lacked clear objectives for MHP development, with the role of MHP never properly defined within the wider energy sector. Frequently, at the project proposal stage, benefits of projects have been exaggerated and the costs involved have been understated in order to gain project approval. This has led to arbitrary site selection and poor planning of load development and power utilisation.

It is necessary to consider the opportunity cost of MHP compared to other energy supply options, both in economic terms and also in terms of the suitability of these energy supply options for meeting the rural needs.

6.1.1. MHP for rural energy needs

The main rural energy requirements are for:

Lighting

Cooking and Heating

Mechanical power for grinding and other agro-processing

Transportation

Other potential uses of power could be for small industrial applications, usually in the form of mechanical power or heat, and for water pumping on a limited scale. The overriding factor in the selection of energy forms is cost. The main costs for the user can be separated into the fuel cost and the cost of appliances or equipment. Two other factors which influence energy utilisation are convenience and availability. For example, electricity is favoured for many applications in rural areas because it is convenient, versatile, clean and has a modern image. However, the two deterrent features against using electricity are the poor reliability of the power supply and the high cost of electricity.

For lighting purposes electricity is by far the most desired option in the villages as it produces a better quality of lighting and in some cases is less expensive, in the long term, than kerosene, as was reported in some of the villages surveyed during this study. However, as has been shown in chapter 5, where the electricity supply is unreliable, as at Dior and Bilkot, households are reluctant to invest in electrical connections.

Using electricity for cooking or heating, in order to reduce the consumption of fuelwood, is perceived as advantageous for the environment and reduces the daily drudgery of collecting wood. The main deterrent against the adoption of electricity for cooking purposes is the cost involved, in the purchase of the cooker and then for the power used. In other developing countries, notably China and Nepal, there have been innovative solutions developed to encourage cooking with electricity, in particular associated with electricity supply from MHP. The off-peak power from a MHP power plant, which is during the daytime in the rural areas, is given almost free of charge for cooking and simple low wattage cookers have been developed, based on the cooking pots commonly used by the consumers. These schemes have been most successful where fuelwood is most scarce [pc: Anderson; Mackay, 1990].

In the villages surveyed by the author, it was frequently established that there was a desire to convert the power source at flour mills from diesel engines to electric motors. However, there was great concern over the reliability of electricity supply - especially at sites where there is presently only evening power supply available - and also there had been little technical or financial assistance to make the conversion. None of the villagers interviewed perceived other commercial or industrial applications, although the study by U.P.NEDA has identified various possibilities for new productive activities such as agro-processing and workshops [DST,1991]. This report also identified the financial, technical and training support required to start these activities, none of which has as yet been implemented. The case studies indicate that there is greater success with projects where there is productive end use of power, as at the Kempti Falls and Sahastradhara projects where the power supply is mainly to tourist facilities.

As identified in chapter 3, the advantages to the hill farmers of pumped irrigation is great. However, the opportunities for applying lift irrigation are limited by the hilly terrain, except in the lower hills and valleys as with the use of hydrams at some of the Dior villages. Feasibility studies into the possibility of increased exploitation of pumped irrigation using electric pumps or hydrams could present new opportunities for development in some hill regions.

In summary, electricity has a perceived practical role to play in the rural energy supply mix. However, it is vital to overcome problems of reliability of supply and to establish an appropriate power pricing policy, as discussed in section 2.3.4. In addition, if the provision of electricity is to encourage productive activities, such as agro-processing or small scale industries, it is essential to provide other inputs such as technical and financial support. This is discussed further in section 6.3.

Chapter 2 discussed how the use of MHP as a source of rural electrification can improve grid supply or provide power supply to isolated villages. MHP can provide a sustainable power source to rural communities which would otherwise be cut off from a reliable power source. The roles of MHP as a renewable energy and as an integral part of RE are discussed in the rest of this section.

6.1.2. MHP as a NRSE

It is important to utilise natural energy resources in an environmentally benign manner. This is particularly important where there is increasing demand on the resources, as is occurring in the Himalayan region. As indicated in section 4.4.3, there is a large potential for renewable energies to supply energy needs in decentralised locations with greatly reduced environmental impact. Currently, however, renewable energies are generally perceived as new and evolving technologies. In the case of MHP the technology has been established since the late 19th century, but became displaced economically during the 20th century as larger hydro plants were developed which offered improved economies of scale. As interest in MHP has been revived in recent years it is again being viewed as a "new technology". While conventional energy supply options in India are considered the most economically and technically viable option, there is reluctance to adopt NRSEs on more than a token or experimental level [Munasinghe, 1992].

In India there has been some progress towards the promotion of renewable energies through the establishment of the DNES and the formation of state agencies for the implementation of NRSE technologies. India is taking initiatives toward developing rural energy systems through the Integrated Rural Energy Programme and the DNES Urjagram scheme. Both these schemes study the rural energy supply and consumption with the aim of creating a self-sustaining, mainly decentralised rural energy system. However, there is still caution and a lack of clear objectives for NRSE development within Indian energy planning.

NRSE Options

There are four forms of renewable energy which are viable options for development in the hill regions: wind; solar; biogas; and hydro. Biogas and solar power have limited applications in the hills due to the unfavourable climatic conditions and other practical problems of implementation discussed in chapter 4. The high cost of solar and photovoltaic equipment also reduces their economic viability for widespread application. Wind power and MHP have the greatest potential as alternative energy sources in the hill regions. Both can be used in direct mechanical power applications and for power generation with grid connection. However, wind power has limited capabilities when operated in isolation from the grid due to the fluctuations in the output power. This restricts isolated applications of wind generation to battery charging, or alternatively as part of a hybrid wind/diesel scheme. Where isolated rural loads are close to a suitable site, MHP may be developed as a flexible power source.

Cost of NRSEs

Cost is the main barrier to the wider adoption of NRSE technologies. Comparison of the cost of NRSEs with those of conventional commercial energies must consider entire lifetime costs and not simply initial capital costs, and must account for the reliability of energy supply. NRSE technology is reducing in cost as it is being indigenised and progressively developed. In India MHP is currently the most cost effective of the NRSE technologies for power production, though in recent years volume production of indigenous wind power equipment has rapidly reduced the unit cost and established an economy of scale which does not occur in MHP. Therefore wind farms are increasingly being viewed as a viable source of power to augment the grid. The lack of economy of scale with mini and micro scale hydro projects means that unit costs remain relatively high. However, there are ways by which costs can be reduced through innovative design and standardisation and bulk production of equipment.

NRSE Reliability

There are certain situations where NRSEs are the appropriate choice for power supply, in particular in remote locations where the supply of commercial energies is unreliable and costly. The supply of commercial fuels such as diesel and the availability of electrical power from centralised sources can be very erratic or non-existent in remote locations. Small scale development of renewable energies remove the difficulty of supply because their decentralised nature means that power generation is close to the point of utilisation. The main technical problems with the adoption and implementation of NRSEs are the reliability and maintenance of the equipment. The successful application of NRSEs in rural areas will require an effective, decentralised infrastructure for operation, maintenance and repair so as to remove the dependence on support from the urban sector. This has not been a priority of NRSE development in India, where NRSEs remain very much controlled by central authorities. This is exemplified by the MHP projects in Uttar Pradesh, where it takes several months to carry out repairs on civil works and equipment because of the dependence on approval from a central office and on skilled labour and materials which have to be transported from urban areas.

Viability of MHP as a Rural Energy Source

By considering the example of the Chinese MHP programme, which has developed since the 1950s, it is clear that MHP can be cost effective and productive in rural areas given the correct national circumstances. One-fifth of China's rural power supply is from MHP, and they have successfully developed agriculture and rural industry and reduced fuelwood consumption through the use of MHP [Zhu, 1990]. The Chinese development has been highly decentralised and projects are frequently community run. The overall achievement has been effective, to the point that the Chinese are beginning to consolidate the MHP system by creating regional grids through its 200 pilot counties programme.

Similarly, the Nepali micro hydro programme, run by NGOs, has developed decentralised support systems for manufacture and maintenance. MHP is now an accepted source of energy which is relied on particularly in the regions in Nepal where fuelwood supplies are very scarce.

In both China and Nepal the rural communities are contributing financially and with labour to the MHP projects as they have perceived the benefits of the energy source. For similar development in the Indian Himalayan region, there would need to be development of decentralised support mechanisms plus the establishment of successful demonstration projects to illustrate the advantages of MHP. Currently, there have been few examples of successful schemes, and the established projects have not given positive role models. The failure of MHP projects has in some cases given MHP technology a bad reputation.

To summarise, NRSEs are progressively becoming attractive rural energy options for many applications. The two barriers to their widespread adoption are the initial capital cost and difficulty of maintenance in remote locations. Capital costs of equipment for utilising renewable energies are reducing rapidly, especially with the indigenisation of equipment within India. It is the infrastructure for maintaining NRSEs, which is currently almost entirely dependent on the urban sector, which will now have to be established in rural areas.

The application of MHP in rural development has already proven to be successful and economically viable in developing countries which have adopted a widespread, highly decentralised programme of MHP development. The appropriate technology, planning and policy decisions for successful decentralised MHP development are further discussed in the rest of this chapter.

6.1.3. MHP and rural electrification

When developing MHP projects it is important to integrate them into the wider RE planning. The role of MHP within RE planning should be defined so that site selection is appropriate to overall electrification needs. It is important to have strategic positioning of grid connected schemes in order to strengthen the grid effectively, and to establish isolated projects near to rural load centres in locations which are least likely to be grid connected or where a MHP is the least cost or least environmentally damaging option.

Of the case study projects, none were grid connected, but all were in the vicinity of a grid extensions or had grid lines extended to the area after the project had been developed. The U.P.SEB sites were somewhat neglected because of the alternative source of power available to the customers. At the U.P.NEDA projects at Ramgad, Dior and Bilkot it was perceived that the state grid would be a more reliable source of power because of poor quality and availability of supply from the micro hydro schemes. At Kempti Falls and Sahastradhara it was perceived that the micro hydro supply was less expensive and also more reliable than the state grid.

It is evident that MHP is successful where:

a) it has a defined, productive role; and

b) the reliability of the MHP power supply is greater than that of the other energy options.

The current dependence in many parts of rural India on diesel generators as a back-up or substitute for grid power supply indicates the poor service given by the rural grid supply. The productive role of MHP in grid connection is clearly to improve the quality of power supply. This should in turn increase confidence in the power source for both productive and domestic uses. Isolated sites can provide power to areas which would otherwise be excluded from grid connection. The MHP sites themselves must be reliable for similar confidence to grow.

Poor load forecasting and planning commonly results in the overloading of MHP plants in the evenings. Frequently too many domestic users are connected and their demand for power exceeds the active power available from the generator, causing frequency and voltage fluctuations or in some cases load shedding when domestic lighting load is at its maximum. Also lack of planning has led to very low daytime loading because of an almost negligible development of industrial or commercial users. The linking of RE, and particularly isolated MHP, with wider development and environmental targets would benefit load planning by identifying and developing useful loads as part of the project development process.

6.2. MHP technology

Design standards and specifications applied to MHP plants in India are excessive as they are usually based on conventional large hydro practice and requirements. With MHP, however, there is greater scope to adapt designs to the specific constraints and requirements of a particular location, as for example in the Himalayan region. There is a need to review the engineering practice for MHP projects and to increase the flexibility of design.

As stated earlier, the two critical factors to consider when designing and implementing an MHP scheme are cost and reliability. This section is concerned with minimising the lifetime cost of MHP schemes and maximising the reliability of power supply from Himalayan MHP projects through appropriate design, manufacturing techniques, construction methods and maintenance.

6.2.1. Design

In order to preserve an economy of scale as plant capacity falls from large through small to mini and micro hydro, the approach to design and specification has to recognise the changing capacities and plant dimensions. Particularly for applications in rural areas, the level of technology must be carefully considered. Large and small hydro applications should remain conventionally designed and specified, but mini and micro hydro may be more cost-effective if designed and manufactured using intermediate and appropriate technology respectively. Operation and maintenance skills must follow suit. Where large and small hydro plants will require highly trained skilled staff, intermediate and appropriate technology plants should be designed for operation and maintenance by adequately trained semi-skilled staff or even by local people.

There are two main ways by which cost reductions can be achieved through design of MHP for rural applications: innovation and standardisation .

Innovation

Innovation will be required in the design of projects to suit local conditions. Developers must learn from problems from previous projects and continually improve methods of overcoming hazards. Feedback from projects is vital for development, to learn from mistakes and to find designs which are most effective.

The sites in Uttar Pradesh have continually repeated past mistakes and therefore problems are recurrent. There has been little attempt at innovation. At sites in the Indian Himalayas the greatest problems are silt, floods and landslides. All of the projects visited in this study have been affected by one or more of these hazards. Innovation is especially required in the civil design of the weir, intakes, power channels, settling basins and spillways in Himalayan projects to avoid the need for costly repair work requiring skilled labourers and costly materials such as concrete to be transported from the urban areas (which may be further delayed by bureaucratic hold-ups).

An example of non-conventional, innovative design strategy for remote hill areas is the use of local labour and local materials, such as stone masonry, gravel, lime or even wood, wherever possible. In this way civil structures can be maintained by local labourers and damages could be repaired far more quickly and at a lesser cost than by conventional methods. This approach has been successful in Pakistan, Nepal, China and other developing countries, but has rarely been considered in India.

Because of the high silt content in the Himalayan streams it is essential to have an adequate desilting mechanism. Regular clearing of the silt from the settling basin and weir will be essential, either by using manual labour or a sluicing mechanism. This is a feature which cannot be economised on at the risk of allowing greater erosion of the power channel and the turbine. Wherever possible, the natural features of the stream should be used to allow "natural" pondage to be used. Non-permanent weir structures can be used where there is a natural diversion in the river which requires to be enhanced during dry periods when the water flow is low, as at Pandukeshwar where large boulders are used as a diversion. The advantage of temporary weir structures is that they are very low cost to build and repair, and in many cases will function as well as a permanent structure.

An option for reducing the incidence of land slides is to plant carefully selected vegetation on the slopes above the power plant and power channel. These bind the soil and therefore help avoid land slips. This method is currently used to protect sections of the hill roads.

Though the case study sites did not in general have problems with penstocks, difficulty has been experienced in transporting heavy steel penstock sections to some sites, as for example at Khokta. In such cases there may be an advantage in using lighter plastic piping. Though this is a less durable material it is also less costly.

In general, design innovation should re-assess the design criteria in terms of the local environment, infrastructural limitations and remote location.

Standardisation

When effective, innovative designs and equipment are established in generic form it will then be most cost effective to introduce design standardisation. Standardisation of civil work design and of generating equipment will only have effect if there is a commitment to widespread development of MHP. By standardising designs there could be bulk production of a basic range of equipment to be used at a wide range of sites leading to a reduction in overall engineering and manufacturing overhead costs. There will not be optimisation of efficiency, but each project could become more economically viable, due to lower capital cost. If standard equipment is used at sites in close proximity, operation, repair and maintenance requirements will be common, therefore simplifying procedures. Additionally, repair costs could be reduced by using a common spare parts inventory. Where it is not possible to standardise on turbines, it is still possible that generators, governors, control equipment and electrical switchgear could be standardised with significant effect.

