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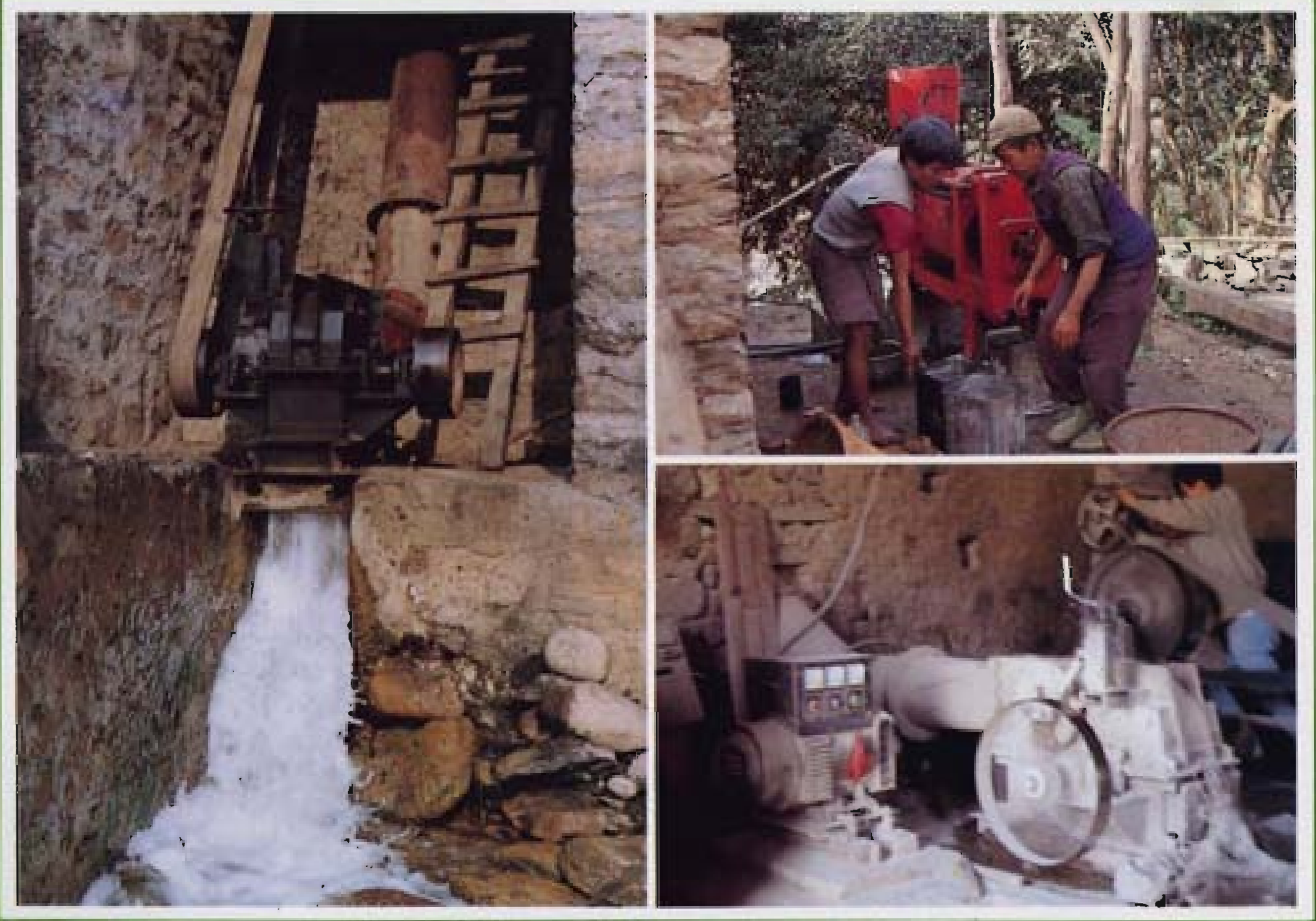
International Centre for Integrated
Mountain Development

MINI- AND MICRO-HYDROPOWER IN NEPAL



Jean-Marion Aitken
Godfrey Cromwell
Gregory Wishart

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Mini- and Micro-Hydropower in Nepal

Jean-Marion Aitken
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Gregory Wishart

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Foreword

Energy plays a significant role in the economic development and technological advancement of societies and, concommitant with these, it plays a crucial role in human welfare. These aspects of energy were focussed upon during the Inaugural Symposium of ICIMOD in December 1983 and in the subsequent consultations, held in the countries of the Hindu Kush-Himalayan Region, where the question of energy supply and demand ranked high on the list of urgent priorities for sustainable mountain development.

Increased energy demand has not only exerted substantial pressure on Nepal's limited forest resources but also has a negative effect on its environment and economy. Nepal has no fossil fuel of its own and all requirements have to be imported. The search for other options, such as biogas, indicates that they have limited application in the more isolated and high altitude mountain areas. Renewable options, such as wind and solar power, are not technologically ready for mass dissemination. The use of mini-and micro-hydroelectricity is, therefore, the most promising option for the remote hill communities in Nepal for the foreseeable future.

Nepal's experience in the use of mini-and micro-hydro plants (MHP) is derived partly from government programmes for rural development and partly from private and community commercial ventures. In the context of public sector enterprises, MHP were seen as a means to stimulate industrial growth, bring about social benefits, and improve communications and the well-being of people in the remote areas. The lack of productive commercial end uses has been seen as one of the main drawbacks resulting in the low profitability of these installations. Private sector installations, on the other hand, initially sought to fulfill the existing need for agro-processing and electricity generation was added on subsequently. This resulted in better integration of the technology with the local economy and fuller utilisation of the advantages offered by micro-hydro technology.

This report has made a comprehensive study of the development of MHP in Nepal. This has been supplemented by examples from other countries. In the context of Nepal, the decentralised approach, as inherent in MHP programmes, is in line with the government policies for rural development through the decentralisation of the administration. The report has highlighted some of the principal issues to be addressed in order to ensure that MHP fulfills its crucial role in meeting the energy needs of rural communities. These issues include lack of clear-cut, overall government objectives, debate over types of subsidies, and the problems of scale.

ICIMOD is publishing this report on Mini-and Micro-hydropower in Nepal as a part of its Occasional Paper Series. There is no doubt that the knowledge and expertise acquired by ITDG from over more than a decade's experience in the development and transfer of MHP technology, for the purpose of rural development in the mountain regions of Nepal, will be useful to those involved in MHP development in the Hindu Kush-Himalayan Region and to others associated with such activities in mountain regions elsewhere. Special thanks are due to Jean-Marion Aitken, Godfrey Cromwell, and Gregory Wishart for their work in preparing this account of Nepal's experiences in the exploitation of its hydropower resources.

Dr. E. F. Tacke
Director General

Preface

Nepal has a long history of water management including a very large number of village water mills for corn grinding. The harnessing of water power on a small-scale has recently become an increasingly important aspect of rural energy supply, particularly in remote mountain areas of the country.

ICIMOD has identified mini- and micro-hydropower as an important area of interest in its search for integrated approaches to the institutional, environmental, and economic development of the Himalayan Region.

ITDG has been involved for more than a decade in assisting the development and transfer of micro-hydro technology as a tool for rural development in the hill and mountain areas of Nepal.

This paper is a synthesis of knowledge and experience in Nepal's mini- and micro-hydro sectors. We hope that it will be an important contribution to current debates concerning the use of the resources of the Himalayan Region to promote sustainable rural development.

Ray Holland
Operations Director
ITDG

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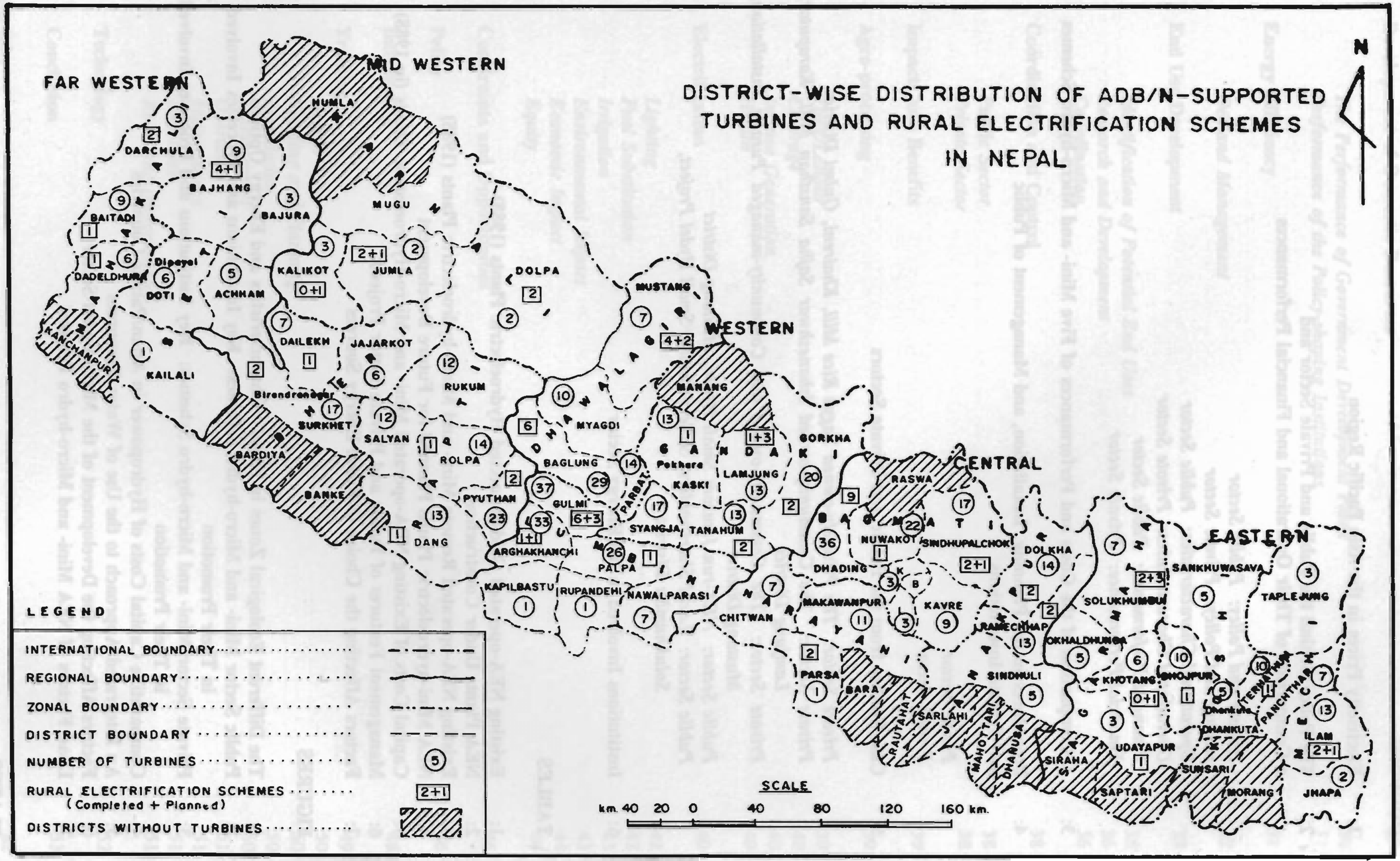

DISTRICT-WISE DISTRIBUTION OF ADB/N-SUPPORTED TURBINES AND RURAL ELECTRIFICATION SCHEMES IN NEPAL

Source: Agricultural Development Bank, Nepal, 1990

I. Introduction*

The supply of energy is often a major constraining factor in the development of a country's economy. Many developing countries spend a large proportion of their development budgets on energy, and, while the developed nations debate the sustainability of fossil fuel sources, for many developing countries the sustainability of these energy sources is more immediately a question of funds with which to buy them. This is the case in Nepal.

Nepal has no exploitable fossil fuel resources and dependence on imports has become both a strain on the economy and a point of vulnerability, as the trade dispute with India in 1989 revealed. His Majesty's Government of Nepal (HMG/N) has given energy supply a high priority in its plans for the country's development, and, since the oil crisis in the 1970s, has shown increasing interest in and support for hydroelectricity as an energy source. This report attempts to assess the use that has been made of hydropower (both mechanical and electric) to date; the relative success of the public and private sector installations, compared to each other and the experience of other countries; issues in the development of the country's hydropower resources; and means by which the role of hydropower in the country's development can be increased.

The first hydroelectric installation in Nepal was built in 1911, but after that there was little further development until the 1960s. The oil crisis then rapidly accelerated the rate of installation of hydroelectric projects as concern over the sustainability of energy sources led to greater enthusiasm for hydroelectricity. At the same time, the Government became concerned with improving its administrative structure around the country and with trying to divert resources from the Centre to the periphery to encourage decentralised economic growth.

Nepal is situated along the Himalayan Range of mountains. Isolated communities are scattered throughout the foothills, their inaccessibility hampering attempts to develop the infrastructure and productive base of the country. Electricity supply was seen as a means to stimulate industrial growth, bring social benefits (such as improved literacy and health), improve communications, encourage government staff to work in the remote areas, and bring these isolated communities into contact with the outside world.

Hydroelectricity in particular was to be the means of achieving the above, while relieving the strain on the country's environment and budget by substituting for fuelwood and kerosene respectively. Detailed research on the environmental, social, and economic impact of hydropower, and in particular hydroelectricity, was beyond the scope of this report. The available information is assessed, however, and the costs, benefits, and implications of hydropower are discussed in terms of all these aspects.

The Small Hydro Development Board (SHDB) was formed in 1975 to implement small hydro installations in the remote areas, usually at district centres. It was unable to fulfill its very ambitious plan of action and the installations that were built have not performed as well as expected either in technical or in financial terms. This is understandable since the country had little experience of hydroelectrification to build on.

In comparison with the experience of other countries the targets were unrealistically high, especially given the lack of supporting infrastructure. Figures from other developing countries' electrification programmes show that Nepal's programmes have produced electricity at a comparable cost per kilowatt, and, in the private sector, even at a lower cost than other countries.

Failure to reach technical and financial targets was largely due to the over-ambitious nature of the SHDB's targets and also to the lack of overall coordination and forward planning in the sector. The rush to commission new sites led to an emphasis on individual projects without the collection of necessary support data or an attempt to develop an integrated design rationale for these small hydro projects. Similarly,

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[*] Figures and Tables without credit lines are compiled by the author(s).

there has been little analysis of data from sites once they have been commissioned, which would have enabled lessons to be learned from early technical and managerial failures.

Electrification was also expected to lead to industrial and social development around the Nepal Electricity Authority (NEA) installations. It was assumed that local productive enterprises would arise with the coming of electricity and that this would not only improve the local economy but also, through increasing the load during the day when light is not required, improve the load factor of installations. Again, comparison with the experiences of other developing countries has shown that this is not generally the case.

Where there is a reasonable standard of infrastructure already present, and a relatively wealthy local economy, electrification has led to industrial growth, but, where the pre-conditions are not fulfilled and access to market, sources of credit, raw materials, and technical advice are not present, electrification is unlikely to create any industries.

The lack of productive end uses has been seen as one of the main causes of low load factors and the poor profitability of NEA installations. There has been no coordinated attempt to develop these, however, perhaps because the area is a large and diffuse one requiring a combination of many different technical skills and considerable inputs of time and funding.

At the same time, hydropower was also developing in the non-government sector, initially for mechanically driven agro-processing rather than electricity generation. The industry arose from the traditional use of water power for grinding grain. Non-government organisations (NGOs) working with local manufacturers developed an improved version of the traditional *ghatta*, the "Multi Purpose Power Unit" (MPPU) and also transferred technology from abroad for more efficient and powerful crossflow and Pelton turbines.

These turbines were disseminated with little direct government intervention, although many were financed with credit from the Agricultural Development Bank of Nepal (ADB/N), a government corporation. They were bought by local entrepreneurs as a means of income-generation, and the growing demand for them, and consequent expansion of the micro-hydro manufacturing sector, are evidence of their success.

Initially, few of these installations generated electricity because of the complicated restrictions governing the sale of electricity by private owners. As disappointment in the government sector's performance grew, however, and it became apparent that the SHDB's targets would not be reached, interest turned to the apparently more successful private sector and in 1984 it was decided to delicense all electricity installations under 100 kilowatt capacity.

This move was a turning point in the mini- and micro-hydropower sector in Nepal. The freeing of restrictions led rapidly to the installation of add-on generators at many mill sites, producing electricity usually only in the evenings when the hydropower was not needed for milling.

This trend was further supported in the financial year (FY) 1985/6 when the Government announced a subsidy on the electrification costs of private installations: 50 per cent of the costs of generator and electromechanical parts (75 per cent in the remote areas). This subsidy was very successful in that it made electrification more financially attractive and, in a growing number of cases, viable on its own without the support of the profitable milling activities. In areas where there were already sufficient mills, stand-alone electrification installations have begun to appear.

This report covers mini- and micro-hydropower, mechanical and electrical, and it is important to remember that many private installations do not yet produce electricity. Nonetheless, the report concentrates on hydroelectric power, since it is in this area that the debate about the national potential of hydropower, and the discussion concerning whether the public or private sectors should produce it, are centred.

The apparent success of the non-government sector in comparison with the escalating costs of the NEA projects (which have cost more in capital costs and considerably more in running costs than envisaged) has led to disillusionment with government-run mini- and micro-hydro projects and suggestions that in future the Government should concentrate on larger projects to supply to the grid and leave the mini- and micro-hydro projects to the private sector.

On first inspection this would seem to be a more effective use of available government budgets, since the load factor of the grid supply is much higher and the apparent costs of mini- and micro-hydro are so high. A more careful inspection of existing government subsidies shows that the decision is not so simple, however. Alternatives to mini- and micro-hydroelectricity, including grid electricity, are subsidised by the Government and, when the additional costs of the necessary infrastructural back-up are taken into consideration, the cost advantage of the grid is not so clear cut.

In examining the country's energy resources, the local context and the needs of the hill communities must be taken into account. Government policies had targetted the rural areas for development through the Basic Needs' Programme and decentralisation of the administration. The programme for electrifying the District Headquarters reflects the desire to target resources to the more remote areas.

Mini- and micro-hydro systems are appropriate in these situations. They use a renewable and non-polluting source of energy which is commonly available in remote areas. As the private sector has shown, these small-scale sites are well within the capacity of local people to construct and manage. In fact, the advantages conferred by their small scale allow them to produce electricity more cheaply than the larger NEA installations of over 100kW could.

Traditional energy sources in the hills consist mainly of human and animal power and biomass. Concern over growing deforestation around population centres has led to many measures that attempt to stem the rate of forest depletion. Improved access to electricity and low-cost electrical appliances may enable substitution of electric energy for fuelwood in cooking and heating uses. Low-wattage cookers have been introduced with initial success in districts such as Mustang where traditional wood fuel is very scarce and needed in large quantities in the winter.

It would be prohibitively expensive to extend the grid to all the hill communities, and, while other options such as biogas and diesel have potential in more populated areas, such as the southern plains, they are not appropriate for the more isolated hill and mountain districts.

Renewable options, such as wind and solar power, have potential for the decentralised production of energy, but the frequency of suitable sites is low compared with those suitable for hydropower. On cost grounds these alternatives are also less suitable for mass dissemination. Mini- and micro-hydroelectricity is therefore the only practical option at present for these remote communities in the Himalayan foothills and is likely to remain so for some time to come.

Experiences in Norway and China, which have large hydropower sectors and which also have to cope with the problems of supplying remote rural communities, have shown that micro-hydro installations can form the basis of an expanding and successful rural electricity supply. However, creating the environment in which this can happen and directing progress to ensure that it supports the nation's development goals require clear policies and directions from the Government. These will be the key to success in the future of the mini- and micro-hydro sector in Nepal.

This report highlights the principal issues that should be considered by government policy-makers and discusses the present constraints to the development of the sector which future policy must address. There is a great need to clarify the Government's overall objectives in its energy policy. If rural electrification is seen by the Government as a desirable means of slowing down environmental degradation and bringing social and economic development to the remote regions of Nepal, it must be prepared to support these installations financially, at least in the medium term.

In Norway and China, remote sites were subsidised for many years. It was recognised that some plants were not operating under conditions in which they could be financially profitable, yet the social, environmental, and economic benefits they were perceived to bring the country were felt to be more valuable than the financial cost incurred. There has been confusion about the benefits that can be gained from electrification (social, financial, or environmental) and the different conditions under which these can be expected.

If rural electrification through public sector installations is to be promoted in Nepal, on the grounds of its perceived social and environmental benefits, then it cannot be expected to make a financial profit as well. Unreasonable expectations have, above all, been responsible for the apparent failures in the sector.

It is very important here to differentiate between the diverging objectives of the public and private sectors. In general, the private sector consists of small entrepreneurs pursuing a financially profitable venture, while the public sector is seen as a means of implementing broader policy objectives which often do not relate, or only relate in part, to profit.

Realistic planning can only be achieved when accurate information about performance, technical problems, and local resources is available. The report discusses the types of information that should be gathered and how they should be made available to planners and project designers.

The information should be used to establish basic standards for equipment and construction which can then be used to guide further project design. One of the advantages the private sector has had over the public is that it uses equipment that is made or obtained locally, is fairly standard in design, and can be repaired by operators on-site or by the Nepalese manufacturer. In contrast, the emphasis on speed of installation and the involvement of different donor agencies have led to much diversity in the public sector. Donors have often specified electro-mechanical equipment and sensitive governing devices from their own countries which have then proved difficult to maintain and, because of the lack of standardisation, much time is lost while spare parts, and even technicians, are brought from abroad.

Once objectives and priorities are clarified, resources must be allocated. The report describes the way subsidies have been used in Nepal and other countries to encourage and expand certain sectors and discusses how energy efficiency and the cost-effectiveness of the sector could be improved by redirecting subsidies. Increased assistance to manufacturers, for developing and producing more efficient devices and storage appliances, should help to reduce and spread demand so that the existing capacity is better utilised. A shift in tariff setting to cover running costs should at least reduce the on-going costs to the Central Government.

If rural industrialisation is one of the objectives of electricity supply, adequate resources must be channelled to the sector. This will require an integrated energy assessment of the needs of villages and investigation of potential end uses on a site-specific basis. The technical development, business advice, and other infrastructural inputs necessary for rural industrialisation should be developed independently of the micro-hydro sector, but micro-hydro should be kept in mind as a potential energy source. The approach should not be that of an energy source looking for applications, but of a comprehensive, integrated rural industrialisation programme closely linked to energy production programmes.

Management of projects is one area in which the public sector can learn many lessons from private experience. The report discusses how restructuring the management of the NEA, to allow the on-site managers more authority for day-to-day decision-making and the allocation of funds, would facilitate a more responsive management, greater local involvement, and less time lost because of breakdowns.

Training is an area in which both sectors would benefit from a greater and better targetted input. Growth in the sector has been accompanied by the development of many skills within the country, but before attempts are made to upgrade the scale of installations further, existing training needs must be answered. Improvement of design, construction, and management standards can only be achieved once there is a skilled base of workers able to understand and uphold them.

All these issues must be addressed if effective policy is to be made and the existing constraints overcome. The report discusses which institutions are best placed to contribute to this and how their efforts could best be coordinated. In terms of hydropower potential, Nepal is one of the richest countries in the world. Although progress to date has sometimes been seen as disappointing, this is not generally due to problems inherent in the nature of hydropower. There is clear evidence that mini- and micro-hydropower can be a dynamic and effective force for rural development. There are many lessons to be learned from a closer examination of the situation and many opportunities for the development of a strong and financially viable sector that could contribute greatly to the development of the country in a sustainable and environmentally-sound manner. In order to derive maximum benefit from these opportunities, clear policy guidelines and targetted public sector investment are essential. The timely provision of, and support for, key inputs, through the use of government and international funds, will ensure that the micro-hydro sector achieves its full potential in contributing to the growth of Nepal's remote areas.

II. The Development of Hydropower in Nepal

The Context of Hydropower in Nepal

Hydropower, in the form of the traditional, vertical axis water wheel (*ghatta*) has been in use in Nepal for centuries. The *ghatta*, made entirely of local materials, provided the only form of mechanised agro-processing in Nepalese villages until the arrival of diesel-powered mills. Despite its low output (about 1 kW), it is still widely used in the hill villages where there are estimated to be 25,000 working at present (GATE 1988).

The first hydroelectric installation in Nepal was the 500kW turbine at Pharping, built in 1911 to supply electricity to Kathmandu. Another installation (900 kW then, 640 kW now) followed at Sundarijal in 1934, but hydropower generation was not a government priority and no more installations were built until the 1960s.

Since then, the provision of electricity has come to be seen as an essential requirement in the modernisation of Nepal's economy and, between 1965 and 1975, five government hydro plants were commissioned, bringing installed capacity to 36 MW. In the following decade the installed capacity of government-operated hydro stations rose sharply to a total of 161 MW by the financial year 1986/7. Installations of 10 MW and more now make up almost 95 per cent of the total installed capacity of government-operated hydro plants (Tables 1,2, and 3).

Although the trend in government installations has been a marked increase in scale, efforts have also been made to upgrade the availability of services in remote areas, particularly to district administrative centres. This led to the creation of the Small Hydel Development Board (SHDB) in 1975 to manage the installation and operation of small, government hydropower projects (up to 5000 kW) in remote areas of Nepal. By 1988 fifteen remote installations had been commissioned, ranging from 32 kW to 240 kW (see Tables 3 and 4) and a further six were reported to be producing electricity in 1989 (Shrestha 1989). Nevertheless, in FY 1985/6 remote government plants generated only 2.44 GWh, less than 1 per cent of the total government electricity generation.

During this time, interest in privately-owned hydropower was growing. As early as 1962, a locally manufactured 5kW propeller turbine was installed in the Kathmandu Valley. A further seven such turbines were reportedly installed, powering agro-processing machinery, but problems with the design led to the temporary abandonment of the project and investigation of alternative turbine types. By 1976 the cross-flow design was gaining acceptance as a more appropriate turbine for sites in the mid-hill regions of Nepal.

Two organisations, Balaju Yantrashala (BYS) and Development and Consulting Services (DCS), played central roles in developing and producing the crossflow turbines. A further seven smaller manufacturers also produce crossflow turbines in Nepal and the total number of non-SHDB cross-flow installations reached 423 in FY 1987/8 (Jantzen and Koirala 1989). In parallel with the development of the crossflow turbine, the Kathmandu Metal Industries (KMI) developed a more powerful form of the traditional *ghatta* using metal components. This turbine became known as the MPPU (multipurpose power unit). For an equivalent power output, its capital cost is about 60 per cent that of a crossflow turbine and, although its efficiency is much lower, it has been very popular where cost is of prime importance. A total of 167 MPPUs were installed by FY 1987/8.

Other turbine designs, such as the Pelton, have also been produced and by 1988 a total of over 600 turbines (total capacity 5.5 MW) were installed at non-government sites. Unlike the government sites, however, over 90 per cent of the private installations were used, primarily to produce mechanical power for agro-processing (GATE 1988), particularly grain milling, rice husking, and oil expelling. Other end uses include beaten rice machines, sawmills, and air compressors on mining sites.

NEA HYDROELECTRIC PROJECTS

Table 1: Existing NEA-operated Grid-connected Hydroelectric Plants (1988)

Plant	Type	Year of Commission	Installed Capacity (MW)
Sundarijal	Storage Reservoir	1934	0.64
Panauti	Run-of-river	1965	2.40
Trisuli	Run-of-river	1967	21.00
Phewa	Storage Reservoir	1967	1.09
Tinau	Run-of-river	1972	1.02
Sun Kosi	Run-of-river	1972	10.05
Gandaki	Canal Drop	1979	15.00
Kulekhani I	Storage Reservoir	1986	60.00
Devighat	Run-of-river	1983	14.10
Seti	Canal Drop	1985	1.50
Kulekhani II	Storage Reservoir	1986	32.00
Total Capacity (including diesel):	190 MW (installed) 169 MW (firm)		
Plants Under Construction			
Marsyangdi	Run-of-river	1990*	69.0
Andhi Khola a)	Run-of-river	1990*	5.10

Source: Warnock 1989

Note:

* expected date of commissioning

a) operated by Butwal Power Company and to be connected to the grid to sell surplus power to NEA.

Table 2: NEA Plants Under Construction

Plant	Development Region	District	Installed Capacity (kW)
Namche	East	Solukhumbu	1000
Accham	Far-West	Accham	600
Bajhang	Far-West	Bajhang	400
Bajura	Far-West	Bajura	200
Serpodaha	Mid-West	Rukum	200
Surnayagad	Far-West	Baitadi	200
Darchula No. 2	Far-West	Darchula	200
Arughat	West	Gorkha	150
Okhaldhunga	East	Okhaldhunga	125
Ruplagad	Far-West	Dadeldhura	100

Source: Shrestha 1989

Table 3: Existing NEA-operated Remote Mini- and Micro-Hydroelectric Plants (1988)

Plant	Development Region	District	Year of Commission	Installed Capacity (kW)
Dhankuta	East	Dhankuta	1971	240
Surkhet	Mid-West	Surkhet	1977	345[1]
Baglung	West	Baglung	1981	175
Doti	Far-West	Doti	1981	200
Phidim	East	Panchthar	1982	240
Dhading	Central	Dhading	1982	32
Gorke	East	Ilam	1982	64
Jomsom	West	Mustang	1983	240
Jumla	Mid-West	Jumla	1983	200
Syangja	West	Syangja	1984	80
Helambu	Central	Sindhupalchowk	1986	50
Salleri-Chialsa	East	Solukhumbu	1986	200
Darchula	Far-West	Darchula	1986	50[2]
Chame	West	Manang	1987	45
Manang	West	Manang	1988	80
Bhojpur a)	East	Bhojpur	1989	250
Khandbari a)	East	Sankhuwasabha	1989	250
Chaurjhari a)	Mid-West	Jajarkot	1989	150
Taplejung a)	East	Taplejung	1989	125
Terhathum a)	East	Terhathum	1989	100
Ramechhap a)	Central	Ramechhap	1989	75

Total Capacity: 950 kW (installed)

Source: Shrestha 1989

Note: a) : Plants generating power by April 1989 (NEA)
[1] : Surkhet grid-connection in FY 1988/89
[2] : First stage only

Table 4: NEA Mini-Hydroelectric Plants Planned for Future Development

Plant	Development Region	District	Status	Expected Installed Capacity (kW)
Diktel	East	Khotang	Detailed Design	500
Lomangthang	West	Mustang	Detailed Design	65
Sirse Gad	Far-West	Dadeldhura	Feasibility Study	240
Shivalaya	Central	Nuwakot	Feasibility Study	130
Dhung Gad	Far-West	Baitadi	Feasibility Study	200
Lukla	East	Solukhumbu	Feasibility Study	110
Dhandruk-Dhansing	West	Kaski	Feasibility Study	140
Godsera	Far-West	Doti	Feasibility Study	150
Dialekh	Mid-West	Dailekh	Feasibility Study	272
Kalikot	Mid-West	Kalikot	Feasibility Study	220
Dunai	Mid-West	Dolpa	Feasibility Study	130

Source: Shrestha 1989

Over 20 per cent of these turbines produce electricity using either add-on or stand-alone generators, and the total capacity of private electricity generation was around 750 kW in 1987/8.

