Department of Economics

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TECHNOLOGICAL CAPABILITY BUILDING: A CASE STUDY OF THE MINI-MICRO-HYDRO TURBINE MANUFACTURERS IN NEPAL

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Declaration of Rights:

This Work is Dedicated to --

My Late Father, *Er. Indra Ratna Sthapit*

who has inspired me throughout my Life

and

to my Loving Little Son, *Nikhil Ratna Shakya.*

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I would like to close with a word of gratitude to my late father who has always been an a source of inspiration for me. His had always wanted me to tread along the economist's path. I hope he is happy with his little girl.

ABSTRACT

The principal objectives of this thesis are to assess the value to Nepal of developing the use of mini-micro-hydro as a modern energy source in the rural areas and, at the same time, of promoting the domestic manufacture of mini-micro-hydro turbines and associated equipment as a means of creating a modern engineering sector within the country.

Development of the mini-micro-hydro sector is viewed as a possible solution to two of the country's urgent economic problems. A sustainable and efficient means must be found of supplying the energy needs of areas remote from the national grid and, at the same time, it is important for the country to develop a nucleus of modern engineering capability in capital goods manufacture: the existence of a capital goods sector is widely understood to be a necessary condition of technological progress and a key to the achievement of on-going economic growth.

This study investigates the potential of mini-micro-hydro development as a means of providing complementary solutions to these two problems. Mini-micro-hydro plants installed in the rural areas generate energy in an environmentally-friendly manner, but what, it may be asked, are the returns in commercial and in social terms on such installations? The manufacture of mini-micro-hydro equipment is already being undertaken in Nepal: does this activity offer the prospect of technology transfer and the development of enhanced technological capability?

A third, subordinate, objective of the study is to determine whether, if a case is made for promoting the installation and manufacture of mini-micro-hydro units, the stance of the government, and of other institutions, is as helpful as it could be to achieving these ends.

The conclusions of the study - from investigation of mini-micro-hydro operations in rural areas, and from examination of the technological capabilities developed by the turbine manufacturing firms - are that a positive case can indeed be made for encouraging in Nepal both the use of mini-micro-hydro units and their manufacture. It would however appear that certain changes in government policy and more active involvement by research institutions would be of assistance for the advancement of the mini-micro-hydro sector.

NEPAL AT A GLANCE

Area: 147181 sq. km.
Length: 885 km. (East to West)
Width: 193 km. (av. From North to South)

Population

Census (1991): 18,491,097

Census (1981): 15,022,839

Annual growth rate: 2.08 %

Urban Population: 9.20 %

Rural Population: 90.80%

	Land Coverage	Population
Mountains:	35 %	7.8 %
Hills:	42 %	45.5 %
Tarai:	23 %	46.7 %

Electricity		
	Major Hydro	250,450 kW
	Small Hydro	1,110 kW
	Diesel Power	57,056 kW
	Solar	130 kW
	Mini-Micro-Hydro	8940 kW

Economy

GDP at current price (1995/96) : NRs. 249,896 million

Contribution to GDP: Agricultural Sector 40.22%

Non - Agricultural Sector 59.78%

(Manufacturing Sector: 8.91%)

Third Edition

Administrative and Physical Division

The country is administratively divided into 5 development regions and 75 districts. Village Development Committee (VDC)/Municipality is the lowest local level administrative unit in each district. Number of VDCs and Municipalities in the country amounts to 3995 and 36 respectively. Each VDC consists of several wards and each ward has few villages.

Ecological Regions

Ecologically the country can be divided into three ecological regions, Mountain, Hill and Tarai (Plain). They are the Mountain, the Hill and Tarai (Plains) and the characteristics of these regions are as follows:

Mountains

The mountains are at an altitude varying from 4877 m to 8848 m above sea level. This region comprises one third of the total land area of the country and about 2% of this land is suitable for cultivation. Due to the cold weather and the high altitude this area is sparsely populated. The population residing in this region is 7.8 % of the total population (1991 Census).