The ESMAP report for canal drop projects produced a range of standard designs for the 52 small hydro power projects included in the report. The equipment standardisation resulted in the selection of eight turbine diameters for fixed blade tubular turbines and induction generators of eight capacities, from 350kW to 3500kW. There are also standardised designs for civil work. If these schemes are all taken up by various private sector companies as planned, and developers accept the designs in the reports, there will be scope for real cost savings to the individual developers. Such a commitment is yet to materialise due to scepticism from the private sector, as discussed in section 4.5.3.

A combination of standardisation and commitment to widespread MHP development could make MHP a viable option for extending RE in the hills, both grid connected and isolated. The present ad hoc development calls for site specific design. In Uttar Pradesh there is opportunity for the U.P.SEB and U.P.NEDA, along with research engineers and manufacturers, to take the initiative for developing a standardised range of designs to reduce the cost of their own projects and to encourage private MHP development. Two requirements for successful development of a standardised range of MHP equipment will be, firstly, hydrological data of potential priority sites on which to base the standardisation and, ultimately, incentives for Indian manufacturers to become actively involved in producing standardised equipment.

Technology Transfer

There has been considerable "North to South" transfer of technology, that is from industrialised countries to the Indian turbine manufacturers and developers. However, many developing countries also have valid experience of MHP development in rural areas which may be more appropriate to the Indian needs. There is opportunity for "South to South" transfer of technology and experience. This is particularly true for very small sites, which do not require high precision or high performance but must be economically viable, robust and reliable.

The requirements for MHP in a highly industrialised country are very different from those of a remote hill area in a developing country. Industrialised countries, which have the skills and infrastructure for installing and maintaining sophisticated designs, mainly install MHP to supply the grid. With such sites there is benefit in optimising efficiency in order to optimise the electrical power production and the revenue generated from the scheme. In remote parts of developing countries equipment of sophisticated design cannot be maintained. The uses of the MHP are directly related to supplying the needs of the local people and not to maximising the production of energy to sell to the grid. Therefore the design of equipment must be simple and cost effective. Learning from the experiences of installation and operation of MHP in developing countries, such as China, Nepal, Pakistan, Vietnam or Peru, could significantly benefit development in the Indian Himalayas.

In summary, for MHP to be effective, there must be commitment to widespread development using simple, innovative designs which suit the local Himalayan conditions and needs. Valuable experience may be gained from projects in other less developed countries.

6.2.2. Turbine manufacturing

India has a relatively advanced mini hydro turbine manufacturing industry. The case studies show that the technical faults at mini hydro projects are not primarily related to the turbines themselves. The main reason for failure of turbines has been silt erosion, due to poor silt and debris extraction. The main concern of the Indian turbine manufacturers must be to increase the economic viability of indigenous MHP.

As stated in chapter 4, some of the manufacturers are aware that there is a need for developers and manufacturers to work together to simplify overall MHP project design. However, MHP developers and contractors continue to specify high performance, state-of-the-art equipment which is both costly and complex to maintain. The manufacturers of mini hydro turbines must be encouraged to take the initiative towards reducing equipment cost, as discussed above, so that MHP is viewed as an economically viable option for rural electrification. Ideally this encouragement should come from the government mini hydro developers, such as the U.P.MHPCorp and the DNES, by initiating competition between manufacturers to produce a low cost standardised range of mini hydro turbines and governing equipment which is suited to the Himalayan needs.

Micro Hydro

It has been shown at the U.P.NEDA sites that significant savings can be made on the cost of micro hydro units by using a simplified turbine and electronic load controller. The current very high cost of the micro-hydro units will have to be reviewed, in particular when compared to projects which are being developed in both Nepal and Pakistan at a fraction of the cost. Decentralised manufacture and repair of equipment for micro hydro turbines, mainly crossflow or simple pelton designs, have been successful in hill regions of several developing countries. Foreign NGOs such as ITDG, SKAT and GTZ have considerable experience with this kind of scheme in various developing countries including Nepal, Peru and parts of Africa. There is scope for India to learn from such development, especially for the most remote sites.

Family Hydro

In China and Vietnam there is widespread application of family hydro power units of capacity between 200 watts and 1000 watts. These units are portable and can be installed by the rural people using simple civil structures and piping. The possibilities for using such units in the Indian Himalayas, for domestic use or for small rural industries, should be investigated. These could offer a viable alternative to the hundreds of small diesel generators which are currently used by families and small businesses in the Himalayan region. The units are relatively low cost, although they would only be an option for wealthier rural families.

6.2.3. Electrical equipment

Synchronous generators are highly versatile and can operate in isolation or connected to any strength of grid. Therefore they are suitable for application on the urban plains of India where the grid is well established, in rural areas where the grid is very weak and un-stable, or even in the most remote locations. There must be caution though when using synchronous generators connected to a particularly weak grid. If the grid frequency and voltage fluctuate widely, then the under-frequency and under-voltage protection will trip the MHP generator and close down plant operation, further weakening the grid. The safety settings for under-frequency and under-voltage must be set to allow for the every-day variations of the rural grid in order to maintain continuous operation of the MHP plant. Where large drops in frequency are to be allowed for it may be necessary to protect the excitation system from over current damage by including further protection such as an excitation voltage limiter which will operate at reduced frequency.

Induction generators are generally less costly and more robust than synchronous machines and operate well when connected to a fully developed grid. However, induction generators are not suitable for isolated use and should not be operated connected to an unstable rural grid, as the induction machine will draw reactive power from the already weak grid. For future reference research by ITDG and other organisations has shown that it may be economically advantageous to use induction generators for isolated micro hydro sites of up to about 30kW, with the appropriate start-up and control equipment [Brazil, 1990]. There has been interest in India in adopting this technology, but no development work has been done as yet.

The use of electronic load controllers has been shown to cut the overall cost of non-grid connected micro hydro power projects considerably. A major criterion of the ELC is that is must be developed for simple repair. The electronic components should be on single printed circuit boards, which can be easily replaced if there is a failure of the electronics. The Indian design has been prone to failure, which has resulted in down-times at some of the U.P.NEDA sites. It is important to continue to improve the ELC design as the ELC will be a key component towards developing economically viable micro hydro units. It will also be useful to develop uses for the ballast load, other than space heating, such as water heating, water distillation or other productive uses of the power.

When designing the electrical components of a MHP project it is important to minimise costs without reducing safety or reliability. ITDG have produced a set of guidelines for micro hydro projects for Nepal [Waltham, 1991]. In producing the guidelines decisions have been made as to the extent cost cutting measures can be made at the risk of reducing reliability. The recommendations clearly show that very small micro hydro units, under 20kW, do not require the same complexity of electrical design as larger projects of over 50kW. In general, with smaller projects more reductions in complexity are possible, for example, using reduced monitoring equipment, simplified protection systems and the use of lower voltage or single phase transmission and distribution. This can be extended to mini hydro, where greater care must be taken to ensure electrical protection and reliability, but not necessarily to the same level of sophistication as conventional small or large hydro power stations.

6.2.4. Construction and maintenance

The main reason for breakdown at the case study projects was damage to the civil works. The worst damage was at projects with long power channels and where there had been lack of attention to the removal of silt and debris.

Lack of maintenance and inadequate training of maintenance staff have contributed to the poor reliability of MHP projects. For example clearing of the de-silting mechanism is commonly neglected, resulting in severe erosion of turbines and their casings. Plant damage and breakdown have put the greatest burden on the running costs of the projects, both in terms of repair costs and lost revenue. Some of the U.P.NEDA projects have had no income due to repeated breakdown causing poor availability of supply. In the Indian Himalayas, the infrastructure for site construction and repair work is weak, so that there is great dependence on the urban sector for these facilities. There has been consistent repetition of the problems of silting, flooding and landslide damage, but there has been no demonstrable attempts to use innovative designs to avoid damage and an absence of preventative maintenance to avoid these problems.

Innovative civil construction and maintenance has not been an active area of research in India, despite civil work failure being one of the main problems of existing projects. Research into appropriate civil design will be fundamental in the development of sustainable MHP projects for the Indian Himalayan environment, and benefit would be gained by South-South exchange of experience and technology.

The training of plant operators is often insufficient to maintain the plant in good working order. At the U.P.NEDA projects the level of training of the operating staff was only for routine operation, without real understanding of the equipment. As a result the staff were unable to cope with breakdowns. Design and construction errors are also common, resulting in plant running problems. Examples of poor competence are shown at the sites, most notably Tapovan, where the units could not be synchronised with each other. At the Bilkot project the diversion weir was inadequately specified and built to divert sufficient flow in the dry season, so that the plant can only run at part load during this period.

As stated in section 6.2.1, simple and repairable temporary structures are often more effective than costly "permanent" structures which cannot withstand the local conditions. Use of local skills and materials for construction will ensure that the repairs can be carried out without dependence on staff and materials from outside the local area. This has the added advantage of creating local employment and training for the hill people, and the use of staff with greater interest in keeping the projects in operation.

6.3. MHP and the Himalayan setting

The Himalayan terrain itself puts constraints on infrastructural development in the region and the highly dispersed nature of human settlement makes the provision of full coverage of services extremely difficult. The poor infrastructural development of the Himalayan region puts constraints on the development of productive activity. Poor marketing infrastructure, difficulty in transportation and slow communication systems combine to restrict the commercial activity required for productive growth in the hills. Another infrastructural problem is a general lack of technical training. Technological development will require complementary education. For the hill economy to grow it will be essential to overcome these difficulties without adverse impact on the hill ecology.

Apathy and poverty are the two main barriers to human development in the rural hill areas. Poverty and lack of access to financing has limited the capabilities and opportunities of the Himalayan communities. In rural India there is continuing dependence on the Government to provide services and other development needs, which has created a reluctance to change or to become actively involved in the development process.

This section assesses the problems facing the development efforts in the Indian Himalayas, in particular how they affect MHP development. It is also noted how MHP can benefit the development process as an environmentally benign and decentralised energy source.

6.3.1. Economic barriers

Opportunity Cost of MHP Development

The development priorities of rural communities are first directed at the basic necessities, such as food supply, clean and accessible drinking water and housing. The village studies in chapter 3 indicate that the development of services such as schooling and medical facilities are the next priority, followed by improved road access. In these terms, power supply is viewed as a luxury commodity. However, it is a desired commodity and is viewed as beneficial to the quality of life.

Energy and Power Pricing

In order to obtain an electricity supply connection a rural household must have sufficient cash income. As a result, electricity is often only an option for the rural elite, accentuating inequalities within the community. There are three financial barriers preventing the rural poor from taking connection: firstly the initial connection charge; secondly the monthly tariff; and thirdly the cost of electrical appliances.

The cost of household wiring and connection is a common barrier preventing poorer households from using electricity. One method of reducing connection charges, used in Nepal, is to omit the use of a meter. A current restricting device is used to limit the current taken by the household and a tariff system has been devised with a set charge per month for the capacity made available to the household, instead of the energy used. In this way, the electricity bill is known in advance and can be set at a level affordable to the householder.

U.P.NEDA has used a similar method, based on the number of electric light points and socket outlets in the house. At some sites U.P.NEDA has also devised a two tier tariff, with a lower rate for SC/ST households. U.P.NEDA has in addition paid part of the connection charge for each household as part of the overall project costs. The advantages of this system are shown at the Khokta project, where every household in the connected villages has taken connection, half of whom are SC/ST households. A major advantage of this is the consolidation of load.

6.3.2. Power utilisation

Two problems commonly experienced in terms of power utilisation at the Uttar Pradesh sites are under-utilisation during the day and over-utilisation in the evenings. Overloading during the evenings occurs due to poor load management with over-extension of the distribution system to more domestic users than the generating plant can adequately supply. Reasons for under-utilisation during the day are directly related to the lack of wider use of electricity, other than for lighting purposes, so that there is very low daytime load.

In order to diversify the daytime load it is important to link power projects with other development initiatives. For example, reduction of fuelwood use could be achieved by the promotion of cooking with off-peak power and the adoption of low cost low wattage cookers, as discussed earlier. Also there are opportunities for controlled expansion of the tourist industry, as has happened in Nepal, where some of the tourist villages in the hills are supplied with electricity by micro hydro power plants. Conversion from diesel driven motors used for milling and small diesel generators to MHP could reduce dependence on costly import and transportation of fuel. Environmental concerns must be priority in all these cases.

Development in the Himalayan region requires careful control and planning because of the fragile ecology. However this does not entirely restrict diversification of economic activities. For example, the urgency for the farmer to sell fresh produce before it starts to rot means that the buyer can bargain for a low price. One NGO is working to promote fruit and vegetable processing by the hill people. The processing of fruit and vegetables increases the value of the product which will also be preserved for a longer period, allowing time for the farmers to bargain for a better price. The NGO hopes to develop micro hydro power projects to provide power for fruit processing using electric cookers, thereby reducing the pressure on fuelwood consumption [pc: HESCO(b)].

The rural people need to be made aware of opportunities for exploiting skills and local renewable resources in order to develop their productivity and establish new trades. As well as availability of financing, there is a great need for education and training in technical skills. This includes the knowledge of electricity and its applications in agriculture, small industry and other commercial activities. There needs to be joint effort between developers and rural communities to develop means of overcoming infrastructural problems of transportation and poor marketing facilities which currently deter much of the commercial activity in the hills.

6.3.3. Hydrological data

There is a general lack of information and collected data in the Himalayan region of India. Data collection is frequently inconsistent and diffuse. Similarly, hydrological data for the region is scarce, in particular in relation to small watersheds. A comprehensive survey of the potential for MHP has not been made, instead MHP development plans have been made on assumptions and extrapolation of the data available. Poor hydrological surveying has resulted in design errors, as described in some of the case studies in chapter 5. Under-estimating flood levels has resulted in the flooding of some power houses. At other sites the over estimation of low flow rates has resulted in lower than expected power output during lean flow periods. If MHP development in the Indian Himalayas is to expand reliably then there will need to be more widespread, consistent and detailed hydrological surveying carried out in the region.

6.4. MHP policy

MHP development in India is restricted by the same failings as the power sector as a whole, and in particular the SEBs, that is: lack of funds; over staffing and insufficient training; poorly co-ordinated planning; inadequate operation and maintenance facilities; cost and time over runs; and bureaucracy. This section re-appraises the MHP institutional and policy requirements.

6.4.1. MHP development strategy

The Indian Eighth Plan document admits that there is an

> "*attitude of passive observance and total dependence on the government for development activities.*" [GoI, 1992, vol.1]

This encapsulates the view of the Indian poor towards the Government development programmes and the public sector. However, the Indian government has identified this dependence as a fault of the highly centralised nature of the development initiatives. The objectives of the Eighth Plan include the development of local organisations and voluntary agencies to play an active role in the development process.