Turbines have now been installed in almost all hill and mountain districts (see frontispiece). In some areas, particularly those close to turbine manufacturers' workshops (in other words, around Kathmandu and Butwal) demand is falling as suitable sites are filled. Other areas, however, have few turbines relative to potential demand and if installation continues at the present rate of 60 to 80 turbines a year, the market for privately and community-owned mills is expected to continue for the next 15 to 20 years.

The Role of Hydropower in the Development of Nepal's Hills

Current Energy Usage

Nepal has a predominantly agricultural economy and in 1987 over 92 per cent of its estimated 17.6 million inhabitants lived in the rural areas. The country rises from 200 metres to 8,500 metres above sea level and consists of three major ecological regions: the plains along the southern border with India (*Terai*), the middle hills, and the mountains. Only 17 per cent of Nepal's land area is cultivable and 54 per cent of this is in the *Terai* (Central Bureau of Statistics 1988). As agriculture accounts for more than 90 per cent of the labour force (and 65% of the GDP and 75% of exports - FY 1985/86) the population is densest in the *Terai*, with communities growing smaller and more scattered towards the north at higher altitudes.

Most rural communities still use traditional sources of energy; fuelwood, agricultural waste, and animal dung; to meet their energy demands. In 1987 use of these energy sources was estimated at 95.4 per cent of the total energy consumption (Central Bureau of Statistics 1988), of which over 90 per cent was for domestic use (almost exclusively for cooking).

Fuelwood, despite its importance in the total energy supply, is still available free in most areas of Nepal, although increasing population pressure and the associated expansion of cultivated areas and energy demands have apparently resulted in depletion of the forest resource base to a less than sustainable level (UNDP/ESCAP/EC 1987). Commercial sources of energy (fossil fuels and electricity) constitute less than 5 per cent of the total energy consumption. Distribution is severely constrained by Nepal's topography and limited infrastructure.

Energy Demands

Demands are changing and consumption of electricity has risen significantly over the past twenty years. The commissioning of Kulekhani I and other large hydro stations in the early 1980s enabled rapid expansion of supply and a dramatic growth in consumption (an average of 17% per annum between 1983 and 1987 [Central Bureau of Statistics 1988]). Hydroelectricity-generation capacity in Nepal has risen approximately two hundred fold over the last thirty years.

A smaller rate of growth is projected for the longer term: by the turn of the century Nepal's government-operated hydroelectric stations are expected to generate 1,613 GWh per annum from a projected, total installed capacity of 500 MW. It is very difficult to predict future demand for electricity and much will depend on trends in agricultural diversification, cottage industries, and tourism development all of which could induce significant demand. The cost per kWh of micro- and mini-hydro electricity is not fixed but depends on the system load factor. As capacity utilisation increases, costs per kWh are reduced, making electricity a more cost-effective power source.

In some areas of Nepal, electricity has also been supplied by government and private diesel plants. In FY 1986/7, total installed capacity of diesel plants was 38 MW. Some southern border areas are supplied with electricity from the Indian grid. A steam plant, with a total capacity of 5 MW, is also used by some larger industries (Central Bureau of Statistics 1988).

Distribution of the electricity has been largely restricted to the Kathmandu Valley and other easily accessible centres. The Central Development Region, which has 33 per cent of the Kingdom's population, consumes over 70 per cent of the total electricity supply. By contrast the Far Western Development Region with nearly 10 per cent of the population receives only 1.4 per cent of the supply.

Electricity consumption in Nepal remains among the lowest in the world: equivalent to one 60W bulb burning for one hour per day per person, about one-hundredth of equivalent consumption in developed countries (Flavin 1986).

Energy Sources

Almost no fossil fuel deposits have been identified in Nepal and dependence on imported commercial energy has placed an increasing demand on Nepal's foreign exchange resources. The rising demand for energy, in the context of a deteriorating balance of trade, has prompted investigation of local and renewable sources of energy.

Traditional energy sources, particularly fuelwood, will continue to meet most of Nepal's energy needs for at least the next two decades. This situation is reflected in His Majesty's Government of Nepal's prioritisation of the creation, conservation, and renewal of forestry resources (HMG/N 1985). The promotion of fuel-efficient cooking stoves is also intended to reduce fuelwood consumption.

Biogas plants already constitute a useful source of energy in some areas. Technical constraints, however, restrict their adoption to the *Terai* and low inland valleys. Furthermore, while over 1,600 plants were installed by FY 1984/5, and 4,000 more are planned for the next five-year period (HMG/N 1985), even full realisation of biogas potential (350,000 family size units) will meet only some 10 per cent of the total energy demand (UNDP/ESCAP/EC 1987).

The harnessing of solar, wind, and geothermal power can, at present, only be employed on a limited scale in specific locations. For certain applications (such as microwave repeater stations, water heating, and pumping), however, these systems may be appropriate, particularly in very remote sites.

Nepal's greatest energy potential lies in the exploitation of its immense water resources for hydropower generation. Although Nepal occupies only 3.3 per cent of the Indian sub-continent, annual runoff from its rivers accounts for 14 per cent and 17 per cent of the total discharge from the rivers of India and Bangladesh respectively (Warnock 1989).

A combination of annual runoff, approaching two hundred thousand million cubic metres, and many technically feasible sites gives Nepal one of the highest per capita hydro-energy potentials in the world. Theoretical hydro-potential, based on average flows, has been estimated at 83,000 MW (WEC Report 4/2/280684/1/1). Some 45,000 MW have been suggested as technically feasible, 95 per cent of which are said to be economically exploitable (Warnock 1989).

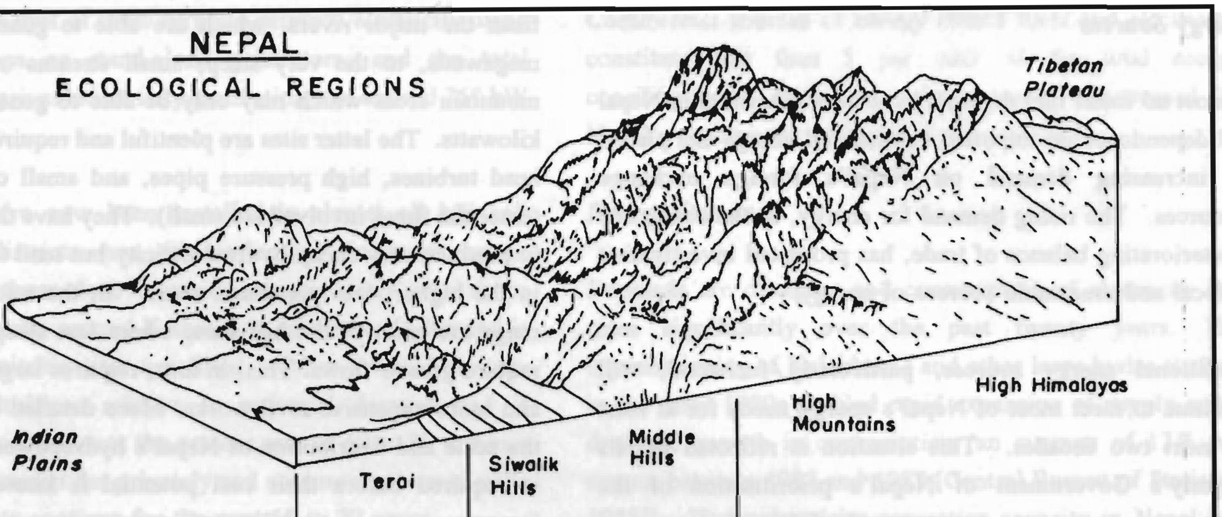
These figures encompass a variety of types or sites, ranging from the major rivers, which are able to generate many megawatts, to the very steep, small streams of the high mountain areas which may only be able to generate a few kilowatts. The latter sites are plentiful and require very high head turbines, high pressure pipes, and small civil works (since the flows involved are small). They have the potential to produce very cheap hydroelectricity but tend to be found in the higher, less populated areas. In the middle of the range are most of the hill sites, where less steep gradients require greater flows. This, in turn, requires larger turbines and more expensive civil works. More detailed analysis of the scale and distribution of Nepal's hydropower resources is required before their real potential is known and the importance or desirability of certain types of energy generation and end use technologies can be assessed. Despite this apparent abundance of renewable hydro energy, less than 200 MW has been harnessed to date (Central Bureau of Statistics 1988).

Thus, at present, hydroelectricity offers the only renewable energy option at present able to fulfill the growing demand for electricity in Nepal. In the scattered and often isolated communities of the middle hills, micro-hydro installations are usually the only viable option for the production of electrical and mechanical power to replace traditional sources.

The environment of Nepal's communities and their most appropriate sources of non-traditional energy change with the rise in altitude towards the north, as shown in Figure 1. In the *Terai*, where the population is much denser and roads and infrastructure easier to develop, biogas, diesel, and the grid are the most suitable forms of power. This changes drastically in the hills because there are few roads and fossil fuels must be carried in. As the population becomes less dense, grid extension over long distances and difficult terrain is also less viable and therefore decentralised mini- and micro-hydropower installations become more appropriate. Finally, at the highest altitudes and most remote sites, hydro and solar power become the most suitable options.

The Demand for Mini- and Micro-Hydroelectricity

Rural energy requirements are almost entirely met by traditional fuels, simple agro-processing technologies, and human or animal power. These remain the most accessible and affordable forms of energy for the vast majority of the rural population. Consequently, remote areas consume a very small amount of government-supplied electricity.



Population	Dense	Grouped	Scattered
Key features	Easy access Roads Imports accessible	Less easy access Some days walk from roads Imports more expensive	Difficult access A week or more from roads Imports impossible unless very portable
Energy options	Diesel/biogas	Diesel/hydro	Hydro/solar

Figure 1: The Different Ecological Zones in Nepal: Characteristics and Energy Options

Mini- and micro-hydro plants have been installed in the hills of Nepal, both as part of HMG/N programmes for rural development and as private and community commercial ventures. While the government projects have been concerned exclusively with the supply of electricity, mainly to administrative centres, the private sector installations generally drive agro-processing machinery directly and may or may not include an electricity generator.

The traditional water-powered technologies are not very powerful or efficient and can only power a very limited range of end uses. The advent of small-scale, diesel-powered agro-processing machinery allowed the replacement of some time-consuming and inefficient traditional methods of grinding, husking, and oil expelling. Despite the inherent difficulties of fuel supply, spare parts' availability, and servicing, several thousand diesel mills are now operating in the rural areas of Nepal. Their widespread use demonstrates the demand and the willingness to pay for more efficient and less physically demanding methods of energy supply in these areas.

The diesel mills require a supply of fossil fuels to be imported, often a costly and arduous process, but the upgraded hydro technologies now available (MPPUs and micro-hydro turbines) use water power - a renewable and locally-available resource. Like the diesel mills, these micro-hydropower installations allow a wider range of end uses than the traditional *ghatta* - including the generation of electricity. While the initial demand for the micro-hydro technology was for mechanical agro-processing, the demand for electricity generation, as an add-on to the mill or even on its own, is rapidly growing.

Electricity is popular: both with politicians and consumers. This fact above all has driven the rapid expansion of electrical supply in Nepal. Electricity is highly valued by consumers, both for its convenience and for its perceived effect on their status.

The demand is not usually financially motivated. At present, most of the supply is for "non-productive" uses, such as lighting and for fans and heaters, so electricity is not seen as an investment opportunity. The reasons for this low industrial demand will be discussed later in the report. Electric lighting may be cheaper than the imported kerosene for which it is a substitute, but often people will use more, because of the greater convenience, resulting in a larger lighting bill. The very high prices of Rs 60 per bulb per month (East Consult 1990), charged by some privately-owned micro-hydro installations, show that consumers may take factors other than financial costs and benefits into account in deciding what they are prepared to pay for electricity.

Exposure to electricity is an important factor affecting demand. After electricity arrives at the district centre, demand for it quickly grows in the outlying villages of the district. The pressure will increase with time as more and more potential consumers are exposed to electricity, either through travel or through the expansion of supplies.

Technological factors also affect the increasing demand for private micro-hydropower. The technology is now well-proven and, as more operators and manufacturers gain experience with it, a body of experience and skills is developing nationally.

Factors Affecting the Use of Mini- and Micro-Hydroelectricity

Use of a resource requires access to it and many would-be electricity consumers do not have access to a supply. Political factors are important in deciding where mini- and micro-hydro schemes will be built. Decisions regarding the siting of government installations and the allocation of subsidies for private installations are made at a high level. Local people may see opportunities but they may not be able to influence decision-makers at the appropriate level. The larger schemes involving more capital usually require credit - again its availability may be influenced by factors beyond the control of the local level.

One of the main reasons for the lack of industrial demand is the level of risk involved. Where a micro-hydro turbine is the sole source of electricity supply, end use investors are very vulnerable. There is potential for electrically-powered industry in the hills but there are many problems with the availability of credit, raw materials, markets, etc and power supply is not usually the only limiting factor. Lack of awareness regarding electricity and what it can be used for limits its consumption. Electricity can substitute for many of the traditional power sources: fuelwood (cooking and heating), kerosene (lighting), batteries (radios), but it will only displace them if the economic factors are right and the awareness of alternative uses is also present.

It has taken decades for electricity to establish its central role in the homes and economies of the more developed countries. Electricity was introduced in certain industries initially (fish factories in Norway, tea estates in Sri Lanka) and only gradually came to substitute for other energy sources as new applications and appliances were developed for it. It may be unreasonable to suppose that familiarity with electricity in the western world will dramatically reduce the time taken for its assimilation into other cultures and economies.

Electricity is radically different from traditional technologies and it will require training and institutional assistance to take advantage of its potential. The appropriate appliances may not be available. Questions of scale and priorities arise: should electrification be used to bring tourists and their money into the area by providing cold beers and hot showers, or to improve the quality and speed of existing local industries such as furniture making?

The Performance of the Public and Private Sectors

Although the management and objectives of micro-hydro projects in Nepal vary greatly between individual sites, they are most importantly determined by whether the site is government or privately operated. Annex 2 outlines the history of the government policies with regard to both sectors and shows that the objectives of the two sectors have differed from the start. Government-operated remote mini- and micro-hydro installations have been seen as a means of extending infrastructure to the remote areas of the country. Electrification was seen as a development tool which would bring social and environmental benefits to rural communities and to the nation as a whole. Somewhat ambitiously, it was also hoped that electrification would prove financially viable, covering at least its own running costs. Beyond this, the aims and objectives of the NEA mini- and micro-hydro schemes were never clearly expounded. This optimistic approach lacked a well-defined and co-ordinated strategy for the sector and is the cause of many of its subsequent problems.

Private sector electrification became more popular in 1984 when the Government recognised that lengthy bureaucratic procedures were stifling a potential growth area. Electrification on such a small scale was not feasible for the NEA and so sites under 100 kW were delicensed. It was this action which stimulated the growth of installations and manufacturers, and hence a local micro-hydroelectric industry. The private hydropower sector was not created in 1984, however. There were already crossflow turbines, MPPUs, and traditional *ghattas* running small commercial agro-processing services, some of them funded through the ADB/N. The aim of both the agro-processing and the electrification schemes is to make a profit and, thus, there is a focus on financial performance from the start.

Information. Mini- and micro-hydro projects in Nepal are designed by using unreliable and often extremely limited support information. Both public and private sector projects are frequently under or over-designed because information essential for project design is not available. This stems from the public sector's emphasis on individual projects rather than from a strategy for the sector as a whole. Little attention has been paid to the gathering and analysis of background information. There are few hydrological records, little appreciation of landslide risk, and insufficient geological information. Even topographical data are, in many cases, very limited. A recurring problem with the use of water from small streams in Nepal has been the absence of small catchment hydrological records.

The private sector has even less access to hydrological and other support information than the public sector and this leads to problems in project design. In general, these problems seem less severe than in the public sector. The reasons for this will be discussed later.

Planning and Design. Because of pressure from the start to meet ambitious electrification targets, SHDB concentrated almost exclusively on individual project planning. This has been exacerbated by the lack of a continuous line of funding for the sector. Various foreign donors have funded projects and each of them have brought to the work their own design specifications and requirements. This has led to disruptions within the programme. Without sufficient background information and no overall programme plans, project designs have often been poor. Common planning errors have included incorrect assessment of demands, the choice of unsuitable designs, and the establishment of plants requiring more water than is actually available. Problems have also been encountered as a result of incorrect assessments of irrigation requirements (WECS 1988).

The lack of clear guidelines and precedents in project design has made it hard to tackle issues such as donor over-specification and general design problems. Many installations are allowed to proceed through construction and into operation with unchallenged design deficiencies. For example, in an effort to reduce costs, designers have relied heavily on temporary intake structures. This may be adequate for irrigation projects, for which water is only required during certain months of the year (usually during low season flow), but is inadvisable where continuous plant operation is required. As a result, mini- and micro-hydro projects using this style of intake have poor supply records because of frequent outages during the wet season.

The design problems are less severe in private sector installations, partly because the projects have tended to be smaller and so the civil works are usually less complex and more manageable at the local level. Where failures in civil works do occur, they can usually be handled using local skills and techniques.

For larger private sector projects (greater than 20-30 kW), however, designs based on traditional irrigation technology have proved inadequate. As an example, the 40kW Bhorletar Project in Lamjung District requires expensive maintenance after every monsoon because of design deficiencies in the intake, canal, and forebay. This places a large financial burden on the owners.

Construction Standards. Large leakage losses are reported from a number of projects. Canals, in particular unlined earth and dry-lined stone channels, are prone to severe losses. Diversion of water for irrigation can also disrupt the smooth running of some projects. Many of the canals are also improperly protected from silt and require costly and time-consuming manual clearance. Improved silt traps and protection against water entering in from hillside slopes will be necessary to improve the performance of canals in future projects. These are all lessons that should be applied when considering future design plans.

There are large variations between projects in the quality of construction. The difficulty of attracting qualified NEA supervisors to the sites means that contractors generally work with little supervision. NEA, is therefore, largely dependent upon the skills of contractors to accomplish work of a suitable standard, and contractors are sometimes technically and managerially incapable of undertaking work of this nature in remote locations.

Examples of poor construction quality are common. Civil works, in particular, often require extensive maintenance and repair. This suggests either inadequate specification of materials at the design stage or improper site supervision during construction.

Projects described as operational are sometimes in poor condition only months after commissioning. NEA records that an installation in Manang was put into operation during 1988. In late 1988, however, the civil works required major remedial action, electro-mechanical equipment was incomplete, and the site had, to all intents and purposes, been abandoned.

The quality of construction directly affects the costs of operation and maintenance. It appears that, for some projects, if quality, particularly of civil works, had been better controlled during construction the mini- and micro-hydro plants currently operated by NEA would be less expensive to operate and maintain.

The quality of civil works' construction within the private sector is generally basic with a minimum cost approach being adopted by the owner. This is usually acceptable when the projects are very small (less than 10 kW). However, as the scale of a project increases, so does the risk that maintenance costs, other than labour, will be incurred. It is important that owners, manufacturers, and those responsible at ADB/N are made aware of the most cost-effective long-term approaches to construction. This may result in slightly higher construction costs but is likely to reduce maintenance outlay.

Construction Time. Construction periods for NEA installations have varied considerably and, although two to three years is usual, some projects have taken in excess of ten years to complete. A number of reasons has been given for this poor performance:

i) the difficulty of attracting experienced contractors to undertake work in remote areas;
ii) the difficulty of transporting construction material and equipment to remote areas;
iii) the lack of experienced personnel for supervisory duties in remote areas; and
iv) the lack of communication in remote areas (Shrestha/Pradhan 1985).

The use of inexperienced contractors has often resulted in serious delays since these firms consistently underestimate the difficulty and cost of operating in remote locations. Tenders priced 20 to 25 per cent lower than the NEA estimates are not uncommon (Shrestha/Pradhan 1985) and it is difficult to reject these quotations using the HMG/N tender evaluation criteria. Additional costs are incurred when new contractors have to be found after inexperienced contractors find themselves in financial difficulties and abandon projects in mid-contract.

The main delays in non-government project implementation occur during the loan consideration stage. Difficulties also arise when equipment has to be imported. Import licenses can be difficult to obtain, particularly for the manufacturers registered under the Cottage Industries' Act. More favourable consideration, by the Government, of manufacturers' requests for import licenses would reduce the difficulties faced by small manufacturers.

Equipment. Donors often stipulate the use of equipment from their own countries, or supply it at highly subsidised prices. This has resulted in equipment from at least five different countries at NEA installations - most of it requiring parts and maintenance and repair skills that are not available in Nepal. Donor specification of extremely accurate and sensitive governing equipment, in particular, has often led to the purchase of equipment that is difficult to maintain properly in Nepal. This has led to long delays and considerable expense following breakdowns.

In the private sector the quality of equipment supplied and supervision offered by the leading turbine manufacturers are generally adequate for the average mill installation. As with any emerging industry, however, there are some new firms which cannot offer an acceptable level of service, nor quality of turbine. It is important that the ADB/N takes a leading role in ensuring that manufacturers offer equipment and service of an acceptable standard. The ADB/N already operates a pre-qualification list of satisfactory manufacturers, but the policing of quality is difficult without a set of agreed industry standards. The compilation of such standards should receive high priority as more projects, particularly those with electric generators, are installed.

Capital Cost. The capital costs of existing NEA-operated mini- and micro-hydro installations are shown in Table 5. The capital cost of installations has varied widely according to various site-specific factors, but has averaged US$ 5,100 per kW capacity installed. Cost overruns are frequent because of inadequacies in design, of contractors, and of supervision.

Annex 3 compares the costs, and some of the site-specific factors which help determine them, of various public and private installations.

Table 5: Capital Costs of Existing NEA-operated Mini- and Micro-Hydroelectric Plants (in 1988)

Plant	Total Cost (US$ thousand [1])	Cost/kW (US$ thousand)
Dhankuta [2]	3.0	2.6
Surkhet [2]	12.6	4.7
Baglung	8.2	4.0
Doti	14.8	6.4
Phidim	11.5	3.7
Dhadhing	2.1	5.0
Gorke	2.4	2.9
Jomsom	14.4	4.1
Jumla	16.6	5.7
Syangja	6.2	4.9
Helembu	4.3	4.6
Salleri-Chialsa	32.8	8.7
Darchula	8.3	8.8
Chame [3]	5.0	5.2
Manang [3]	9.3	5.0

Source: NEA, Small Hydro Division 1989

Note: [1] USD 1 = Rs 23.5; adjusted to FY 1987/88 values using National Urban Consumer Price Index
[2] WEC 1988
[3] NEA Estimated Costs (Small Hydro Division 1989)

Electrification of an agro-processing plant requires additional investment of US$ 300 per kW, while stand-alone electrification projects have been installed for around US$ 1,500/kW (inclusive of 50% HMG/N subsidy).

Cost overruns of private sector turbines and milling equipment are rare. This is largely because financial considerations are crucial from the start in the motivation for, and planning of, private sector schemes. A fixed price is quoted and additional costs are normally only charged if installation teams spend a longer time on site than anticipated. There is evidence, however, to suggest that the real cost of civil works undertaken by the owner is often underestimated. Cost overruns in the early stages are often absorbed by reducing the specification of subsequent civil works, a practice which should not usually be encouraged.

Operation and Maintenance. Many operational difficulties have been experienced by the NEA at remote mini- and micro-hydro installations. Serious problems have included lack of water during the dry season, destruction of intakes, breaching of canals, and continuous difficulties with electromechanical equipment. In particular, governor performance has been inadequate and automatic control systems appear to have poor reliability (WECS 1988).

Since each site usually has only one or two turbines, any operational difficulties are immediately felt by the consumers. Lack of spare parts and rigid purchasing regulations limit the speed with which plant operators can repair damaged equipment. In addition, operation and maintenance manuals are not available in the Nepalese language (ITECO 1986). Little responsibility is delegated to the managers of remote mini- and micro-hydro sites. Discretionary expenditure limits are very low and site staff are unable to undertake immediate repairs following major breakdowns or unforeseen damage.

The lack of standardisation of equipment in public sector installations has contributed to problems in training operation and maintenance staff properly.

Regular maintenance requirements of canals, turbines, and milling equipment are reported as the major operational expenses of private sector micro-hydro (Jantzen and Koirala 1989). Minor problems with canals and equipment are generally dealt with by the operator or others within the local community. Difficulty is experienced, however, in trying to gain technical assistance from outside the community. There is a tendency for owners and operators to continue operating damaged machinery until a major breakdown occurs. This is because of both a lack of proper technical training and pressure from users to provide milling and electricity services regardless of plant condition. Additional training for operators and owners would go some way towards remedying this situation.

Operational Characteristics. Much of the disappointment in the performance of NEA installations has centred on their poor load factors. The average load factors of 21 per cent in 1985 (WECS 1988), compare poorly with the initial estimates of 40 to 50 per cent, but they compare well with the experiences of other countries, such as China, where load factors are similar for isolated plants. Frequent breakdowns have added to consumer discontent and reduced revenues.

Unreliability also characterises the services of private mills and generators, but, since the equipment is fairly standard and many problems can be dealt with locally, breakdowns tend to be resolved more quickly. Both public and private consumers complain of irregular supply and a recent study found that irregularity of supply was positively related to additional demands for power (IDS 1988).

Staffing. Staff numbers at government installations appear excessively high. Figures reported in 1986 show staff numbers ranging from 15, at the smallest site (Dhading), to 52, at the largest site (Surkhet). Three reasons are suggested for this over-staffing:

i) large numbers of support staff,
ii) poorly trained or unproductive technical staff, and
iii) the nature of public sector management/employment (ITECO 1986).

Staffing at private installations tends to be low; usually one or two operators, and these are often members of the owner's family.

Running Costs. NEA installations have incurred operation and maintenance costs that are greater than envisaged and which are high in relation to similar installations in other countries and to installations in the private sector in Nepal. Revenues meet less than half of current costs, even at plants where demand has reached plant capacity, and the shortfall is met by the NEA from HMG/N budget allocations. This has led to increasing concern within the Government as the income on NEA mini-hydro sites averages only 32 per cent of operation and maintenance costs and the sector is seen as an ongoing drain on scarce resources.

There are two major constraints on NEA revenues: the tariff structure used, which was not designed with cost recovery as its main aim (see later sections), and the low load factors of the installations which result in their rarely achieving full potential output. The difficulties of NEA-operated installations are caused by both management and technical factors and a more detailed study is needed to identify these difficulties, to critically evaluate them, and to suggest steps for improvements.

There is little accurate information about revenue from private installations but studies suggest that they generate a positive income and the ADB/N has estimated a 15 per cent return on investment at non-electrified private schemes and a 4 per cent return for add-on electrification (if the government subsidy is included). Gross income from agro-processing is estimated well above recurrent costs and tariffs for electricity are determined by the local willingness to pay. All evidence suggests that villagers are prepared to pay well above NEA tariffs for the convenience of electric lighting and that both activities can be run profitably in most well-managed sites.

In order to explain this disparity in performance between the public and private sectors, it is necessary to examine their respective implementation procedures.

Management and Organisational Aspects of the Two Sectors

Given the disparity in performance between the public and private sectors, the Government's concern over the rising cost of their small hydro installations, and more projects under construction, it is worth considering the planning and implementation approach of this sector and, in comparison with the private sector, identifying areas where changes could have a significant effect on the future sustainability of projects. As described earlier, the Government's remote mini- and micro-hydro projects arise as a result of the political policy of supplying electricity to District Headquarters. The need has been defined at the top levels of planning and the process of implementation follows the same pattern. The organisations involved and the lines of influence between them are shown in Figure 2.

In contrast, installations in the private sector are almost always initiated locally. An entrepreneur or local grouping may see the opportunity, or the local ADB/N staff may identify a site and then look for possible investors. The process is shown schematically in Figure 3. Further details of the planning and management of typical public and private schemes and case studies of various indvidual installations can be found in Annexes 4 and 5. The critical management features of the two approaches are summarised in Table 6.

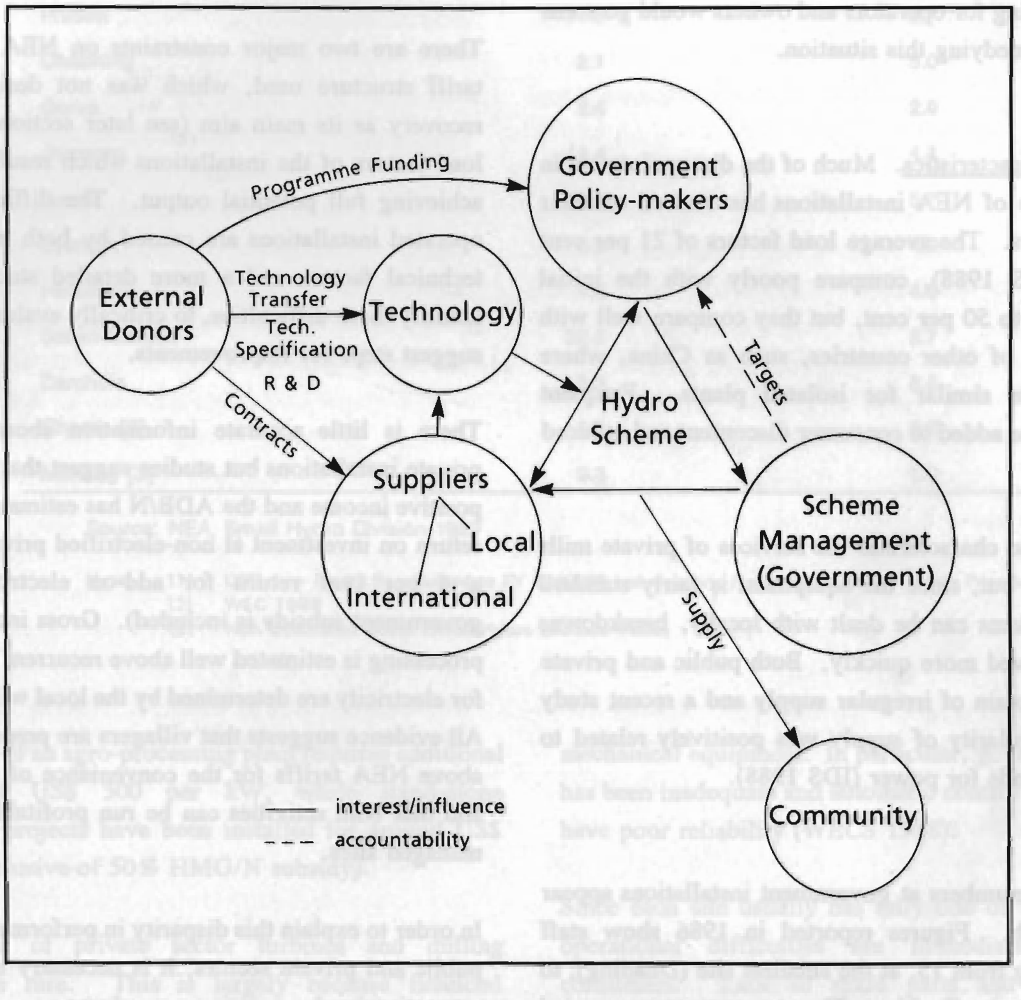


Figure 2: Public Sector Mini- and Micro-hydro Schemes: Key Institutions and Processes Involved in Their Promotion

Public Sector

Most of the NEA's difficulties stem from managerial shortcomings rather than technical ones. Its projects are usually technically sound as planned, but the management skills to run them are not.