Hills

It lies between 610 m to 4877 m above sea level. It is sandwiched between the mountains and the Tarai and runs from east to west. There is about 45.5 % of the total population residing in this area (1991 Census).

Tarai (Plain Area)

This region extends from east to west along the southern side of the country. It forms the low flat land and includes most of the fertile and forest area of the country. About 40% of the land is suitable for cultivation. This region is home for about 46.7 % of the total population of the country (census 1991).

Climate:

Nepal has a great variety of topography, which is reflected in the diversity of weather and climate. The country experiences tropical, mesothermal, microthermal, taiga and tundra types of climate. 60 to 80 percent of annual rainfall falls during the monsoon season (June to September). The highest mean rainfall was 4216.7 mm in Pokhara in 1993. The maximum temperature of 43.7 C was recorded in Bhairahawa Airport (1989) and minimum temperature of -6.1 C was recorded at Jiri in 1992 among the listed stations.

River System:

There are more than 6000 rivers totalling more than 45000 km in length. There are four major river system in Nepal are:

Name of River System	Course
1. Koshi	Eastern Nepal;
2. Narayani (Gandaki)	Central Nepal
3. Karnali	Mid-Western Nepal
4. Mahakali	Far-Western Nepal

Ethnic Composition:

Nepal is a multiracial and multilingual country. Various linguistic and ethnic groups live together in nationalism and cultural harmony. While the tropical and sub-tropical regions are largely inhabited by the people of Indo-Aryan origin, people of Mongoloid features are predominant in the temperate highlands. The national language is Nepali, understood and the script is Devnagari. There are more than 30 ethnic groups and as many languages and different types of scripts.

Population, Area, Airport Facility in Various Districts of Nepal ***(Census 1991)***

District	*Population*	*Area sq. km*	*Population Density*	*Airport*	*Population*	
					Urban	*Rural*
Manang	5363	2246	2	1		5363
Dolpa	25013	7889	3	1		25013
Mustang	14292	3573	4	1		14292
Humla	34383	5655	6	1		34383
Mugu	36364	3535	10			36364
Rasuwa	36744	1544	24	1		36744
Solukhumbhu	97200	3312	29	3		97200
Jumla	75964	2531	30	1		75964
Taplejung	120053	3646	33	1		120053
Bajhang	139092	3422	41	1		139092
Sankhuwasabha	141903	3480	41	1		141903
Bajura	92012	2188	42	1		92012
Myagdi	100552	2297	44			100552
Darchula	101683	2322	44	1		101683
Kalikot	88805	1741	51			88805
Jajarkot	113958	2230	51			113958
Rukum	155554	2877	54	1		155554
Dadeldhura	104647	1538	68			104647
Gorkha	252524	3610	70	1		252524
Dolakha	173236	2191	79	1		173236
Doti	167168	2025	83	1	12360	154808
Sindhuli	223900	2491	90			223900
Lamjung	153697	1692	91			153697
Surkhet	225768	2451	92	1	22973	202795

Population, Area, Airport Facility in Various Districts of Nepal *(Census 1991)*

[continued]