The U.P.SEB MHP case study projects are implemented and run entirely by electricity board staff and administered from a centralised office. U.P.NEDA are taking steps towards involving the rural people in the projects, and have made efforts to include local people, usually the village leaders, at every stage of development. However, the results of this co-operation have been limited, as the projects are still viewed as the government's responsibility. This is exemplified by the dispute at the Bilkot site between the locals and U.P.NEDA which eventually resulted in the closure of the project.

This leads to the dilemma of whether MHP development should remain with the public sector or be undertaken by NGOs and community groups. A third possible alternative could be a joint development effort between the government agencies and NGOs. Each of these options have inherent constraints or limitations. When assessing this, it is important to consider micro hydro separately from mini hydro, as the scale of the development will determine the capabilities of the community to participate. Also, it is essential to consider here how MHP can best be integrated into wider rural development and environmental objectives.

Government Sector

The government sector has the technical expertise and the financial backing required to undertake MHP development. However, as the U.P.SEB case studies show, the state electricity boards are restricted by standards and regulations on technical design, staffing and administration which are based on conventional power projects and are over specified and too restrictive for mini and micro projects. The U.P.MHPCorp has inherited the highly centralised and hierarchical organisational structure of the U.P.SEB and also many of the restrictions which regulate project development.

The other drawback of public sector development is the sectoral nature of public departments, and the lack of co-ordination of development activities. This has been a particular drawback of most U.P.NEDA projects which have failed to develop any daytime loading. There has been lack of focus for MHP development in the public sector, with little consideration of the function of MHP within the context of wider RE objectives in the hills. This is evident when considering that many of the sites in Uttar Pradesh which are isolated from the grid now have grid supply in the same locality as the projects, though none of the projects can be synchronised to the grid.

Non-Governmental Organisations

NGOs have greater involvement with grassroots level development, and have greater scope for flexibility and innovation. Therefore they are well suited to integrate MHP with other development activities. However, the NGOs lack some of the necessary technical capabilities and have a weak financial base.

The author's view is that micro hydro projects are best developed by NGOs along with community groups. This way MHP can be integrated into rural development without the constraints of project departmentalisation or apathy of the users as found in government projects. The Indian NGOs would require to learn from the experience of successful foreign NGO schemes and be aware of indigenous technologies which have the potential to work well in the rural context. In addition, appropriate financing from the Indian government to the NGO run projects would greatly increase the feasibility of NGO involvement.

There have been initial indications of NGO initiative, with HESCO in Uttar Pradesh and the Ladakh Ecological Development Group both interested in emulating the micro hydro developments in Nepal. An engineer from HESCO attended an ITDG micro hydro training course in Nepal during 1992 and the Ladakh NGO has been using SKAT crossflow designs for very small micro hydro projects in the region. Both of these initiatives have been motivated by the energy requirements of other rural development projects of the NGOs. The author's experience of the HESCO initiative, at meetings held with women's organisations during a visit to remote villages in the Uttar Pradesh hills, was that the local people were keen to be involved with the micro hydro projects if they were to be used to help improve the productive activities in the villages.

Government/NGO Co-operation

The state governments should include mini hydro development in their larger rural electrification plans. The government sector must, however, start to view RE as a useful tool for rural development. A framework to ensure co-operation with NGOs and other government development agencies is essential, linking RE targets with those of rural industrial, agricultural, social and environmental development.

Co-operation between NGOs and the public sector could have significant impact. NGOs could be involved in education, load development and fuelwood replacement projects, and the government could support NGO and community based micro hydro with technical guidance and financing. However, the author's experience indicates that there is considerable mis-trust between the public and the NGO sectors. Each doubts the others motives and commitment. It is important to build confidence between the relevant organisations and to establish formal means of interaction and co-operation. This will require the government agencies to acknowledge the role of the NGOs and to effectively delegate aspects of project development to selected NGOs.

When working in co-operation it is essential that there is clarification of responsibilities of the various parties involved. This is necessary in order to avoid situations such as occurred at the Sugandhagiri site in Kerala, where a transmission pole fell but the developers, the construction contractors and the local community all denied responsibility for the repair work, leaving the scheme out of service. It may be required that clearly defined conditions of contract, or at least a written agreement for co-operation, be established so as to avoid confrontations of this kind.

6.4.2. Financing MHP in the Indian Himalayas

The IREDA and DNES financing for MHP has been well targeted at remote hill projects and those projects promoting research and innovation. However, for MHP development to be sustainable financial support must be available for more than the initial project capital cost. The GEF funding now presents an opportunity to develop the rural infrastructure for operating and maintaining MHP, as well as centres for training, research and development. Care must be taken to direct the funds towards grassroots development and not only at institutional development. Rural infrastructural development for MHP could be a key element in the success of future project. Appropriate financing should be offered to private, community and NGO MHP projects as well as public sector agencies, to optimise the development opportunities. This may require subsidies as well as loans to the non-government sector, depending on the type and purpose of the project. Priority should be given to those projects which promote productive activities and environmental conservation.

Making available similar tax and duty concessions to MHP equipment manufacturers, on the same basis as those currently available to manufacturers of other NRSE equipment, would reduce overall project costs and encourage manufacturers to develop the MHP equipment market.

Load development will require financing, but is often ignored as the responsibility of a different sector of development. There may be advantages to be gained in linking the financing of MHP to financing of power utilisation projects, including cooking with electric power, agro-processing and rural industries. This will require appropriate provision of local financing facilities to enable rural people to acquire electrical appliances or equipment.

In other developing countries, such as China, Nepal and Pakistan, community run micro hydro projects often require financial contributions from the user community. In this way the community gain part or total ownership and control of the project. In China, for example, the community usually pay most of the costs, with government subsidies of about one third of the overall costs. Alternatively, poorer households will contribute labour to the construction and upkeep of the projects which will earn them a share in the project. Care must be taken not to bias financing solely towards the rural wealthy and therefore perpetuate the rural inequalities common among other development projects.

The objectives of financing will require careful consideration for future project development, with the users requirements for power considered along with MHP installation. The eventual aim must be to create a sustainable MHP plant, which will be self-financing once it is set up and running.

6.4.3. Monitoring and Feedback

There is little indication of constructive feedback from previous projects or of effective monitoring of the success or failure of new projects in the Uttar Pradesh hills, or in any of the Himalayan states. Repeated failures and mis-management have been characteristic of MHP development. Monitoring of projects must be systematic and the results must be incorporated into new project developments. Monitoring should assess:

- equipment success/failure
- management success/failure
- financial performance
- end-uses of electricity
- equity of access to power by various sectors of the user community.

The project performance must be compared with the initial project objectives as stated in th DPR and to the outcome of other similar projects.

One result of absence of project monitoring is that DPRs continually fail to address the problems and failures of previous projects, none of which has come close to achieving the results predicted in their own DPRs. Priority must be given to projects which attempt to avoid the failures of past projects, in particular the technical faults, capital cost over-runs and failure of load development. DPRs should clearly state how such problems will be addressed and overcome and monitoring should assess the progress of this aim.

6.5. Development ideology

India is a country with technical capability, but has problems with implementation: poor training and infrastructure; excessive bureaucratic restrictions; and lack of will for decentralisation.

A city or town based, narrow and sectoral perspective will not attack the real problems or consider fully the rural constraints and limitations. Developers often want "high technology" solutions when the real need is for appropriate or intermediate technology. From the experience of the author, the Indian developers often look towards the industrialised countries for "state-of-the-art", prestige projects when often their best example for rural development is in another less developed country or indigenous development.

MHP could have an impact on the Indian Himalayan development, but its implementation will have to be re-appraised. The way to real development is not just through the arbitrary supply of electrical power. It is asserted in this study that MHP is not a solution in itself, but merely a tool to be used in solving rural development problems. Power supply will not by itself replace fuelwood in a poor remote area, but power supply along with a fuelwood substitution programme for encouraging and subsidising the use of electric stoves would have significant results. Involvement of the rural consumers is vital to sustain the development.

An analogy may be made between the dissemination of micro hydro power and the dissemination of electric tubewells. Tubewells have been installed across the plains of India in great numbers to meet the irrigation requirements and increase the use of modern farming methods, therefore enabling India to increase its food supply to meet almost all its needs. Tubewells are highly subsidised and are given high profile promotion. The rural infrastructure was created to meet the operation and maintenance requirements. Some of the wells failed, but many more have been effective and have had a great impact on the agriculture on the plains. The wells have been successful because they were built for the specific end purpose of promoting agricultural productivity, and not simply because it was thought a good idea to pump water. With this impetus the development has been sustained†.

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† Though the tubewell development has been effective, there is controversy as to whether ground water supplies are sustainable at the present rate of extraction in

If similar progress is to be made in the area of renewable energies, and in particular mini and micro hydro, to replace much of the fuelwood consumption or to promote rural industry - in the same way tubewells supported the green revolution - then a real move towards sustainable development can be made. For MHP to be widely adopted it will have to be proven viable. Progress is required in

- the design and manufacturing of equipment for bulk production,

- the means for disseminating the equipment,

- training local people in the installation, implementation and use of the technology,

- the provision of financial support, and

- the infrastructure for maintenance and repair in the rural area.

However, there has been criticism that the benefits of the private and state controlled electric tubewells have been pre-dominantly for wealthier farmers. It might be argued that this *completes* the analogy. The problems of centralised control and dominance of the rural wealthy, which are common in many development programmes, must be learned from.

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some areas. Shiva describes the present lift irrigation patterns as "mining of underground water resources" [Shiva, 1991].

CHAPTER 7
CONCLUSIONS AND RECOMMENDATIONS

The main aims of this study were to investigate the need for and the viability of mini and micro hydro power in the North of India. It is concluded that there is a perceived need for an alternative to existing power sources in the Himalayan region of India, both to reinforce the rural grid supply and, more significantly, to serve remote, isolated communities. The requirement for decentralised power production varies between states and between districts within states. The more developed regions, such as in Himachal Pradesh, generally already have an adequate coverage of power supply. However, there are many regions of the North Eastern states, the Uttar Pradesh hills and Jammu and Kashmir (especially Ladakh) which are poorly served by unreliable supplies of electrical power and other forms of energy.

Another significant conclusion of this study is that, under the present means of implementation, MHP is not a viable power source in the Indian Himalayas. The case studies and supporting examples of MHP in North India clearly indicate that MHP has achieved very limited success, and in many incidents has completely failed. Within the rural Himalayan context in India, the present MHP development projects have not been sustainable or economically viable. However, it is argued here that the reasons for the failure are rooted in the development approach and not because MHP technology is in itself in-appropriate for development in the Himalayas.

This chapter summarises the conclusions of the study and the recommendations for achieving successful and viable MHP development in the Indian Himalayas.

7.1. Project development - problems and solutions

The overriding requirement to achieve success is to perceive MHP development as more than just the installation of individual projects. It is essential to plan and design MHP projects in the Indian Himalayas within the overall scheme of rural development and as an integral part of wider rural energy planning. Projects have to be designed for the environmental and infrastructural setting in which they are to operate and must consider the requirements and capabilities of the local communities.

The scale of the project and its purpose are also important factors. The requirements for micro hydro projects will differ greatly from mini hydro projects. Grid connected schemes will differ from those operated in isolation. It is important to define the role and objectives of each type of MHP project in order that they may be utilised for optimum benefit.

Figure 7.1 gives a summary of the problems examined at the various MHP projects in the study, and also a list of suggested solutions which have emerged from the analysis and discussion. Assuming that there will be continued commitment to the development of MHP in the North of India, as can be surmised from the establishment of organisations such as the U.P.MHPCorp and the availability of funding from the GEF, proposals are made in the table for a new development approach. The table is divided into three categories: technical design and implementation; bureaucratic constraints; and development issues. Each category cannot, however, be viewed in isolation as there are several overlapping and inter-linking factors. Key themes which recur through the conclusions are:

- innovation
- standardisation
- decentralisation
- NGO and community involvement
- rural infrastructural development
- co-operation and co-ordination of rural development efforts.

These are considerations which can affect every stage of project development and implementation.

The principle behind this new development approach is to focus on wider objectives, rather than simply the extension of rural electrification to an increasing numbers of villages. The objectives must become the establishment of MHP projects which are sustainable in the very extraordinary Himalayan conditions and which will supply power with the purpose of achieving environmental and developmental goals, such as fuelwood replacement or increasing productive

Figure 7.1 Problems and suggested solutions for MHP in the Indian Himalayas

Problems	*Solutions*
Technical Design and Implementation	
High capital cost	*Apply correct level of technology*
	Standardise equipment
	Manufacturing incentives to encourage production of mini and micro turbines at competitive prices
	Use local materials and labour where possible
Poor design/construction competence	*Improve hydrological surveying*
	Use innovative design to overcome recurring natural hazards, using R&D where necessary
Poor technical reliability	*Learn from feedback from previous projects*
	Reduce complexity of design
Poor infrastructure for maintenance and repair	*Increase level of project staff training*
	Utilise local labour and materials for O&M and repairs where possible (ie decentralise)
	Decentralise the manufacture of micro turbines
Bureaucratic constraints	
Poor co-ordination between RE, MHP and other NRSE development	*Increase communications between agencies and integrate development plans*
Excessive bureaucracy for interaction between agencies	*Simplify or establish new procedures for co-operation*
Excessive administrative bureaucracy	*Decentralise control and decision making process for implementing and running projects as far as possible, with micro hydro developed and run by NGO/community groups*
	Establish effective system of delegating duties and clarifying responsibilities
Design requirements for small scale projects based on conventional large scale project standards	*Develop simplified design standards for small scale projects*
High running cost	*Minimise staffing level*
	Use local staff and labour
	Increase user participation
Development Issues	
Low load factor, therefore low revenue	*Develop daytime load*
Poor Co-ordination between RE and Rural Development	*Educate users on the practicalities and benefits of electricity - possibly done by NGO*
	Link RE targets with development targets (eg. small industry, clinics, etc.)
	Couple finance of MHP with financing of productive uses of power or with environmental protection aims (eg cooking by electricity) or equity targets (eg subsidised tariff for poorest)

activities in the villages. Improved organisational structures will be important to integrate each project into a wider programme of development.

7.1.1. Technical design and implementation

The roots of the technical problems affecting MHP projects in the Indian Himalayan region may be divided into four categories: high costs; poor technical competence; natural hazards; and the remote location. These are not all technical issues in themselves, but are the main obstacles presently frustrating project design and limiting more widespread development of MHP sites.

The first problem which must be overcome is the achievement of economic viability, and hence to develop cost effective projects. This can be achieved by moving from conventional, individually designed equipment to plant of simplified and standardised design. Co-operation of the manufacturers will be required to achieve this, with the government providing incentives for the manufacturers to produce competitively priced, standard range equipment. In the case of micro hydro power, the most practical progression may be the decentralisation of manufacture and repair of simplified turbines. Example should be taken from similar development in other developing countries such as Nepal, Pakistan, China and Peru where micro hydro turbines are produced and repaired in small workshops close to the areas in which the turbines are to be installed.