In the public sector, the project originates from the Central Government and all subsequent decisions regarding funding, management, location, planning, payment, and so on are taken at that level. As is shown in Figure 2, the community is not part of this process at any stage and the lines of accountability are all to the Central Government. The on-site managers (if they are on-site - in many cases they do not stay in their posts) have very limited maintenance budgets and no contingency funds for emergency repairs. They, therefore, have no power and little incentive to carry out preventive maintenance or to anticipate breakdowns. They must wait until the failing part breaks and then apply to the Centre for money and/or new equipment. This takes time in coming and the station may be down for many months. Since they are accountable only to the Centre, the inconvenience caused to the consumers is of little account.

It is rare for the Organisation and Management (O&M) staff at the station to be local people and so, although they may be resident in the area for a year or two, they do not feel any particular loyalty or responsibility towards the community. This contrasts strongly with the private sector. As shown in Figure 3, the community is a central part of the hydropower context, and although the installation may be a money-making venture by the richest man in the village, the community still retains a certain amount of control and he is accountable to them. If it is felt that the charges for milling or electricity are unreasonably high, users revert to using their traditional technologies.

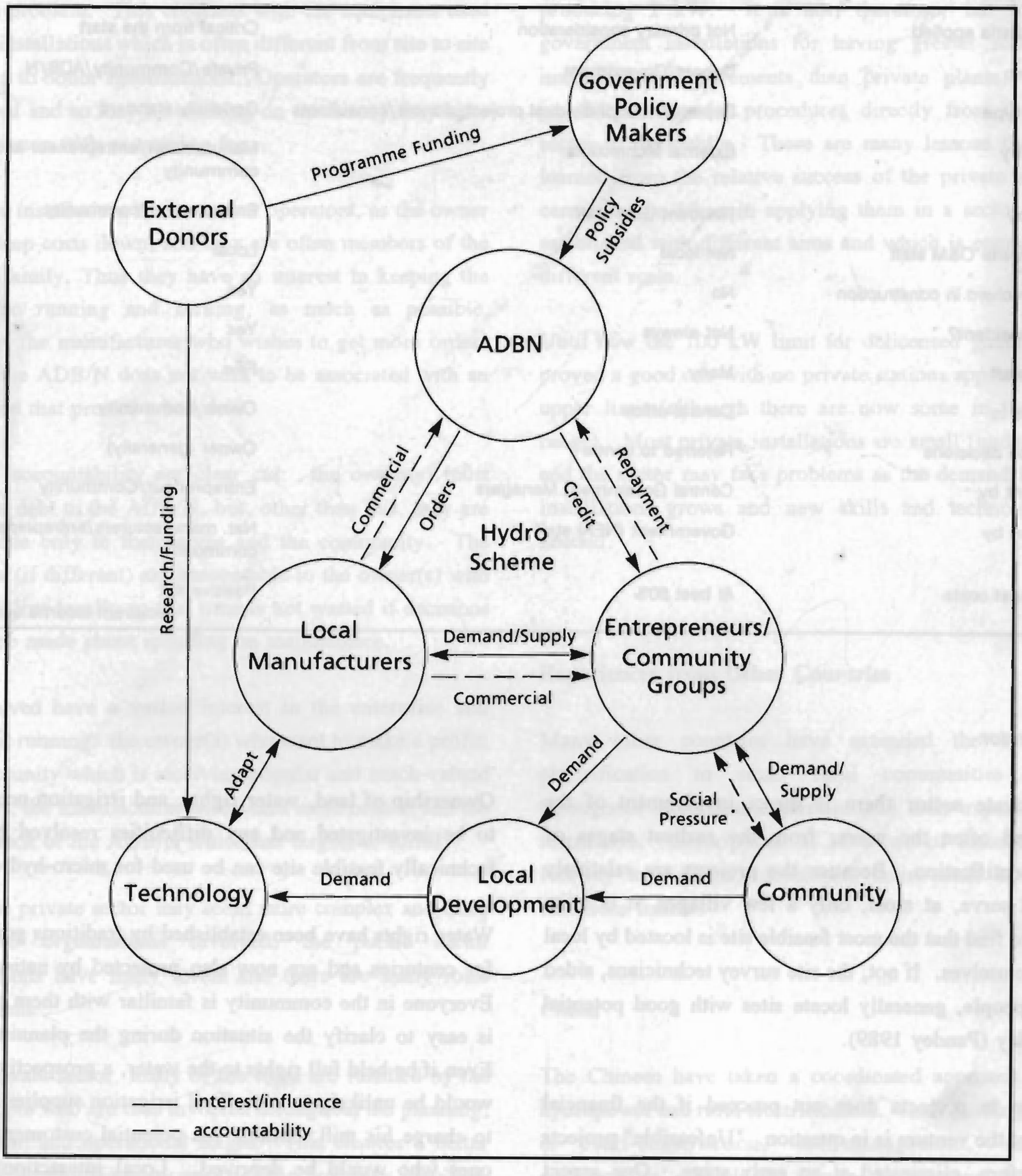


Figure 3: Private Sector Mini- and Micro-hydro Schemes: Key Institutions and Processes Involved in Their Promotion

Table 6: Management Features of Public and Private Sector Projects

Activity/Strategy	Public	Private
Project initiation	Government (High level)	Local
Site identification	Largely determined by political factors	Based on local knowledge
Survey	Outsiders - Govt appointees or foreign experts	Outsiders with locals
Water rights	May not be clarified	Discussed at survey
Design acceptable to	Donors/NEA	ADB/N local branch, owner
Financial criteria applied	Not primary consideration	Critical from the start
Funding from	Donors/Government	Private/Community/ADB/N
Equipment type	Dependant on individual project, donors/consultants	Generally standard
Installation by	External technicians	Manufacturer/entrepreneur and community
Operation by	Resident Govt staff	Entrepreneur/community
Origin of on-site O&M staff	Not local	Local
Operator involved in construction	No	Yes
O&M staff resident?	Not always	Yes
Operating staff	Many	Few
Accountable to	Central office	Owner/community
Maintenance decisions	Referred to centre	Owner (generally)
Management by	Central Government Managers	Entrepreneur/Community
Maintenance by	Government (NEA) staff	Nat. manufacturers/entrepreneurs/ community
Ability to meet costs	At best 50%	Positive net recurrent income usually

Private Sector

In the private sector there is direct involvement of the owner, and often the users, from the earliest stages of project identification. Because the projects are relatively small and serve, at most, only a few villages, it is quite common to find that the most feasible site is located by local groups themselves. If not, the site survey technicians, aided by local people, generally locate sites with good potential within a day (Pandey 1989).

Investment in projects does not proceed if the financial viability of the venture is in question. "Unfeasible" projects are, therefore, eliminated at an early stage. One aspect which is often overlooked is that, although there are numerous technically feasible sites, the number of projects that are socially or economically acceptable is often much smaller.

Ownership of land, water rights, and irrigation needs have to be investigated and any difficulties resolved before a technically feasible site can be used for micro-hydropower.

Water rights have been established by traditions going back for centuries and are now also protected by national law. Everyone in the community is familiar with them and so it is easy to clarify the situation during the planning stage. Even if he held full rights to the water, a prospective owner would be unlikely to cut off all irrigation supplies in order to charge his mill, because his potential customers are the ones who would be deprived. Local interactions are so complex and interrelated in small, largely self-sufficient communities that, even if financial power is not equitably distributed, there are many ways in which the landowner's behavior can be affected by those who live around him.

Thus, the private sector has been successful because it is locally controlled from the start and is based on the satisfaction of traditional, ongoing, essential, rural energy demands (milling and grinding). It has followed existing demand rather than being expected to create it (thus electrification has followed milling as local demand for it was expressed) and this has improved its financial viability.

The level of technology is appropriate to the local setting: the water management is based on traditional irrigation techniques, and, because the equipment is standard, parts are less of a problem. This contrasts with the equipment used in NEA installations which is often different from site to site according to donor specifications. Operators are frequently transferred and so may be working on machinery they have no experience with or training for.

In private installations there are few operators, as the owner tries to keep costs down, and they are often members of the owner's family. Thus they have an interest in keeping the installation running and earning, as much as possible. Similarly, the manufacturer who wishes to get more orders through the ADB/N does not wish to be associated with an installation that proved a bad debt.

Lines of accountability are clear cut: the owner(s) must repay the debt to the ADB/N, but, other than this, they are accountable only to themselves and the community. The operators (if different) are accountable to the owner(s) who generally live locally so that time is not wasted if decisions have to be made about spending on maintenance.

All involved have a vested interest in the enterprise and keeping it running: the owner(s) who want to make a profit; the community which is receiving popular and much-valued service(s); the manufacturer who wants more orders; and the local branch of the ADB/N which has targets to fulfill.

While the private sector may seem more complex and there are more organisations involved, the public sector organisations have many levels and there are many roles within them.

In the private sector, many of the roles are fulfilled by the same people who are thus involved throughout the planning, installation, and operational stages. This ensures a better understanding by the participants of the processes involved. The operator will probably have been involved in the construction of the intake and canal and the installation so he is able to carry out routine maintenance and repairs. Maintenance of irrigation canals is, anyway, a routine part of village life. The machinery is simple and robust, having been adapted in Nepal for just such conditions.

Scale

The issue of scale is one that affects the comparison between the public and private sectors. The management and maintenance requirements of an NEA mini-hydro station producing 240 kW are very different to those of a small mill producing 2 kW. It is not, therefore, fair to crticise government installations for having greater staffing and maintenance requirements than private plants, nor is it possible to transfer procedures directly from the private sector to the public. There are many lessons that can be learned from the relative success of the private sector but care must be taken in applying them in a sector that was established with different aims and which is operating on a different scale.

Until now the 100 kW limit for delicensed generation has proved a good one with no private stations approaching that upper limit (although there are now some in the 50 kW range). Most private installations are small (under 10 kW) and the sector may face problems as the demand for larger installations grows and new skills and technologies are needed.

Experiences from Other Countries

Many other countries have extended the benefits of electrification to small rural communities scattered throughout mountainous terrains and their experiences are instructive. Descriptions of how two of these countries, Norway and China, developed their small hydropower resources follow.

China

The Chinese have taken a coordinated approach to small hydropower and rural electrification. Their guiding principle is 'self-construction, self-management, and self-consumption'. While the Central Government has set and enforced technical standards, funded research into new technologies, and provided some funds to target backward areas, most of the capital for small hydropower development has come from the regions themselves. A multipurpose approach has been emphasised, in which the water resources of a province or district are seen and developed as a whole; irrigation and flood control works being integrated into SHP projects. This helps to avoid the situation where a hydropower project is in conflict with irrigation needs.

There is an emphasis on the local manufacture of equipment, both to reduce costs and to facilitate repair and maintenance. Construction and management staff work on the construction of the installation in order to gain a close knowledge of how it functions.

Regional self-sufficiency extends to the management of the profits - which stay at the regional level and are used to fund further electrification - a clear incentive to produce economic stations. While all SHP stations are considered for connection into a larger grid where feasible, to improve reliability and spread load, this is only done where local requirements are satisfied and the ownership and management rights remain unchanged.

In this way the Chinese have managed to combine within a rigid system and clear designation of authority, a high degree of local control and initiative.

Norway

Norway is a mountainous country which still has a large, but scattered, rural population. Like Nepal its terrain and hydrological resources are ideally suited to hydroelectrification and, by 1980, 99.8 per cent of its electricity was based on inland water power.

In 1983, 75 per cent of the population had electricity and the remainder were scattered in the remote areas and islands of the country. This situation led to political concern and the decision to subsidise distribution companies in remote areas from a levy on all electricity consumption. This subsidy was later extended to include consolidation of the system as demand grew, but it was still not sufficient to make expansion of the load economic in its own right.

Financial support was also provided to enable the companies supplying sparsely-populated areas to merge with companies supplying densely-populated areas.

In 1962, central planning units within the Directorate of Electricity were established with the task of preparing nationwide plans for the system and of ensuring that each component (power production plants, transmission systems, and so on) was suitably sized and operated in such a way as to be of best possible benefit to the system as a whole, irrespective of who owned the component. There is close cooperation between the central planning units and planners employed by the power companies, but, at the same time, it is ensured that the planning units can act independently and produce nationwide plans based on socioeconomic methods and principles.

A paper on the development of Norway's hydroelectric supply concludes, "*A policy aiming at rapid electrification of the rural areas should be based on strong involvements of the consumers themselves*". It goes on to say, "*The experience which can be drawn from the history of electrification of Norway ...... demonstrates the efficiency of placing responsibility for the electricity supply on local undertakings. However, experience also shows that a strong national co-ordination body is required, especially at a later stage*" (Vinjar 1980).

Lessons Derived from the Experiences of Other Countries

Key elements emerge from the experience of China and Norway. Both had to cope with the problem of remoteness and solved it by emphasising local initiative and control. The "localisation" of the projects extended to the local production of equipment and the use of local resources. Thus, instead of trying to fight the remoteness of these sites and bring them under central control, the governments devolved the responsibility, and also the necessary authority, to local bodies.

This did not result in the central governments giving no support to those local bodies, however. In both the Chinese and Norwegian cases, the central governments targetted areas in which electricity was felt to be necessary on social or political grounds, but would not be cost-effective in financial terms, and provided subsidies.

In both cases, the governments were also involved in actively promoting key industries that would increase and spread the load. This multipurpose approach, in which hydropower is viewed in the context of the other local resources and demands (such as water for irrigation) of these remote, "uneconomic" stations, was always seen as part of the national power resource and, where possible, the projects were gradually linked into wider grids.

This "incremental" approach is probably the most effective in such situations. Production is oriented to the scale of current needs rather than ambitiously projected demands, thus reducing the cost of the initial installation and improving its load factor from the start. If the station is locally controlled, the managers can monitor the inevitable rise in demand as awareness about and consequent use of electricity increase, and they will know when the station is approaching capacity. These decisions are based locally, so that the decision-makers will also be aware of the local factors (planned industries, etc) affecting demand and can plan for the future more accurately than planners at the central level.

As demand rises beyond the capacity of the first installation, others can be built in the area around it (none of these countries are short of potential sites) and, as these are linked up, a "mini-grid" emerges. This gives the advantages of a grid (more reliable supply, load spreading, etc) at far less cost than that which would be incurred by extension of the national grid. In Norway's case, these mini-grids are now coalescing into one large, national grid, but this takes time as demand and capacity rise.

These mini-grids have been successful in Peru also. Two or three generation points, each of up to 2 MW, are linked to provide a grid of 1-5 MW, supplying two to three thousand people in small communities. Although the development starts with pockets of supply, the intention of upgrading and moving towards coordination is there from the start (Edwards 1990).

In Nepal's case, advantage could be taken of the fact that private micro-hydro installations produce electricity more cheaply than the NEA mini-hydro installations or grid extension over long distances, and these micro-projects could be used to "seed" the demand for electricity. Different scales of demand require different types of technology and in hydroelectrification, as will be discussed later, an increase in scale does not necessarily bring a reduction in costs. Thus an incremental approach could be very cost-effective. A shift to localised control will require government support and coordination to a far greater extent than is the current norm, and the implications of this are analysed in the section on Coordination.

Micro-hydro as a National Development Tool

Nepal's traditional sources of power (fuelwood and human and animal power) are not sufficient to satisfy the demands of a growing population on a sustainable basis, as is evidenced by the expanding deforestation around growing towns. Increasing demands for more sophisticated technologies and sources of energy have led the kingdom into a situation of dependence on its neighbouring countries for imported fossil fuels. These represent a drain on the economy and make the country extremely vulnerable as was made clear during the trade blockade with India in 1989.

Plans for national development and industrialisation will require still more power and, since Nepal has no fossil fuels of its own and a very limited national budget, renewable sources of energy could provide a solution. As discussed earlier, although biogas, wind, and solar power cannot yet provide for the country's needs, Nepal has a tremendous resource in its hydropower potential.

Electricity is a versatile form of power which could substitute for many of the traditional sources of power and would also permit many new applications, thereby improving the opportunities for national development. The problem is how best to supply electricity to consumers? Nepal's hydro resources are sufficient to supply stations of many megawatts and this has been the direction taken by the NEA - using hydropower to supply an expanding national grid. Once the densely-populated southern plains (*Terai*) are supplied, however, the situation becomes more complicated. The remaining settlements in the hill and mountainous regions are small, scattered, and separated by difficult terrain which is geologically unstable and prone to climatic extremes.

There is a strong and growing demand for electricity in the hills, but experience to date, both in Nepal and in other countries, has shown that, while demand for electricity may be strongly expressed, its actual consumption initially will be low - mainly confined to domestic lighting. The availability of electricity does not automatically lead to industrialisation, particularly in isolated communities where there are many other limiting factors such as the availability of raw materials and markets.

In a recent report that was based on the experiences of rural electrification in many countries, it has been suggested that grid extension is only suitable where minimum economic standards and infrastructure are already present (Foley 1989). This is certainly not the situation in most Nepalese hill villages, and the cost of extending the national grid over long distances, to supply initially very small demands, would be prohibitive.

It is in exactly these conditions, however, that micro-hydropower is proving a commercial success and could play a crucial role in the development of Nepal. There are huge numbers of potential micro-hydro sites spread across the Nepalese hills and the decentralised production of power at the point of demand avoids the necessity for long and expensive transmission lines. As discussed earlier, the production of electricity on a very small scale has actually resulted in a lower estimated cost per kW than the NEA's larger installations (US$ 1,500 estimated for non-government projects as opposed to US$ 5,100 for the NEA mini- and micro-hydro installations).

The decentralised production of power also reflects the nature of the local economies which tend to be almost self-sufficient in basic goods, with little import or export of products, because of the arduous nature of the trails along which they must be carried and the limited markets available. The decentralised production of power is also more socially equitable as it is independant of the road system and thus spreads benefits to isolated communities. Many have argued that the supply of electricity to remote regions may help to slow the pace of urban drift, but, at present, there is little evidence to support or disprove this.

It is clear, however, both from the increasing number of private milling and generating installations, and from the number of turbine manufacturers in Kathmandu and Butwal, that these micro-hydro installations are producing power in a form that the local community wants and at a price it is willing to pay.

The non-government sector has already developed the skills of many engineers and operators through training courses run by non-government organisations, such as Development Consulting Services (DCS), and practical work experience with manufacturers. ADB/N training schemes for owners and operators have also contributed to the growing pool of people with skills and experience in the micro-hydro sector. These skills are a resource that the public sector could build on. They are also the basis of a potential export industry: Nepal is on the way to developing national expertise in micro-hydropower which is already in demand in other countries, as enquiries to Nepalese manufacturers have shown.

Hydropower has the advantage of being a clean and non-polluting source of power, thus relieving the strain on the country's environment as well as on its budget. Very small-scale, scattered hydro installations are not simply the least-cost solution at present to the energy needs of the hills. They could form the basis of a sustainable system which would grow in response to the growth in demand and, as the small installations spread and link up, produce a system of mini-grids, giving the reliability of a grid supply but with the lower costs and local accountability of decentralised supply.

III. Issues in the Development of Hydropower Resources

The Cost of Hydropower

The costs of government installations, both in terms of capital cost per kilowatt and in terms of running costs, have been much greater than in the non-government sector. The relatively low capital per kilowatt cost of private sector mini- and micro-hydro installations can be attributed to the following:

i) use of traditional water management skills,
ii) effective in-country technical support,
iii) largely standardised equipment and end use machines,
iv) acceptability of lower standards of performance, and
v) a government subsidy of 50 to 75 per cent of the capital cost of rural electrification from the FY 1988/9.

The ADB/N usually gives loans for about 70 per cent of the cost of private mill installations and 50 per cent of electrification costs. In addition, the bank extends working capital credit to some 54 per cent of its clients installing mini- and micro- hydro plants (ADB/N 1987).

The recurrent costs of non-government installations are kept low because:

i) staff are employed only when required for specific tasks,
ii) local skills and materials are usually sufficient for the maintenance and repair of civil works, and
iii) the use of equipment manufactured or available in Nepal usually ensures the relatively low-cost repair of electro-mechanical equipment.

Thus, the main reasons for the private sector's success are: its small scale, which allows the use of traditional techniques in civil works, reducing both construction and maintenance costs; a high degree of local involvement and accountability, which improves project identification and management; and the standardisation of equipment, which greatly facilitates both construction and subsequent maintenance.

Scale

Although smallness of scale is an advantage in terms of costs, it is not really likely nor would it be feasible for the NEA to become involved in installations under 50 kW. Its bureaucratic structure could not cope efficiently with management on such a small scale. Experiences in other countries have shown that trying to scale down the bureaucracy of a national corporation to this extent only pushes up costs. It only becomes possible if a specialist small-scale group with appropriate training for that level is formed.

NEA small hydro-installations at present range between 30 and 250 kW and at that size some of the advantages of the micro-scale are lost. As capacity is enlarged, the volumes of water required become greater and traditional water management techniques are not adequate for the civil works. Above 100 litres/second, more advanced engineering is required, and this adds to construction costs and requires more skilled maintenance.

At 300 kW, a further technological barrier is reached, beyond which larger scale equipment and more complex monitoring and management techniques are required, but output can be greatly increased. It is unfortunate that the scale of NEA remote installations is within the problematic 100 to 400 kW range. At this level, the advantages of the small scale, due to simplicity, are lost, but the advantages of the large scale, due to bulk production, are not gained. NEA installations, therefore, suffer the disadvantages of both scales and the advantages of neither. The other reasons for the private sector's success could be much more easily incorporated into the NEA's procedures, however, and there are valuable lessons to be learned.

Local Accountability

The costs of government projects could be greatly improved by increasing the degree of local involvement and accountability. As the Chinese and Norwegian experiences have shown, devolving control for decentralised power production results in more motivated and responsive management. Electricity is popular and local politicians and managers would have considerable interest in ensuring its supply. Supply could be improved if those controlling it were more accessible to consumers.

Similarly, if each institution was financially accountable and had control over the use of its earnings, as in China, there would be much more incentive to anticipate breakdowns, maintain equipment properly, and generally ensure that the installation continued running and therefore earning. At present, local government is not involved at all in the NEA installations and so the electricity is perceived as a free good and there is little local political pressure to make it pay.

The local component of the capital cost could be increased. The demand for electricity in many communities is such that the prospective consumers would be prepared to commit some communal funds or labour to assist in the construction costs. This would also have the advantage that local people would become familiar with aspects of the construction and could become involved in subsequent maintenance of the installation for this reason.

Reducing the numbers of operating staff in NEA installations would also greatly reduce the running costs. At present, installations are over-staffed and many of the staff are not effective, partly due to lack of training and partly due to the great variety of equipment used in NEA projects.

Standardisation

The standardisation of equipment is another area where lessons can be learned from the private sector. The variety of equipment specified by project donors, combined with the frequency of staff transfers in government service, often means that operating staff are not familiar with the machinery they are running. When breakdowns occur, obtaining spare parts is usually a costly and lengthy process and outside technical assistance may also be required.

The specification of imported, and often more sophisticated, equipment is justified by donors on the grounds of its better performance and reliability. However, under the conditions in which the equipment is usually operated its promise is not fulfilled. Therefore, controls are needed to discourage imported equipment when locally-made equivalents are available as well as action to ensure a continuous supply of parts and expertise to maintain plants. Standards of back-up can be more important than standards of construction. A technology that breaks down more frequently, but can be quickly repaired on-site using cheap, locally-produced parts, could prove more effective.

Often the imported equipment is given to the NEA at a subsidised price. If the costs of the downtime and parts were added to the capital cost of the installation, this would give a much truer picture of what these imported technologies are actually costing the country.

Technological Alternatives

There are new technological developments that could also help to reduce the costs of very small hydro projects. Electricity is presently generated at micro-hydro installations using conventional alternators and this requires the import of expensive generating equipment. For small projects, however, electric induction motors can be used as generators. These motors are more easily available since they have a wide range of applications in local industries (for example, pump motors, industrial fans, and manufacturing equipment). Consequently, these "induction generators", built from motors, are cheaper than purpose-built generators of an equivalent size and can be produced by using second-hand motors and the skills that are available in Nepal. The technology is simpler and more robust than that of conventional generators and so induction generators are more suitable for use in remote areas where reliability and ease of repair are crucial.

Similarly, the induction generator controller, which controls the frequency of the electricity generated, also has the potential to reduce the costs of micro-hydro projects when used with induction generators. Both these technologies are currently being developed and tested in Nepal through the collaboration of ITDG, ADB/N, and local manufacturers.

The development of local manufacturing capacity to produce other turbine designs would enable the exploitation of a greater range of sites. For example, suitable low-head turbines could be used in canal drops and other low-head sites. Similarly as low-head sites are filled, more attention will have to be given to technologies suitable for high-heads. Already, the traditional Nepalese craft of lost wax casting has been adapted to manufacture high head Pelton turbine runners.

These initiatives are all likely to require substantial investment in research, development, and technology transfer, possibly on a loss-leading basis. Consequently, public sector funding and international funding and expertise will be required for some time.

Another area in which the costs of NEA installations could be greatly reduced is metering. At present, the amount charged to households for connection is estimated by NRECA to average Rs 1,000 per household. Not only does this debar many poor families, who might be able to afford a monthly bill but cannot raise the initial lump sum, but the shortage and cost of metering equipment is also one of the major factors delaying the extension of electricity supply to more households.

Positive thermal cut-out devices (PTCs) are already being used successfully in many non-government installations, such as those in Mustang, and miniature circuit breakers are now being tried out at the NEA installation at Salleri-Chialsa. If the customer uses appliances that jointly consume more than the agreed number of watts, the PTC cuts out the supply. The consumer, therefore, pays to use a certain capacity of power rather than a certain quantity. If the appliances are run all day it will make no difference to the bill.

This system of charging for electricity is actually much better suited to the nature of hydropower, which is available all the time at no extra cost (other than wear and tear and the operatives' wages), unlike fossil fuel. It also encourages load spreading as, in order to keep costs down, consumers will try to use appliances in sequence rather than all at once. Fixed current connections were used in Norway and are in use in other countries, for instance, Zimbabwe. PTCs are small, easily installed, maintenance-free, and, at present, available in Nepal.

Since most (50-70%) NEA customers use less than 25 kWh per month and therefore pay only the fixed, "lifeline" rate, the introduction of PTCs (or slightly bigger miniature circuit breakers) would release a lot of metering equipment for the use of larger consumers and also considerably reduce the connection costs for the small consumers (NEA charges Rs 800 for meters but probably costs them at much more).

Butwal Power Company's 5 MW installation at Andhi Khola is an exciting development based on localised knowledge and skills. It has shown that it is not necessary to import all the expertise and that costs can be greatly reduced by not doing so. It is based on engineering skills that have arisen in the country from its micro-hydro industry and which can now form the basis of a national industry. This would not have been the case had imported technologies been used and reliance on outside consultants continued.

The Comparative Cost of Micro-hydro

Before considering the costs of electrification, it is worth considering why it is being done. Rural electrification schemes all over the world have been criticised for not proving to be "economic", but financial considerations are often not the first priority in the decision to electrify. The demand for electricity is usually based on social factors (convenience, status, and so on). The initial demand is almost entirely domestic, for lighting, and it is only slowly that electricity comes to substitute for other traditional energy sources or to supply new industries. Thus, the initial demand for electricity is all at the same time, in the evening, and this peaking load results in a poor load factor.

Another reason why electricity has appeared to be so uneconomic is that expectations have been unreasonably high. Over-ambitious targets for load factor and recurrent costs have led to the NEA installations appearing to give a poor performance, whereas, in comparison with other countries, their record is reasonable and the private sector in Nepal has proved to be substantially cheaper than its counterparts elsewhere. This is to a great extent due to the local manufacture of equipment and to the competitive nature of the industry.

Even in China and on Sri Lankan tea estates where the base load is good because of the use of industrial machinery, load factors of only 30 per cent and 50 per cent respectively are achieved, and it has taken China almost twenty years to achieve these load factors.

The low load factors are mainly due to:

i) hydrological variation in the year (so the plant is not always able to produce to capacity),
ii) load variations (the demand is not always there),
iii) the lack of industrial load (the domestic load peaks in the evening),

iv) frequent breakdowns (when the plant is not producing at all), and

v) small scale (individual loads are therefore a proportionately larger part of the whole demand).

There is a need for more detailed cost analysis, incorporating the load factor, to examine the true competitiveness of mini- and micro-hydroelectricity. Further research is required to establish the cost components of existing schemes in Nepal and to compare these to schemes in other countries. This information could then be used to recommend cost-reducing approaches and to guide planners.

Demand analysis and management could improve the load factor and thus improve economic efficiency without further investments in equipment.

Figure 4 gives the comparative costs per kilowatt generated for hydropower stations in various countries and shows that the Nepalese performance is by no means poor, especially considering the lack of other infrastructural facilities. An area in which Nepal's performance could do with improvement, however, is its running costs: these are very high but could be reduced by streamlining staffing, management, and budgetting procedures, as discussed earlier.