District	*Population*	*Area sq. km*	*Population Density*	*Airport*	*Population Urban*	*Population Rural*
Rolpa	179621	1879	96	1		179621
Sindhupalchok	261025	2542	103	1		261025
Udayapur	221256	2063	107			221256
Achham	198188	1680	118	1		198188
Dang	354413	2955	120	1	51704	302709
Ramechhap	188064	1546	122	1		188064
Banke	285604	2337	122	1	47819	237785
Salyan	181785	1462	124			181785
Dailekh	187400	1502	125			187400
Kailali	417891	3235	129	2	44753	373138
Makwanpur	314599	2426	130		53836	260763
Okhaldhunga	139457	1074	130	1		139457
Baglung	232486	1784	130	1		232486
Bhojpur	198784	1507	132	1		198784
Baitadi	200716	1519	132	1		200716
Pyuthan	175469	1309	134			175469
Ilam	229214	1703	135		13197	216017
Khotang	215965	1591	136	1		215965
Panchthar	175206	1241	141			175206
Bardiya	290313	2025	143			290313
Dhading	278068	1926	144			278068
Kaski	292945	2017	145	1	95286	197659
Tehrathum	102870	679	152			102870
Arghakhanchi	180884	1193	152			180884
Chitawan	354488	2218	160	2	54670	299818
Kanchanpur	257906	1610	160	1	62050	195856
Dhankuta	146386	891	164		17073	129313
Palpa	236313	1373	172		13599	222714
Tanahu	268073	1546	173		20124	247949
Nawalparasi	436217	2162	202			436217
Kapilvastu	371778	1738	214		17126	354652
Nuwakot	245260	1121	219		18694	226566
Gulmi	266331	1149	232			266331
Kavre	324329	1396	232		22349	301980
Syangja	293526	1164	252			293526
Parsa	372524	1353	275		69005	303519
Parbat	143547	494	291	1		143547
Saptari	465668	1363	342		43245	422423
Bara	415718	1190	349	1	18498	397220
Morang	674823	1855	364	1	170709	504114
Rauthat	414005	1126	368		20434	393571
Sunsari	463481	1257	369		85004	378477
Jhapa	593737	1606	370	1	15210	578527
Rupandehi	522150	1360	384	1	83745	438405
Siraha	460746	1188	388	1		460746
Sarlahi	492798	1259	391		14142	478656
Mahottari	440146	1002	439		18088	422058
Dhanusa	543672	1180	461	1	54710	488962
Lalitpur	257086	385	668		115864	141222
Bhaktapur	172952	119	1453		61405	111547
Kathmandu	675341	395	1710	1	421258	254083
Nepal - Total	**18491099**	**147181**	**126**	**44**	**1758930**	**16732169**

Source: Statistical Pocketbook 1996, Nepal Year Book 1991

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LIST OF ABBREVIATIONS, ACRONYMS AND LOCAL TERMS

ABB	:	ABB National Transformer AS
ACAP	:	Annapurna Conservation Area Project
ADB/A	:	Asian Development Bank
ADB/N	:	Agriculture Development Bank, Nepal
AEW	:	Agro Engineering Works
APCTT	:	Asia Pacific Centre for Transfer of Technology
AVR	:	Automatic Voltage Regulator
B/C	:	Benefit-Cost
BEW	:	Butwal Engineering Works
BMTI	:	Balaju Mechanical Training Institute
BPC	:	Butwal Power Company
BTI	:	Butwal Training Institute
BYS	:	Balaju Yantra Shala
CBS	:	Central Bureau of Statistics
CH	:	Central Hills
Chiura	:	Beaten Rice (Rice Flakes)
CI	:	Cottage Industry
CIDB	:	Cottage Industry Development Board
CIF	:	Cost Insurance Freight
CM	:	Central Mountains
crore	:	ten million
CRT	:	Centre for Rural Technology
CSI	:	Cottage and Small Scale Industry
CTEVT	:	Council for Technical Education and Vocational Training
DCS	:	Development Consulting Services
DCVI	:	Department of Cottage and Village Industries
Dhiki	:	Traditional Rice Huller
DOC	:	Department of Commerce
DOI	:	Department of Industry
E	:	Electricity
EB/C	:	Economic Benefit-Cost
ECB	:	Electronic Control Board
EH	:	Eastern Hills
EIRR	:	Economic Internal Rate of Return
ELC	:	Electronic Load Controller
EM	:	Eastern Mountains
ENPV	:	Economic Net Present Value
ERS	:	Effective Rate of Subsidy
ESCAP	:	Economic Social Co-operation in Asia Pacific
FAKT	:	Association for Promotion of Appropriate Technology (Germany)
FB/C	:	Financial Benefit-Cost
FIIR	:	Financial Internal Rate of Return
FITA	:	Foreign Investment and Technology Transfer Act
FNCCI	:	Federation of Nepalese Chambers of commerce and Industry
FNPV	:	Financial Net Present Value
FOB	:	Free on Board
G	:	Grinder