In addition, civil works costs may be reduced by utilising local labour, skills and materials. In this way civil works can be maintained by the rural people themselves, resulting in increased project autonomy. Also repair of damage due to landslides, flooding or silting may be more effectively and efficiently accomplished.

Choice of site location will be important for avoiding damage due to natural hazards. It may be more cost effective in the long term to build a project at a location further from the point of utilisation if it is in an area where the land is more stable, with better vegetative cover to fix the soil and which is less prone to flooding. Factors of land stability must be considered along with hydraulic investigations and when making the final site selection.

It is essential to begin with competent designs which have been evolved to suit the local Himalayan environment. This must be complemented by adequate operator training and the establishment of a rural infrastructure for maintenance and repair.

The current approach by contractors in India is to develop MHP with conventional designs which have so far consistently failed in the Himalayan setting and depend on urban based contractors for the necessary repair work. There is an emerging need to re-appraise the role of the contractor in the development. Initiatives will be required to encourage a decentralised approach and for contractors to co-operate with local organisations and NGOs, to work towards meeting the rural communities' needs and not purely for commercial gain. Priority approval and funding must be given to projects adopting this approach.

7.1.2. Bureaucratic constraints

Development projects are constrained by the excessive and inflexible Indian bureaucracy and hierarchical administrative systems. The excessive bureaucracy is illustrated by the example of Chamoli District where the responsibility for the MHP projects of the U.P.SEB is dispersed between the offices for electro-mechanical equipment, civil works, transmission and distribution and administration, which are located in different towns across the district. This has resulted in fragmented record keeping and poorly co-ordinated implementation and running of the projects, including delays in carrying out repair work. Similar disorganisation can be found at central and state government level also. The creation of the U.P.MHPCorp is a first step towards combating this at the state level in Uttar Pradesh, by designating one office in charge of mini hydro development.

Inflexibility has resulted in over-specification of MHP project designs, administration and staffing requirements. This in turn has increased overall project costs and reduced economic viability.

There is urgent need to streamline and rationalise the bureaucratic process. This will require effective delegation of responsibilities for project development and implementation. The first initiatives must be:

- at central, state and district government level, to have one co-ordinating department for MHP which holds project records and delegates responsibilities. In this way, at each government level all administration and decision making will be managed at one focal point only.

- the allowance of greater flexibility in design for mini hydro power projects, within safety standards. This will both enable a move away from costly conventional designs and recognise the need for a non-conventional approach in remote areas.

- the assessment of project staff and administration requirements at MHP sites, rationalising where necessary to employ the minimum number of staff necessary to operate the site successfully. This must account for the much reduced scale of MHP projects in comparison to large or small hydro sites.

- delegation of micro hydro development to the NGO sector.

Another restriction of the Indian bureaucratic system is the sectoral nature of departments and the bureaucratic barriers for interaction and co-operation. There will need to be effective co-ordination of development sectors if MHP projects, and similarly other NRSE projects, are to be viewed as a tool for development and environmental purposes, and not just as part of RE programmes. Ways of achieving this are discussed in the next section.

7.1.3. Developmental issues

Means of linking MHP and other NRSE projects with wider development targets may be established through: education; policy changes; and joint financing.

Educating the users about the benefits and applications of power will be the first stage in achieving lasting development. This must be supported by appropriate policy decisions, linking the targets of MHP development with those of economic, social and environmental needs of the Himalayan communities. One way of ensuring that these targets are central to MHP development would be to link the financing of MHP with financing of productive uses of power or with environmental programmes, such as cooking with electricity. In this way, the economic assessment of the project will not only be the profit or loss of the power plant but also the achievements of the overall development of the user communities. Financial policies must be carefully planned to benefit the poorer members of the community and not to create greater economic divisions.

7.2. Organisational requirements

In pragmatic terms, in order to achieve the above objectives it will be essential to establish an appropriate organisational approach.

If MHP projects, or RE projects of any kind, are installed in remote areas in India purely as a social service, then it can be assumed that they will run at a loss or depend on continual subsidies. End-use of power for economic activities will have the dual outcome of benefiting rural income and increasing the power plant load factor. In addition, where the power produced by MHP is utilised for environmental objectives, such as reducing consumption of fuelwood or diesel, then it will provide more than just social benefit. If the provision of power and the adoption of MHP are to be incorporated into the wider perspective of Himalayan development, then a means for co-operation and co-ordination between development efforts must be established. Organisational structures must be created or modified to achieve this.

The present organisational structure has failed to achieve lasting results in the implementation of MHP in the Indian Himalayas. Government organisations are very departmentalised, with departments very restricted in their scope and with limited means of interaction. The Government approach up to the Eighth Five Year Plan has always been "top down", that is development programmes have been formulated and implemented from centralised authorities, with the rural people dependent on the government initiative, organisation and financing. In India's Eighth Plan there is a realisation of the importance of involving the rural communities, local organisations and NGOs in formulating future development strategies.

None-the-less, the government will retain the principal role of promoting MHP development. MHP development in the hills will never produce great commercial gain for a private developer, therefore private interest will be very limited. NGO development of micro hydro power projects will be directly related to attaining other development objectives of the NGO, and will require technical and financial support if their projects are to succeed. Therefore the policy decisions and financing from the government sector will shape the way in which development proceeds. The DNES and the state agencies have a pivotal role in MHP development in the Himalayan region of India. It is essential that a clear initiative comes from both the central and state government levels.

The role of the DNES and the state agencies will be vital as the co-ordinator of MHP development activities. The power authorities and NRSE agencies must be willing to delegate aspects of development and promotion of projects to other organisations, both governmental and non-governmental. This will not remove their role in MHP development but alter their emphasis to the initiation of what will be a wider development programme than simply the installation of power plants. The government's role should become that of the incentive giver to researchers, manufacturers, NGOs, development agencies and rural communities to develop and diversify development activities in the Indian Himalayas using MHP and other NRSEs as the energy source.

The Role of the DNES

The DNES must initiate a new perception and approach to MHP by making a positive policy statement directly linking the MHP development aims with productive and environmental objectives. This statement must insist that MHP development programmes and individual MHP project proposals include:

- realistic proposals for developmental and environmental goals which will accompany MHP installation;

- plans for how these goals are to be achieved, including identifying government departments or NGOs who will collaborate in the development; and

- a statement of how funding is to be provided through joint financing from, for example, government SSI or environment departments.

The financing policy of IREDA must reflect this directive by giving preference to projects which have wider developmental goals and clearly state how these are to be achieved. This must be accompanied by a strict monitoring procedure requiring developers to be made more accountable for project failures. As part of its co-ordinating role the DNES should provide a central base for information on indigenous and foreign MHP development.

The Revised Role of the State Agencies

State agencies developing mini hydro projects must ensure that projects are implemented with full co-operation with the REC and SEB rural grid extension programme and that the productive purpose of grid connected projects is fully acknowledged.

Operation, maintenance and staff training have proven to be very poor at many mini hydro projects in the Indian Himalayas. Neglected or poor maintenance is one of the main reasons for project failure. This is a key area which must be tackled at state level. In addition, a review of failures due to natural hazards such as landslides and floods must be made, with the objective of developing means to overcome these problems. DPRs should explicitly state how such breakdowns are to be avoided in new projects.

The state agencies should initiate collaborations with other government development organisations and NGOs for co-operation in load development for productive and environmental purposes. This should happen as an integral part of project development and not as an after thought.

Whereas agencies such as U.P.NEDA have failed to develop micro hydro projects with explicit developmental objectives, it is highly feasible for NGOs and rural communities to develop micro hydro in remote areas to assist their wider development objectives. The state agencies must encourage micro hydro development in the NGO and private sector by providing technical training and assistance, and co-ordinating research into sustainable micro hydro development and appropriate technology, taking example from successes in other developing countries and from foreign NGOs.

The Global Environment Facility Programme

The funding provided by the GEF offers an ideal opportunity for making a positive step towards the use of MHP installation programmes for environmental and developmental purposes in the Himalayan states. However, there is a real danger that most of the funds could be allocated to the development of institutional and bureaucratic structures, and that very little of the funding will go to actual rural development.

The GEF programme proposals so far do not consider how NGOs and local organisations are to be involved in the programmes or how the schemes are directly to affect the local communities. The immediate objectives of the programme give little regard for the development of rural infrastructure for constructing and implementing MHP, but only of institutional facilities for training skilled staff and for technical research. Therefore, the terms of reference of the GEF need to be expanded to include:

- the initiation of co-operation between government agencies and NGOs to optimise the development efforts accompanying MHP installation;

- provisions for developing the capabilities of NGOs as well as government departments, including the training of NGO staff in the design and implementation of micro hydro projects; and

- the establishment of rural infrastructure and training for construction, maintenance and administration of MHP projects.

In creating pilot projects there must be caution against concentrating on installing the technology with no regard for how it is to be effectively maintained or administered, or how the electrical power is to be utilised. This approach has failed at nearly all government developed pilot schemes, such as the U.P.NEDA projects. At the pilot projects consideration must be given as to how appliances such as electric cooking pots are to be successfully disseminated to the target population. Further there must be a re-appraisal of energy pricing policy to make the development accessible to all sections of rural society.

7.3. Future research

Research on MHP development in India has so far focussed on mechanical and electrical equipment, such as indigenous crossflow turbine design and electronic load controllers. Although the indigenous production of equipment is important for progress in India, it must not be the exclusive focus for research.

Civil Works Design

Civil design is important, as civil works failure is the most common technical failing of MHP projects in the Indian Himalayas. Innovative designs, materials and maintenance procedures will be required if future projects are to overcome the repeated weakness of previous projects. Research is needed into means of cost reduction and improvement of reliability of civil works.

This thesis has identified the causes of civil works failure as primarily due to damage by landslides, floods and silting. It will be essential to consider those aspects of civil construction which have contributed to continued project failure and require costly repair work, so that the designs can be modified to avoid repetition. The advantages and opportunities for using local materials and labour should be compared to conventional methods. This will require research into the materials available in the Himalayan region and their suitability and economic viability for replacing conventional materials. This should also consider the option of using temporary weir and intake structures which can easily be repaired or re-constructed by local labourers. Also, there should be an investigation of how projects can be sited to avoid damage, or how landslides and floods can be best avoided in the project area, either through added protection or by plantation of soil fixing vegetation on the banks above and below the sites. It would be useful to assess designs and methods used in other developing countries where such techniques have been implemented for several years.

Load Development

Load development and diversification for the use of daytime (off peak) power is important for the success of MHP projects. For example, the production of low cost, low wattage cookers and other domestic devices for daytime use will increase load factors and also reduce dependence on fuelwood. Innovative devices for agro-processing or small industries should be a development priority. Research into low cost devices for productive power use, in conjunction with the environmentally benign power source from MHP, may lead to small scale industrial development in the hill without adverse effects on the fragile ecosystem. For optimal benefit to the Himalayan communities, the opportunities for manufacturing and repairing the cookers and other electrical devices in the rural areas should be investigated. The funding for such development studies must come from a joint initiative between MHP agencies and rural industry departments.

It may be possible to develop skills already available in the hills by using electrical power to replace the traditional fuel or to introduce automation. For example weaving and knitting, which could be mechanised, are common in some districts.

Also, some skills used for household purposes could be utilised for larger scale production and marketing, such as chutney making which could use electric cookers instead of wood stoves. Alternatively, new skills may have to be taught in order to develop new productive activities. One commercial activity which will increase in many parts of the Himalayan region is tourism. Using a more environmentally sound energy source will be key to sustainable tourist development.

Comparative Cost Analysis

Finally, there is a need for comparative cost analysis of NRSEs against conventional energy sources. It is important that real costs are used, and not projected costs using unrealistic assumptions. The actual cost of supply to the rural user must be considered, including all lifetime costs, from project initiation to decommissioning. This analysis should avoid any bias, for or against NRSE technologies, and should conclude under which circumstances NRSE technologies are most economically viable. In addition to economic considerations, the final decision as to where NRSE technology is appropriate must account for environmental impact and sustainability in the rural setting.

To date, no standard or unbiased method of cost comparison has been established and data collection of actual project costs has been hindered by poor record keeping. An independent organisation should be nominated or established to carry out such cost analysis, with full access to project records.

In ultimate conclusion, it has become clear that research and development of MHP and other NRSE technologies for rural India must examine project sustainability. Technological development alone will be insufficient if it is not accompanied by the development of appropriate infrastructure, policies and financing. Most importantly, development of renewable energies must have a clearly defined, productive purpose and promote real rural development.

The conclusions and recommendations presented in this thesis will be sent, by request, to the DNES, DST, U.P.NEDA, AHEC, SHERPA, HESCO and the Indian Institute of Science.

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Personal Communications

Note: Listed here are all personal communications referred to in the text, including interviews and letters.

pc:Anand
Meeting with Mr I.S.Anand, Chief Engineer, Rural Electrification Corporation, New Delhi, September 1992

pc:Anderson
Discussion with Dr T.Anderson, Department of Electrical Engineering, University of Edinburgh, November, 1993.

pc:ASTRA
Visit to the Application of Science and Technology to Rural Areas unit of the Indian Institute for Science, Bangalore, February, 1991.

pc:Bist
Meeting with Mr B.S.Bist, Superintendent Engineer, U.P.SEB, Srinagar, Chamoli District, May, 1992.

pc:Bhutani
Meeting with Mr D.R.Bhutani, Plant Director of Boving Fouress turbine manufacturing company, Bangalore, December, 1991.

pc:Das(a)
Discussion with Prof. D.Das, Water Resources Development Training Centre, University of Roorkee, April, 1992.

pc:Das(b)
Discussion with Prof. D.Das, Water Resources Development Training Centre, University of Roorkee, August, 1992.

Das(c)
Letter from Prof.D.Das, Water Resources Development Training Centre, University of Roorkee, November, 1993.

pc:Dawa
Discussion with Mr Sonam Dawa, Ladakh Ecological Development Group, at the Small Hydro Power 1992 Conference in New Delhi, November 1992.

pc:DNES
Meeting with Mr Varshney and Mr Chopra of the Department od Non-conventional Energy Sources, New Delhi, February, 1992.

pc:Goel(a)
Meeting with Mr A.K.Goel, Superintendent Engineer and Head of Micro Hydro, U.P.NEDA, Lucknow, January 1992.

pc:Goel(b)
Meeting with Mr A.K.Goel, Lucknow, August 1992.

pc:HESCO
Meeting with the Himalayan Environmental Studies and Conservation Organisation, and visit to one biogenerator project, Kotdwar, August 1992.

pc:HESCO(b)
Visit to HESCO project site and meeting with women's organisations in the Pakhi Block, Chamoli District, Uttar Pradesh, October 1992.

pc:Krishna
Meeting with Mr Vinay Krishna, Managing Director, and other staff of U.P. Mini Hydro Power Corporation, Lucknow, January 1992

pc:OPGC
Site visits to three hydro sites with the Orissa Power Generating Corporation, July 1992.

pc:Pandey
Meeting with Mr G.S.Pandey, Engineer, U.P. Mini Hydro Power Corporation, Lucknow, January, 1992.

pc:Rhudra
Letter from Mr A.K.Rudra, Executive Engineer, U.P.SEB, Almora District, June, 1992.

pc:Singh
Meeting with Mr. Ashok Kumar Singh, Executive Engineer (Electrical), Lucknow, January 1992.

pc:Singh(b)
Meeting with Commodore Narendra Singh, the Adviser of the Department of Non-conventional Energy Sources, New Delhi, December, 1991.

pc:Soundranayagam
Site visits in Karnataka and Kerala with Professor S. Soundranayagam of the Department of Mechanical Engineering, Indian Institute of Science, Bangalore, September, 1992.

pc:Tiagi
Meeting with Mr A.K.Tiagi, Executive Engineer, U.P.NEDA, Dehradun, April 1992.

pc:Verma
Meeting with Mr Brij Kumar Verma, Sub-division Officer (Civil), U.P.SEB, Uttarkashi District, October 1992.

pc:Wallace
Letter from Dr A.R.Wallace regarding the visit of Mr D.Williams of Gilkes Turbine Manufacturers, U.K., to small hydro site in the North East of India during 1992.