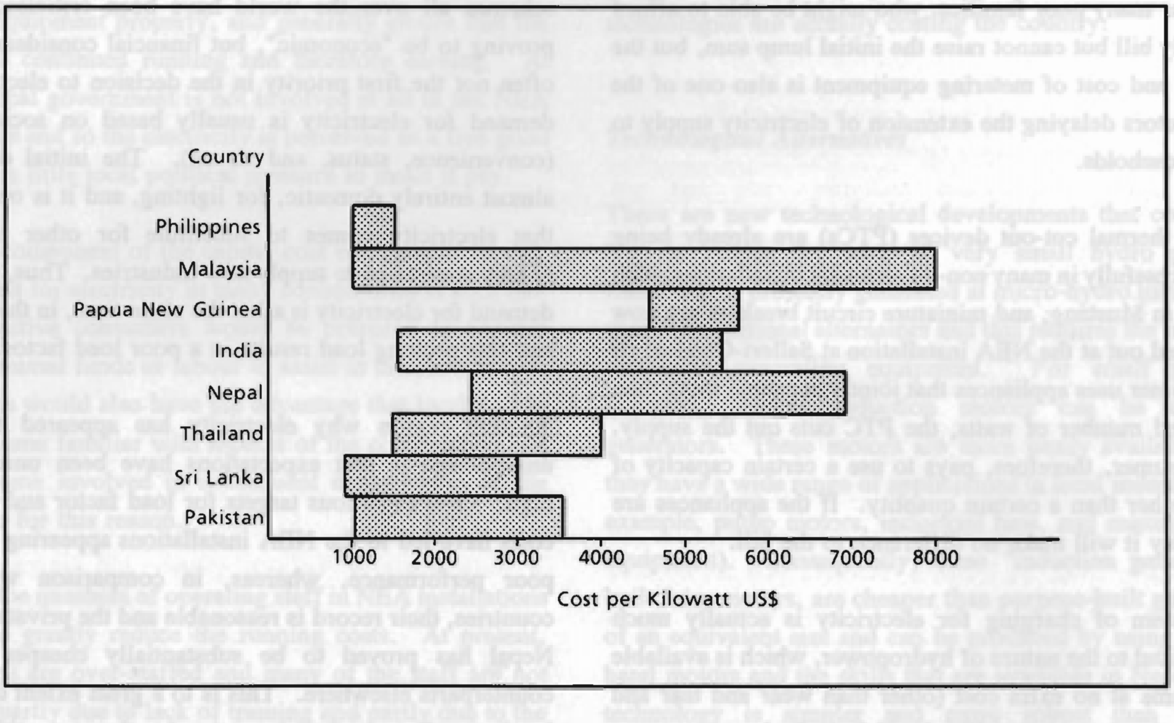


Figure 4: Comparative Capital Costs of Hydropower in Asian/Pacific Countries

Grid Extension versus Stand-alone Installations

In comparing the costs of grid extension with the establishment of decentralised hydroelectric installations, it is critical to have a complete and accurate picture of the costs involved in both. This is not easy.

In Nepal, as in many other countries, the grid is subsidised directly and indirectly from so many sources that it is very difficult to establish its true cost. The grid is heavily subsidised by the Government by allowing tariffs to be set very low. The private sector has shown that consumers are prepared to pay much higher prices for electricity than those charged by the NEA. The grid also requires more backup and infrastructure (roads, communications, maintenance) to support transmission over long distances, adding to the burden on the State.

In Nepal, at present, there are no guidelines on grid extension but the report of the WECS Task Force on rural electrification favoured grid extension for distances of up to 30 km from the existing grid.

However, the financial comparison made by the Task Force between grid extension and micro-hydro installations did not take into account the capital cost of the grid.

If the costs of building a new power station to supply the additional connections were included in the calculation, grid extension would only be financially viable over a much shorter distance. Micro-hydro installations are financially competitive in many of the more remote locations once the subsidies on competitors are taken into account.

Future government policy is likely to be influenced by the WECS Report and by the Rural Electrification Master Plan that is being prepared. In considering the economics of rural electrification and hydroelectricity, the Government must decide what electrification is worth to the country, taking into account the political, social, and environmental benefits as well as the financial implications of hydropower and other sources of energy. Kerosene, for lighting, and diesel, to run generators, must both be imported and distributed at great cost, and grid extension is heavily subsidised.

The potential for local manufacturing and industry should also be taken into account. China is a good example of a build-up from micro-hydro plants to a major turbine export industry. Nepal shows signs of the same kind of development. No such parallel is likely with diesel sets or grid extension technologies.

A political decision must be made concerning what kind of cost is acceptable for electrification - this will determine the degree of subsidy and the amount of tariffs to be charged to cover the outstanding costs. Once these are determined and accepted, the target should be to maximise the efficiency of production and distribution rather than to maximise the return on investment.

Government Subsidies

The Present Situation

It is difficult to compare the economic performance of different power sources since they are all subsidised in different ways and to different extents. Diesel and kerosene are subsidised by the Government when the prices are set. The Government controls and subsidises the price of fuelwood sold in the Kathmandu Valley and government subsidies are also available for micro-hydro installations in various ways.

Subsidies in the electrification sector are more complex. NEA tariffs are kept below even cost-covering levels and require a large government input. WECS has estimated that the NEA remote small hydro projects receive an average of U.S.$ 330 per installed kW per year over the life of the project when depreciation is included. In 1985 this worked out at nearly U.S.$ 100 per customer (WECS 1988). A one million dollar subsidy will be required to meet the operation and maintenance costs of the 29 mini- and micro-hydro installations projected for 1990 (WECS 1988).

These costs may seem high but should be compared with the 5 million dollars spent supplying electricity to 4,000 households in one hundred communities around Pokhara (WECS 1988). The NEA tariff structure gives a big subsidy to consumers, with those who use little and are charged the minimum, "lifeline" rate, receiving a particularly large share. Many poor people are unable to take advantage for this, however, because of the initial high connection charge.

The Government also subsidises the private micro-hydro sector. There is no specific subsidy for the agro-processing as private and community-owned mills are now well-established and an attractive investment, but the financing for them often comes from the ADB/N (a government corporation) at a concessional rate (about 15% as opposed to the commercial rate of 18%).

Non-government electrification is subsidised in various ways. Until March 1990, HMG/N offered a 50 per cent subsidy (75% in "remote" districts) for the capital costs of the electricity generation components (generator, cables, and electronic load controller) of private sector schemes. This subsidy was introduced in FY 1985/6 but then removed the following year, only to be reinstated in FY 1988/9. In March 1990 it was announced that while the level would now cover the total costs of the schemes rather than simply the electricity generating components (The Rising Nepal 1990). The annual budget was not announced. Previously it had been Rs 2 million but it is fixed on a yearly basis and this adds greatly to the uncertainty of investors.

This subsidy has been limited by fiscal constraints and there was no guarantee that it would be continued in the following year. The budget was not, in the past, sufficient for all to receive a subsidy, so that access to the subsidy was often determined by other, more "political" factors. Major subsidies tend to precede or immediately follow the King's visit to a region (a five-yearly cycle).

The subsidy takes the form of a once only opportunity administered through the ADB/N and, since March 1990, also through other commercial banks. Thereafter, financial viability depends upon the owner's ability to establish a tariff that generates an adequate revenue. There is no government involvement in the running of these projects except in a few group schemes in which the ADB/N plays a role in the day to day management.

While electrification on the basis of this subsidy does not currently offer the return on investment available from agro-processing activities, the marginal capital cost (generally some U.S.$ 300 per kilowatt, about 36% of the total capital cost of agro-processing installations) enables the owners to invest in what promises to be an expanding market.

Donors also distort the situation by providing equipment at very low or no cost, thus subsidising the cost of an installation. The investigation into alternative energy sources (wind, solar, etc) is very heavily donor-subsidised with the community contributing 5 per cent or less of the installation costs.

The Way Forward

Rural electrification on a national scale has required government financial assistance in almost every country in which electricity has been introduced. There are two related issues that require resolution when considering subsidisation of rural electrification projects:

i) the value of the expected benefits, and
ii) the opportunity cost of the resources invested.

Both issues are essentially policy issues relating to the political and development priorities of HMG/N. The levels of benefit and opportunity costs of investment in mini- and micro-hydro rather than say, road, water supply, education, or health are difficult to quantify systematically or comparatively, however.

Tariff Subsidies. Nevertheless, experience suggests that, since the poor are heavily constrained by the cost of commercial fuels (particularly when wiring and appliance purchases are required), fiscal controls or incentives are irrelevant to their patterns of fuel use (Bjonness 1983). Artificially low tariffs, therefore, constitute a subsidy to the wealthier and urban sectors of the population and this, in turn, places additional fiscal burdens on the rural majority (WECS 1988 and Ranjitkar 1986). Evidence from elsewhere in the Himalayan Region indicates that benefits accruing to the poor from mini- and micro-hydro electrification are less than the cost of government subsidies on operation and maintenance costs (Royal Government of Bhutan n.d.). Studies in Nepal have reached similar conclusions and both government bodies and non-government organisations have advocated the discontinuation of subsidised NEA tariffs (WECS 1988). "*If energy prices are set below the economic cost of supply, the wrong priorities may be assigned to investments that will consume energy, and technologies may be chosen whose use is not in the nation's economic interest*" (Baum and Tolbert 1985). This, of course, must be balanced against the argument that subsidies for electricity may help to reduce dependency on fuelwood in some areas.

Experience in the private sector has suggested that consumers are prepared to pay much more for electricity than the NEA charges, but there is political pressure on the NEA to keep the prices down. The price of electricity could certainly be allowed to rise to the same level as its competitors, fossil fuels, and this would improve cost recovery.

For the sake of the sustainability and subsequent expansion of the government sector, it is important that tariffs are not subsidised as these would become a continuing and growing drain upon the economy, but sustainability may not be the only consideration. If the Government wished to encourage consumers and industries to change to electricity, it could consider subsidising tariffs and thus speed up the rate of substitution for other energy sources. It is a risky strategy as, once a subsidy is in place, expectations are created and it becomes hard to remove the subsidy. Tariff substitution could, therefore, be used to stimulate demand, but this would only be effective given the generating capacity to satisfy that demand and it would require a pre-defined timescale to allow the subsidy to be withdrawn without consumer protest.

If the Government should decide that it is not prepared to pay the cost of subsidising remote installations, the owners of such installations should be permitted to charge whatever they need to cover their costs (at present NEA tariffs are fixed at the same level for all installations regardless of capital and running costs).

Capital Subsidies. For NEA-operated plants, WECS (1988) suggests subsidisation of capital costs followed by tariff setting based on recovery of operation and maintenance costs. The Salleri-Chialsa Project is currently being used to develop a locally controlled management model for future NEA-operated projects. Central to the goals of this project is a cost recovery tariff. In Peru there is a scheme whereby consumers pay more on their connection charges for the first few years to cover the cost of the soft loan taken to build the plant.

Some government and non-government organisations advocate increased levels of government subsidy on civil works, transmission costs, and electrical end uses in the private sector (ADB/N 1987 and SKAT 1989). This is because government incentives for private hydro-electrification appear to be extremely successful. The current subsidies have brought positive responses and led to an overall increase in the number of private installations. These installations are producing electricity more cheaply and more efficiently than the Government could on that scale.

Subsidising private sector installation costs stimulates further expansion of the sector and does not tie up the Government's budget in ongoing commitments. However, it restricts the number of beneficiaries. The only direct beneficiaries are the project owners (community groups or, more usually, individual entrepreneurs). In this way, those who are usually among the wealthiest in the community receive a cheap opportunity to make a potentially profitable investment. Whether the benefits of this are passed on to the consumers or not is dependant on the extent to which they can influence the prices the owner sets. The manufacturers are also indirect beneficiaries of the subsidy on installations since it may stimulate more orders for them.

If the level of capital subsidy is set too high, it will encourage the building of schemes that would not otherwise be technically or financially viable. It is better to tailor the subsidy to the level of demand. That the loans and subsidies being given are acceptable and financially attractive to investors is clear from the demand for them. The Rs 2 million allocated by the Government in the FY 1988/9 was not sufficient to cover all applications, indicating that, at that price, it was a popular investment. Keeping the value of the subsidy constant and subsidising more installations would have been a fairer and more reliable way to distribute the funds available.

To encourage the sector further, a longer term policy is required so that potential investors can be sure that the subsidy will be available to them. It should be fixed every five years rather than annually, and, rather than raising the subsidy, provision should be made for more subsidies if money cannot be diverted from grid and NEA-hydro subsidies (the money presently spent on the private sector is insignificant compared to that spent on the public sector).

<u>Subsidies for Research and Development</u>. At present all direct electrification subsidies go to capital costs and tariffs, and none go towards research and development in the sector. The need for subsidies for the former categories could be reduced by improving the efficiency of NEA installations, as suggested earlier, and thus reducing their operating costs. Similarly, improving the efficiency of electrical appliances would increase the number of consumers a station could supply. HMG/N should consider subsidising research and development work into more energy-efficient appliances and their local manufacture. The Government could also reduce import costs by supporting the local design and production of generators and of other hydropower components which are generally imported. In other countries this kind of subsidy has been administered through tax incentives for manufacturers to engage them to undertake R&D.

Funding more staff, training, and branches for the ADB/N would also be an effective way to increase the spread of remote micro-hydro installations and would establish hydroelectricity on a more viable, sustainable basis than supplying loans at an artificially low interest rate.

Thus, subsidies in the government sector should be targetted: the emphasis should shift from subsidies for ongoing costs to subsidies for initial (capital) or high risk (R&D) costs. In this way the money would act as a catalyst for further development and expansion, and the national budget would not be tied to long-term, ongoing spending commitments. As in China and Norway, the energy needs of different regions could be prioritised and areas targetted for development. The move towards and emphasis on cost recovery by each installation is also consistent with a move towards local accountability and involvement. The policy implications of tariff raising for other issues (import substitution, reforestation) should be kept in mind however.

Development of Domestic Resources

The power sector has, since the mid-1960s, consistently occupied an important place in Nepal's Five Year Plans. Emphasis has been on the generation of hydroelectricity and the installation of diesel plants to meet supply shortfall.

During the Seventh Plan Period (1985-90) HMG/N planned to increase hydropower capacity by 107 MW. Three large-scale hydro installations were to make up the bulk of this capacity: Kulekhani II (32 MW), Marsyangdi (69 MW), and Andhi Khola (5.1 MW). New NEA-operated small-hydro installations were expected to total 3,529 kW capacity (3% of the total increase projected).

Alternative energy technologies were also included in the Seventh Plan. Establishment of biogas plants, distribution of fuel-efficient cooking-stoves, and the installation of micro-hydro projects were all targetted for expansion and received varying levels of subsidy. Micro-hydro turbines and mills were allocated approximately 10 per cent of the Plan's Rs 50 million budget for alternative energy. Micro-hydro projects of less than a 100 kW installed capacity were to be installed by the private sector with State concessionary credit.

Government plans over the past years have also expressed a commitment to regionally balanced development. This approach has resulted in the extension of the central grid and the establishment of decentralised electricity generation facilities in remote areas. The costs of electrification, particularly those of the remote small hydro plants have proved much higher than anticipated, however, and the growing need to reduce or reverse the drain on resources, that such government-operated small hydro projects entail, contributed to the formation of the NEA in 1985. Since its formation, the NEA has been expected to spend within the limits of the grants and revenues it receives. The implication of this restriction is that non-profit making projects will be curtailed and, unless sufficiently remunerative end uses are initiated and/or tariffs raised significantly and/or costs reduced, government-run, small hydro expansion will be stifled.

This adds to the pressure for the streamlining and restructuring of operations at government-run installations and also to support for the increasing of subsidies to the private sector which has shown itself more able to produce cheap electricity than government installations (albeit without any evidence that the private sector installations could be successfully upscaled).

It would be a great mistake for the Government to simply abandon small hydropower however. As discussed earlier, much of the disappointment in small hydro plant performance arose from unreasonable expectations. There are also many ways in which the running costs of the NEA installations could be reduced.

Hydropower is a cheap and sustainable energy source for the nation in comparison to imported fossil fuels. It is also a cheap energy source for consumers when full account is taken of the subsidies on kerosene, diesel, and grid extension. Hydropower, as it takes over from traditional energy sources, could relieve the strain on fuelwood resources and thus the environment. At present, none of the other renewable energy sources is technologically ready for widespread dissemination in Nepal.

Even if it was economic, grid extension to supply the whole country would take years to complete. Twenty years is an acceptable lifespan for a hydro station and during that time it should recover its costs. Thus, micro-hydro is not only the best long-term solution, in terms of environment and national resources, it is also the only technologically viable solution to rural electrification needs in the remote parts of Nepal, at least for the next twenty years.

The Performance of Government Development Plans

Interest in small hydro generation arose in the 1970s as a response to the oil crisis. The Small Hydro Development Board was extremely ambitious in its early aims and, as described earlier, it failed to fulfill them. The Board was dependent upon outside donors (75% of capital works are donor-funded) who had their own priorities and regulations and this led to much oscillation in both policy and practice.

There has been a constant tension between the pressure to reduce the costs and localise manufacture and the desire for reliability, and the latter has led to the use of imported, more sophisticated machinery. This imported equipment is not compatible with the other machinery in use and is often not understood by operators. Spare parts are expensive and can take months to obtain.

Because projects have been separately funded and planned, there has been no overall policy, there has also been no linking of the aims of the SHDB (and subsequently the NEA) with the resources available to it.

Projects have not been properly costed or monitored to enable lessons to be learned from the earlier installations. Funds saved by economising on construction quality, or by using donated or heavily subsidised foreign machinery, are often later lost because of breakdowns in the civil works or in imported equipment which operating staff cannot repair.

Initial estimates of demand and the ability to supply it were much too optimistic. Industries have not sprung up wherever electricity was supplied, as was expected. The construction of projects with a larger than necessary capacity has resulted in increased capital costs and poor load factors.

The motivation behind projects was often political, and this led to sites that were not technically ideal. Where financial and technical factors are given low consideration in project planning it is hardly surprising that the results prove to be "uneconomical".

The planned speed of implementation and the number of sites were very optimistic and needed better coordination. The simultaneous construction of several sites put a strain on manpower resources. There is still a lack of adequately trained manpower and this has led to poor construction supervision and installation management.

The management structure of the NEA and the Government, which emphasises central control, has reduced the involvement of local people and staff. This, in turn has led to a lack of local responsiveness and accountability, to the detriment of the supply. Budgetting procedures that deny site managers discretionery funds to manage or anticipate minor breakdowns, and which collect all revenues for central funds, remove any incentive to keep the plant maintained and producing electricity.

Performance of the Policy-shaping Institutions

Many institutions have a role in shaping policy for the energy sector in Nepal. Foremost among them are the National Planning Commission (NPC), the Water and Energy Commission (WEC), HMG/N Ministries, the NEA, the Royal Nepal Academy of Science and Technology (RONAST), and the ADB/N. Annex 7 shows the relationships between these and the other institutions involved.

Policy, as discussed above, has not fulfilled its potential and has often proved to be misguided. The large number of policy-making institutions is one of the causes of this. The lines of communication are not clear and information coming from one institution may not be known in another. The existing planning structure needs to be better coordinated and better able to communicate iteratively within itself so that lessons learned in one institution can be applied quickly, as appropriate, in all the others.

There is a need for clear policies on issues such as subsidies and imports. As discussed above, these factors crucially affect whether hydroelectricity appears competitive or not in comparison with alternative energy sources and their various subsidies. The constantly changing policies and priorities have led to an atmosphere of uncertainty, particularly in the private sector where entrepreneurs are reluctant to commit their capital in the face of uncertain subsidies and rumours of grid extension.

There could be an important role here for an agency like ICIMOD in facilitating the starting of ideas and the effective coordination of activities between existing public and private sector agencies. The primary objective would be to bring together policy-makers to enable them to identify the key variables and needs for action within the sector. This could take the form of seminars, hosted by ICIMOD, at which representatives of the various institutions could meet to discuss priorities and to improve the lines of communication between their institutions.

Energy Efficiency

Efficiency in supplying electricity is not only good for public relations (at present consumer satisfaction is not very relevant to the NEA because the managers have no local accountability), it can also play a role in delaying capital expenditure on new installations. By getting more output from its present sites, the NEA could cope with increasing demand without the need to build more expensive projects, at least in the short term.

Increasing financial shortages in many developing countries make continued rapid expansion of the energy supply increasingly difficult and this has resulted in a perspective of energy efficiency as a more cost-effective solution to energy needs in developing nations. The World Bank estimates that saving a kilowatt of electricity by improving the distribution system may cost only a third of the production of an additional kilowatt from new generating equipment (Baum and Tolbert 1985).

Ways in which the NEA could improve its site efficiency through measures such as reduced staffing, equipment standardisation, and increased local budgetary accountability are suggested in the section on the cost of hydropower.

Efficiency is not only important at the points of production and distribution, however. By improving efficiency at the point of consumption, demand can be spread or reduced, thus enabling more consumers to be supplied by existing resources.

Recent studies in Brazil and India have shown that a shift to efficient lighting technologies would cut costs to consumers and reduce the required capital investment in unnecessary power plants. It has been calculated that the installation of efficient fluorescent bulbs in India would cost one sixth of the cost of building new power plants, while, in Brazil, higher plant costs mean that efficient fluorescent bulbs cost approximately one tenth of the building and operating of new power plants (Gadgil and Jannuzzi). These efficient fluorescent bulbs give off a more balanced, comfortable light at the same intensity but draw approximately one fifth of the electricity (16 watts instead of 75) of standard incandescent bulbs.

The NEA may have been constrained by its brief, which appears to have been to concentrate its efforts on increasing supply. It should start to plan energy requirements from the bottom up: rather than taking demand for granted, it should try to influence it. Load spreading would improve the profitability of present installations and the use of more efficient appliances would allow the benefits of electrification to be spread among more consumers. If the extent and pattern of demand could be adjusted (through the use of more efficient or storage appliances) the capital cost of new installations could be deferred.

The private sector has fewer efficiency problems because there are economic pressures from the start that discourage over-sophisticated equipment, over-staffing, and lengthy breakdowns. The economic pressures tend to result in least-cost designs which can reduce efficiency. Training is required: for owners and operators and also for manufacturing and Bank staff so that designs and construction can be better checked at each stage.

Demand Management

Improving energy efficiency requires positive action as regards subsidies and tariffs.

Pricing is an essential instrument of energy demand management because, since energy prices are artificially low, consumers do not have sufficient financial incentive to use energy more efficiently. Investments in improved efficiency appliances, which may well be more expensive, are not likely to be profitable if the equipment has to be purchased at commercial prices; but the electricity saved is subsidised: a further argument for raising NEA tariffs to a more "economic rate".

Lower tariffs can be used to spread demand, however, through introduction of a cheaper "off-peak" rate, as has been done very successfully in the UK and many other countries.

Pricing policy also determines in what form electricity is sold. If it is sold by the watt (as it is effectively in private installations that charge a monthly rate per bulb) rather than by the kWh (as in NEA installations at present) storage appliances will be encouraged. Using lower power over a longer period will reduce consumers' bills in instances where electricity is charged by the watt. Spreading demand in this way will improve the load factor of the installation. Since hydropower is available all the time at no additional cost, other than operators' salaries and depreciation of the equipment, it is logical to encourage consumers to use less power and to spread their use over longer periods.

Charging by the watt also permits the adoption of different metering technologies. As mentioned earlier, positive thermal cut-out devices (PTCs) are already successfully in use in some private installations. They considerably reduce connection costs, as there is no meter to be paid for, and also administration costs, because a fixed fee is paid each month and there is no meter to be read. The PTC simply cuts the supply if demand exceeds the amount it is set for and resets itself when demand is adjusted back to the correct level.

PTCs function up to about 200 W, but, above this, miniature circuit breakers are being developed to cope with currents of one ampere upwards. These can be assembled in Nepal, are a much cheaper alternative to meters, and would allow electricity to be bought by the watt. Other countries, such as Peru and Sri Lanka, which are interested in reducing connection charges, particularly for the small consumers, have shown interest in these devices and they are already in use in other countries, including Zimbabwe.

Improving the efficiency of electrical appliances is another area in which savings could be made in both private and public sectors. This again requires government intervention. The market for appliances is growing and there is a potential for local industry to develop. If manufacturers are encouraged to produce efficient appliances, it would be to the kingdom's benefit. They are not likely to do this independently, however, as there are economic pressures to choose least-cost designs, and, once these become an established industry, it is hard to substitute more efficient appliances.

The Government can encourage manufacturers to develop efficient products through various mechanisms: regulations governing the type of appliances to be produced and incentives in the form of tax incentives or grants for the production of appliances conforming to these regulations. Tax incentives can be used over a short period to encourage research and development work: if a manufacturer is involved in government-approved R&D work, tax is waived on the costs of that project. Similarly, regulations can be used to reduce the national energy bill - in Israel, for example, all buildings over a certain height must have a solar water heater. Both these actions would require careful overseeing if they are to work, but to involve manufacturers in R&D, rather than leaving it to academic and research institutions, increases the possibility of appropriate products being designed and then produced and sold.

Heat storage and low-wattage electric cookers are already being introduced as part of private micro-hydro schemes in Mustang, as are high efficiency bulbs. By using less than a quarter of the power required by conventional bulbs to produce the same amount of light, these bulbs allow the use of more appliances that can be supplied by the output of a small site. Substitution of low-wattage bulbs effectively increases the capacity of micro-hydro installations, again deferring the need for additional sites while accommodating growing demand. The Government should encourage the sale of these appliances through subsidies or incentives to the manufacturers, or through a subsidy on the appliance itself.

Finally, there is a need for training, particularly in the private sector. Users need training in how to use electricity, general safety measures, and how and why not to overload the system. Electricity is an unfamiliar energy source and an understanding of it will require assistance and time. Electricity awareness training is also necessary for owners and operators so that they can recognise the limits to the system's capacity and the need to improve efficiency.

Manufacturers are another group which would benefit from training. The sector is expanding rapidly and as new manufacturers compete for orders there is a growing need to assist and regulate the sector. Technical training is needed for some of the new manufacturers, and minimum design standards should be set during discussions with all manufacturers. Acceptable and realistic standards would protect investors, consumers, and manufacturers from poor quality work and under-bidding. A degree of design standardisation would also facilitate subsequent maintenance arrangements.

The training of ADB/N staff should not be overlooked. They play a crucial role in the non-government sector throughout the whole process from project identification to operation. They are, in effect, the supervisors who check the manufacturers' work at each stage. A thorough understanding of the processes and equipment involved would help to ensure the quality of private installations and thus the security of the investors' and the bank's money.

Energy efficiency, therefore, requires a variety of supporting measures from the Government, possibly with the assistance of external agencies. The measures required include:

i) research and development programmes,
ii) incentives to manufacturers to develop and produce more efficient appliances,
iii) educational and promotional programmes to increase awareness concerning energy efficiency among producers and consumers, and
iv) regulatory measures in the form of agreed standards that can be enforced.

End Use Development

Much of the disappointment with the performance of rural electrification in Nepal has been concerned with the lack of industrialisation associated with it. A purely domestic load gives low load factors, leading in turn to poor financial returns. One of the main justifications for the sums spent on rural electrification by HMG/N has been that electrification has many social benefits and leads to rural industrialisation, thereby contributing to the national economy and, at the same time, stemming urban drift.

The overwhelming evidence is that this has not happened. Given the experience of other countries, however, this is not surprising. In a recent study of rural electrification, it was concluded, "*It is, in fact, obvious that bringing an electricity supply to an area, is, in itself, not sufficient to cause development to occur*". It continues, "*Rather than electrification causing development, it may be the other way round with development creating the conditions under which* *successful rural electrification programmes can be implemented"* (Foley 1989). Similarly, A.G. Vinjar concludes from the Norwegian experience, *"It was not least industrial development, based on water power, that led to electrification of the Norwegian society"* (Vinjar 1980) (Figure 5).

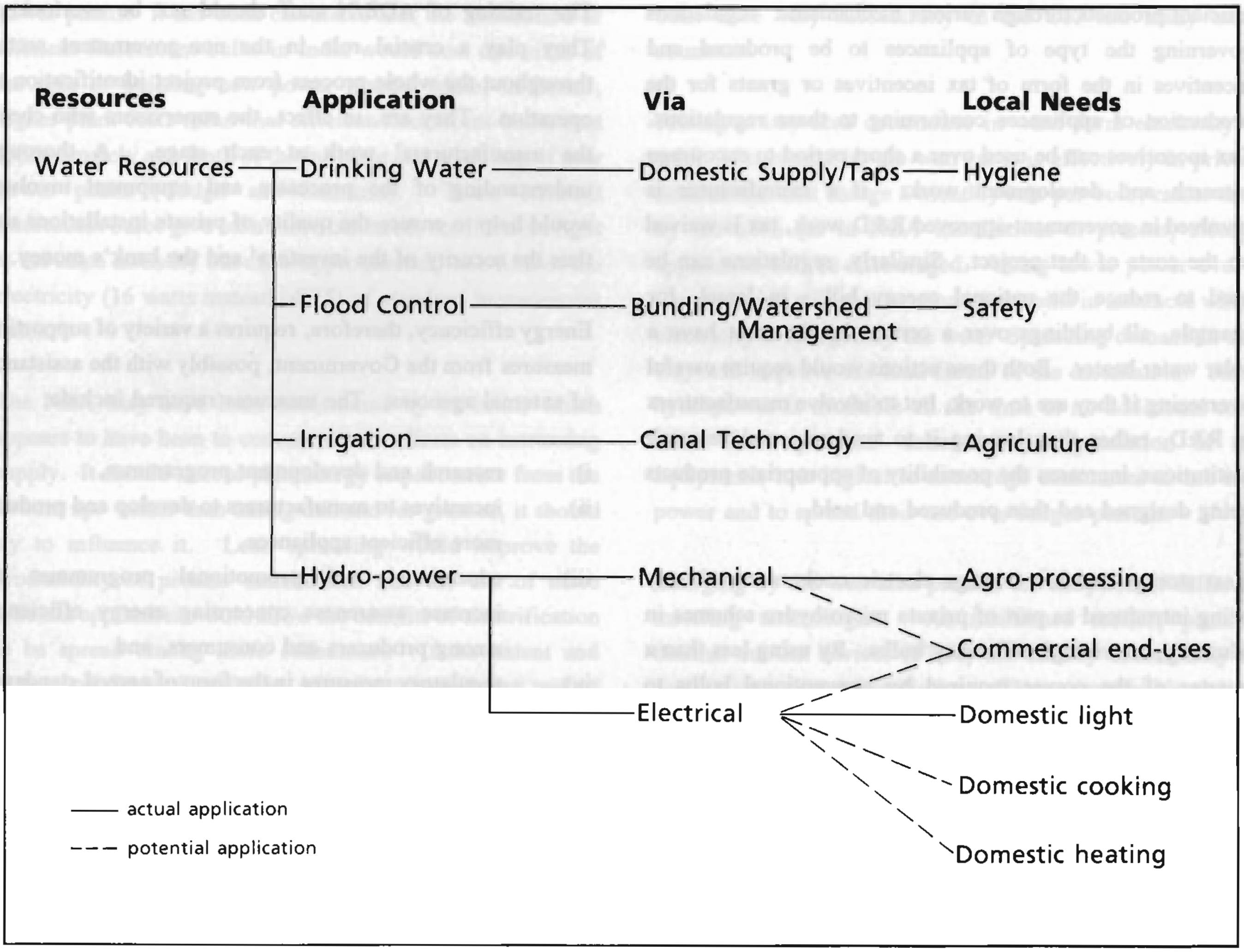


Figure 5: An Integrated Approach to the Use of Water Resources

There are very many reasons offered for the lack of industries associated with hydroelectricity, among them are:

- limited end use opportunities,
- limited purchasing power of potential consumers,
- few market opportunities,
- policy constraints,
- lack of complementary infrastructure,
- cultural and political factors,
- lack of training and support, and
- unreliable supply.