GDP	:	Gross Domestic Product
GEF	:	Global Environmental Facility
GJ	:	Giga Joules
GNP	:	Gross National Product
GP-ELC	:	Electronic Load Controller Developed by Gerry Pope
GTZ	:	German Agency for Technical Co-operation
HDPE	:	High Density Polythene
HMG/N	:	His Majesty's Government of Nepal
HRC-SHP	:	Hangzou Regional Centre for Small Hydro Power (China)
IAAS	:	Institute of Agriculture and Animal Science
ICIMOD	:	International Centre for Integrated Mountain Development
IEDI	:	Industrial Enterprises Development Institute
IGC	:	Induction Generator Controller
ILO	:	International Labour Organisation
INGO	:	International Non-Governmental Organisation
IOE	:	Institute of Engineering
IOF	:	Institute of Forestry
IREDA	:	Indian Renewable Energy Development Agency
IRR	:	Internal Rate of Return
IRs.	:	Indian Rupees
ITDG	:	Intermediate Technology Development Group (UK)
ITDG/N	:	Intermediate Technology Development Group/Nepal
ITL	:	Inter Tech Limited
Janto	:	Manual Operated Grain Grinder
KEN	:	Kvaerner Energy
KG	:	Krishna Grill
KMI	:	Kathmandu Metal Industry
Kol	:	Traditional Oil Expeller
kVA	:	kilo Volt Ampere
kW	:	kilo Watt
kWh	:	kilo Watt hour
LDC	:	Least Developed Countries
Lokta	:	Raw Material for Nepali Paper
MCB	:	Miniature Circuit Breaker
MHP	:	Micro Hydro Plant
MMH	:	Mini-Micro Hydro
MMHP	:	Mini-Micro Hydro Plant
MNES	:	Ministry of Non-Conventional Energy Sources (India)
MOC	:	Ministry of Commerce
MOF	:	Ministry of Finance
MOI	:	Ministry of Industry
MOIC	:	Ministry of Industry and Commerce
MOST	:	Ministry of Science and Technology
MPPU	:	Multi-Purpose Power Unit
MTC	:	Mechanical Training Centre
MW	:	Mega Watt
MWH	:	Mega Watt Hour
NCST	:	National Council for Science and Technology
NEA	:	Nepal Electricity Authority
NGO	:	Non-Governmental Organisation

NHECO : Nepal Hydro Electro Company
NIC : Newly Industrialised Countries
NIDC : Nepal Industrial Development Corporation
NMHDA : Nepal Micro Hydropower Development Association
NMSS : Nepal Metal and Steel Structures
NOC : Nepal Oil Corporation
NORAD : Norwegian Agency for Technical Co-operation
NPC : National Planning Commission
NPEDC : National Productivity and Economic Development Centre
NPP : National Power Products
NPV : Net Present Value
NRB : Nepal Rastra Bank
NRs. : Nepalese Rupees
NSEC : National Structure and Engineering Company
NSIC : Nepal Standard Industrial Classification
NTC : National Technological Capability
NYS : Nepal Yantra Shala
O&M : Operation and Maintenance
OECD : Organization for Economic Co-operation and Development
OGL : Open General License
Pani Ghatta: Traditional Water Mill
PCAT : Pakistan Council for Appropriate Technology
PF : Plant Factor
R : Rice Huller
R&D : Research and Development
RADP : Rural Area Development Project
RECAST : Research Centre for Applied Science and Technology
REDP : Rural Energy Development Project
RET : Renewable Energy Technology
RONAST : Royal Nepal Academy of Science and technology
S&T : Science and technology
SAARC : South Asian Association for Regional Co-operation
SATA : Swiss Association for Technical Assistance
SBPP : Small Business Promotion Project
SEI : Stockholm Environment Institute
SHDB : Small Hydro Development Board
SHDP : Small Hydro Development Project
SKAT : Swiss Centre for Development Co-operation in Technology and Management
SLC : School Leaving Certificate
SPV : Solar Photo-Voltaic
Tarai : Plain Area in South Nepal
TC : Technological Capability
TEI : Thapa Engineering Industry
TPC : Trade Promotion Centre
TTDP : Technology Transfer and Development Project
TU : Tribhuvan University
UK : United Kingdom
UMN : United Mission to Nepal
UNCTAD : United Nations Conference on Trade and Development