Appendix A People and Organisations Visited

Commodore N. Singh	Advisor, Department of Non-conventional Energy Sources
Arun Kumar	Dy. Secretary, Department of Non-conventional Energy Sources
A.K. Varshney	Scientific Officer (Micro Hydro), Department of Non-conventional Energy Sources
A.K. Chopra	Scientific Officer (Biogas), Department of Non-conventional Energy Sources
D.R. Butani	Plant Director, Boving Fouress Ltd.
Prof. S. Soundranayagam	Mech. Eng., Indian Institute of Science, Bangalore
A.K. Goel	Head Eng. (Micro Hydro), Uttar Pradesh Non-conventional Energy Development agency
A.K. Tiagi	Project Officer, Uttar Pradesh Non-conventional Energy Development Agency
J.K. Varshney	Project Officer, Uttar Pradesh Non-conventional Energy Development agency
Vinay Krishna	Managing Director, Uttar Pradesh Mini-hydro Power Corp.
Arun Kumar	Alternate Hydro Energy Centre
K.R.S. Krishnan	Senior Scientific Officer, Department of Science and Technology
A.N.N. Murthy	Director, Department of Science and Technology
K. Raghavan	Research Associate, Tata Energy Research Institute
Arinjai Kumar	Chief Eng. (Hydro O&M), Uttar Pradesh State Electricity Board
B.S. Bist	Superintendent Eng., Uttar Pradesh State Electricity Board
M.S. Dharamshaktu	Executive Engineer, Uttar Pradesh State Electricity Board
T.P. Rajasekhar	Managing Director (Power Eng.), Steel Industrials Kerala Ltd.
Dr. C Shastri	Secretary, Society for Himalayan Environmental Rehabilitation and People's Action, and Uttar Pradesh Development Systems Corporation
I.S. Anand	Chief Eng. (Monitoring), Rural Electrification Corporation
C.M.Dinanath	Deputy Chief Eng. (Monitoring), Rural Electrification Corporation

Robert Ruxton	Regional Representative, Oxfam India
Narendra Rautela	Hill Representative, Oxfam India
I.C. Das	Managing Director, Orissa Power Generating Corporation
P.K. Lenka	General Manager, Orissa Power Generation Corporation
Dr Anil P. Joshi	Director, Himalayan Environmental Studies and Conservation Organisation
Kamal Joshi	Press Trust of India
P.D. Nair	General Manager, Jyoti Ltd.
L.C. Amin	Sales Manager, Jyoti Ltd.
Dr I. Natarajan	Director, National Council for Applied Economic Research
Prof. U. Srinivas	Organiser, ASTRA (Application of Science and Technology to Rural Areas), Indian Institute of Science
Niomala Das	Librarian, ASTRA, Indian Institute of Science
	Kerala Agency for Non-conventional Energy and Rural Technology

Appendix B Mini and Micro Hydro Power projects Visited

(Listed by development agency, stating name, installed capacity, and working order when visited)

Uttar Pradesh State Electricity Board

Chamoli	4x200kW	Closed due to power channel damage
Pandukeshwar	3x250kW	Two machines working
Badrinath	1x30kW	Power supply back up
Tapovan	2x400kW	Working, machines will not synchronise
Tharali	1x400kW	Closed due to power channel damage

Uttar Pradesh Non-conventional Energy Development Agency

Sahastradara	1x10kW	Working
Kempti Falls	1x10kW	Working, 6kW output maximum
Khokta	2x50kW	Under Construction
Dior	1x50kW	Electronic Load Controller failure
Bilkot	1x50kW	Closed due to dispute with users
Ramgad	2x50kW	Working

Orissa Power Generation Corporation

Kendupatna	500kW	Under construction
Barboria	650kW	Under Constructon
Binbati	650kW	Under construction

Kerala Agency For Non-conventional Energy and Rural Technology

Pookot	1x10kW	Working
Sugandhagiri	1x10kW	Power line damaged

Karnataka - Indian Institute of Science/Department of Science and Technology

Keragodu	1x40kW	Under construction

Hariana - Alternate Hydro Energy Centre

Kakroi	3x100kW	One unit working

Appendix C

Site Proforma

Information to be gathered for each mini/micro hydro station:

1. Site name:

2. Turbine size and type:

3. Site location and means of access:

4. Engineer in charge (name and address):

5. Year wise generation (kWh) for as many years possible:

6. Breakdown periods:

7. Discharge available (Firm power and secondary power):

8. Annual expenditure:

    Staff pattern and salaries:

    Maintenance expenditure:

9. Expenditure on construction:

    Civil works:

    Electro-mechanical works:

    Other:

10. Loading characteristics and types (domestic, agricultural, industrial):

11. Other notes and comments:

Appendix D

Case Study Sites

U.P.SEB Sites

Five U.P.SEB projects are presented individually. The case study sites are all located in the Chamoli District, on a pilgrimage route to the Badrinath Temple. These were chosen as typical U.P.SEB site as a district study.

Case Study 1: Chamoli

Capacity: 800kW (4x200kW) Head: 106m
Design Flow: 1.07 cumecs
Turbine Type: 3 x Turgo (Jyoti), 1 x Pelton (Ernstutte Coburg)
Generator Type:Synchronous
Length of Power Channel: 2.3km
Length of Penstock: 230m

Chamoli MHP project comprises of four turbines of equal capacity, totalling 800kW, with two turgo impulse turbines installed in 1967, one two jet pelton installed in 1970 and a further turgo machine installed in 1987. The turgo turbines are Indian built by Jyoti and the pelton is imported from Germany. The site has a head of 106 metres, with a 2.3 kilometre long power channel and 200 metre penstock. It was built to service the towns of Chamoli, Gopeshwar and Joshimat plus surrounding villages, which in recent years have also had grid supply available when the power plant is out of operation.

Technical Performance

The site generation figures and breakdown periods since 1982 are recorded in the figure below. This indicates considerable trouble with power channel damage in recent years, with a marked reduction in generation as a result. The final breakdown in 1991 has never been repaired, with little indication as to when or if this will be done. The repair cost was estimated at 700,000 Indian Rupees, which is prohibitively high, particularly as the alternative power source is available from the grid. In addition, the casing for one of the older turgo turbines is cracked and leaking and the generator windings have burned out. This machine had been removed at the time of the visit to the power house.

Year Wise Generation of Chamoli Power House		
Year	Generation (in 1000 units)	Break Down Periods
1982-83	1027	
1983-84	2162	
1984-85	1857	
1985-86	1806	
1986-87	1383	Power Channel Breakdown (10/7/86 to 22/7/86)
1987-88	1482	Power Channel Breakdown (6/87 and 7/87)
1988-89	N.A.	
1989-90	1447	
1990-91	528	Power Channel Breakdown (8/7/90 to 12/7/90)
1991-92	152	Power Channel Breakdown (15/8/91 onwards)

Source: U.P.SEB records

When in operation it is only possible to synchronise the three older machines to each other, with the fourth fed into a separate transformer and distribution network. The reason given for this was a "*generator defect in the DC supply*". It is not possible to synchronise the plant to the grid network as fluctuations in the grid supply voltage would trip the synchronous generators.

Full capacity supply is only feasible during the rainy season, that is for about three month per year. For the rest of the year there is only sufficient flow to run three turbines. Peak demand on the generating plant is too great, so that the voltage commonly drops from 415 volts to 300 volts during evening hours. As the Chamoli power plant cannot supply the full demand there is conflicting opinion as to whether the MHP site or the grid supply could give the better quality power supply.

Economic Performance

Accurate figures of actual capital cost for this project could not be obtained, particularly because of the time span over which the four units were installed. The initial phase of three 200kW turbines was estimated to cost a total of 2.60 million rupees in 1962 prices, and the 200kW extension in 1987 was predicted to cost 3.38 million rupees.

Staffing and monthly salary patterns at the site, when operating are:

4 Turbine/switch board operators	4 x Rs.2500
4 Oilers	4 x Rs.1800

Plus the following who are shared with other sites

1 Junior Engineer	Rs.3100
1 Mechanic	Rs.2500

The scheme supplies over 100 000 unit per month when it is fully operational, so is capable of operating profitably at the U.P.SEB tariff of Rs.1 per unit.

Utilisation

As well as the domestic load in the three towns and surrounding villages, there is a small industrial load of 10 flour mills and a compressor for inflating tyres. Commercial load to tourist enterprises - such as fans and refrigerators for hotels and restaurants - also improve the day time load, which is on average one quarter of the full capacity. Loading increases in winter. The average load factor for the site between 1983 and 1992 is 20%, though between 1983 and 1985 the load factor was over 40%. The frequent breakdowns in recent years are the main reason for the reduced load factor.

Comments

The tailrace water was also utilised for irrigation purposes, so that when the power plant is out of operation the irrigation facility is not available either. However, the irrigation department is not willing to contribute to the cost of power channel repair.

Case Study 2: Therali

Capacity: 400kW (1x400) Head: 80m
Design Flow: 0.7 cumecs
Turbine Type: Turgo (Jyoti)
Generator Type: Synchronous
Length of Power Channel: 2.15km
Length of Penstock: 160m

Therali project has an installed capacity of 400kW, using an Indian built 2-jet turgo impulse turbine on an 80 metre head. The project supplies power to the town of Therali and the surrounding villages, though now there is also a grid supply in the area. The plant was commissioned in 1989 after a 4 year construction period.

Technical Performance

The 3 kilometre long power channel has been damaged twelve times since commissioning, the last time in May 1992. This damage had not been repaired five months later, and the site was expected not to be operating for at least a further month. Repairs to the concrete channel are done by contractors, so that both materials and work force have to be transported from outside the region.

The electro-mechanical equipment has operated well, and the voltage and frequency have been steady. However, it is not possible to synchronise the generator to the state grid, primarily due to the instability of the frequency and voltage of the grid supply to the region which the power plant cannot accommodate.

Economic Performance

The capital cost of Therali MHP was 38,090 Indian Rupees per kW, at 1992 prices [Das, 1992b]. Almost 60% of this was on civil works. The construction cost over ran by more than 150% as compared to the estimated cost in the initial project report, produced in 1975.

The project employs 4 turbine operators and 4 oilers/helpers for only one machine. Over staffing and frequent repair work means that capital outlay on the project has been high since commissioning. The reliability and loading would have to be improved for the project to be made viable.

Utilisation

Utilisation of the plant was low in the first year operation, with a plant load factor of under 5%. The loading increased between 1990 and 1992, with load factors of about 20%. The loading has been boosted by the connection of commercial loads for 10 flour mills, 3 oil mills and cotton and wool processing machines. The peak load recorded is 395kW. There is little variation between the Summer and Winter demand. In the year 1992/93, availability of power from Therali MHP has been very low due to power channel damage.

If reliability of the project could be improved, therefore boosting the confidence of the users in the supply, it may be possible to increase the loading and the revenue to the plant.

Comments

The power house staff are required to remain at the plant even when it is out of order for several months. This not only entails unnecessary cost but causes low staff moral. The Therali staff expressed unhappiness at the frequent stoppages in operation due to damage to the power channel.

Case Study 3: Pandukeshwar

Capacity: 750kW (3x250kW) Head: 100m
Design Flow: 1.08 cumecs
Turbine Type: 3 x Turgo (Jyoti)
Generator Type: Synchronous
Length of Power Channel: 0.7km
Length of Penstock: 427m

This 750kW site has three equally sized Indian built turgo impulse turbines, of which two were commissioned in 1975 and one in 1982. The turbines operate on a 100 metre head, with a 0.7 kilometre power channel and 427 metre penstock. The construction period of the site was 4 years, one year longer than planned. The site was originally to supply power to Pandukeshwar, Joshimat, Guvindgaht and Badrinath, plus the surrounding villages. This project took over the supply to the pilgrimage site of Badrinath, which was previously serviced by the micro hydro unit discussed later. Since one of the turbines is currently out of order, the supply to Joshimat has been discontinued and supply to the town is now from the grid.

Technical Performance

Pandukeshwar site makes use of the natural diversion of the stream at the intake, which is enhanced by using boulders to create an artificial weir and raise the water level to increase diversion of the flow during the dry season. The power channel has suffered minor land slide problems, but less so than other projects in the Uttar Pradesh hills. Maintenance of the channel has been poor as it is mostly covered and little effort has been made to clear silt from sections of power channel which are difficult to reach.

The main technical problems are due to the lack of provision for silt removal and poor cleaning of the power channel. This has resulted in severe erosion of the the turbines and turbine casings. Photograph 5.4 shows the effects of erosion on one turbine from the project. At the time the site was visited, one turbine was out of operation due to silt damage to the runner and the casing. A second unit had a badly damaged casing, but had been temporarily patched, as shown in Photograph 5.5, which prevents excessive leakage, but affects the efficiency of the unit. The third unit was functioning well.

Economic Performance

The capital cost of Pandukeshwar was the lowest of the case study sites, at 21,180 Indian Rupees per kW, at 1992 prices [Das, 1992b]. Civil works and electro-mechanical equipment constituted less than half of the outlay.

Staff levels and monthly salaries were as follows:

4 operators	Rs.2500
4 oilers/helpers	Rs.2500
1 line worker	Rs.2500
1 line helper	Rs.2500

In addition, the site shares a mechanic with Chamoli MHP and the area junior engineer for local distribution.

So far the loading, and therefore the revenue, have been low, while repair costs to the site have been high.

Utilisation

There was very little daytime load on the Pandukeshwar MHP site. The industrial load consisted of one flour mill, though when Joshimat town was connected there were four additional mills supplied. The daytime load without the Joshimat load was under 100kW, whereas it was over 200kW with the town load added. The average load factor on the site since 1983 had been 23%, peaking at 34% in 1989/90. The loading decreased again after Joshimat was disconnected in 1991.