All of these are applicable to varying extents in different situations. Electricity is new to the hills: until people are aware of what can be done with it, entrepreneurs will not spring forward to invest in new industries.

The reason that the private sector is so commercially successful at the moment is that it is based on a clearly identified traditional use: mechanical power for agro-processing. Where electricity has been supplied to these private mills it has, again, almost entirely been used for domestic lighting. Government electrification projects in the hills were motivated, at least in part, by social considerations: to improve the facilities and conditions at district headquarters. Vague and optimistic statements were made in the Five Year Plans, assuming industrialisation would follow, but it did not. In 1988, WEC reported of the consumption of government offices at NEA-electrified district headquarters that *"At small hydro sites the total demand of this class is at least twice the industrial demand"* (WECS 1988).

The hill settlements are isolated, often only accessible by several days' walk along difficult trails. The population is small, scattered, usually illiterate, and very poor. Traditionally these communities have been almost self-sufficient and, even today, salt, kerosene (for lighting), plastic shoes, and possibly rice are often the only goods a household buys.

Given the difficulties of transporting agricultural produce and the small size of holdings, little surplus is produced. Therefore, would-be entrepreneurs face a situation of limited raw materials, difficult transport in and out of the areas, and a small local market with little disposable income - power supply is not the only limiting factor. As one study found: *"70% of sample industries reported plans for future expansion. But it is, as reported by them, due mainly (86%) to market potential rather than electricity supply (approximately 8%)"* (East Consult/IDS 1987).

Another factor discouraging potential entrepreneurs from establishing small industries is the unreliable supply produced by many of the micro-hydro installations. WEC found that "*Industrial growth in consumption appears to be particularly influenced by security of supply*" (WECS 1988).

Although some "productive" uses of electricity are already present and examples can be found of sawmills, furniture-making, electric looms, video as cinema, hot showers for tourists, poultry raising, radio repair, etc, these enterprises are small and have not arisen immediately following the introduction of electricity. Other technologies, such as electric furnaces (for ceramics) and refrigerators (for agricultural produce), could be modified to suit local conditions, but the problems are not only technical.

In most countries the hydro sector has developed to serve a specific industry: e.g., fish factories in Norway, agro-processing in Nepal, tea estates in Sri Lanka. In each case, the hydroelectric sector developed when an ongoing industry required power and identified hydroelectricity as an appropriate source. After its introduction to fill an existing need, electricity was gradually applied to other uses. Establishing an end use programme to "create" end uses for hydroelectricity would have to take great account of local social and economic factors when attempting to start new hydropower applications.

Any sustainable use of hydropower will have to be based on financially viable local enterprises. Hydroelectricity should be seen as just one of a variety of possible energy sources (diesel, mechanical power, etc) for these industries, however, and should be introduced only where it offers the best source of power for a particular enterprise at a specific site.

Given all the constraining factors listed above, and the fact that if productive end uses have not arisen in areas served by the NEA grid, from which larger amounts of more reliable power are available, it is hardly likely that mini- and micro-hydro schemes will lead to industrialisation. It might be better to consider them as "rural lighting" schemes and assess their impact according to different criteria. The use of electricity for lighting has provided sufficient load for profitable micro-hydro installations in Nepal. This demonstrates that end uses that improve the locally perceived quality of life and bring social benefits can form a sufficient body of demand to make such projects viable. Productive end uses, within the catchment area of the plant, would, however, improve the load factors and increase the incomes of these plants.

While some productive end uses are being installed, progress in general has been slow. Currently, the main area of opportunity for drawing additional income into many rural communities in Nepal appears to be tourism. Thus, the provision of hydro-powered services to tourists is an important area for development. Current uses of this type include lodge lighting, electric cooking, and hot water supply. Clearly, if more end uses of this type (productive or service) could be initiated, it would greatly improve the profitability of micro-hydro electrification. The need for a greater number of end uses has been widely recognised but it requires the coordination of many different tasks.

Identification of Potential End Uses

The first step is the identification of opportunities. End use development must be based on the specific local situation. The approach should be both integrated and decentralised. Integrated in that end uses should be considered at project design stage and written in from the start so that they can be taken into account in estimates of demand and future projections. This is the approach the Chinese have taken with their integrated regional planning. At the NEA Salleri-Chialsa installation, potential end uses were instigated at the project planning stage and a dyeing project was started.

The approach should be decentralised in the sense that every site is unique in terms of its resources, infrastructure, and problems: there is no single "end use solution" for all sites. This will require networking among many different organisations involved in different aspects of the work: research, credit, marketing, and community development.

In the longer term, the aim should be to help local communities vocalise their needs at a level at which they can get assistance. This requires:

i) assistance in the form of research and technical advice and
ii) channels of communication giving rural communities access to this assistance.

Ideally projects should be end use led. Potential end uses should be identified at the start of the project and ranked as follows:

i) existing products/markets that could change to hydropower,
ii) existing supply of raw material not presently processed (i.e., new process, existing resources), and
iii) new products, new processes.

The first are the most straightforward; sawmills and furniture-making fall into this category. Initiating new products based on imported materials requires the most support and outside assistance.

What is important is to match resources to opportunities on a site-specific basis, assessing everything from the point of view of the villagers and what is viable for them. This requires knowledge about the energy needs in villages and investigation on a site-specific basis into potential end uses. Organisations working in community development must be made aware of energy needs and the potential of hydropower.

Research and Development

Producing technologies and techniques that could be the basis of productive, profitable enterprises requires research work and funds. The Government should direct money into research activities and also encourage donors to take a broader perspective. Groups with research facilities could perform a great service by investigating areas of opportunity but the work must be integrated into existing manufacturing facilities.

Ideally, research work should be sub-contracted to manufacturers as they have more detailed knowledge of the problems encountered in the hills. If R&D work is done in the existing manufacturing environment, it will both increase the manufacturers' understanding of the technologies and processes involved and also result in appropriate and sustainable technologies which can be produced locally.

At present, the micro-hydro market is approaching a recession, as the number of mill installations approaches a peak in some areas and stand-alone electric installations are less profitable. If nothing is done and the market dries up (some manufacturers claim they are already receiving fewer orders) manufacturers will go out of business and the present opportunity to exploit Nepal's hydro-potential will be lost.

Without support, manufacturers will not innovate, but will always go for the least-risk option. If manufacturers are to research, develop, and field test technologies there will have to be an element of risk sharing in pilot projects with part of the cost being borne by the implementing agencies. At present, the ADB/N gives contracts to manufacturers to develop technologies but payment is only made once the work is completed. This presents many would-be researchers with cash flow problems. The dispensing of grants or incentives to manufacturers for approved research work will create problems in policing the funds, and it will also require coordination among the various funders to ensure work is not duplicated, but it is the most promising way forward. At present, the lack of appropriate end uses is seen as a blockage to the further expansion of rural electrification. It could also be seen as an area of opportunity.

Coordination

The field of end use technologies covers many different organisations: handicraft producers and those producing equipment on a small scale, government infrastructure, credit-giving banks, technology researchers, community development programmes. All of these have vital inputs to make in the development of productive end uses for electricity in the hills and their work must be coordinated to ensure information transfer. There needs to be an understanding of the implications of different end uses in the socioeconomic and environmental context and, further, a consideration of the way in which they are introduced. Equipment may be offered free by a donor, but what kind of back-up is required? How will it fit into other development plans for the area? A careful line must be drawn between risk-sharing and subsidy - if free equipment is given for testing it will affect the finances of the schemes and may lead to raised expectations among other potential investors.

More can be achieved if organisations collaborate. Fuelwood substitution programmes are unlikely to succeed where wood is still available at low, or no, cost. If its use can be banned, however, and if that ban is enforced, as the King Mahendra Trust has done with tourist lodges in the Annapurna Area, then substitution does take place. By producing an integrated plan for end uses at the project design stage, the Chinese are able to ensure that all the necessary inputs are provided.

Ideally there should be greater communication between NGOs and the government institutions involved, in order to coordinate research and investigate local needs and promote end uses. There may not be a single institution that is well enough placed to coordinate this. It may be appropriate for specialist organisations, with thorough knowledge of particular end use areas, to take the lead, but the overall objective should be to ensure a consistent approach. Electricity itself should also be promoted: raising awareness of what can be achieved with it and of where the opportunities are. This awareness raising is needed at several different decision-making levels: policy-making, programme planning, and individual projects. Good communication between these levels will result in future changes in demand being anticipated and provided for.

Micro-hydro is a least cost solution to Nepal's present energy needs and cannot be expected to result in rural industrialisation unless the other infrastructural inputs required are also provided. It may be unreasonable to expect end uses to develop in a couple of years when their development in other countries has taken decades. Demand for electricity is increasing and there is the potential to substitute for current energy sources which are expensive in environmental and economic terms, but this will require a substantial commitment to the sector and to the rural areas (Fig.6).

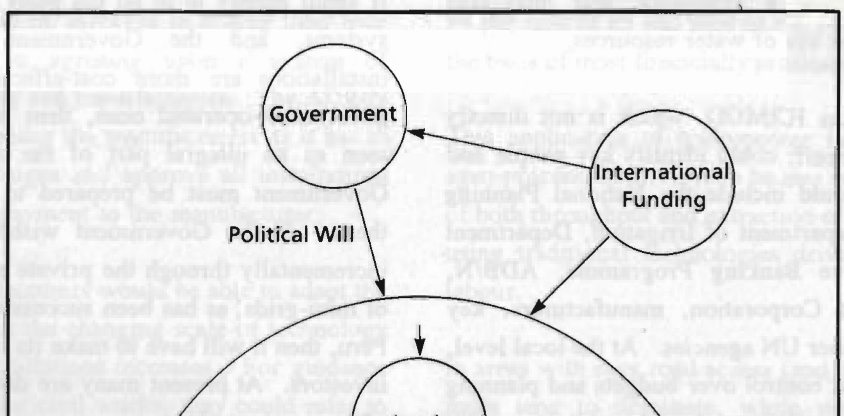


Figure 6: Factors Affecting the Development of the Micro-hydro Sector

Coordination and Control

The present difficulties mostly stem from the lack of a logical framework for planning mini- and micro-hydro projects on a national scale. Project plans are currently shaped in isolation by planners. The Master Plan for development of mini- and micro-hydro is currently being finalised so that projects can be planned in a more logical and systematic manner.

Public Sector

Improving the coordination and control of the public sector installations should lead to more efficient production and better financial returns.

At the policy level, coordination among the various bodies concerned would be greatly facilitated by a series of seminars or "think tanks" to identify policy shortcomings and recommend how policy can be better coordinated in the future. This would allow a systematic and integrated approach to planning the use of water resources.

An organisation, such as ICIMOD, which is not directly involved in the sector itself, could identify key people and institutions. These should include the National Planning Commission, WEC, Department of Irrigation, Department of Hydrology, Intensive Banking Programme, ADB/N, Industrial Development Corporation, manufacturers, key donors, UNIDO, and other UN agencies. At the local level, a greater degree of local control over budgets and planning at NEA small hydro installations should result in greater coordination as the decision-makers will be local and in frequent contact with each other.

Private Sector

The private sector has already benefitted from the central role the ADB/N has played in almost all private installations. The presence of one coordinating body bringing manufacturers and investors into contact and overseeing installations in an advisory capacity at least, has led to improved communications and efficiency in comparison with the public sector. The ADB/N's pivotal position in the sector should allow it to focus the credit and subsidies available. Similarly, its contacts with the manufacturers and entrepreneurs enable it to identify new manufacturers as they arise and incorporate them into training programmes.

To what degree the private sector should be coordinated or controlled by the Government is a more complex issue however. The limit of 100 kW for delicensed installations is a good one. It reflects a technological break between the small installations, which can basically rely on traditional water management techniques for their civil works and do not require advanced technological or administrative management systems, and the more complex higher capacity installations. At present, no private installations in Nepal have approached the 100 kW limit, although they are increasing in capacity.

It is not feasible for the NEA bureaucracy to become involved in building and running extremely small installations, especially as the private sector has been shown to do it more cheaply. This is also the case in countries such as Sri Lanka where the government Central Electricity Board has not attempted to regulate the production of electricity for private use in micro-hydro installations or to produce it on that scale itself.

If small supply is to be the basis of remote hydroelectric systems, and the Government decides that private installations are more cost-effective on that scale than government-operated ones, then private systems must be seen as an integral part of the national system and the Government must be prepared to encourage and support them. If the Government wishes to build up capacity incrementally through the private sector to create a system of mini-grids, as has been successfully done in Norway and Peru, then it will have to make its intentions clear to private investors. At present many are deterred by the uncertainty of government plans.

The lack of a clear strategy for grid extension has left many would-be investors reluctant to risk their capital in a venture that might be put out of business by the arrival of the grid that sells electricity at subsidised tariffs they cannot compete with. One possibility is that the Government should guarantee to buy the electricity privately produced in areas that later receive the grid. Buying small amounts of locally-produced electricity would increase the administrative load but would at least ensure that in the short term installations continue to be built and supplies extended. In fact, the Chinese have used micro-hydro stations at the end of long grid transmission lines to compensate for line losses. Similarly, the uncertainty about future government subsidies for hydroelectrification, and the inadequacy of the supply, deters many investors. Kerosene and the grid supply are currently subsidised and, if the Government expects micro-hydro electricity to compete with these, it must subsidise this as well.

There is also the question of to what extent the Government should try to control the quality of private micro-hydro installations. In addition to concerns about safety, if private stations are to be incorporated later into the national system, there are arguments for fixing certain minimum standards. If standards are too high there is a risk that they will be ignored or that all initiative in the sector will be stifled. It is not reasonable to impose very high standards and then expect the industry to be self-financing. Once again it is a question of government priorities: setting a level consistent with adequate safety and yet affordable.

If standards are to be effective they must be both realistic and enforceable. At present there are unlikely to be the resources or sufficient qualified personnel to enable the Government to enforce standards, and a voluntary code of practice, agreed upon by the manufacturers and policed by themselves, seems more realistic.

The manufacturers should be involved in setting their own quality standards and in agreeing upon a system of identifying approved work and manufacturers. The ADB/N could coordinate and monitor the manufacturers as it has to check all tenders and designs and approve all installations before making the final payment to the manufacturer.

The association of manufacturers would be able to adapt the code of practice to reflect the changing scale of technology as the size of private installations increases. For guidance in setting the standards for civil works, they could refer to the standard drawings produced for water and irrigation projects by the Department of Irrigation.

This does not leave the Government without a role however. In Sri Lanka, the Central Electricity Board (CEB) has a monopoly on the sale of electricity and the only other installations are for private use, often in industries or on tea estates.

The CEB is actively involved in the micro-hydro sector, however, giving training, keeping track of progress in other countries, and, through networking with them, learning about new technological developments.

By keeping in touch with the private sector, the CEB is in a good position to link them into the grid in the future and for the present acknowledges that they have a role to play.

Impacts and Benefits

Many hopes have been pinned on mini- and micro-hydro by HMG/N policy-makers and by non-government organisations alike. Both mini- and micro-hydro have been seen as a means of promoting rural development while also assisting the conservation of natural resources. HMG/N bodies, NGOs, and consultants have conducted studies on mini- and micro-hydro and, although cause and effect are not always clearly separable, a number of impacts have been identified.

Since mini- and micro-hydropower have been used to produce both mechanical and electrical power, the impacts and benefits of these applications will be discussed separately.

Agro-processing

The processing of agricultural products by milling, hulling, and oil expelling is still by far the most common use of private sector hydro installations in Nepal, constituting some 94 per cent of all end uses in FY 1987/8 (Jantzen 1989) and the basis of most financially profitable projects in this sector.

This application of hydropower has enabled demand for agro-processing services to be met more effectively in terms of both throughput and extraction efficiency than is the case using traditional technologies driven by water or human labour.

In areas with easy road access (and hence fuel supply) diesel mills tend to dominate, while water turbines are more common in less accessible areas. With the exception of oil expelling, for which the traditional technology has been almost entirely replaced by mills, the traditional techniques for husking and grinding are still used occasionally. This is usually when there is a small amount to be processed, when the mill is not operating, or when the family prefers to use its own labour at no financial cost. Thus hydropower has not, in this case, made consumers more vulnerable through dependence on it.

Time/Labour

Important reasons for the popularity of mechanical agro-processing are perceived savings in time and labour. Against these savings must be set the possibly increased time required for travel, queuing at the mill, and processing.

Several studies have computed time accounts for the different agro-processing technologies available, and, even where the time saved appears negligible, the willingness of users to pay a cash or kind charge for these services is perhaps the clearest evidence of local preference for such mills (Jantzen 1989, Metzler et al. 1984).

It seems that, often, the quality of labour involved is perceived as more important than the quantity of time. Grinding and husking manually, using the traditional *dhiki* and *janto*, is arduous and boring work. Users often prefer a walk to the mill, even with a heavy load, since it is often in the company of neighbours, with the compensations of a rest and social interaction at the mill.

The traditional method of oil expelling is particularly arduous and inefficient, and, for this reason, the traditional *kol* has almost disappeared from the hills (Jantzen 1989) and, if the mill is out of action, farmers will keep their mustard seed and process it once the mill is repaired.

Another effect of the mill is a change in the traditional division of labour: while all agro-processing tasks were traditionally women's responsibility a recent study found that in many installations men constituted 20-50 per cent of the users (East Consult 1990). There is no information to date on how the women use the time thus gained.

Coverage

ADB/N estimates (1987) suggested that an average turbine project serves an area of 203 hectares (145 households) and a national total of 71,050 households in 57 districts use micro-hydro installations (ADB/N 1987). Thus around 400,000 individuals are involved. A subsequent study calculated an average of 180 households (4-5 villages) served from within a maximum radius of 5 hours walk.

The coverage of each site varies with local population density, availability of other mills, and the crop being processed. Customers will walk up to five hours to process mustard seed oil but only up to two hours to grind maize and husk rice because the traditional technologies for these require less hard work.

It is clear that rural producers are prepared to walk considerable distances with heavy loads in order to use, and pay for, mechanised milling, hulling, and expelling services.

Income Generation

If turbines are correctly sited in relation to competing services, are not excessively time-consuming or arduous to reach, and are based on the provision of agro-processing services to surrounding areas, they are generally financially attractive investments. Individual performances vary widely from negative to 37 per cent return on investment (East 1982 in Jantzen 1989) but are generally positive. ADB/N estimated an average return on investment for agro-processing turbines of 15 per cent and a total national gross income from associated agro-processing of Rs. 29.9 million (net Rs. 8.3 million) in 1987 (ADB/N 1987). The net values of labour and time savings depend on the shadow prices used. The popularity of the installations indicates that the values are positive, however.

Health

There has been little detailed investigation of the health impacts of hydro-powered agro-processing. The reduction of physically arduous tasks should have a beneficial impact on women's health, although carrying loads to the mill will impose different physical strains.

The mechanised processing of rice results in a more highly polished product with less vitamin content and there is concern that this may affect health if rice is the staple food. Consequently, because the residue contains bran as well as husk it can be fed to livestock and this by-product is highly valued by those with livestock (East Consult 1990). Conversely, mechanised oil expelling extracts more oil which benefits the producers but results in a less nutritious residue. This oil cake is fed to buffalo and cattle and a reduction in its fat content could have implications for their milk yield and, consequently, human nutrition.

Electrification

The goals of rural electrification were not formally stated until a study was carried out by a WECS Task Force (WECS 1988). The report identified six goals based on analysis of previous government planning documents. These are:

i) to promote increased agricultural output through tube well pumps and small-scale industries,

ii) to promote tourism through the provision of services,

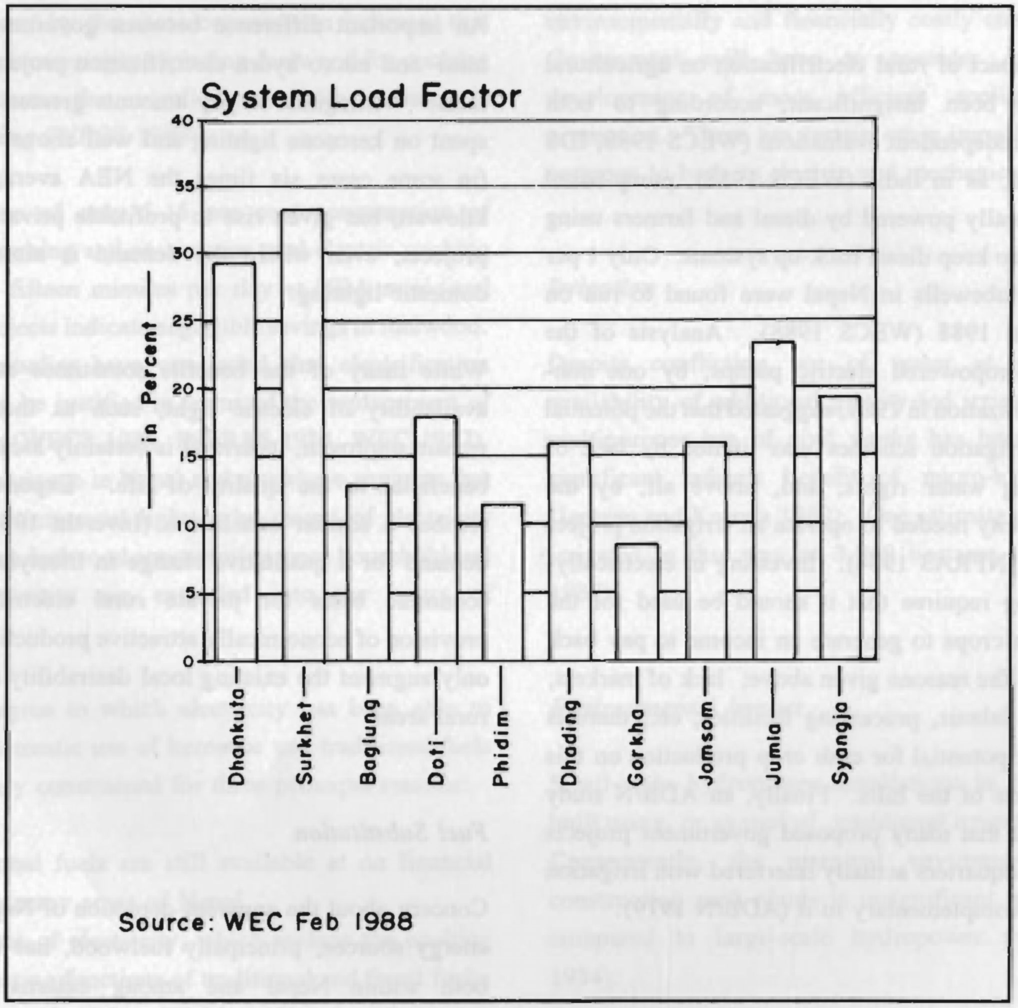
iii) to conserve scarce fuel resources,

iv) to assist effective decentralisation by electrifying district headquarters,

v) to allow more productive use of leisure time, and

vi) to facilitate provision of social and medical services.

Correlating rural electrification and socioeconomic change is seldom straightforward. As discussed earlier, rural industrial development has generally followed electrification in relatively prosperous areas where economic expansion and the development of markets are already in progress. Poorer and more remote areas, on the other hand, require development of physical and service infrastructure (roads, credit, training, etc) in order to use electricity for productive end uses. The growth of end uses is likely to take place over decades, not years, and to depend on numerous factors, electrification being only one of these (Fig. 7).



Source: WEC Feb 1988

Figure 7: Load Factors of NEA Mini- and Micro-hydro Projects

The growth centre approach to rural electrification has largely failed because of the absence of other key requirements (local capital, physical infrastructure, adequate promotion, and reliable power supply). The absence, in many cases, of these prerequisites, combined with the present infancy of appropriate productive end uses has severely constrained the development impact of rural electrification. End uses are not an inevitable result of electrical supply and their scarcity has not been adequately accepted by planners (FAKT 1989, SKAT 1989). Consequently, consumption patterns and load factors assumed for some government installations have been over-optimistic (SHDB 1985). These unrealistic projections of demand, combined with a heavily subsidised system of domestic tariffs, have had strongly negative impacts on the economic viability of government-operated mini- and micro-hydro projects. Despite their general profitability, private and community electrification schemes are similarly constrained by a lack of end uses. Estimates of the income-generating potential of non-government schemes vary; the World Bank estimated a potential 50 per cent increase in earnings when electricity was provided to an existing agro-processing plant, whereas ADB/N calculates generally negative returns because of the lack of end uses and correspondingly low load factors (UNDP/World Bank 1983, ADB/N 1987).

Similarly, the impact of rural electrification on agricultural productivity has been insignificant, according to both government and independent evaluations (WECS 1988, IDS 1988). In Nepal, as in India (WECS 1988), pump-based irrigation is generally powered by diesel and farmers using electric pumps also keep diesel back-up systems. Only 1 per cent of shallow tubewells in Nepal were found to run on electric power in 1988 (WECS 1988). Analysis of the potential for hydropowered electric pumps, by one non-government organization in 1984, suggested that the potential for electrified irrigation schemes was limited by lack of water, conflicting water rights, and, above all, by the amount of electricity needed to operate an irrigation project of suitable size (INFRAS 1984). Investing in electrically-powered pumping requires that it should be used for the irrigation of cash crops to generate an income to pay back the loan. For all the reasons given above; lack of markets, surplus land and labour, processing facilities, etc; there is not yet sufficient potential for cash crop production on this scale in most parts of the hills. Finally, an ADB/N study (1979) concluded that many proposed government projects near District Headquarters actually interfered with irrigation instead of being complementary to it (ADB/N 1979).

Lighting

The poor quality and low reliability of electrical supply, as well as the current scarcity of end uses, mean that lighting is likely to be the main load on mini- and micro-hydro plants for the foreseeable future.

Over 50 per cent of the demand for electricity from public sector installations is for lighting. At private electrification projects, where demand from government offices (which have been found to use a disproportionate amount of fans, heaters, radios, and cookers [WECS 1988]) is absent, this proportion is likely to be even higher.

Electric bulbs provide bright, clean light at a lower cost (at most sites) than would be required to produce equivalent light using kerosene. Although there is no evidence that rural villagers would be prepared to pay for the kerosene equivalent, electrification, by providing an improved lighting source, often results in villagers consuming more light than before, sometimes with a resulting increase in expenditure. Since they do pay for it, however, it seems to be within the financial resources of rural communities.

An important difference between government and private mini- and micro-hydro electrification projects is their tariff rates. Willingness to pay amounts greater than previously spent on kerosene lighting and well above the NEA tariffs (in some cases six times the NEA average revenue per kilowatt) has given rise to profitable private electrification projects, even where the demand is almost entirely for domestic lighting.

While many of the benefits sometimes attributed to the availability of electric light, such as increased literacy, remain unproven, its arrival is certainly locally perceived as beneficial to the quality of life. Experience elsewhere reaches a similar conclusion (Inversin 1983). It is local demand for a qualitative change in lifestyle that forms the economic basis for private rural electrification. Any provision of economically attractive productive end uses can only augment the existing local desirability of electricity in rural areas.

Fuel Substitution

Concern about the apparent depletion of Nepal's traditional energy sources, principally fuelwood, has been increasing both within Nepal and among external organisations. Alternative sources of energy, including mini- and micro-hydro, have been seen as important potential contributors to a reduction in demand for traditional fuels. Initial hopes of extensive substitution, however, have now become realistic in light of the social, technical, and economic realities of rural energy use in Nepal's mountain areas.

In view of the high proportion of electricity used for lighting purposes, significant savings by substitution of kerosene lights have been expected. Estimates vary regarding realizable savings. A UNDP/World Bank report on Nepal's energy sector in 1983 estimated the micro-hydro potential generating capacity, linked to agro-processing, to be 50 MW. The report calculated that the lighting supplies from such installations were equivalent to 80 million litres of kerosene per annum (UNDP/World Bank 1983). An ADB/N study estimated that replacement of kerosene lamps by electric light saved the national economy 60,000 litres of kerosene in 1987, equivalent to US$14,468 (using costs of Rs. 5.70 per litre, US$1 = Rs. 23.5) (ADB/N 1987). This level of substitution, however, allocating approximately 72 litres per customer per annum, differs markedly from some other estimates. WEC (1987), for example, estimated a replacement of only 1 litre per capita per year in hill areas, and another report by the same organisation indicates that kerosene is also increasingly replacing fuelwood for cooking purposes and hence the overall demand for kerosene is actually increasing (WECS 1988).

WEC's estimates of only 5-15 per cent consumption of electricity for cooking and an average total electric cooking time of five to fifteen minutes per day at NEA mini- and micro-hydro projects indicate negligible savings in fuelwood. A number of studies have concluded that electrification cannot currently be justified in terms of the replacement of traditional fuels (WECS 1988, INFRAS 1984, WEC 1987). In addition, experience in Nepal and elsewhere suggests that the provision of improved lighting by means of electricity actually increases fuelwood consumption since household and commercial activities are extended into the hours of darkness.

In sum, the degree to which electricity has been able to substitute for domestic use of kerosene and traditional fuels has been severely constrained for three principal reasons:

i) traditional fuels are still available at no financial cost in many areas of Nepal,
ii) end uses of electricity, which replace the cooking and heating functions of traditional and fossil fuels, are not yet widely available in Nepal, and
iii) those electrical end uses which are available for such purposes generally require not only a significant financial investment by the user but also abandonment or reorganization of traditional cooking methods (for example, by adopting heat-storage cookers).

Traditional fuels are unlikely to be replaced by alternative energy sources to any significant extent for at least the next ten years. Consequently, forest resource management and conservation hold the major practical potentials for alleviating widespread rural energy scarcity.

The potential for substituting electricity for traditional cooking fuels is greatest in areas where such fuels are no longer available on a "cost free" basis. Where cash payment for fuel coincides with areas visited by tourists this potential is maximised since the provision of electrical services (cooking, light, water, and space heating) to tourists can generate a financial return capable of justifying investment in alternative energy technologies and end use equipment.

In other areas, if electricity is to substitute for the present environmentally and financially costly energy sources, the Government will have to consider investing in the development of more efficient appliances and their promotion. There are certain other impacts of hydropower common to both its electric and mechanical applications.

Irrigation

Despite conflicting use of water at some sites, the availability of additional gravity-fed irrigation facilities by multipurpose use of civil works has been identified as a significant indirect benefit of micro-hydro installations (Jantzen and Koirala 1989). One estimate puts the total land irrigated in this way at 3,969 hectares in 1987 (ADB/N 1987).

Environmental Impact

Small-scale hydropower installations in Nepal are mainly built using, or as part of, traditional irrigation technologies. Consequently, the marginal environmental impact of constructing such plants is insignificant, particularly when compared to large-scale hydropower projects (Rodgers 1984).

Much of the intuitive appeal of hydropower lies in its potential for environmentally-sound energy generation. Operation of mini- and micro-hydro installations is essentially the control and exploitation of a renewable resource to produce useable energy in a pollution-free manner. Similarly, although the current ability to substitute for traditional or fossil fuels is limited, these resources are not required in significant quantities to operate the plant, so hydropower is not contributing to their further depletion.

The capital-intensive investment required to install mini- and micro-hydro projects has meant that the construction of many private sector projects is financed on credit. There is evidence that, where repayment schedules prove to be too demanding, agriculture can become over-intensified (for example, by multiple cropping to the detriment of soil condition and fertility) in order to raise the necessary funds (East Consult 1990).

These problems, although serious, generally result from the site-specific problems of poor technical design and of over-optimistic revenue projections rather than any inherent environmentally damaging qualities of mini- and micro-hydro.

Economic Impact

Mini- and micro-hydropower generation facilitate exploitation of one of Nepal's major renewable resources and, at the national level, hydropower is widely seen as a means of reducing foreign exchange payments for imported energy and fuels. At the local level mini- and micro-hydropower can reduce import-dependency and increase energy sustainability by using a local source of energy for an operating cost below that of alternatives.

Nepal's in-country mini- and micro-hydropower manufacturing base means that foreign exchange expenditure is only required for raw materials and component purchases. Manufacture, assembly, and installation costs all occur locally. Similarly, recurrent costs (operation, maintenance, and repair), other than costs of imported parts, raw materials, and lubricants, are also incurred locally.

Direct employment generation from mini- and micro-hydro installations appears to have been relatively small. At least one operator will be required to run any plant and, at non-government installations, a number of other positions may be created. Estimates of average levels of employment at non-government turbine sites range from 1.5 to 3 per site (ADB/N 1987). Any displacement of employment from *ghattas* has not been conclusively analysed.

All employees appear to be men with low skill levels and employed under terms favourable to the employer. In addition, hydropower turbines do not appear to generate employment at levels greater than diesel equivalents. The total ability within communities to pay for electricity and electrical appliances will determine the income-generating potential of hydroelectric generation at the local level. Unless employment-generating end uses can be developed, forward linkages from mini- and micro-hydro will generate little employment.

Backward linkages to a local mini- and micro-hydro equipment manufacturing base of some ten Nepalese companies have implications both for employment and for the development of local and exportable technical skills. One estimate attributed 90-100 jobs to the mini- and micro-hydro manufacturing sector in 1987 (Hislop 1987) while ADB/N estimated 294 employees in the same year. The total number of employees currently working in companies that undertake work in mini- and micro-hydro is probably in excess of 400 people.

The development of local industries, technologies, and manufacturing capabilities based on the hydro sector could influence significantly the levels and types of non-agricultural employment available in Nepal in the future if these skills are then used to set up other local industries and services. It is, therefore, important not to underestimate the potential contribution of mini- and micro-hydro manufacturing companies and their trainees in this field.

By providing investment opportunities for local entrepreneurs and communities, private sector mini- and micro-hydro installations can contribute to the local economy, to rural institution-building, and to the dissemination of technical and managerial skills. It is also possible that the ongoing migration from the hills to the towns and *Terai* may be slowed down by upgrading the locally perceived quality of life through the availability of electric light and other facilities.

Equity

The majority (80%) of non-government schemes are owned by private entrepreneurs, and even those nominally owned and/or managed on a community basis tend towards individual ownership over time (Jantzen 1989). ADB/N credit to finance such installations is generally easier to obtain for individuals than for a group and where such 'farmer groups' have been formed through the ADB/N's 'Small Farmer Development Programme' insufficient time and attention have been given to correctly form and support them, therefore they tend to be dominated by the more powerful members of the community. In one case, described in Annex 5, where the group was formed at

ADB/N's instigation rather than that of the farmers, they felt themselves to have become worse off because of the scheme. If micro-hydro is expected to promote community development and spread the benefits of the investment among several owners, adequate time must be put into supporting the groups and building them as institutions - in turn, this will increase the costs of the schemes.

The effects of ownership inequity vary markedly from site to site. As far as the users are concerned, Jantzen and Koirala suggest that the clientele of both private and cooperative/community mills are generally satisfied with present ownership patterns in view of the relative time, labour, and price relief the mills offer over traditional, diesel, or electric processing methods in remote areas (Jantzen and Koirala 1989).

A more critical factor determining consumer satisfaction is whether the owner is a local person. Where the owner was resident and subject to social pressure, installations were found to provide a more satisfactory service (East Consult 1990) with breakdowns fixed more quickly and prices set at a level acceptable to consumers.

Investment in any non-essential commodity is inevitably related to levels of income. The installation of electricity is, therefore, a function of both the ability and the willingness of rural communities to pay for appliances and the energy to run them. The ability to pay at different socioeconomic levels within the community will affect the degree to which existing inequalities are heightened or perpetuated. Experience in Nepal has shown that social stratification and the degree to which access to electricity is shared (for example, by public lighting) varies between communities, but the availability of electrical power does tend to reinforce social divisions (for example, see Flavin 1986).

One important difference between rural electrification and mechanical agro-processing is that electricity may require a capital cash payment by the consumer for connection, followed by cash payment of energy bills either on a metered or on a flat tariff basis. Agro-processing, by contrast, fills a more basic need, generally allows more flexible payment (in cash or kind), and requires payment only sporadically and for quantities if so desired.

In NEA installations the connection charge is high (on average about Rs 1,000) and is a deterrent to many poor consumers who resort to buying their electricity from a richer neighbour with a connection. This results in a very inequitable situation with the officially connected consumer benefitting from the highly subsidised NEA tariff and charging the client considerably more on a "per bulb" basis.

At non-government installations there is often no connection charge, the costs of distribution up to the houses being borne by the owner, but there is some evidence that the poorest sectors of the community may still not receive a supply if their perceived ability to pay is doubtful. There are also some instances reported in which communities have donated labour to construct the installation and maintain the waterways, but, again, the poorest have not been connected (East Consult 1990).

Payment in cash is a major deterrent for many non-monetised communities. A recent study found that, for agro-processing, cash rates worked out considerably cheaper than payment in kind, reflecting the high value placed locally on cash. Only the poorest (with no access to cash income) paid in kind and so, effectively, paid more (East Consult 1990). However, this is not always perceived as inequitable. Payment in kind usually involves leaving the residue with the miller. Residues are used for livestock feed and, as the poorest people often have no livestock, it is of little value to them.

As yet, there is insufficient information to assess accurately the impact of electricity on inter- or intra-community equity in Nepal. Its potential impact on both local and individual opportunities and perceptions, however, will be an important issue in future rural electrification policy. While mini- and micro-hydro installations are not a panacea for the problems of rural poverty, productivity, underemployment, inequity, or environmental degradation, the services that they provide are locally perceived as beneficial to many rural communities. Mini- and micro-hydro can contribute positively to many aspects of rural development in Nepal and the real achievements made to date should not be underestimated by direct comparison with the extravagant claims sometimes made concerning the sector.

IV. Constraints and Opportunities

Policy

At present, one of the main constraints to the expansion and improvement of mini- and micro-hydropower in Nepal is the lack of a clear and consistent government policy for the sector.

The relative importance attributed to the sector to date by HMG/N reflects wider government policies seeking:

i) rural economic development,
ii) regional economic development,
iii) social and political benefits, and
iv) use and development of locally available resources.

Nevertheless, while the overall policies are clearly stated, realistic and implementable sectoral and ministry level objectives are generally lacking.

Planning has failed to take account of the experience to date. Achievements have often been significantly less than the optimistic targets set in national plans and have consequently resulted in disappointment at the sector's performance. If planning is to result in realistic and realisable objectives, it is vital that the performance of earlier projects be assessed so that the lessons they have to teach can be learned. A realistic evaluation of the potentials and limitations of mini- and micro-hydropower and rural electrification is required.

Programmes seeking to introduce electricity, either as a replacement for traditional fuels or to stimulate decentralised industrial development, have not taken sufficient account of actual patterns of energy use in rural areas. Electrification will only replace traditional fuels where electricity is locally perceived as either socially or economically preferable.

The three main factors which presently determine the choice of fuel are cost, availability, and familiarity. Their relationship with three major energy sources is shown in Table 7. To encourage the use of hydroelectricity as a substitute for other fuels, the Government should consider the following policy options:

a) subsidise hydro installations, as is done at present, thus reducing their capital cost;
b) subsidise tariffs on hydro schemes and thus the recurrent costs to consumers;
c) tax or ban the alternatives to hydroelectricity to discourage their use (as has been done in the Annapurna tourist areas by the King Mahendra Trust); and
d) increase the government's involvement in training and the promotion and extension of hydroelectricity as an alternative to traditional and fossil fuels.

Table 7: Factors Affecting the Choice of Rural Energy Sources

Energy Source	Cost	Availability	Familiarity
Wood	Nil/very little	Declining	Very high
Fossil Fuels	Cash cost in small amounts, but determined by external forces	Expanding	Expanding
Hydroelectricity	Capital and recurrent	Limited but expanding	Limited but expanding

All of these options, apart from (c), will require funds for subsidies, and any tax or ban on the use of traditional fuels will require funds to encourage and/or police it. Furthermore, none of these approaches will succeed unless there is sufficient cash income in rural households to pay for the hydroelectricity or other alternatives offered.

Policy decisions concerning continuation, expansion, or reduction of HMG/N subsidies will reflect the government's assessment of the relative value in social, political, and development terms of different options for rural energy supply. These should be based on a realistic assessment not only of the impacts of mini- and micro-hydro to date, but also of the degree to which the Government can and should be involved in supporting or directing development and dissemination. At the national level this should include appraisal of the alternative investment options available for public funds, and HMG/N's priorities within these possibilities.

The emphasis on rural development evinced by HMG/N's current Basic Needs and Decentralisation programmes seems consistent with support for decentralised energy production in remote districts, largely under local control. Although the Eighth Five Year Plan (1990-1995) is not yet published, the indications are that it will continue with the current policies of spreading resources to the remote areas to promote more equitable national development.

Once the levels of funding to be made available are determined, explicit prioritisation among different programmes will need to be established. Resources could then be allocated in accordance with levels of priority. Consistency and continuity of objectives are required at all levels to develop the diverse sectors of the economy in a complementary manner. While shifting priorities and objectives are, to some extent, inevitable, the effectiveness of State involvement in Nepal's energy sector will be reduced if long-term support cannot be assured.

Temporary assistance can even be counter-productive. Expectations were raised by the introduction of government subsidies in 1985. When the subsidy was discontinued, it led to a crisis of confidence in the industry and, although the subsidy was reintroduced, this was done against a background of nervousness and the rate of investment slowed.

The importance given to mini- and micro-hydro needs to be clearly established and the respective roles of public and private installations better defined. If government perception of, and support for, complementarity between the two sectors' roles can be clearly spelled out, subsequent integration will be more easily and effectively achieved.

The delicensing of electricity sales from installations below 100 kW has greatly assisted the spread of micro-hydro installations by reducing the procedural burden on installers and manufacturers. However, there are other structural problems constraining expansion. Most micro-hydro manufacturers are registered under the Ministry of Cottage Industries. As a result, they are not expected to require import licences. Given that many of the raw materials required for micro-hydro manufacture are imported (steel, bearings, etc), this imposes a serious block on planning and production by the manufacturers. Registration under different criteria or the award of import licences to specified producers would go a long way towards removing this constraint.

The availability of credit via the ADB/N has played a vital part in spreading private sector micro-hydro to date. In order to make credit for micro-hydro more accessible, however, there has for some time been a need for a wider base of credit-giving organisations. This has been recognised by HMG/N and it is expected that other commercial banks will soon be using the ADB/N model of credit supply for micro-hydro installations. The commercial banks lack the ADB/N's expertise in technical support, however, and may need external assistance to establish adequate support services. While it remains to be seen if these banks can match the performance of the ADB/N, greater access to credit for both manufacturers and investors is needed to accelerate the spread of micro-hydro.

The use of micro-hydropower is approaching saturation in some areas of Nepal, particularly with regard to hydro-mills. Other areas, by contrast, have very few installations. This is due to their distance from manufacturers, who are all located in Kathmandu or Butwal, and also due to little or no exposure to the technology. Experience, for example, at the ADB/N's ATUs in Dang and Surkhet, indicates that raising local awareness of hydropower can significantly increase the number of installations in an area. If further promotion is sought, manufacturers may require assistance to publicise their services either through self-promotion or through government or non-government agencies.

The diversity of government organisations involved in Nepal's energy sector are not organised into a coordinated, multi-sectoral approach. Mini- and micro-hydro installations, as a source of energy both affecting and affected by sectors ranging from irrigation to industry, are particularly vulnerable to a lack of coordination and intersectoral linkages.

There could be a role for a policy-makers' seminar to identify existing policy constraints and ensure that the mini- and micro-hydro sector is considered by all those who make policies that affect it. The sector is still vulnerable and will require protection if it is to continue to grow. The present industry could be destroyed by even a relatively modest donation of equipment by a donor nation. An "infant industry" policy may be needed to protect the local manufacturers from under-priced imports. It might be decided to levy a large import duty on all turbines under 100 kW to ensure that the private sector continues to develop local skills and capacity.

Nevertheless, the trap of over-regulation should be avoided. The seminar should not attempt to make additional policies for the sector, but should confine its role to one of advocacy for mini- and micro-hydropower installation and raising the issues that affect them. Policy decisions could be made at the seminar, but by the relevant government bodies. The opportunity to raise issues, however, ensures that effects on the mini- and micro-hydro industry are considered as part of the decision-making process.

Future success rests on the commitment of HMG/N to the sector. The emphasis of current policy on basic needs and the decentralisation of government services would seem to be consistent with the promotion of small-scale, decentralised power production. Devolving some of the authority and responsibility for these installations, either through a reorganisation of the NEA structure, or through promotion of the private sector, should both increase local accountability and involvement and lead to more efficient and responsive power production.

Information

Mini- and micro-hydro projects in Nepal are designed using unreliable, and often extremely limited, support information. Both public and private sector projects are frequently under or over-designed because information, essential for project design, is unavailable. There are few hydrological records, little appreciation of landslide risk, and insufficient geological information. Even topographical data is, in many cases, very limited. There is little evidence of HMG/N, through NEA or any other organisation, actively building data bases of information for use in future mini- and micro-hydro projects. The lack of a small catchment hydrology programme is particularly disturbing.

A recurring problem with the use of water from small streams in Nepal has been the absence of small catchment hydrological records. Survey teams, therefore, generally measure streamflow during the site visit. If the visit does not coincide with the dry season, incorrect dry season flows may be assumed in the design. In any event, dry season flow during one year does not usually give an accurate picture of the long-term streamflow pattern. The estimation of flood flow also presents difficulties as minimal flood data are available and local recollection of flood events is generally unreliable. Similarly, accurate geological and topographical information is not widely available and is difficult to use without adequate training.

Accurate information is essential for the implementation of reliable water resource projects. The collection and presentation of this data in a form accessible to both NEA project designers and the local manufacturers who plan and build private installations require a large investment of time and funds. This may be beyond the capacity of government resources but is an area in which donor agencies could make a very valuable contribution. Once the investment is made and these systems are in place, the information will save much of the time that engineers currently spend investigating sites and should result in more appropriately planned projects. The data have an additional value in that much of it will also be of use to other sectors such as irrigation, watershed management, and transportation.

Key areas for which information and understanding are currently inadequate are discussed below.

i) Topographical. There has been very little mapping in Nepal and many of the maps produced are only available to the military authorities for security reasons. Good maps are essential for identifying potential sites (and so saving walking time in the initial stages of project identification) and also for tracing the sources of streams and rivers, thus determining catchment areas and flows. Many sites can be eliminated from the air or by using topographical and hydrological data, without the necessity of a site visit.

ii) Hydrological. Accurate hydrological data are valuable tools which can be used to help predict streamflows. Overall hydrological data need to be linked specifically to information on small catchments to enable models of streamflows to be made. Building an accurate hydrological data base should be a higher priority than other exercises, such as inventory studies, in the immediate future.

iii) Performance. A review of the performance of existing installations and the use of this information to feed back into the design process would ensure that lessons from past experiences are learned. An ongoing iterative process would allow design and management to be adjusted progressively until a degree of standardisation is achieved. The production of standard drawings and design manuals to save engineers' time, ensure minimum standards, and assist operators and maintenance workers has been successful in the Department of Irrigation and the MPLD bridge building programme.

iv) Demand Projection. Performance data will also enable more accurate prediction of future demands. An analysis of the load patterns and growth in demand of existing installations would facilitate more accurate load planning in the future and could avoid the building of unnecessarily large installations initially.

v) Geological. In a region highly prone to geological disturbance and landslides, an understanding of local geology is essential to geological risk assessment.

vi) End Use Identification. An integrated approach to rural electrification and development must be based on a knowledge of potential end uses and the development of criteria to assess their suitability in a particular situation.

Major efforts are required to collate existing information, identify lacunae, and implement programmes of targetted research. WEC have already taken a leading role in the analysis of Nepal's water resources. A large commitment of skilled manpower and financial resources is required to provide adequate support to the mini- and micro-hydro sector. A range of programmes is needed, both in base-line data collection and in upgrading in-country expertise. Obtaining the necessary information and expertise should be made a priority for the appropriate line ministries. If such programmes are implemented using public sector resources, WEC would be the most suitable coordinating body.

It is important that the above data be also available to the private sector, either via the ADB/N or directly. Access to information will be an important aspect of the upgrading of the sector and, particularly as private installations grow in size, the availability of accurate data and designs will help smooth the transition in scale.

Access to information is also an important factor in improving coordination. Data on private sites and their design and performance would assist the ADB/N and owners in identifying the higher quality manufacturers and also in establishing design guidelines. In Peru, access to information was not coordinated initially, but now a directory of users and services is being compiled.

Given the importance of natural resources (particularly water) to Nepal's economy, a detailed understanding of the country's resource base should be seen as an essential investment. The national, multi-sectoral, and long-term importance of this information means that public sector support is essential. The collection and analysis of all the types of data discussed above may require funds and expertise beyond the resources of HMG/N, however. There is an opportunity here for ICIMOD and other external agencies involved in this sector to make a valuable and lasting contribution to the development of hydropower in Nepal and, through this, to the development of the country itself. By bringing in experts on hydrology, geology, and engineering, as required, to gather information and establish a resource centre to build on and complement the micro-hydro experience already in the country, a centre of excellence that can be of value to the whole region could be established.

Training

Design skills, planning expertise, construction and supervision skills, and end use introduction are some of the areas in which further training is required. In order to identify training needs and target the appropriate recipient groups, it is necessary first to identify the roles to be fulfilled in the hydropower sector.

These roles are largely dependant on the scale of installation. The Chinese, in giving responsibility to different levels of the community according to the installation size, recognise that different technical standards and management techniques are required for different scales. The first breakpoint occurs with water flows of about 500 litres per second (this corresponds to a capacity of about 100 kW for an average site). Beyond this size, non-traditional methods of water management and construction are necessary. A further breakpoint occurs at around 250 kW when the scale of equipment involved requires additional management, technical skills, and access roads. As mini- and micro-hydro installations are upgraded, additional training on enlarging water systems and on new skills required must be an integral part of the process.

Design, supervision, management, and operation skills are fulfilled by different groups in the public and private sectors, as shown in Table 6. It is, therefore, important to target training carefully.

Design

Developing training programmes in design skills will require regional experts at some stages. This should be combined with the setting-up of agreed minimum standards in an iterative process, whereby standards are continually modified in the light of performance feedback from operating sites and also in the light of the technical capabilities of the designers. Standards are bound to be ineffective until there are people who are sufficiently skilled to adapt designs to them and to enforce them. As the design skills of the local engineers improve, it will be possible to raise gradually the minimum standards at both NEA and non-government sites (coordinated through the ADB/N).

Funding and Planning

While funding organisations do not require training as such, coordination of the sector will improve by regular meetings and briefings. These could be convened especially for the purpose, or, if such meetings already take place, micro-hydro could be made a regular item on the agenda.

Links should be made with agencies working in the end use field at this stage so that potential end uses can be investigated and built into estimates of demand while the project is still in the design stage.

Installation

Technical training is required for those who will construct the site and install the equipment. In the government sector this will be private contractors, supervised by NEA staff; in the private sector it will be local manufacturers, supervised to some degree by ADB/N branch staff.

Training at this level should be closely linked to the development of minimum standards and quality control. It could be greatly facilitated by a degree of standardisation in the types of equipment used by the government sector.

The training of more supervisory staff should reduce past problems caused by poor construction quality and ensure that installations are brought up to the standards set. Involving the operating staff in the construction, as the Chinese have done (Hangzhou Regional Centre 1985), would act as another form of training, by improving their understanding of the equipment and processes involved.

Management

The management of projects in both the public and private sectors is an area which must be given priority if the performance of mini- and micro-hydro is to be improved.

In the NEA-run installations, management systems need to be redesigned to give more authority to the on-site managers. A greater degree of local accountability and freedom in decision-making should improve the project's response to local demands, but managerial and operating staff may need to be trained to take on these new responsibilities. If local staff are able and if they are required to monitor demand and predict how it will increase, additional demands can be predicted in advance and capacity can be adjusted with a minimum of load shedding. Load shedding results in consumer frustration and lack of confidence in the service, thus adversely affecting demand.

In the non-government sector, management is less of a problem when there is an individual owner living in the community and responsive to it and to pressures to repay the ADB/N loan. Management has been a problem in the group-owned installations, however, and if micro-hydropower is to be seen as an income-generating opportunity, which will spread the benefits of ownership to poor farmers and promote equitable development, then it must receive the necessary support. The potential for group formation should be considered in the feasibility study and more attention should be given to the selection and orientation of the group members than is given at present. This will require training, both for group members in accounting, management, and decision-making as a group and for the ADB/N branch staff who are responsible for identifying and supporting these groups. They will require guidelines for the appraisal of groups and for their long-term support. Much can be learned from the approach of the Department of Irrigation whose field staff have worked well with villagers by building on their traditional methods and gradually upgrading them. They have based their work on indigenous institutions and strengthened them so that now the traditional decision-making bodies have legal status.

Operation

The standardisation of the equipment used in NEA installations would go a long way to simplifying the training needs of operators. It is important to target the actual operators and ensure that the topics covered are appropriate to the functions they perform. In the past, most of the training has been given to local engineers, while the day to day operation is usually in the hands of much less qualified people. Allocating more of the responsibility for O&M to the on-site staff will require more training, but might also improve their motivation.

Maintenance

The setting of standards for the industry should include establishing procedures for operation and maintenance. Routine maintenance has not been satisfactory in either public or private installations and further attention should be given to it if breakdowns are to become less frequent.

Where possible, the training for both maintenance workers and operatives should be conducted on-site so that its applicability and relevance to their work is more directly perceived.

End Uses

The promotion of electrical end uses to increase rural industrialisation and improve the use of hydroelectric installations will require skill building and awareness raising at all levels. Villagers will require training in "electricity awareness" to familiarise them with electricity, its risks, and its potentials.

Project designers, be they NEA engineers or local manufacturers, must be made aware of possible end uses and their implications for demand, so that they can be taken into account at the initial design stages. ADB/N branch field workers will also require training in the different income-generating opportunities arising from electrification and in how to assess the suitability of each in a certain situation. Once an opportunity has been identified, skill training will be required for production, management, and marketing as appropriate.

Roles and Opportunities

There are many examples of constructive training activities, both in Nepal and around the world, which suggest the way forward.

In Sri Lanka, initial training was on the job and very informal, but as the sector developed and a base level of ongoing activities was established, the need for training has become clearer and is more appreciated. Now training in the sector is more formalised and has led to a large pool of trained engineers who, in turn, are a resource for further training. The Sri Lankan Central Electricity Board now gives training to operators but there is still a big gap between the urban, educated engineers (usually trained to degree level) and the operatives who do much of the basic work. This tendency to pitch training too high and forget the different training needs of the important lower roles is common to many countries, including the public sector in Nepal. In the private sector, the very small pool of professionally trained engineers in the country has led to an emphasis on reducing and simplifying all tasks to enable the least-qualified person possible to do the job. While this may lead to some losses in efficiency, it will give gains in terms of lower costs through lower salaries.

DCS in Butwal gives courses to its client owners and operators once a year. The ADB/N would like other manufacturers to be involved in these activities, but they are mostly reluctant to do so because of the costs involved and because they do not have the training skills. These seminars are popular among the participants as they provide an opportunity to convey feedback to the manufacturer, to share experiences with other owners and operators, and for general networking.

It is possible that DCS might be able to extend its seminar programmes with further funds; alternatively the ADB/N might be able to coordinate this. While the Agricultural Credit Training Institute (ACTI) is responsible for the training of the ADB/N's own staff, ADB/N has been responsible for running its technical training for owners and operators independantly. The NEA has been responsible for training its own staff separately.

In Peru, what began as a seminar on "Hydroenergy and Rural Development", attended by NGOs and also representatives of the government organisation, Electro Peru; has led to the compilation of a users' directory, to the establishment of a technical forum and an "Association of Hydro-energy Users", and to several series of regional seminars based on pilot projects: one set for electricity consumer groups and community leaders, another for planners and policy-makers, and a third for those involved in the technical aspects (Edwards 1990). This illustrates the catalytic role that improved communications among different branches of a sector can have.

ICIMOD, as a policy influencing organisation with links around the region, could fulfill a similar catalytic role in the Himalayas. By coordinating an informal, occasional "think tank" for policy-makers, it would not only improve the awareness of rural electrification and the communications among associated policy-making bodies, but would also help to identify training needs. The proceedings of these seminars would be disseminated and recommendations acted upon. Monitoring training courses and redirecting funds accordingly could be undertaken by the higher level organisations not directly involved in grassroots' level training.

The role of NGOs will be crucial at this grassroots' level. Their comparatively smaller sizes and greater flexibility allows them to take the initial catalytic role in many areas of development. NGOs are able to provide some of the essential pre-conditions for the development of new technologies: initial funds, research capability, awareness raising, training, institution-building, and coordination. Their catalytic role is central as shown in Figure 6, but they can only sow the seeds of development; a climate in which they can grow is formed by political will acting on local conditions. It is this which can be influenced by organisations working at the higher, policy level.

The micro-hydro sector requires action on several training levels simultaneously. The consciousness of policy-makers must be raised over the next two years, in order to improve planning and coordination, to assess achievements to date, and to set standards and goals for the future. Meanwhile, training at the grassroots' level is required to improve the capabilities of operators and installers and raise awareness about electricity and its uses. The capability is there: the King Mahendra Trust has a good record of training lodge owners in the Annapurna Region to substitute electricity for fuelwood and kerosene; the ADB/N has the staff and training skills and is well placed to continue training owners and operators; and the sector as a whole has gained valuable knowledge and experience from the Andi Khola and Salleri-Chialsa installations.

Once both the policy and operative levels are up to standard, it will be possible to start planning and training for the management of larger micro-hydro installations and mini-grids. All roles will be affected by the changes in scale and so retraining will be necessary, but before this is attempted it is vital that current problems are resolved and that support and back-up are brought up to a minimum acceptable standard.

Technology

While policies of subsidy and concessional credit have assisted the spread of mini- and micro-hydro in Nepal, both the technologies concerned and the manufacturing base of the sector have developed largely independantly of government intervention. Nevertheless, further progress will require substantial research and development. Experience to date indicates that such technical development is best carried out by manufacturers rather than by research centres. The research costs involved are too great for individual manufacturers to bear, however, and realisation of mini- and micro-hydro's full potentials in Nepal will be constrained unless manufacturers are assisted by risk and cost-sharing initiatives.

In the past, SHDB supported the use of locally manufactured equipment in government-operated mini- and micro-hydro installations. More recently, this approach has been replaced by the use of world tenders for electromechanical equipment. This has limited potential markets for local manufacturers and increased the capital and foreign exchange costs of projects. The use of equipment from at least five countries outside Nepal has led to non-interchangeable parts and expertise in addition to costs and delays because of having to obtain parts and technicians from abroad. In addition, some equipment purchased on the basis of low prices has given continuous, unresolved operational difficulties. The selection of equipment must be based on a well-informed appraisal of the probable lifetime costs of any equipment chosen. A policy giving preference to locally made equipment would result in long-term benefits to the technology sector in Nepal. Unless local manufacturing and design capabilities are developed in-country, any increase in the number of NEA-operated projects will only add to the existing problems of maintenance and repair. While standardisation will not remove the problems of operation and maintenance entirely, equipment procurement should involve a more thorough analysis of the long-term implications for cost and sustainability.

The growing demand for electricity and thus for larger private installations and for upgrading the capacity of NEA installations require an improvement in the technical base of the country, but that should not be the first priority. Before attention is turned to new technological levels, the existing national skills' base must be consolidated and upgraded. One of the main shortcomings of the public sector has been the attention given to individual projects at the expense of a coordinated national policy. The lack of standard procedures, design guidelines, and management training has led to inefficient installations and lost opportunities in terms of building on the experience which has been gained. Improving the quality and management of present installations could greatly increase their output and bring them up to capacity.

Another means of extending the benefits of electricity is the use of more efficient appliances. These include higher efficiency light bulbs and heat storage technologies for cooking and heating. Although these technologies tend to require higher initial investment compared to less efficient appliances, it may be to the Government's advantage to subsidise the efficient use of electricity rather than increasing the capacity of existing isolated systems or build new plants.

What is required is a balanced and careful study of the sector as a whole followed by the establishment of clear policies prioritising the development of skills and processes in the short term, rather than additional new technologies and individual projects.

Conclusion

It appears that many of the factors that have limited the growth and performance of the mini- and micro-hydro sector in Nepal are related to the lack of clear and consistent government policies. The absence of a long-term policy for the country's energy supply has led to planning in the different sectors on a rather *ad hoc* and uncoordinated basis. If entrepreneurs and community groups are to be encouraged to invest in micro-hydro electrification, plans for grid extension must be made available. At present, many would-be investors are deterred by the fear that the grid may be extended to their area, putting their plant out of business by providing electricity at subsidised prices.

Frequent breakdowns at NEA installations stem from management difficulties inherent in the centralised nature of the bureaucratic structure and the lack of accountability at local level. Technical problems are often related to the use of imported and unfamiliar technologies and frequent over-specification by donors and their agents. The lack of coherent guidelines on equipment specifications and standards has led to project planning on an individual basis by donors, resulting in the installation of diverse equipment from different countries.

Despite these problems, there have been some significant developments in the sector and the signs are encouraging. A new institutional model is being tried at the Salleri-Chialsa installation and a new technical approach, based on the use of skills and equipment available within the country, is being implemented at the Andi Khola site. Both of these projects should provide valuable lessons for the NEA and the sector in general and strengthen attempts to use hydro-projects that build on the skills and industries developing in the country.