Case Study 4: Tapovan

Capacity: 800 (2x400kW)   Head: 280m
Design Flow: 0.50 cumecs
Turbine Type:2 x Turgo (Jyoti)
Generator Type: Synchronous
Length of Power Channel: 1.4km
Length of Penstock: 650m

This 280 metre head site with 1.4 kilometer power channel has two 400kW Indian built turgo impulse turbines. It was commissioned in 1989 after a five year construction period, two years longer than planned. It was built to supply the power demand for Tapovan plus the surrounding villages, and also supplied the army departments in the Tapovan valley and an agricultural research centre.

Technical Performance

Tapovan MHP has been badly designed and poorly constructed. The generators have never been synchronised, so that only one turbine can be operated at any time. This problem had not been investigated and reasons for the lack of synchronisation were unknown to the project operators. The penstock is mis-aligned and was leaking badly when the site was visited. As there is only a single penstock, neither machine can operate due to the leakage. The power house structure is cracking badly due to land subsidence. The delay in construction period was caused by due to damage of the power channel in 1987 not repaired until 1989. The voltage and frequency of generation fluctuates greatly, with voltage reductions from 415 volts down to 340 volts when the load exceeds 250kW.

Consequently the power house has been out of operation frequently due to power channel, penstock and machine problems.

Economic Performance

Despite the time delay in the construction work the capital cost of the project was only 23,090 Indian Rupees per kW [Das,1992b], though with only one machine in operation at any time this figure is effectively doubled. 65% of the expenditure was on the civil works and 22% on electro-mechanical equipment.

The staff pattern is 4 operators, 4 oiler/helpers, 1 line worker and 1 line helper.

Under present operating conditions Tapovan MHP project will never be economically viable.

Utilisation

There is an industrial load connected to the site, comprising: 1 wool carding machine, 1 saw mill and 4 flour mills. None the less, the load factor of the site has averaged at only 5%, peaking at 9% in 1991/92. In the first half of the year 1992/93 the load factor dropped again to 3.5%, primarily due to the breakdown of the system due to the leaking penstock. The maximum load on the site is only around 260kW.

Comment

The operating staff at Tapovan were unhappy about their working and living condition and all expressed a wish to be transferred to another district.

Case Study 5: Badrinath

Capacity: 30kW Head: 27m
Design Flow: 0.16 cumecs
Turbine Type: Turgo (Gilkes)
Generator Type: Synchronous
Length of Power Channel: none
Length of Penstock: 365m

Badrinath Powerhouse was commissioned in 1968. It has one 30kW turgo impulse turbine imported from the United Kingdom which works on a 27 metre head. At a height of over 3000 metres above mean sea level, this site was installed to supply power to the pilgrimage site of Badrinath Temple but now only operates when the supply from Pandukeshwar is not available.

Technical Performance

The turbine is in good working order, though there have been problems with the generator windings. A heavy snow slide had damaged the powerhouse, but had not damage the equipment in any way. The intake uses the natural physical features of the river to divert the flow into the forebay. There is no power channel.

Economic Performance

The project was said to have been profit making when it was in full operation, though no information was available as to whether it paid back its initial costs. It did, however, have a staff complement of six - 3 operators, 2 helpers and a line worker - so it is doubtful that this micro hydro project will have made significant gain. The project is not permanently staffed at present.

Utilisation

There were no generation records available for the site. As it is at a busy pilgrimage centre, it would have been heavily utilised in the Summer season, but under utilised in the Winter when the centre is effectively closed due to bad weather conditions.

Comments

At the same site a 25kW Francis machine has also been installed. This was commissioned in 1988 but has never been used. The turbine is a renovated second hand machine, which was intended to supply power for the construction work of a 240MW project at Joshimat. The Joshimat project has been postponed, making the Francis turbine redundant at present.

A renovated turbine would not be allowed under normal U.P.SEB regulations as all equipment in new sites are required to have a life span of 35 years. This turbine was allowed as it was for temporary use only.

U.P.NEDA Sites

Six of the nine U.P.NEDA sites are described here.

Case Study 6: Kempti Falls

Capacity: 12kW

Head: 40m
Design Flow: 0.04 cumecs

Turbine Type: Crossflow (DST)
Generator Type:Synchronous (single phase)
Length of Power Channel:none
Length of Penstock: 250m

The Kempti Falls project was the first of the U.P.NEDA MHP sites commissioned in 1989, and as such was primarily an experimental scheme. It is nominally of 12kW capacity, though the maximum possible output at the time of visiting the site was 7kW. The site head is 40 metres, with a short power channel but a 250 metre long penstock pipe. The project is located at a tourist area, near to the popular hill resort of Musoorie and supplies power to the restaurants and tourist services. The state grid has been extended to the area since the project was installed.

Technical Performance

The reasons given for the low efficiency of the system are, first, due to calcium deposits on the inside of the penstock caused by the high calcium content of the stream, and, secondly, that the turbine efficiency is not as high as expected, at under 65%. The turbine was the first of the crossflow turbines developed under the DST/IISc programme, and did not perform as well as laboratory tests had predicted. There were plans to chemically flushed calcium deposits from the penstock.

The quality of power output from the project has been stable, with almost no voltage or frequency variation on the single phase distribution network, so that many customers prefer to take electricity supply from the MHP site rather than the weak grid supply. The scheme has had several minor problems over its life span, though has never been closed for any length of time. Even when the electronic load controller panel burned out and took two and a half months to be replaced, the load control was done manually by the operator switching on and off 2kW ballast loads as external loading changed.

The intake weir has silted up twice, and has been built up using local materials, as shown in photograph 5.17. There is only a short power channel, but a lengthy penstock which shows considerable damage from weathering and falling rocks. Several of the large concrete anchor blocks were cracking. On one occasion the rain water washed stones into the penstock, denting the pipe. The power house was closed for four days to repair this.

Economic Performance

The capital cost of Kempti Falls site was 660,000 Indian Rupees in 1989, the electro-mechanical component of which contributing 36% and the civil component 64% of the total. The capital cost was subsidised 100% by the Uttar Pradesh state government.

The tariff was set at only 0.8 rupees per unit after negotiation with the user community. The revenue collected is only expected to cover annual operation and maintenance costs, with U.P.NEDA covering any major damage repair costs. The site has only one operator, who was initially paid 600 rupees per month, which was reduced to 450 rupees when it was found that the monthly revenue was not sufficient to pay for minor repair work.

Site income was said to be

March to November (Tourist season) - 700 to 900 Rs/month

December to February - 450 to 500 Rs/month

Annual income - Rs.7200

Utilisation

The loading is entirely for the tourist centre, with no domestic connections. This consists of lighting, refrigeration and fans for 23 shops, two hotels and one restaurant, plus 16 street lights. There is no supply given between mid-night and morning. The load factor is claimed by U.P.NEDA to be between 30% and 40%, though with the plant output at only 7kW, it is doubtful that this load factor has been sustained.

Management and Administration

The user community was involved in the project from an early stage. A local association was established to collect the tariff. This association has now taken over the running of the scheme, with assistance from U.P.NEDA as required.

Case Study 7: Sahastradhara

Capacity: 10kW

Head: 6m
Minimum Flow: 0.4 cumecs

Turbine Type: Crossflow (DST)
Generator Type:Synchronous (single phase)
Length of Power Channel: 180m
Length of Penstock:15m

This is another pilot scheme for the Indian built crossflow turbine, set in a tourist area, though it does also supply power to two small villages. It is expected to have a life span of only 10 years. It works off a 6 metre head, with a short penstock taken off a large forebay (see photograph 5.12) and has an installed capacity of 10kW.

Technical Performance

Technically Sahastradhara has been successful, with no major faults. There has been minor damage to the power channel caused by falling rocks, but with no significant affect on the running of the plant. During the 1992 monsoon season a huge flood, larger than any expected damaged the intake and flooded the power house. The generator was out of order for some time, but has since been operating as normal.

Economic Performance

This site is one of the projects sponsored under the DST crossflow turbine projects who provided the electro-mechanical equipment. The rest of the expense was covered by state government grants. The capital cost of the project was Rs.530,000.

There is only one operator, who lives in the powerhouse and is paid Rs300 per month. The tariff is set at a monthly rate of Rs30 per month for domestic connection and Rs50 per month for commercial connections. The average monthly income was quoted as Rs.500 to Rs600. The ballast load for the ELC is to be a water distillation plant,as shown in photograph 5.10. Sale of distilled water should produce an income of Rs120 per month to the plant.

The income from th plant is covering its annual expenditure, but would be unable to pay for any major repair work if damage should occur. This would be paid for by U.P.NEDA.

Utilisation

The plant has 22 domestic connections, 5 commercial connections and 22 street lights on its single phase distribution network. The average domestic load is 400 watts per household, with U.P.NEDA providing one bulb and one strip light, with additional power outlets added at the user's cost. The commercial load is for lighting, refrigeration and fans for shops at the tourist centre which are open for only six months in the year. The day time load is usually 4 to 5kW and the evening load is from 9 to 10kW, with an average load factor between 30% and 40%.

Management and Administration

The local people were consulted on the running and management of the project, including participating in decisions as to tariff rates. The project is now run by the local people, with support from U.P.NEDA.

Case Study 8: Ramgad

Capacity: 100kW (2x50kW)
Head: 50m
Design Flow: 0.30 cumecs

Turbine Type: 2 x Turgo (Jyoti)
Generator Type: Synchronous
Length of Power Channel: 0.84km
Length of Penstock: 125m

Ramgad micro hydro scheme has two 50kW turgo impulse turbine which operate on a 50 metre head. It is connected to five "gram sabhas" (village groupings), with 10 villages connected. In two of the gram sabhas some of the villages have electricity supply from the state grid. This project was originally proposed in 1987, but was delayed for two years by problems of land acquisition. The project was eventually commissioned in 1990 after a construction period of one year.

Technical Performance

The initial project report recommended a semi-permanent, bush boulder diversion using local materials and a stone masonry power channel. However, it was decided to install a stone masonry diversion and concrete power channel. The 840 metre long power channel has been damaged three times causing plant stoppage of a few days and once with a down time of five months. A landslide destroyed a section of the power channel, taking with it the embankment on which it was built. The embankment had to be rebuilt, at a cost of Rs300,000, before the section of channel could be reconstructed. A cover was put on to protect the channel in case of a second landslide, which has since occurred, leaving the channel under a layer of earth. Stoppages of the plant for repair had accounted for about 25% of the time since the plant was commissioned. In the gram sabha which also has grid supply, it was felt that the U.P.SEB grid supply was more reliable that the supply from Ramgad because of the amount of time it had been closed.

The electro-mechanical equipment has performed well, though there have been faults in the 11kV distribution lines which needed repair. Only one village complained of voltage fluctuations in the supply. This village is the furthest from the power house and requires distribution lines of over 6 kilometers.

Economic Performance

The expected capital cost for the project in the detailed project report in 1987 was Rs510,000 (including distribution lines). The actual cost of construction in 1990 was Rs718,500. The expenditure breakdown was Rs212,800 for civil works, Rs206,800 for electro-mechanical equipment and Rs298,900 for transmission and distribution lines. About one third of the distribution network had been bought from the U.P.SEB, who had installed the lines years before, but had never used them. The site was entirely subsidised by the Uttar Pradesh Hill Development Programme.

The site has three operators from the local area, who are paid Rs20 per day (Rs600 each per month when the site is in full operation). The tariff rate has been set at Rs16 per household per month if the bill is paid on time, but Rs25 if paid late. U.P.NEDA has contributed Rs60 per household to install two lighting points, any other connection must be paid by the user.

Utilisation

The detailed project report for Ramgad claimed that when the site was commissioned *"flourmills, cottage/tiny industries for fruit processing, sawmills and a match factory will come up instantly"*.The day time loading was expected to exceed the evening lighting load. However, in reality, the power house does not even operate in the daytime hours. The peak load recorded in 76kW, and often only one turbine is require to meet the load. There are no agricultural, industrial or commercial loads, although there are possibilities of electrifying a few flourmills. There are 275 household connections, a school connection and ten street lights. Lighting is the main load, with a few wealthier households using a television or heater. In some villages U.P.NEDA have encouraged the use of cooking by electricity for no extra charge. This was an attempt to develop the loading on the system.

A report was produced by the DST on the use of off-peak (day-time) power use of a micro hydro plant, which used the Ramgad micro hydro power project as its model. This report gave details of productive uses of the power and indicated the education and training required to implement them and the financial investment required. The activities suggested included mushroom cultivation and poultry farming as well as more conventional options of carpentry and multi-purpose workshop. There has been little, if any, action taken to implement the recommendations of the report, mainly due to lack of co-ordination or co-operation between U.P.NEDA and other development agencies.

Management and Administration

Local input to the project development was more evident at this site than at most others. Though the site was constructed by contractors, they did occasionally employ local people for construction work. Otherwise the labourers were brought from outside the local areas, as had been usual practice at other U.P.NEDA sites.

Administration of the project is in the process of being handed over to the local people. A joint bank account has been opened between U.P.NEDA and the local association so that every day transactions can be dealt with from the power house. At the time of the visit to the power house there was a meeting between U.P.NEDA and the village leaders to discuss the future running of the plant.

Case Study 9: Dior

Capacity: 50kW

Head: 35m
Design Flow: 0.25 cumecs

Turbine Type: Crossflow (DST)
Generator Type: Synchronous
Length of Power Channel: 0.60km
Length of Penstock: 355m

Dior was commissioned in November 1991 but was closed by July 1992 when the electronic load controller burned out. The project is sponsored by the DST crossflow turbine programme and is installed with a turbine rated at 50kW, though it has never produced more than 37kW. Also, the power house was built for two 50kW turbines, but the river flow is insufficient to produce 100kW at the low efficiency of the crossflow turbine (less that 60% efficient). The project is connected to four gram sabhas.

Technical Performance

The villagers had been supplied with electricity for a total of between 1 and 2 month from commissioning to the time of the site visit. The site was not provided with a trash rack, so that stones have entered the penstock and damaged the turbine twice times. The first turbine was replaced by a second, which subsequently was damaged and was replaced by the original after repair. Neither of the turbines achieved the rated efficiency.

The Indian made electronic load controller with water heater ballast load burned out in July 1992. The operators were not properly trained to deal with this situation, so consequently there was a long breakdown period.

The low power output has meant load shedding at peak hours and power supply to each village is scheduled, by switching in and out sections of the power lines on alternate days.

There has been breaching of the forebay and power channel during the flood season, indicating inadequate design for high flow.

Economic Performance

The capital cost of Dior was Rs252,800 plus Rs238,500 for transmission and distribution, which was 25% greater than the predicted in the detailed project report [Das, 1992b]. Though the civil works were constructed for a plant capacity of 100kW, the site will never be capable of producing this power. The electro-mechanical costs were covered by the DST crossflow programme, and the remaining costs was paid for by Uttar Pradesh state grants.

The site has two operators who are paid Rs600 each per month when the site is working. U.P.NEDA pay Rs150 towards household wiring, though locals say that a two point connection costs Rs300. The tariff agreed upon is as follows:-

Households with:

5 electrical points or less - Rs16 per month

5 to 10 electrical points or less - Rs22 per month

Over 10 electrical points - Rs33 per month

So far no tariff payment has been made due to the poor availability of power supply.

Utilisation

The power house was not in operation during the day. This is partly due to lack of load, but also because the water is used for irrigation purposes during the daytime. There was no industrial load, though there are 4 flour mills in the area which currently are run by diesel engines and could be converted to electricity. There is no agricultural load, though there were some hydrams near to the power house. Almost all of the hydrams were not working due to neglect by the irrigation department. The load was almost only for lighting, though a few wealthier households also had radio/tape-recorders.

There were no adequate generation figures available because the meters were not working.

Management and Administration

The construction work had been done by contractors using labour from outside the local area. There had been some discussion between U.P.NEDA and the local people, including negotiation of the tariff rate. There was insufficient experience with running the power plant for the local people to take over responsibility of running the project, so that management and administration was done by U.P.NEDA. The operating staff were local people, but there were complaints about the lack of training given to the two men, who could only just cope with normal operation and maintenance.

One village within the catchment of Dior had taken the initiative to propose a site for a second power project, which could compensate for the poor peak power capability of Dior. The site was an 18 metre drop in the irrigation canal. This village was wealthier than the others and showed most willing to utilise the power for other purposes, including water boiling and space heating. Some villagers had not taken connection to Dior because of its poor reliability.

Case Study 10: Bilkot

Capacity: 50kW

Head: 22m

Design Flow: unknown

Turbine Type: Francis (Jyoti)
Generator Type: Synchronous
Length of Power Channel: 0.42km
Length of Penstock: 35m

Bilkot uses a 50kW Francis turbine operating on a 22 metre head. It is 8 kilometres from a motorable road and 6 kilometres from the nearest grid connection. It is connected to three villages. It was commissioned in December 1991, but was closed in June 1992 because of a dispute between U.P.NEDA and the local village leaders.

Technical Performance

Equipment for the project had to be carried to the site by porters, so the turbine was supplied in sections and assembled on site. The Francis turbine was installed with adjustable guide vanes and butterfly valve to set the speed and control the flow of the turbine. The site also has an ELC with space heater ballast, which would make the adjustable guide vanes redundant. Initially there were problems with the ELC, causing speed increases, though this has been rectified.

The maximum power output has been 48 kW. Water is available all year, but the design of the diversion and intake are not adequate to divert sufficient water in the Summer season. Otherwise the plant has been functioning well.

Economic Performance

The unit cost of the Bilkot project was Rs.64,800, with transmission and distribution almost doubling this amount. The site has three operators, who are paid Rs600 per month when the plant is in operation.

At the time of the visit, the tariff system had not been agreed upon, and so there had been no payment for power supply. U.P.NEDA is to pay Rs150 per household for the connection and house wiring.

Utilisation

The plant operates only between 6pm and 8am, supplying 250 household connections, predominantly for lighting purposes only, though three villagers in Bilkot had bought television sets. Load shedding has been required, especially in the summer season.

Interest was shown in the electrification of some of the diesel run flour mills if the supply is made more reliable.

Management and Administration

There has been very little involvement of the local people. A few locals were employed during construction, but this was mainly carried out by contract workers from outside the area, including the use of 25 porters from outside the local villages to carry the equipment to site. Negotiations were held between U.P.NEDA and the village leaders to discuss how the project could fit into the local needs and plans. These discussions did not even address the problem of a tariff system and eventually ended with the shut down of the plant due to a needless dispute.

The operating staff are local people, though it was complained by the villagers that they were poorly trained, and could not cope with more than simple repair work without outside assistance. An unfortunate side effect of the site location inside a national conservation park has been that the staff refused to leave the powerhouse to conduct repairs in the evenings due to fear of wild animals which, by law, can not be shot.

Case Study 11: Khokta

Capacity: 50kW

Head: 35m
Minimum Flow: 0.30 cumecs

Turbine Type: Crossflow (DST)
Generator Type: Synchronous
Length of Power Channel: 0.10km
Length of Penstock: 640m

Khokta is a 50kW project set up as part of the DST crossflow turbine project, with additional funding from state grants. It is possible that the site may have a second unit of 50kW installed after some time. The site is located on a barely motorable track, about 6km from the main road and 5km from the nearest grid connection. At the time of visiting the site it was under construction, with plans to commission the site within a few months. Four months later the site had not been commissioned on time due to problems with the electronic load controller.

Technical Features

The site consists of a concrete diversion weir and short power channel to a large desilting tank/forebay. The penstock is 640 metres long, though the head drop is only 35 metres, and leads to an over sized powerhouse. The electronic load controller is planned to be connected to a "leaf plate" maker - a heated mould for shaping leaves to form disposable plates.

Economic Features

Khokta had a unit cost of Rs43,000 per kW at 1992 prices, with cost of civil works contributing over half. Transmission and distribution lines added Rs142,300 to the project. The entire capital cost is covered by grants. There are to be 4 staff at the site. A set monthly tariff system had been devised at the time of the site visit, with ordinary households required to pay Rs15 per month, scheduled caste households required to pay Rs.7.5 per month and industries and commercial connections being charged Rs.50 per month. No subsidies have been given for connection charges.

There has been some disruption of farm land to make way for the civil works, so that Rs40,000 has had to be used to compensate the farmers.

Utilisation

There have been 550 household connections taken up already, half by scheduled caste households. There are possibilities for industrial connections, for a saw mill, 5 flour mills, a potato chip maker and a leaf cup maker (the ballast load). Whether these industrial loads are developed remains to be seen and may depend on the reliability of the electricity supply.

Management and administration

The negotiations with the local people at this site have so far been very positive, though at the time of the visit to the site there was a dispute over the disruption of the farm land and the water rights of a local water mill owner, who's water supply was from the same stream as the project, with the penstock blocking the water access to the mill. However, a 13 member co-operative of local people plus a U.P.NEDA engineer has been set up to run the project . There have been several meetings to decide on tariffs and loading patterns, and it was planned that the co-operative will take over the management and administration soon after commissioning.

Local input to the construction of the site was only the employment of porters, carrying the equipment and penstock to the site. The rest of the work was carried out by contractors, who delayed the construction by six months because of lack of available financing.

Appendix E

Publications

A.Doig, A.R.Wallace and D.Das, *A Technical and Economic Appraisal of the Future of Small Hydro Power in the Northern Indian States*, Proceedings of the Fifth International Conference on Small Hydro Power, New Delhi, 1992.

A Technical and Economic Appraisal of the Future of Small Hydro Power in the North Indian States

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1. Introduction

In 1990 the World Bank reported that,[1] "In parts of India growing landlessness and disproportionately little access to irrigation, electricity and social services have perpetuated concentrations of deepest poverty and accentuated income and irrigation disparities." This aptly summarises the immense development problems in rural India, among which access to electricity supplies is fundamentally important. The Rural Electrification Corporation (REC) defines "electrified" villages as having at least one supply connection to the village. Studies consistently show that, even in electrified villages, less than 15% of the households are able to take electrical connection. It is usually the wealthier members of the rural community who are able to afford electricity supplies and who benefit by this connection. Also, of the villages not yet served by electricity supplies, nearly all are in the most remote and backward areas. It is therefore ironic that the rural poor, who are the appropriate and principal targets for Rural Electrification (RE) programmes, are least likely to benefit by provision of electricity supplies. This suggests that a new approach is required to ensure that the rural poor can share the benefits of electricity supplies.

The Indian Government's commitment to RE and the development of the country's abundant renewable energy resources is demonstrated in the government's Seventh Five Year Plan (1985-1990), which states that "The aim is to achieve a transition to an economy in which an intensified programme of rural electrification and a viable renewable energy programme together make a significant contribution to meet energy needs in rural areas.", [2]. Recently there has been increasing interest in small hydro-power (SHP - classed as between 2001kW and 15,000kW) in India as a mature and viable technology. By designating the Department of Non-conventional Energy Sources (DNES) as the nodal central government department which will be responsible for encouraging the development of SHP up to 3 MW installed capacity, the importance and significance of SHP in the overall national energy scenario has been recognised and emphasised. SHP is no longer viewed as a subsector of conventional large hydro-power systems, but is seen as an entirely separate renewable source of power.

The eighth Five Year Plan (1991-1995) proposes that SHP should be amplified as a critical area of non-conventional energies, by allocation of funds to the DNES for this purpose. Under this initiative 30% of the available funds for SHP projects is to be used to develop mini/micro-hydro power (MHP - classed as between 101 and 2000 kW/below 100 kW, respectively) in the hill areas of India. There has also been considerable interest from the World Bank Global Environment Facility in developing MHP in the Himalayan regions. Their assistance will help finance a three year programme focused on the hill regions. The objectives of the programme include: the implementation of demonstration projects; development of appropriate technologies; and the formation of a national infrastructure for optimal implementation of MHP sites in the hills.

Development must be carefully planned to ensure that it will be most effectively implemented in the Himalayan environment. The programme must not simply provide rural power supply systems, but must also include among its aims the social and economic uplifting of the rural poor. This paper discusses some of the technical, economic, and social factors which must be recognised.

2. Scope for Developing SHP and RE in the Himalayan Region

The current status of RE in India is that nearly 79% of villages are provided with grid supplies. Individual statistics are shown in table 2.1 for Northern India, [3,4]. While Jammu and Kashmir and Himachal Pradesh are almost completely electrified, Uttar Pradesh and the North Eastern States, where many rural hill communities are still to be supplied, are below the country average for rural electrification. This confirms the urgent need for development in these unconnected areas.

State	Number of Villages	Number of Villages Electrified	% Rural Electrification
U.P. (Hill districts)	15117	9514	63
Himachal Pradesh	16807	16778	100
Jammu and Kashmir	6807	6010	92

North East States *(as at 31/3/89)*	Number of Villages	Number of Villages Electrified	%Rural Electrification
Arunchal Pradesh	3257	1179	37
Assam	21995	19545	88
Manipur	2082	1057	52
Meghalaya	4583	1937	40
Mizoram	721	307	43
Nagaland	1112	1097	98
Tripura	4727	2454	52

Table 2.1 - Rural Electrification in the Indian Himalayan Region

Even where grid supplies are available there are still acute power shortages in the hill regions, especially at peak hours. In times of high demand power failures and load shedding are frequent occurrences. The RE transmission system is usually not sufficiently reinforced and voltage variation, large system losses and rural line failures are common. The average transmission losses in rural India are around 20% of the power conveyed, with extremes in the rural hill districts of such as Chamoli, in U.P. which incurs transmission losses of around 40%. Rapid development of a dependable, flexible power source close to rural load centres is required to ensure a reliable power supply, which is essential to sustain the growth of more modern economic activities in the rural areas. The SHP potential in India is frequently quoted as about 5000 MW, of which 40% is located in the hill regions. At the time of writing 119 MHP sites are in operation, with a total capacity of 109 MW, and construction work is in progress at 122 sites with aggregate capacity of 161 MW, [5]. The majority of these sites are in the Himalayan region. Some N.E. states rely almost totally on SHP as their main power source. Very often Himalayan villages are located close to small perennial streams which could be tapped to provide local power supply. Small, mini and micro hydro power schemes should be ideal power sources by which hill regions, with the correct rainfall, hydrology, and topography might be developed. However there are many barriers which frustrate any form of development work in the in the Indian hill region. In addition to the frequently encountered geographical, climatic, infrastructural, and socio-economic constraints on general development, there are problems specific to the hill regions which hinder the expansion of SHP as a rural power source.

3. Conditions in the Himalayas - Constraints on Development

3.1. Geographical problems

The Himalayas are the youngest mountain range in the world, and - still evolving - are the most ecologically fragile. Human activities are already having far reaching effects on the region, so great care must be taken in the planning of development projects. With the population growth rate in the hill region significantly higher than the already high national average and much unplanned development in the region, pressure on the land and natural resources of the area is constantly increasing. The expansion of the tourist industry is adding to the demands on natural resources. Fuelwood contributes up to 98% of the rural energy consumption in the hill regions, so that reserves of this deceptively "free" energy source, which for many years have been taken for granted, are rapidly reducing. Deforestation has the immediate secondary effect of reducing soil stability on the hillsides, increasing deposits in the already silt laden streams and increasing landslides during the rainy season. While development of SHP and RE could offset demands on the forests there are many areas where the deforestation may have already rendered the land and the rivers unsuitable for development.

3.1.1. Floods, Land Slides and Falling Rocks

With wet:dry season flow ratios in the order of 1000:1 cases of MHP sites being washed out during floods are quite common in the hills. Also, less devastating, but problematic, is the recurring damage to weirs, power channels and penstocks caused by minor floods, landslides and falling rocks. These problems are especially prominent in India as its lower hills are the youngest and most dynamic in the Himalayan range.

3.1.2. High Silt Content in Streams

The silt in Himalayan streams rapidly erodes power channels, penstock pipes and turbines. This silt must be removed before entering the power system to avoid frequent repair and maintenance which adds to the project operating costs. If the silt can be removed the frequent cleaning of sand-traps is likely to increase the operating costs of plant and may reduce plant availability.

3.2. Climatic problems

Climatic problems are those of extreme conditions. In winter snow blocks many access routes to interior areas and extreme cold climates prevent construction work and make maintenance work difficult. Similarly in the rainy season flooding is a major problem, again stopping construction work and in addition creating the hazard of landslides and falling rocks. This problem is unavoidable but predictable. Construction and maintenance can be scheduled carefully to optimise work during the periods of better weather. One positive effect of the mountain climate is that during the dry months many of the streams are fed by snow and ice melt, so providing a year round dependable flow.

Generating plant must therefore be designed taking account of the prevailing environmental conditions which include: high ambient temperatures; strong sunlight; high humidity; low ambient temperatures; frost; airborne dust; waterborne sediment; seismic activity; insect or rodent attack; or corrosive atmospheres, [6]. With unprotected equipment there is frequently a high incidence of failure through incorrect installation and operation or improper fitness for duty.

3.3. Infrastructural limitations

The lack of infrastructure in the hills is a further drawback. Access and communications are very poor. Many villages can only be reached by foot or by pony on steep winding tracks. The remoteness of the villages from markets and services greatly restricts the scope for developing economic activities, such as small scale industries, since the transport of raw materials and finished products is both difficult and expensive.

3.3.1. Remoteness and Transport Difficulties

The lack of roads which provide vehicular access to many remote areas can be solved in two ways. The first is to build suitable roads before construction starts. However, this not only increases the overall capital cost of the project, but in many cases requires significant forestry clearances. In some areas the provision of construction roads has resulted in further denudation of the forest by providing easy access to outside markets for illegally felled trees. The other option is to use human or animal power to carry in the equipment to be built. This concept may realistically only be applied to smaller plants in the micro and mini hydro power range, where the weight of the heaviest single component is limited by the means of transport.