The apparent failings of the sector, in general, and the government-run projects, in particular, are the result of over-optimistic planning which created unrealistic expectations. When compared to the experiences of other countries, the NEA's record for both capital costs and load factors is quite creditable and the record of the private sector is competitive. The provision of government subsidies to the private sector and the delicensing of sites below 100 kW has caused the growth of an industry that is not only supplying valuable services to the country but has also the potential to become an export industry.

Reasons for the profitability of the private sector installations include the fact that many started by providing agro-processing services and electricity generation was only added on later. The private hydropower industry has been based, therefore, on an existing need for which there is considerable local demand. Mechanical milling has often subsidised electricity generation, initially, as demand for a new energy source takes time to grow. By contrast, the government installations produce electricity only and have been expected to cover their running costs, at least, from the start. Given the lack of disposable incomes in remote areas and the lack of the other infrastructural inputs required for industrialisation, it is hardly surprising that there has been little demand for electricity for productive end uses.

Private installations have also had the advantage of scale: below 50 kW, traditional methods of water management and construction can be used, thus reducing the skills and training required for construction and operation staff. NEA remote hydro-installations (existing and under construction) range from 30 to 1,000 kW and most are over 100 kW. At this size they lose many of the advantages of small-scale installations since more sophisticated and costly construction and management techniques are required.

Another cause of the poor financial performance of public sector installations has been the nature of their management systems. The centralised decision-making structure has left on-site managers with little authority over budgets and they are accountable to the centre rather than to the local community. A greater degree of local involvement in the management of NEA schemes, perhaps at the district level through the contribution of some funds or labour and representation on the management committee, might increase the motivation and ability of the operating staff to maintain the installation and to respond quickly to breakdowns.

Decentralisation of the management of remote installations (successful in Norway and China), would require a restructuring of the NEA management and retraining of staff to cope with changed or increased responsibilities. It should not reduce the involvement of the central levels in the sector but merely change its nature. While plant level management decisions would be left to on-site managers, the centre should become more involved in gathering hydrological and topographical data, analysing the performance of existing installations, setting design and construction standards, and giving clear direction and greater coordination to the sector.

Technical training is needed in both the public and private sectors, particularly at the operative level, to improve present standards. As pressure to increase the size of installations grows in both sectors, it is important to bring existing manpower and skills up to an acceptable standard before attempting to work on a larger scale. The private sector has already contributed to skill development in the sector, through the training programmes of DCS and the ADB/N and the informal training given by manufacturers to their staff, but these skills will require consolidation and upgrading if the sector is to grow. Enquiries to Nepal turbine manufacturers from other countries are evidence that the mini- and micro-hydro industry has the potential to become a national export industry as well as a local supplier.

Mini- and micro-hydropower offer both a renewable and non-polluting energy source for the mountainous areas of Nepal. It is also the most appropriate and the least costly solution to the problem of supplying energy to the small, scattered communities in the hills. The installations are on a scale that can be locally managed, use equipment that can be produced and maintained within the country, and are the only source of power that has the potential to meet many of the perceived energy requirements of hill communities in the medium term. Other renewable sources, although they have potential, need further technical development, while grid extension to cover the whole country cannot be achieved in less than twenty years.

There are many lessons to be learned from the extensive experience which Nepal has acquired. There is no doubt that micro-hydropower and its associated end uses are already contributing significantly to rural development in certain areas. Much of this success has been based upon an entrepreneurial private sector, with some technical assistance. The public sector use of micro-hydro has generally lacked clear objectives, rationale, and management mechanisms. Nevertheless, important lessons from public sector experience can be learned and the sector has crucial roles to play both in the support of private sector initiatives and in the provision and management of its own mini-, rather than micro-, hydro projects. The results of experience to date suggest that a redirection of resources, and a change from a target-based emphasis on commissioning large numbers of individually designed projects, to an emphasis on the development of integrated systems, is required. This would enable designs and standards to be refined, in order to create a system that reflects Nepal's priorities and fulfills its needs. As the manufacturing base and the awareness of micro-hydro expand, the use of micro-hydro will extend to new areas in Nepal. A strategic vision of the direction in which the sector needs to develop, and clear and supportive policies to guide it, will create an environment in which a successful industry, firmly based on the country's own resources of skills and hydro- energy, can develop.

Annex 1

Electricity Prices in the Asia Pacific Region

Table 1. Electricity Prices, by Consumer Group, 1987 ($/kWh)

	Industrial	Commercial	Residential	Average
Japan	11.3	19.9	19.2	16.8
South Korea	6.6	15.9	9.0	8.0
Philippines	10.1	9.9	5.4	8.4
Malaysia	6.6	8.7	8.4	7.7
Indonesia	4.3	10.2	6.2	5.7
China	2.0	-	4.1	2.3
Nepal	3.9	6.1	4.4	5.0

Source: Fesharaki, F. and Razavi, H. Electricity in Asia Pacific-Power Station Fuel Demand to 2000. The Economist Intelligence Unit Special Report No. 1184, April 1989.

Annex 2

The Policy Behind the Public and Private Sector and a Comparison of Their Operational and Financial Performances

History and Policy: Public Sector

The oil crisis of the early 1970s led to a renewed interest in alternative sources of energy and decentralised power generation, both worldwide and in Nepal. In 1975 the mandate for development of small hydropower projects was given to the Small Hydro Development Board (SHDB) under the Electricity Department. With the merger of the Nepal Electricity Corporation and the Electricity Department to form the Nepal Electricity Authority in 1985, the SHDB was dissolved and all aspects of government mini- and micro-hydro work are now carried out by NEA Directorates. Faced with a large demand for rural electricity, the NEA has prioritised project and supply areas as follows:

i) district headquarters,
ii) multipurpose projects,
iii) supply to cottage industries, and
iv) supply to tourist areas.

It is expected that all district headquarters will be electrified by FY 1991/2 (Shrestha 1989).

Results to date of the NEA approach have not been encouraging. Not only are the capital costs considered by the Government and donors to be too expensive, but operation and maintenance difficulties are widespread and cause consumer frustration and reduction in revenues.

One of the main reasons for this is that, from the formation of the SHDB to the present day, the aims and objectives of the programme have not been clearly expounded. Finance, both grants and loans, for NEA-operated mini- and micro-hydro has come from a variety of sources. HMG/N, UNCDF, ADB (Manila), OPEC, and the Governments of Yugoslavia, Switzerland, and Austria have all contributed to the NEA small hydropower programme. The lack of a continuous supply of funding for the construction of NEA-operated mini- and micro-hydro has caused disruptions to the programme, a difficulty common to all HMG/N capital works' programmes where external funds are involved.

The external funds have been accompanied by a wide variety of stipulations, including the use of home-country equipment and consultants. A common donor stipulation is the requirement for extremely accurate and sensitive governing equipment. In its February 1988 report, WEC noted that seven out of ten installations had governors out of commission or not functioning efficiently. Over-specification can often result in the purchase of equipment which is difficult, if not impossible, to maintain properly within Nepal.

A number of studies have emphasised the poor planning of public sector mini- and micro-hydro projects in Nepal (ITECO 1986, East/IDS 1987, WECS 1988). This problem extends beyond individual projects. HMG/N set an ambitious target for SHDB in the Fifth Plan: to install 40 mini- and micro-hydro projects by Fy 1980/1. In reality only four installations were commissioned by SHDB during the Fifth Plan and an additional ten during the Sixth Plan. In the ten years following the establishment of SHDB, an average of only 50 per cent of the allocated budget could be spent each year (Shrestha/Pradhan 1985).

Despite the enthusiasm of government plans, it was impossible for SHDB to mobilise resources with sufficient speed to meet HMG/N targets. In an attempt to commission as many installations as possible, SHDB concentrated almost exclusively on individual project planning. Little work was undertaken on the establishment of an overall programme of mini- and micro-hydro development. Inventory studies, feasibility assessments, and project ranking received low priority. Some fifteen years after the establishment of the SHDB there is still no Master Plan and projects are still designed in isolation with little consistency in design specifications and procurement procedures.

History and Policy: Private Sector

While government involvement in mini and micro-hydro has been in the provision of electricity, private sector activities have, until recently, centred on the use of water to power mechanical agro-processing devices. Since 1982, however, an increasing number of electrical generators has been retrofitted to mechanical schemes. In addition, some 17 privately-owned, stand-alone electrification projects were installed by the end of FY 1987/8.

Until 1984, operating licences were required for all private electrification installations. The lengthy procedures involved proved a major disincentive to prospective installers. Following recommendations from WEC and others, HMG/N acknowledged that direct government involvement at this level was ill-conceived and sites less than 100 kW were delicensed. Furthermore, private financing of projects and unrestricted tariffs were now permitted for these installations.

Finance for over 90 per cent of private micro-hydro projects in Nepal has been provided by the ADB/N. In addition, the bank actively encourages exploitation of micro-hydro sites through its banking offices and Appropriate Technology Units (ATUs). Bank officers receive training in aspects of micro-hydro technology and annual turbine installation targets are set for each zone of the country.

Funds are made available to prospective owners at rates of interest slightly less than equivalent commercial rates. Rates have historically ranged from 11 to 18 per cent per annum. The repayment period is generally seven years from acceptance of the completed installation by the owner.

In FY 1985/6, HMG/N encouraged expansion of this sector by announcing a 50 per cent subsidy for private sector rural electrification. The subsidy was discontinued in the following financial year but re-installed in FY 1988/9 when HMG/N set aside NRs 3 million for subsidies. The subsidy which was administered through the ADB/N reimbursed 50 per cent (75% in remote areas) of electrification costs (but not the costs of civil works or of mills). In March 1990, it was announced that the subsidies would henceforth cover the total cost of installations and that they would be available through the commercial banks in addition to the ADB/N (The Rising Nepal 1990).

Thus the private sector approach has been to start with a clearly identified end use (generally milling) and projects are identified, demanded, and paid for at the local level. Individual or community ownership and the pressure to run profitably ensures that the projects are responsive to local demands. Overall direction and strategy are determined by the ADB/N and project planning and implementation have been integrated into the traditional management of local resources, as is described elsewhere in this report.

The private sector therefore involves close cooperation among three parties: the prospective owner(s), the manufacturer/installer, and the financier. There are some ten turbine manufacturing companies capable of installing crossflow turbines or MPPUs and the associated equipment for milling projects. Six of these companies are able to install add-on or stand-alone electric generators and organise simple rural electrification projects. These companies are based in Kathmandu and Butwal. The major financier of private sector projects is the ADB/N, which also plays a major role in the promotion of activities within the sector. With support from WEC and various national and international organisations, the ADB/N coordinates training activities for turbine owners, manufacturers, and operators. The ADB/N also organises appropriate technology exhibitions regionally, featuring equipment from various manufacturers, and these provide an avenue for technology dissemination. The Bank's ATUs, located in Baitadi, Surkhet, Tulsipur, and Dhankuta, provide a further means of dissemination to the rural areas and are largely responsible for the penetration of large numbers of micro-hydro projects in these areas.

Operational Characteristics: Public Sector

NEA-operated mini- and micro-hydro stations are characterised by low load factors. Initial estimates expected load factors of 40 to 50 per cent. Actual use has been much lower however (15-34%), with a 9 per cent load factor in one case (see Figure 7). Even for projects where load has reached plant capacity (Dhankuta, Dhading, and Baglung), uneven demand has meant that plant factors of less than 20 per cent resulted. In 1985, the ten NEA plants had an average load factor of 21 per cent (WECS 1988). This reflects the peaking nature of demand and short operating hours of the stations. By comparison, in FY 1987/8, the NEA central grid had a load factor of 53 per cent (or 38% if consumption rather than generation figures are used).

Despite the disappointing performance of NEA-operated mini-hydro, load factors are comparable to those for isolated plants in other countries. In 1979, for instance, China's small hydro plants had an average load factor of about 21 per cent (Taylor 1981). The longest serving stations at Dhankuta and Surkhet reached load factors of around 30 per cent before demand exceeded capacity and load-shedding commenced. This suggests that, although improvements in the load factors of individual plants may be possible, the average load factor of the NEA-operated remote plants is unlikely to rise much above 30 per cent.

Breakdowns ("outages") are also a common feature of these remote projects. Using reported outages as an indicator, since actual information on breakdowns was not available, WEC estimated that NEA-operated mini-hydro had an average outage of three hours a week (WECS 1988). This is almost ten times as long as the outages reported for the central grid and may help explain why so few industries are using public sector mini- and micro-hydroelectricity. A study of the impact of rural electrification in Nepal found that all consumers of electricity (whether NEA or privately supplied) complained about irregular supply and found that irregularity of supply was positively related to additional demands for power (IDS 1988). In fact the 1988 WEC report goes as far as suggesting that, due to the peaking demand of a mainly domestic load, *"an appropriate feature of remote electricity service may well be suppressed demand"* (WECS 1988).

Operational Characteristics: Private Sector

Private sector micro-hydro mills operate only when there is demand from users. This demand is dependant on the agricultural season and mill opening hours are flexible, reflecting this fluctuating demand. Although milling functions are spread throughout the year, a large proportion of private sector micro-hydro projects close completely for up to four months because of lack of water or after damage to intakes or canals. During this time, users revert to traditional methods of husking and grinding but, because the traditional method of oil expelling is particularly arduous, users will often wait until the mill reopens to process their mustard seed. Where electricity is also supplied, its production tends to be equally unreliable - a source of irritation to customers and a disincentive to potential users.

Financial Performance: Public Sector

In 1989, NEA was operating 15 mini- and micro-hydro installations ranging from 32 kW to 345 kW and with a total installed capacity of 2.2 MW. Total public expenditure on these fifteen projects, commissioned between 1971 and 1988, was approximately NRs 156 million. Capital cost per kW has ranged between US$ 2,600 and 8,800 and averaged US$ 5,100 per kW capacity installed (see Table 1, Annex 1). The capital costs appear to be largely independant of scale but significantly affected by a range of site-specific factors, including design specification, equipment sources, civil works, and access.

It is extremely difficult to compare and assess these "site specific" factors because the technical and economic data on each site are not of a comparable level. Most studies to date have been narrow in focus and have not tried to assess which factors affect performance and why. What is needed is a series of post-project studies to gather this information and then a national planning process which can take this information into account and learn from earlier mistakes. Annex 3 gives the economic and technical data for a variety of public and private installations.

NEA mini- and micro-hydro have generally been planned by assuming operation and maintenance costs of 2 per cent capital cost per annum (SHDB 1985). Actual costs, however, have historically averaged 4.4 to 14.1 per cent of capital costs (WECS 1988). Revenues from government-operated mini- and micro-hydro installations have failed to meet operation and maintenance costs. WEC calculated that in FY 1984/5 revenues from NEA mini- and micro-hydro projects averaged 32 per cent of operation and maintenance costs, excluding depreciation (WECS 1988). Even at plants where demand has reached plant capacity the highest revenue is less than 50 per cent of recurrent costs. Projects are therefore heavily subsidised by the NEA which has to meet the shortfall from HMG/N budget allocations. Because of political commitment to the provision of electricity to district headquarters, implementation of NEA-operated mini- and micro-hydro projects is likely to continue for some years. However, government concern about rising financial commitments to this sector, in terms of both capital and recurrent costs, is likely to hinder subsequent activities.

The two major constraints on revenue at NEA-operated schemes have been the tariff system used and low load factors. Uniform tariffs are charged throughout Nepal irrespective of location. The higher costs associated with remote mini- and micro-hydro projects are not taken into account when setting tariffs, in spite of willingness among consumers to pay considerably higher rates (WECS 1988, ITECO 1987). In addition, 50 to 70 per cent of NEA mini- and micro-hydro customers pay only the "lifeline" rate of Rs 0.44/kWh because they consume less than 25 units (kWh) per month.

Low load factors reduce potential revenue because the stations are not always producing or selling at their maximum capacity.

While capital costs per kilowatt of government-operated mini- and micro-hydro installations in Nepal are generally comparable to expenditure incurred by similar programmes in other countries (Elliott 1981), recurrent costs appear excessive (WECS 1988). Possible reasons for this are discussed in other sections.

Financial Performance: Private Sector

Over 600 non-government mini- and micro-hydro installations are currently operating in Nepal. Of these, 114 had retrofitted or add-on electrification capacities and a further 17 stand-alone electrification schemes had been commissioned by FY 1987/8 (Jantzen and Koirala 1989).

By November 1987, total capital expenditure on non-government water turbine projects was Rs 57.7 million, including Rs 1.3 million for electrification. The average capital cost for agro-processing installations during this period was Rs 115,000 (crossflow Rs 128,000, MPPU Rs 73,000) and cost per kilowatt-equivalent of mechanical energy averaged US$ 650. Electrification of agro-processing plants required an additional investment of US$ 300 per kilowatt (ADB/N 1987). Stand-alone electrification projects, including electronic load controllers, have been installed for around US$ 1,500/kW (total capital cost, excluding 50% HMG/N subsidy).

There is little precise information available concerning the operation and maintenance costs and revenues of non-government installations - few of the entrepreneurs keep accounts. Studies to date, however, suggest that privately operated mini- and micro-hydro installations, particularly those equipped with agro-processing facilities, generate positive net income for their owners. ADB/N has estimated a 15 per cent return on investment for non-electrified private schemes and a 4 per cent return for add-on electrification (after the government subsidy).

Annex 3

A Comparison of the Costs and Performances of Five Mini- and Micro-hydro Schemes

PROJECT	LOCATION	OWNERSHIP	DISTANCE FROM ROAD	SIZE OF INSTALLATION	COMMISSIONING YEAR	TOTAL COST	ELECTRICITY:								OTHER SERVICES
							INSTALLED COST/kW (1989 prices)	COST TO CONSUMER	CONNECTION CHARGE	AREA SUPPLIED	NO OF HOUSEHOLDS SUPPLIED	ANNUAL REVENUE	ANNUAL O&M EXPENDITURE	STAFF	
Salleri-Chialsa Small Hydro	Salleri, Solukhumbu	NEA/local shareholders	2 days' walk	200kW/ 400kW total	1986	Rs. 32.8m	US$ 8,200* (1989 prices)	Set by management committee	Share purchase	2 hours' walk	427 (anticipated)	Rs 770,000 (projected)	Rs 273,000 (projected)	Six	Sale of electrical appliances
Jharkot micro-hydro	Jharkot, Mustang	Community	5-6 days' walk	40 kW	1990	Rs 1.7m	US$ 1,500 (1989 prices)	Rs 20 per 40W bulb/month	Nil	1 hour walk	200	Not known	Not known	Two	Nil
Yagya Rice Mill	Khaireni, Gulmi	Private	4 hours' walk	10kW	1979	Rs 0.2m	US$ 700	Rs 16 per 40W bulb/month	Nil	Immediate vicinity	103	Rs 20,000	Rs 3,500	Owner plus two	Paddy Rs 0.25/pathi Wheat/millet Rs 1.00/pathi Mustard Rs 2.00/pathi Maize Rs 0.75/pathi Annual Revenue Rs 42,000 Annual O&M expenditure Rs 6,000
Ishanashwar Sajha Sansthan Mill	Karapatar, Lamjung	Sajha cooperative	6 hours' walk	38 kW	1981	Rs 2.3m	US$ 2,200	Rs 15 per 40W bulb/month	Nil	2 hours' walk	324	Rs 96,000	Unknown	Three	Hulling Rs 0.20/kg Grinding Rs 0.50/kg Expelling Rs 1.50/kg Annual revenue Rs 70,000 Annual O&M revenue unknown
Jomsom Small Hydro	Jomsom, Mustang	NEA	4-5 days' walk	240kW	1983	Rs. 14.4m	US$ 3,909	Standard NEA tariffs	Standard NEA charge	1 days' walk	662 (1985)	Rs 222,334	Rs 591,277		Nil

* Installed cost/kW to be reduced with second stage.

Annex 4

Procedures in the Planning, Installation, and Management of Public and Private Installations

Public Sector

Pressure to electrify district headquarters has affected the choice of sites, and these are generally within a few hours walking distance of the district centre. This has often led to the development of sites that are not ideal from a technical point of view and which have been established without proper consideration of project feasibility and alternatives.

Initial site survey is carried out by NEA staff from Head Office, with subsequent survey work being carried out by the project consultants. A substantial number of foreign and local consultants and contractors work for the NEA, and provide specialist services on a project-by-project basis.

Demand is also assessed during the survey and projects are designed to meet demand projections for the next twenty years. The design activities are carried out in Kathmandu. Projects are designed on an individual basis with little standardisation of components. Tenders are then issued and construction is undertaken by various contractors overseen by the Small Hydro Department of the NEA Construction Directorate. While civil works are generally carried out by local contractors, the electro-mechanical transmission and distribution works are normally undertaken by Kathmandu-based or foreign organisations.

Once the completed plant has been tested and NEA officials are satisfied, it is handed over to the O&M (Operation and Maintenance) Directorate of the NEA. Plants are generally run by an engineer, supervising both technical, administrative, and support staff. These staff are responsible for generation, transmission, and distribution of electricity in the local area. Maintenance is normally carried out by the site staff, although electro-mechanical problems are often referred to Kathmandu staff or the equipment supplier.

Projects are run as separate cost centres. All revenue generated, however, is deposited into HMG/N accounts and cannot be used directly by the project. HMG/N funds are allocated annually for all anticipated expenses, including salaries and capital expenditure. It is extremely difficult to raise additional funds for unforeseen expenditures.

Private Sector

A site survey is requested and usually carried out by one of the turbine manufacturers, often accompanied by ATU or local ADB/N staff. If the site is not satisfactory, the process will be halted at this stage. A nominal fee of Rs 200 is charged by most turbine manufacturers for the site survey. During the site survey it is also common to agree upon water rights if the site is owned by more than one person.

A design is then prepared by the manufacturer, based on the information collected and the prospective owner's preferences. Standard equipment is normally used except in special circumstances. A quotation based on the design is sent to the prospective owner who then decides whether to proceed, requests quotations from additional manufacturers, or halts the process at this stage.

There have been few cases of direct purchase or of financing through commercial banks. In the majority of cases a loan request is forwarded to the local ADB/N branch office. This request is then processed by the ADB/N staff who check the acceptability of the quotation, the credit-worthiness of the prospective owner, and the acceptability of the security offered. The economic and technical viability of the micro-hydro installation is also assessed.

Once approval is given, a "coupon" is sent by the ADB/N to the turbine manufacturer. The coupon guarantees full payment by ADB/N when equipment is installed and tested. A 50 per cent advance is also forwarded to the manufacturer.

The equipment for the installation is mostly manufactured in Nepal, but some items such as oil expellers and rice huskers are imported. When the equipment is ready for dispatch the owner is informed.

The owner is responsible for organising preliminary work at the site, and this includes the construction of the intake and canal (usually using traditional irrigation techniques), preparation of the turbine site, and collection of construction materials. The owner also has to arrange for the transportation of the equipment to the site. Once there, the turbine manufacturer is informed. He then sends a team of technicians to supervise the final construction and the installation of the equipment.

Most installations are completed within twelve months of the survey request. Construction is generally swift and efficient. Many of the manufacturers/installers charge a daily rate for their installation teams. The owner, therefore, takes great interest in completing the installation as quickly as possible. The larger turbine manufacturing firms all retain full-time installation teams, trained to undertake installation and supervision work with minimum support from their home base. Each installation is very similar and can be completed and commissioned in a short period of time. The installation is then tested and owner and operator are trained in operation and maintenance. Once owner and technicians are satisfied, a document of acceptance is signed. The ADB/N releases the final payment to the manufacturer and loan charges/repayments start.

The station is operated by the owner or by staff appointed by him. Staff numbers are low: generally no more than three full-time employees. Operating hours vary according to the demand at the time and charges for milling and electricity are based on a market price acceptable to both owner and users. Routine maintenance is carried out by the operators. Civil works are maintained by the owner, often with the assistance of the local community. Major electro-mechanical maintenance and repair is handled by technicians from the manufacturer.

Annex 5

Case Studies from the Public and Private Sectors

Private Sector: The Privately-owned Yagya Rice Mill, Khaireni, Gulmi District

The mill is situated on the Jumdi Khola, in Arunga Village, which is about three to four hours walk from Ridi Bazaar. It was established in 1967 by two entrepreneurs from a nearby *panchayat* about five hours walk from the site. This partnership did not prove to be very successful because of the distance the owners lived from the site and because of the problems between them. After five years they sold the mill to another entrepreneur, also not from the local *panchayat*. He ran the mill for a further five years before (because of his involvement with a diesel mill at Ridi, and his dependance on an unsatisfactory operator who rendered the mill unprofitable) he in turn sold it. The mill was then bought by a single entrepreneur, who, although he is not from the local *panchayat*, has a house near the mill site and lives there. He has been operating the mill since 1977.

In 1980 a flood demolished the mill. It was rebuilt with a loan from the ADB/N only to be demolished again later that year by another flood. The mill was relocated and rebuilt again with a further loan from the ADB/N. Both loans were repaid in installments within five years, the stipulated time for repayment. In 1983 electricity was installed, also with an ADB/N loan. This loan was also repaid on schedule, giving an indication of the mill's profitability.

The mill operates an oil expeller and a grinder and husker as well as the generator, and an operator and assistant are employed. The mill is in good condition as the owner carries out minor repairs himself and has maintained a stock of bearings which are replaced regularly.

The river flow drops during the dry season and can only take one load instead of the usual two. During the peak seasons for each crop (wheat, rice, and mustard) the mill is open from 7 a.m. to 6 p.m.; the rest of the year it operates for about four hours each day.

There are four other turbine mills within an hour's distance from the mill site. The mill's rates have not changed since 1983 and the owner does not want to change them in the near future because, as he said, maintaining the goodwill of the community was more precious to him than earning extra profit through rate increases. The proximity of competing services could also have influenced his decision.

The community felt that it had benefitted from the advent of milling technology because of the increased speed of the new technology and the relief in drudgery for the women. The very poor, however, scarcely used the mill except for oil expelling and so the traditional modes of processing also persisted. One poor farmer observed that the money spent on processing at the mill could be better used in providing a good meal for one of his children.

While a group of rich agriculturalists have benefitted from the mill's services and are largely responsible for its profitability, the poor have, if anything, been exploited by it, since they are the ones who cannot afford cash and have to pay in kind, a form of payment which works out to be more expensive.

When there were only a few mills in the locality, the owner of the Yagya Rice Mill used to operate at night, but, with increasing competition, his business at night decreased. To compensate for this he decided to generate electricity. The mill's location close to the village facilitated this and electricity is presently supplied to 103 houses in the bazaar with plans to extend this to neighbouring farms. The beneficiaries are almost exclusively the more prosperous members of the community.

The quality of lighting is good without any fluctuation in voltage. The owner does minor repair and maintenance work himself.

Charges are fixed at a rate of Rs 16 per bulb per month for a 40 watt bulb and Rs 14 per 25 watt bulb. Households receive electricity from 7 to 11 p.m. during the summer and from 5 to 11 p.m. during the winter. There has been a problem with households using more electricity than they have paid for and the owner is planning to install PTC switches in each of the subscribing houses to control this.

This mill is fairly typical of the privately-run installations. Problems arising from the poor siting of the mill house often result in the mill being damaged by floods, but more minor construction problems can often be dealt with locally. As in so many installations, the agro-processing was already running successfully before electricity generation was added on.

Effective management is the key to success, as is shown by the fact that although earlier owners did not find the mill profitable the last owner has. One of the main reasons for his success is his local residence and close involvement with the management and maintenance of the mill. When owners are not resident nearby, and operation is in the hands of a paid operator, maintenance and operation tend to be less satisfactory.

Price setting is also affected by the residence of the mill owner. When the mill is bought as an investment, by either an immigrant to the area or a local man who has now moved away, the services tend to be perceived locally as less satisfactory, as the owner is less sensitive to social pressure regarding water rights, pricing, availability of supply, and so on. In the case of the Yagya mill, the presence of competition from other mills nearby, as well as social pressure, had kept prices to a level that was obviously profitable to the owner but which was not felt to be unreasonable by the users.

Private Sector: The Community-owned Ishaneshwar Sajha Sansthan Mill, Karaputar, Lamjung District

The mill is situated about six hours' walk east of Pokhara, on the confluence of the Medim and Madi kholas. The mill has two sponsors - the Sajha cooperative organisation and the ADB/N - and their diverse objectives and management structures have caused many problems for the local farmers. The Sajha cooperative was established in 1978, primarily for providing better agricultural inputs such as improved seeds and fertilisers. It initiated a process of canal improvement in 1978. The mill itself resulted from the establishment, in 1980, of the Small Farmers' Development Programme (SFDP) of the ADB/N which encouraged the formation of a SFDP group through Sajha to operate the mill and the irrigation system. Construction was begun in 1980 and the canal was partly operational by the following year. The mill was financed by a combination of ADB/N loan, HMG grant, Sajha contribution, Hill Food Programme donation, and community labour.

In the early stages of the ADB/N's expansion it was government policy to use the ADB/N to support the country's cooperative movement because it was then in difficulties. The ADB/N loans were therefore channelled through the Sajha office in Karaputar, which took 4 per cent of the loan as a service charge and performed the auditing function.

Expenditures made by the operators for emergency repairs of canals or the purchase of bearings, as well as the salaries given to employees, are classified as irregular expenditures under the Sajha auditing system and are hence left pending. Sajha has not remitted any community initiative in reorganising the functions of the mill operation or its expansion.

The Sajha organisation was formed to cover a large region rather than a village. The Sajha office, which operates the Ishaneshwar Mill, covers the *panchayats* of Ishaneshwar, Karapu, Bhorletar, and Bangre. Only a fraction of this population falls within the catchment area of the mill for irrigation, milling, or electricity services and so the Sajha committee does not represent the mill's immediate beneficiaries and their needs have suffered as a result.

The Karaputar mill is a multipurpose scheme with many competing users for the water and its power. The canal system has traditionally irrigated three conflicting zones among which the interests must be carefully balanced. The total area irrigated by the canal system is about 100 hectares and the irrigation facility is supposed to benefit 218 families. The Sajha cooperative collects water charges for this amounting to about Rs 30,000 per annum.

The mill operates oil expeller, grinder, and huller, all of which are popular services. People come from up to eight hour's walk away to expel oil and from up to three hours walk away to grind grain. Rice husking only draws customers from the immediate vicinity since there are diesel mills operating in the locality offering the same service.

Electrification was added on by DCS five years after the mill was built. It was financed by an ADB/N loan, HMG grant, a Sajha contribution and a DCS contribution (yet to be paid).

The electricity supply, while generally good, has problems of quality control, caused by voltage fluctuations when the oil expeller is in use. There is also some unauthorised consumption which frequently causes the load to rise above the equipment's capacity. The operator handled this by disconnecting one phase of the supply - a method of load-shedding which is not good for the machinery. This excess consumption could have been controlled with the use of PTCs (which were present but had not been installed). No training in the use or benefits of the PTCs appeared to have been given and few of the Sajha committee or the SFDP seemed to understand what they were for.