3.3.2. Low Technical Skill of Rural People

Small and mini-hydro schemes may require some or all of the following ancillary plant which must be considered carefully in terms of simplicity, cost and reliability: inlet valve and operating system; drainage and dewatering pumping systems; governor compressed air and oil systems; gearbox; unit and auxiliary transformers; neutral earthing equipment; synchronising equipment; switchgear; bearing lubrication system; cooling water system; electrical protection; crane or lifting tackle; braking or jacking equipment; HVAC and fire protection systems.

Plant designers must recognise that the manual skills available may not be compared with that in industrialised countries. Construction and installation techniques must be rationalised taking account of the relative skills in the rural community. Operation and maintenance tasks should be de-skilled so that the continued operation of the plant does not rely on expensive assistance from manufacturers. Lack of financial and human resources frequently results in poorly maintained and operated equipment, leading, in turn, to an increase in the number of failures with consequent reduction in availability of supply to the community. Unreliable plant, unquestionably, damages the reputation of SHP in the opinion of the rural communities, and is frequently a powerful disincentive. Generating plant and ancillary equipment should therefore be simplified so that basic maintenance and repairs can be done by local people and on the job training can be given.

3.4. Socio-economic barriers

The main economic activity in the hill regions is subsistence farming, with most farms of marginal size (less than 1 hectare). The fragmented fields, topography of the land and poverty of the people make it difficult to adopt modern farming methods. Small industries do not contribute significantly to the economy of the hill regions - in the Uttar Pradesh hills only 3.7% of the income and 4.5% of the employment is from manufacturing, [7]. Poverty is widespread in the Himalayan rural communities. There is a general lack of basic amenities such as drinking water, health care and education and scarcity of some foods and fuels. Little of their income of the rural people can be spent on such luxuries as electrical appliances which would constitute the domestic load in village electrification. Also, banks and financial institutions are unwilling to lend to those without financial security, making it virtually impossible for communities or households to improve their economic activities without aid from outside. Finally in many remote areas there is a resistance to change, such as using electricity instead of traditional forms of energy, even if subsidies are given.

<u>4. Technical and Economic Appraisal</u>

4.1. Indigenous capabilities

India has almost 100 years experience with SHP. In the early 1900s SHP plants constructed in hill stations and tea estates were often the principal power sources. Over time, the state grid expanded and as large hydro schemes began to take a prominent role, small hydro projects were relegated to a low priority, supplementary status. This situation lasted for a considerable time but, none the less, SHP technology has advanced in India and plant manufactured in India is of a high standard. SHP technology in India is now well developed and many new innovations are being adopted at mini-hydro plants. There are now seven SHP turbine manufacturers in India, most of whom collaborate with overseas manufacturers. India is an exporter of small hydro equipment, selling to countries such as the USA and Canada. Recently a micro crossflow turbine has been developed in India, manufactured by a local engineering firm and has been successfully installed in demonstration sites in the hill regions. There is currently only one small turbine manufacturer which is able and willing to produce equipment for the micro-hydro range. As a result, there is an absence of indigenous competition in the market at this power level and little incentive to reduce costs or develop new, cheaper technology. This situation should be considered carefully and, if possible, the government should encourage the dissemination of micro-hydro plant manufacture. It could identify suitable standardised turbine technologies and a few manufacturers in the private sector who have existing manufacturing facilities who could produce such equipment in reasonable scale. The government could act as a catalyst by providing suitable financial assistance in the establishment of the new product lines. An example is that suitable micro-hydro sites are now being installed with an Indian designed and manufactured electronic load controller, which reduces the cost and complexity of the sites.

4.2. Perspective, approach and cost

For effective and economic SHP development the correct approach and perspective must be adopted. After safety, the over riding consideration when designing SHP plants for the rural market is cost. It is an observed effect that as site capacity falls, the total capital cost of a scheme does not reduce linearly with output power. With most of the engineered components, (rather than bulk commodities), the unit costs (cost/kW) of the plant rises as the rating or capacity falls. The unit cost of SHP is much higher than for large hydro. In India the unit cost of large hydro is in the range of Rs.12,000-20,000/kW whereas MHP generally costs between RS.20,000 and Rs.35,000/kW. Project reports for ten micro-hydro sites (40-100 kW capacity) proposed by the Non-conventional Energy Development Agency (NEDA) in U.P. estimate costs between Rs.36,000 and Rs.60,000/kW, [8]. These projects, however, envisage use of high efficiency, precision built machinery. Civil works will be constructed at high labour costs through contractors. Conventional, low risk methods will be used and structures will be built to withstand all but the worst possible flood or landslide. The basic hydraulic and electric principles in the design of SHP is the same as that of large hydro power. However, for small, mini and micro-hydro plants different approaches must be taken to reduce unit costs. Cheaper and less sophisticated equipment which offers lower efficiency may be more suitable for the hill regions where capital costs may be more of an economic barrier than operating costs. For lower power sites there may be merit in continuing to select impulse turbines for lower head applications to reduce power house civil costs. Provided that turbine performance and generator speed remain acceptably high more mini-hydro power plants may become affordable with this approach. In view of the increased costs of site-specific designs it may be prudent to standardise designs for modular construction provided that the performance of non-site specific designs remains acceptable. Where possible local materials and labour should be used for civil works and access roads, since this has the numerous advantages. In addition to potentially reducing unit costs, construction of the plant involves local people and injects labour costs into the local economy as construction wages.

In Nepal, micro-hydro plants are being installed using the lowest possible technology at a unit cost around Rs.22,000/kW, which is lower than that for small-hydro. The plant is simple and robust, offering lower efficiency and depends on regular maintenance by local people. A similar phenomenon has occurred in Pakistan, where local people are voluntarily involved in implementation, management and operation so that costs have been reduced dramatically to a range of Rs.8,000-16,000/kW, [9]. Civil works are constructed completely by local people which minimises the construction labour costs. Co-operation from local people has been the key to keeping costs down. So far in India local people have been more reluctant to become involved in the implementation and running of sites. Compensation is frequently requested for land disturbed by construction, with local people demanding large payment for carrying equipment to the site. MHP developers in India should assess how cost reductions might be achieved by encouraging community involvement.

4.3. Co-ordination of SHP and MHP Programmes

It appropriate to consider the role that Non Government Organisations (NGOs) or voluntary agencies can play in organising the villagers and in educating them of the advantages of rural development in harmony with preservation of the environment. Before an MHP project is developed education of the rural people in the merits of electricity supplies, and the associated benefits to themselves, could create an eagerness to attain this technology and a willingness to participate in implementation. Extension work by NGOs/voluntary groups for this purpose could be effective in stimulating community involvement and might also encourage the productive end use of the power once it is available. In the existing socio-political scenario, beneficiary participation in the development activity is best provided through the NGOs and voluntary organisations. Until there are equally flexible government bodies who might undertake these activities it is to be hoped that government will assist and encourage such organisations and channel funds to the rural poor through these agencies.

5. Site Selection

Conditions in the Himalayas frustrate the development of MHP in the hill regions. These must be anticipated and overcome by innovative means and project planning must utilise past experience learned in the design and implementation of past sites.

5.1. Planning for site selection

So far site selection for MHP in the Indian hill region has been conducted on a fairly ad hoc basis. If the MHP programme is to be accelerated, careful planning and guidelines for identifying priority sites for development will be essential to optimise the benefit of new schemes and at the same time reducing environmental impact. There must be greater co-ordination of rural grid expansion and location of MHP schemes, with the role of MHP within RE plans clearly defined - both to reach the most remote communities and to supplement the grid at weak points. Also, the increasing necessity to incorporate environmental conservation in rural energy planning has highlighted the need for the application new and renewable sources of energy. Finally, the ultimate aim of RE must include rural socio-economic upliftment. MHP schemes have the potential to become a focal point of development

5.2. DPRs and project approval

The DNES is to provide grants for the preparation, by contractors, of Detailed Project Reports (DPR) on potential MHP sites. This will provide a list of projects from which to choose sites for implementation. The DNES criteria for approval of MHP schemes is that they should be more cost effective than the alternatives of rural grid extension or small diesel generation. Unrealistic figures of capital cost and potential load in DPRs may lead to the approval of less viable sites. This can lead to shortfalls in the provision of funds and therefore delays in construction, which must be avoided. Extracts from H.P. State Electricity Board records, in table 5.2a show where this delays have occurred in SHP schemes in Himachal Pradesh,[10]. Under utilisation of plants as a result of overestimated loads is also common. Table 5.2b shows examples taken from U.P.S.E.B Board records, [11].

Project	Capacity (MW)	Cost (Million Rs.) Time (Years)	Original Estimate	Actual Likely	Overrun (%) Years
Binwa	6	Cost Time	43.2 4	144.6 7	204 3
Andhra	17	Cost Time	97.4 4	259.6 8	166 4
Rongtong	2	Cost Time	36.2 5	151.2 9	318 4

Table 5.2a - Cost and Time Overruns of Some Projects in Himachal Pradesh

Site	Capacity (kW)	**Assumed** production (kWh/year)	Load factor (%)	**Actual** production (kWh/year)	Load factor (%)
Terali	400	2,000,000	60	1,200,000	34
Guptakashi	200	453,000	26	320,000	18
Tilwara	200	770,000	44	285,000	16
Tapovan	800	2,000,000	30	600,000	8.5

Table 5.2b - Assumed and Actual Generation for Projects in U.P.

As costs are reduced rural loads are consolidated these problems will reduce. Also, comparison of MHP with the alternative sources of electricity on a broader basis than cost alone could improve the case for many MHP projects. For example, the large line losses in RE transmission, the reliability of the grid supply as compared to that of MHP plants, and the potential environmental impact should all be considered in the assessment.

6. MHP and Total Rural Development

In order to achieve the dual objectives of MHP projects of socio-economic advancement of the rural people, and provision of cost effective power supply a "Total Development" approach must be taken. The MHP should not be implemented in isolation, but as part of an overall rural community development scheme. In the hill region RE has failed to have a significant impact on the rural economies. It was originally assumed that supplying electrical power would automatically lead to proliferation of new and improved economic activity, and that benefits would percolate down to the weaker sections of the community. This simply has not happened, as an Uttar Pradesh Development Systems Corporation (UPDESCO) report in 1981 analysis of the socio-economic impact of RE programme in the Uttar Pradesh hill district shows that the agricultural and industrial load only accounted for 15% and 7% of the planned capacity, respectively, and only 17% of expected domestic connections were taken up. Similarly, in 1986 a NCEAR report on the RE in Uttar Pradesh state concluded that in rural areas "there is no impact of electrification on industrialisation" and states the main reason for this is a lack of "complementary inputs".

Within the constraints of the Himalayan region, co-operation between utilities, rural development organisations and rural people is essential for genuine rural development to occur along with RE. This should include education and training, identification and implementation of viable economic activities such as food processing and cottage industries, availability of suitable financing facilities and development of community social services such as health care, schools, community centres and supply of drinking water. Initiative from grass roots level is very important as it is the actual needs of the village people that must be addressed, not those perceived or assumed by outsiders. It has been suggested that the MHP programme should include encouragement to cook using electricity. This would first reduce the dependence on the use of fuel wood, while at the same time increase the day time load on the MHP plants. If this is to be seriously undertaken, a considerable subsidy will be required as an incentive to rural people to replace their traditional chulas with electric cookers. Not only will the cooker itself have to be very low cost, but the electricity tariff must be made free or at best a nominal charge, which the beneficiaries are willing to pay, as the traditional cooking fuel, fuelwood, is effectively cost free. It is unlikely that rural people will be willing to adopt more costly alternative. Also, basic training will be required for women be able to adapt to the new cooking methods.

The "Total Development" concept and MHP development are actively mutually complementary. Not only will total development improve the loading on MHP plants, hence reducing generation cost but MHP plants as decentralised, self sustaining units, give a focus for rural development. If local people can perceive the advantages of MHP through total development, community involvement should be more forthcoming. Total development requires specific incentives for the weaker sections of the community, through realistic tariffs, education and well directed development activities. It was shown in the UPDESCO report that in the district of Uttar Kashi connections by scheduled caste and tribal people were significantly higher than in other hill district of UP as a direct effort was made to encourage power uptake among the weaker sections of the communities. An example of a site where the ideas of total development have been incorporated is at the NEDA 100 kW site at Kokhta, in Dehradun district, scheduled to be commissioned this year. From the initiation of the project discussions were held with local people. These interactions resulted in the development of a tariff system suited to local economic conditions, with a special tariff for scheduled/tribal households. Also methods of local development were discussed. Consequently, 550 domestic connections have been taken up, half by scheduled castes and tribal people. Three flour mills and a saw mill are to be electrified and two cottage industries are to be started. Administration, operation and maintenance of the plant will be the responsibility of the local consumer co-operative. While the scheme will work as an independent unit, NEDA will continue to provide technical guidance and assistance as required.

7. Financial Support for the MHP Programme

The MHP programme will require initial subsidies, as well as appropriate and accessible sources of finance. Financial support will be required both for the implementation of MHP schemes and to encourage the development of productive end-uses of the power. The low purchasing power of the rural people means that they cannot carry the financial burden of initiating these projects without aid. Financial assistance should especially target the poorest and weakest members of the society to ensure they obtain an equitable share of the benefits of the power supply. Ideally, financial support should be gradually phased out to leave a self sustaining, productive community system. Presently the DNES are giving priority status to MHP sites which serve remote communities and have a significant effect on the economies of hill villages. However, direct capital subsidies from the DNES is only given in very specific circumstances. The main means by which DNES finances SHP projects is in the form of interest subsidies on loans given through the Indian Renewable Energy Development Agency, a public sector corporation. NEDA sites currently receive a 100% subsidy on capital cost from the state government as these are viewed as a social service to rural communities and not as commercial activities.

8. Conclusions and Recommendations

A sound, practical policy is required to ensure the effective dissemination of MHP schemes in the Indian Himalayan region, which requires a holistic view of the role for MHP within hill development plans. MHP cannot be approached in an insular way, with arbitrary targets, but should be integrated into a wider planning perspective. The following recommendations are proposed to optimise the impact of MHP development:-

- Appropriate design perspectives for small, mini and micro hydro must be adopted, where possible, by taking a conceptual step away from conventional methods.

- Local turbine manufacturers must be encouraged to produce equipment in the micro-hydro range, to assist in the creation of a competitive market and associated reduction in machinery costs.

- For micro hydro less sophisticated plant should be considered and there should be high community involvement in the project, as successfully used in other developing countries.

- The design of the MHP should be adapted to the rural environment through the use of innovative ideas and by incorporation of a knowledge feedback process in project planning.

- Realistic site selection and project approval procedures should be instated within the framework of rural electrification, environmental protection and rural development objectives.

- MHP should be conceived as a focal point of total development for rural communities to improve plant load factor, and to provide rural socio-economic upliftment.

- Subsidies and financial assistance should be made available to establish MHP schemes to give benefit to the weakest sections of the community and to establish productive, self sustaining demand for power, ultimately rendering projects self supporting.

- NGOs/voluntary organisations should be involved in the education of rural communities in the advantages of electrical power with the aim of increasing the acceptance of the new technology and encouraging active participation of local people in the implementation of the scheme.

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