Nonetheless, electricity has proved to be an important earner, with gross earnings from its sale almost equal to the combined earnings from irrigation fees and agro-processing. The charge is Rs 15 per 40 watt bulb and electricity is supplied 24 hours per day, unless breakdowns occur. These are quite common and generally involve failure of the belts or bearings. Leakages and landslides cause problems with the canals and the increased size of the new canal had adverse effects on agriculture. The larger volume and higher velocity of the water carries with it less organic silt and more sand and pebbles, and this reduces the fertility of the fields.

In Ishaneshwar, payment of irrigation fees was mandatory before electricity connection became valuable, but this was not the case in Kaski and caused conflict. Landless families had contributed labour to the installation of the mill, with assurances that this would be converted into shares. This has not occurred, however, and the people have not received electricity either. They have been told that they will receive a supply when a second generator is added, but this would involve increasing the headrace capacity and exacerbating the problems caused by the large water flow, unless assistance can be obtained for an expensive canal improvement programme.

Many of the problems in this installation can be found in other "forced" community installations, in cases in which the initiative has come from outside the community rather than from the farmers themselves. The pressure on SFDP branches to achieve targets in group formation has sometimes led to the formation of groups that are not truly homogeneous or internally well regulated, and the result is that they often come to be dominated by one or two of the richer farmers in the community. This can lead to the further exploitation of poorer farmers who contribute to the investment but profit little from it.

If installations are to be communally owned, the necessary time and support must be given to them to ensure that they are established and run on an equitable basis. This will require institution-building by ADB/N or SFDP staff and consequently a greater input of staff time and resources.

Private Sector: The Community-owned and Community-managed Purang Installation, Mustang District

Purang is five to six days walk from the roadhead at Pokhara. The water source is a perpetual spring and the intake is below the Muktinath Temple grounds. The water is discharged from the turbine into the irrigation system, so few fields are deprived of water. This is an arid area where irrigation and careful water management are crucial.

The installation was established because of a local demand for electricity. There was no felt need for milling facilities in this case and so the installation consists of a generator only. The generator is Indian-made, whereas the crossflow turbine and electronic load controller (ELC) were manufactured by DCS. The 12 kW installation provides electricity for the village of Purang and the Muktinath Temple nearby. The supply is mostly used for lighting (both ordinary and high efficiency bulbs) but some households also have DCS low-wattage (200 kW) cookers (*bijuli dekchis*).

Demand for the installation originated with the local people and was coordinated by the District *Panchayat* Chairman. He is based at the District Headquarters in Jomsom and has been responsible for the coordination of community electricity projects all over the district - all very similar in organisation to the one at Purang. Local demand has thus been channelled through existing political and economic structures to achieve projects characterised by a very high degree of community participation.

At the Purang installation there was no initial external assistance or bank loan, although later some of the cost was donor-assisted. The total cost was about Rs 470,000, including local costs, transport, and labour, of which ITDG contributed about 2,000 pounds (approximately Rs 100,000) towards the costs for the ELC and DCS costs. This is equivalent to US$ 1,400 per kW capacity. Local people contributed money in proportion to the amount of power they were subscribing to and the labour was organised through the traditional system of communal labour, characterised by strict rules about how much work each household must contribute.

The consumers are charged Rs 25 per bulb (high efficiency bulbs are charged at the same rate as incandescent). Detailed accounts are not kept as the capital cost was paid at the outset and there is no bank loan to repay, but the installation is covering its operation and maintenance costs. The plant has already achieved capacity, supplying about 100 houses with, on average, 120 watts each and there is a demand from the village for an increase in supply. This could be done by increasing the head and substituting a Pelton turbine for the present crossflow one.

The plant operates 24 hours a day and village women take their washing down to the ELC output in order to take advantage of the heated water from the ballast load. This hot water is available free to the community, but there are plans for income-generation by selling hot showers to tourists and pilgrims who trek through the village, by using off-peak electricity to heat the water. The hot water is highly valued as the site is at high altitude and the water very cold.

There is a strongly perceived need for electricity in these areas where the winters are dark and cold and fuelwood is very scarce. Lighting permits indoor income-generating activities, such as carpet-making, during the winter months when the villagers are rendered housebound because of the weather.

By using the traditional irrigation system, conflicts with agriculture are reduced, as are construction costs, and no new decision-making structure is imposed on the community. One of the main reasons for the success of these community installations in Mustang is the way that their management is so well integrated into the existing social, political, and economic structures. This ensures that all participants in the scheme understand its management and have access to the decision-making process. Strong and supportive representation at the district level has facilitated the villagers' access to manufacturers and subsidies and enabled coordination between the sites.

Ethnic homogeneity in the area is another powerful factor for success. Strong local traditions of community labour and organisation are shown by a consistent record of successful community projects. The community feels it owns the installation and the operators are chosen from among the villagers and then trained by DCS.

There are plans for similar installations all the way up the Kali Ghandaki River. All will be small scale, intended for local generation and consumption, and established on a full cost-recovery basis. Some may take loans but many will not. All will qualify for the HMG/N 75 per cent subsidy for remote area electrification. There is the potential to link these small installations into a series of mini-grids and this is already being discussed at the Purang site where the installations at Purang, Jhong, and Jharkot could all be linked up to take advantage of the spare capacity at the Jharkot installation.

It is still early to gauge the success of these community run installations in Mustang but progress so far is very promising. The combination of community participation and ownership, initiated by the community and coordinated through existing political and decision-making channels, creates a high degree of local accountability and a project that is able to respond to local priorities and market forces.

Public Sector: NEA-run
Jomsom Small Hydro, Mustang District

This 240 kW installation was completed in 1983 at the Mustang District Centre in Jomsom. The procedures for its construction and management are as outlined in Annex 4. The project was initiated, planned, constructed, and operated by the SHDB with little involvement from the local people. The site was chosen primarily for its proximity to the district centre since electricity supply to the District Headquarters was the purpose of the project. Initial estimates of demand were ambitious and after seven years the system has still not reached capacity.

In common with other NEA small hydro sites, there is a lack of motivation among the operating staff who have limited decision-making powers, and this leads to a slow response to breakdowns. There is little status associated with managing remote hydro installations, and, since management is seen as, and promoted as, an administrative function, there is little incentive for technically trained people to do the job. There is little emphasis on the preventive aspects of management -it is seen as a reactive rather than as a pro-active role.

There are few incentives for good performance since the income from installations is pooled at the central level and does not relate to the installation's further budget. Since the manager is usually not a local person, and not accountable to the local community, little pressure can be put upon him to improve supply.

Public Sector: Local Shareholders
Salleri-Chialsa Small Hydel Project, Solukhumbu District

In 1984 the Swiss Government and HMG/N agreed to construct a 400 kW (initially 200 kW) hydroelectric plant on the Solu Khola in the Solukhumbu District of Eastern Nepal. The plant was designed and constructed by the Swiss Company for International Technical Cooperation and Development (ITECO) and it began generating in February 1986.

At the outset of the project the two Governments agreed that it provided an opportunity to address the problems of effective management and utilisation of small hydroelectric installations by attempting to create a new model for the management of such isolated schemes.

Various ownership structures were investigated and it was decided that the most appropriate would be a Joint Ownership Share Company. This company, the Salleri-Chialsa Electricity Company (SCECO) was initially owned by the Swiss Government and NEA with users receiving shares on being connected to the supply. Preferred shares representing the value of the existing assets (approximately Rs 15 million) were issued equally to the Swiss Agency for Technical Assistance (SATA) and the NEA. In addition, SATA and NEA each purchased one thousand ordinary shares and a further one thousand were authorised for electrical connections. Preferred shares have rights over company assets, should SCECO be liquidated, and also to board representation.

The board of directors consists of representatives from NEA, representatives of the other preferred shareholders (initially SATA), and representatives of consumers selected by each of the three user associates. Each user association elects a five-person management committee, one member of which becomes a member of the board. One association represents the largest single user, Chialsa; another represents the main governmental and commercial centres of Salleri and Phaplu; and the third represents the remaining villages receiving power.

The user associations are the crucial links ensuring that the electricity system becomes identified as a locally responsible, self-sustaining, and financially sound operation. They ensure that all users see themselves as involved and responsible and that they participate in important decisions such as those regarding connection policy, tariff levels, system maintenance, and user service.

It is expected that SCECO can be managed, and the plant operated, with a much smaller staff than has historically been the case with mini-hydro plants in Nepal. The corresponding reduction in operating costs allows the staff of fewer than ten to be paid salaries that are highly competitive. Furthermore, substantial additional earnings (SCECO shares as bonuses and cash raises) will be distributed if the company is efficiently and profitably run.

It was proposed that progress would be reviewed after three years and a schedule drawn up for the withdrawal of the Swiss Government from SCECO and the terms of the transfer of its shares negotiated. It was anticipated that common shares could be transferred to a body able to assist in long-term support or divided amongst users. Asset holding preference shares will be transferred to a reputed Nepalese third-party.

The load and load factor were estimated in advance, through interviews with potential consumers, and an assessment of possible end uses, such as a dye house at Chialsa, was made. Account was taken of the historical demand patterns at other mini- and micro- installations and also of the likely demands of the local infrastructure (hospital, district offices, etc). The load factor is expected to remain low, at approximately 17 per cent, once the total generating capacity of 400 kW is installed.

In order to limit the peak load, and thus spread the benefits of electricity to the largest number of consumers, each domestic connection is strictly limited to 2 kW and no office may take more than 8 kW. In addition, offices and industries are not permitted to receive power during peak periods.

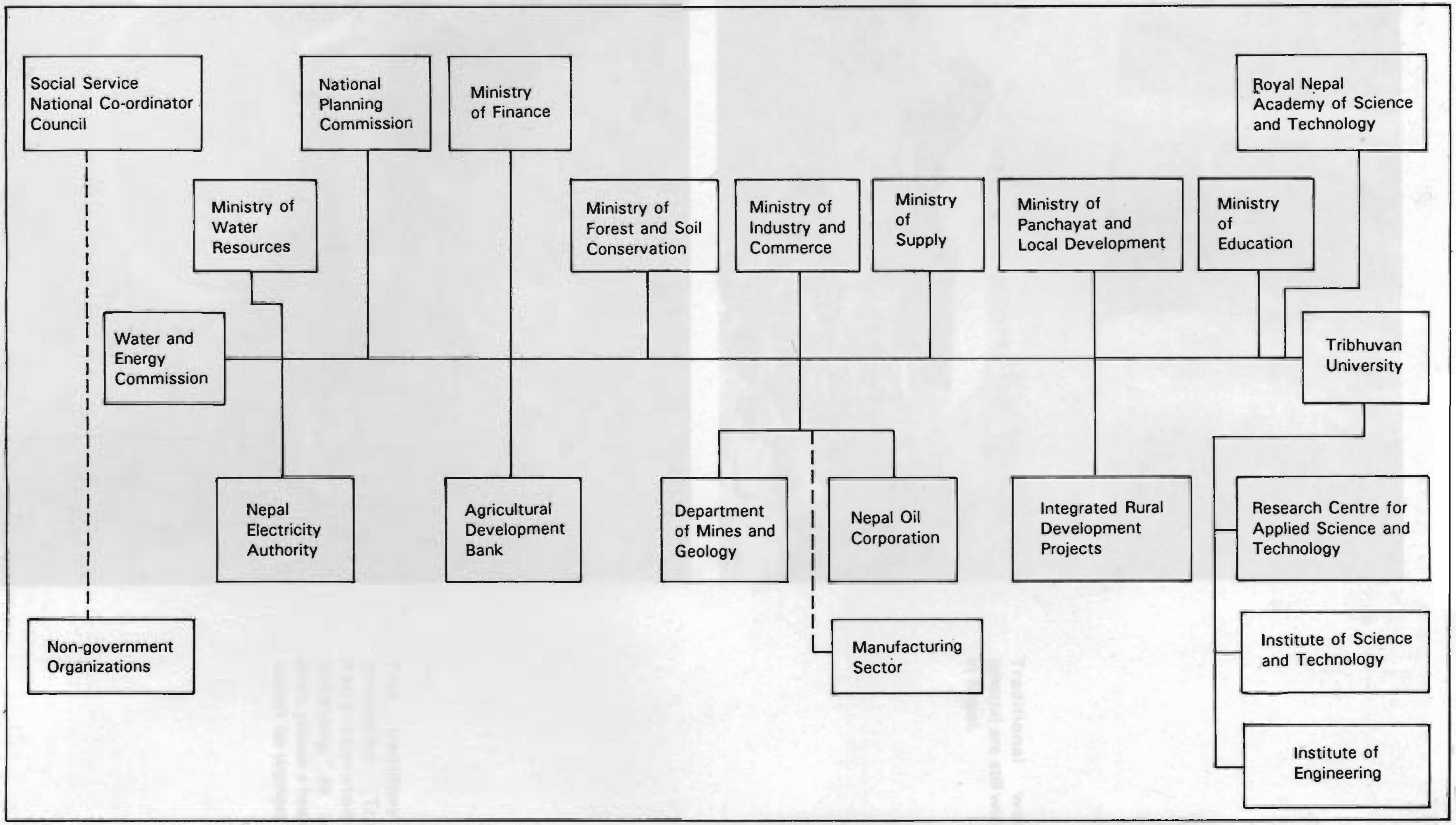
The connection charge policy is that consumers should bear the cost of their connections. Instead of charging connection fees, however, applicants for connections buy company shares in proportion to the cost of their connection.

The tariff structure provides for fixed monthly charges for about 75 per cent of consumers, special low rates to encourage the development of small industries, and meter-based bills for all middle level users and government offices. The average tariff was fixed at Rs 1.5 per kWh. This gives minimum charges of Rs 25 and Rs 80 for fixed rate users.

These tariffs result in power at a price not significantly different to existing fuel costs, but they cover all operating and maintenance costs and provide sufficient income to pay full depreciation after five years. The possibility of investing some of the operating capital locally would also permit SCECO to achieve its true ends, i.e., becoming a community-based investor in development projects. Although this project was externally instigated and has received considerable external assistance, it appears to be a very promising development and could produce a new model for the management of remote NEA mini- and micro-hydro installations. Questions remain regarding its replicability and sustainability, the degree of influence of wealthy shareholders, and procedures for long-term decision-making; but early progress is very encouraging.

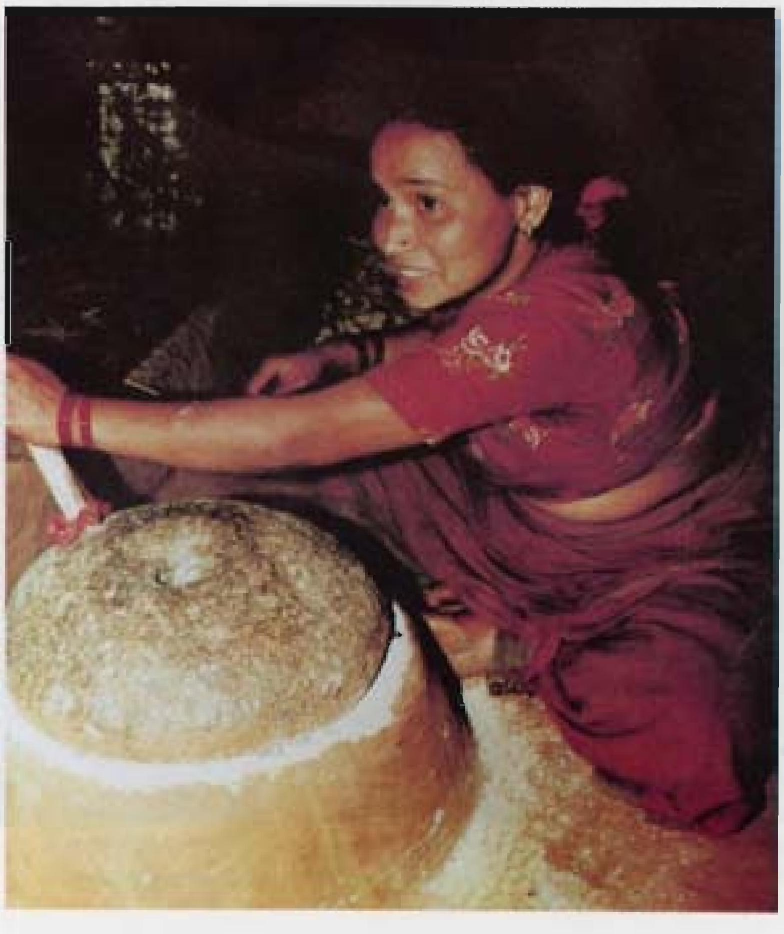
Annex 6

Institutions Involved in the Energy Sector



Source: Nepal: Institutional Structure of the Energy Sector
Adapted from APCTT (1986) and ESCAP/EEC (1987)

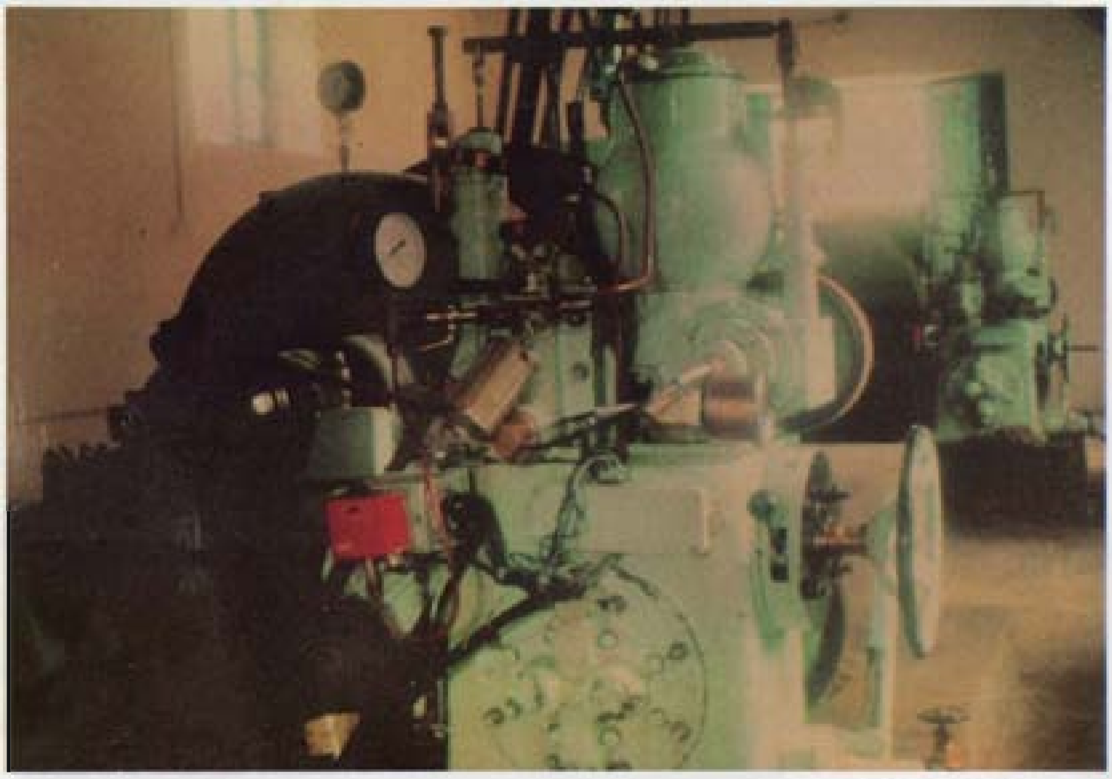
Traditional watermills (*ghatta*) are still widely used in Nepal.



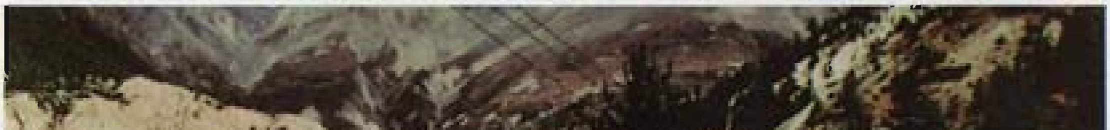
True traditional agro-processing. Traditional hand-operated agro-processing, as with the *janto*, places a heavy labour burden on women.

Demand for less arduous agro-processing has led to the rapid spread of mechanised methods.

Many private sector schemes use traditional water management methods.



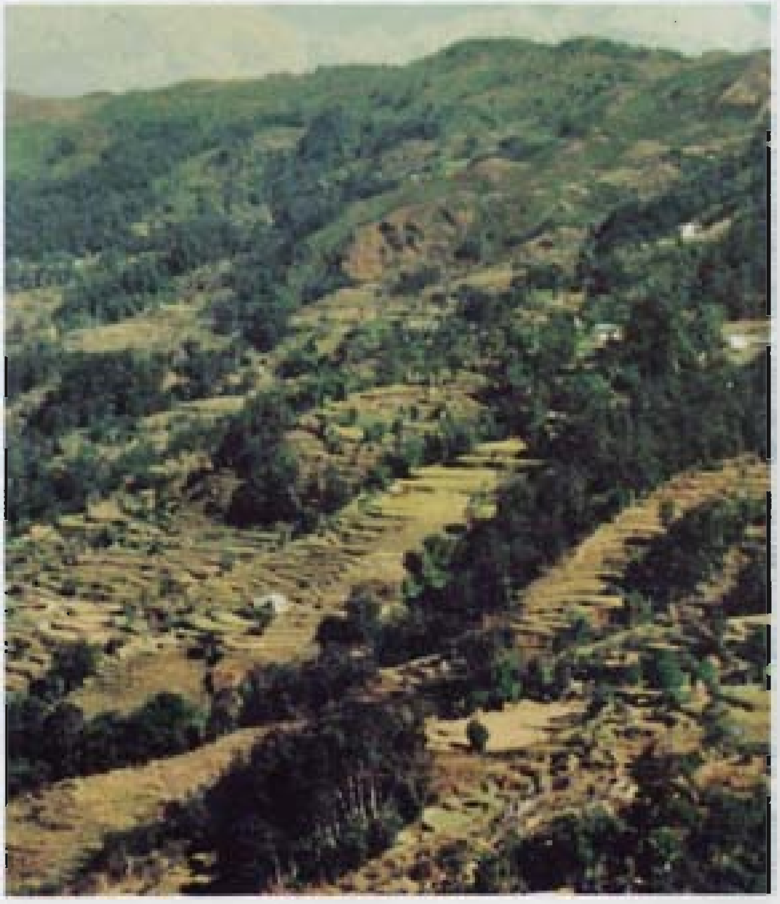
Sophisticated governing equipment is both costly and difficult to maintain.



A public sector installation in Manang District which was not operating due to shortcomings in its design and construction.

Porter carrying pipes: Nepal's lack of transport infrastructure is a major problem in project implementation.

Entrepreneur and manufacturer in discussion: owners have a close personal interest in their projects and are involved at all stages.

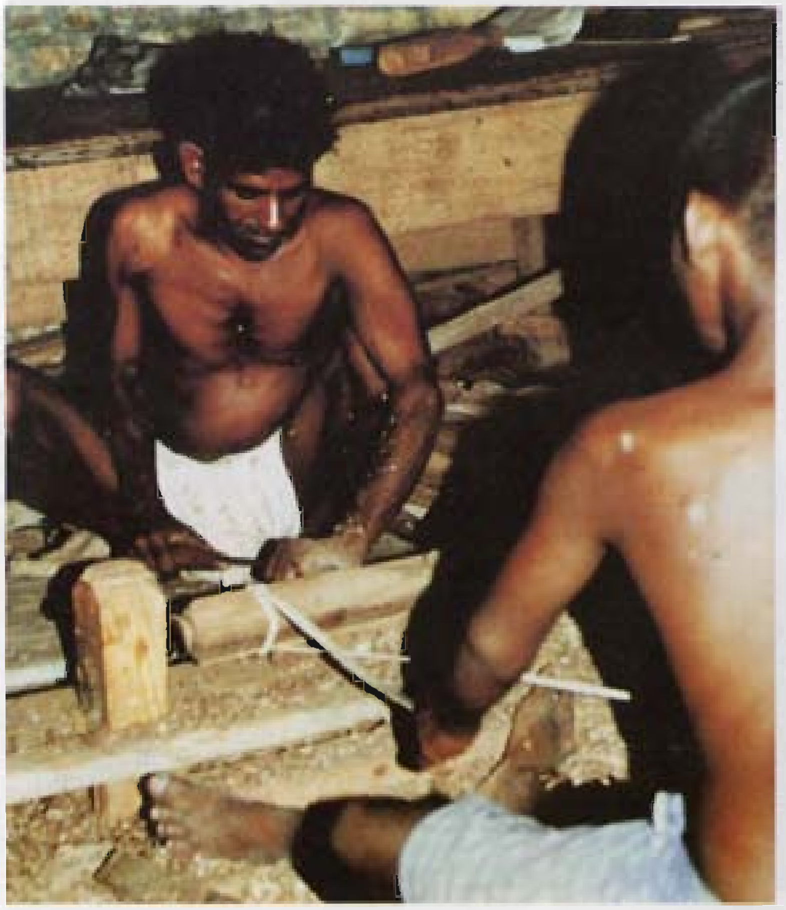


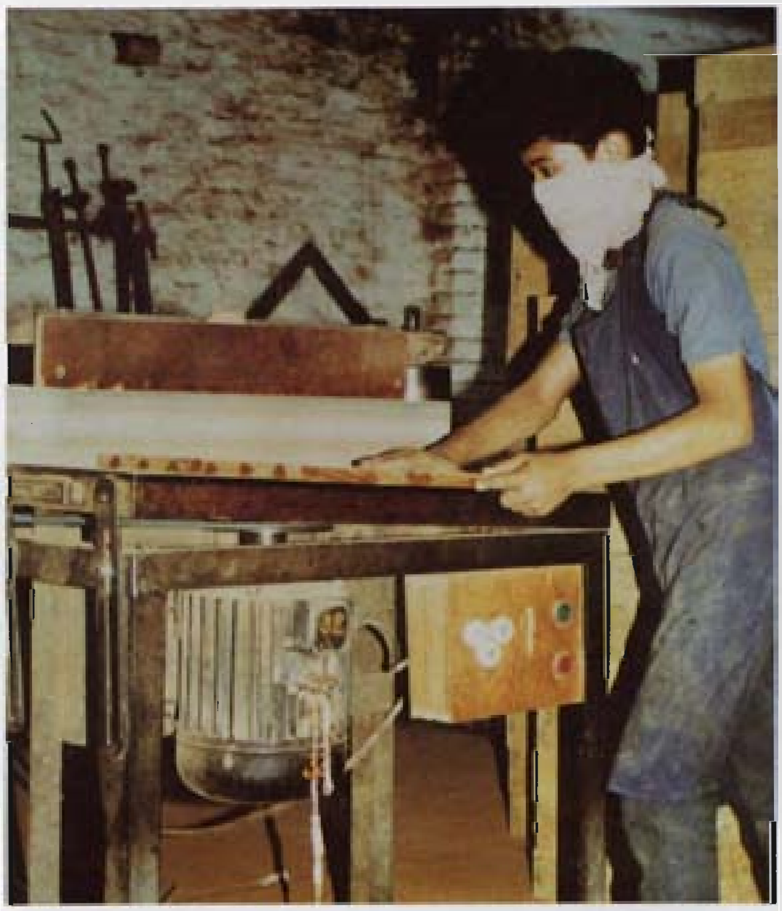
Mid-hills of Nepal: to date most private sector installations have been in this region.

Larger projects, generally state-owned, require more sophisticated and more expensive equipment.

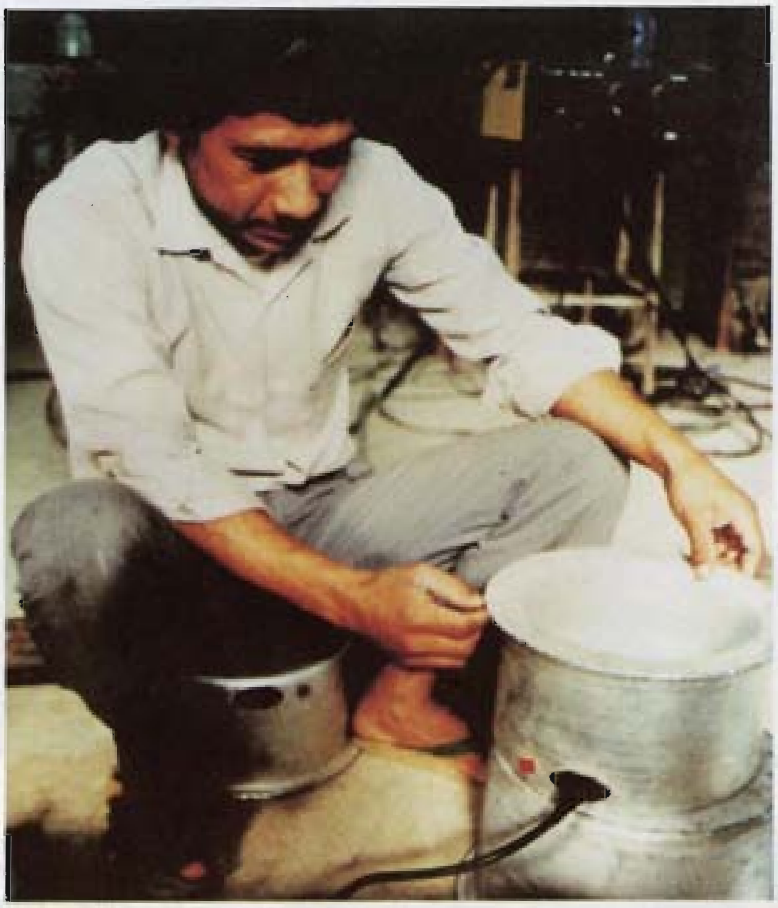
Village labour: the use of local labour and skills not only reduces costs but also ensures community commitment to the project.

A hydro manufacturer's workshop. Production of micro-hydro equipment is now an important sub-sector of Nepal's manufacturing base.





Traditional and electrified wood-working enterprises. In some situations the existing productive enterprises can be expanded through the use of electricity.



Assembling low wattage electric cookers. These allow efficient use of the limited electrical output of micro-hydro installations.

Traditional rice hulling using the *dhiki*: the most profound impact of micro-hydropower in Nepal to date has been its replacement of the labour required for agro-processing.

Biomass is still the major source of energy in rural areas.

Tourists in Manang District. Tourism places demands on local resources but, if managed carefully, can contribute to the local economy.

Lodge kitchen in the Annapurna Conservation Area where fuelwood is not available, or its use prohibited. Electrical substitutes are being adopted.

Local manufacturers testing turbines. An 'infant industry' policy may be needed to protect local manufacturers from under-priced imports.

Rural electrification course in Butwal. Skills' development will be central to the success of the hydro industry in Nepal.

Micro-hydro workshop in Butwal. For the sector to reach its full potential support will be required for manufacturers' research and development efforts.

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