UNDP	:	United Nations Development Programme
UNESCO	:	United Nations Educational Scientific and Cultural Organisation
UNICEF	:	United Nations International Children's Fund
UNIDO	:	United Nations Industrial Development Organization
US$	:	United States Dollar
USAID	:	United States Agency for International Development
VDC	:	Village Development Committee
W	:	Watt
WB	:	World Bank
WEC	:	Water and Energy Commission
WECS	:	Water and Energy Commission Secretariat
WH	:	Western Hills
WM	:	Western Mountains

CHAPTER - 1

SCOPE AND OBJECTIVES OF THE STUDY

1.1 INTRODUCTION

Nepal, situated in the lap of the great Himalayan range, is sandwiched between China and India. It is a unique country endowed with Mount Everest and other eight mountain peaks in the north, which are higher than 8000 meters and form the perennial source of the country's rich water resources. Within a span of about 180 kilometers, this terrain changes into fertile plains in the south with an elevation as low as 200 meters above sea-level. The mid-belt comprising of hills and valleys is home to nearly 45.5 percent of population, whereas the major population, 46.7 percent live in the southern plains and 7.8 percent are settled in the mountains.

Nepal is rich in culture, heritage and traditional arts and crafts. But its highly scattered settlement pattern and difficult terrain have challenged development efforts. It is therefore not surprising that Nepal has been categorised in the World Development Report (*World Bank, 1997*) as the ninth poorest 'least developed country' (LDC). Of a total population of 21 million, 89 percent lives in the rural areas. As is characteristic of an LDC, the country's economic performance is limited by various constraints which reflect the lack of energy resources and the low level of industrialisation; both of these deficiencies are particularly severe in rural areas. Given the rural energy problem and the country's lack of advanced technological manufacturing capability, a principal purpose of this study is to assess the benefits to Nepal of promoting mini-micro-hydro power technology (MMHP) - promoting not only its use as an energy source in rural areas, but promoting also the domestic production of MMHP equipment as a means of developing a manufacturing capability in engineering. The present study investigates whether this double-pronged strategy, focusing on MMHP, is a promising one - and if it looks to be so - seeks to identify the difficulties and obstacles that may have to be overcome, and what part the government should play, in order to advance successfully in this direction.

In the following section (1.2) of this introductory chapter, we sketch in the background to the study, examining key elements of the economic and of the intellectual context in which the development of MMHP is being considered. In 1.2.1 the rural energy situation in Nepal is reviewed and in 1.2.2 an introduction is given to current thinking on the importance of encouraging machinery manufacture in a developing economy as a means of building up technological capability. In the light of the scene-setting discussion of section 1.2, section 1.3 returns to the objectives of the study - to the questions being asked about the potential of MMHP development in Nepal to contribute both to meeting energy needs and to the establishment of a technologically competent manufacturing sector. Subsequent sections of the chapter (1.4 and 1.5) deal with matters of methodology and data sources. The chapter concludes (1.6) with a general outline of the format of the study as a whole.

1.2 THE BACKGROUND TO THE STUDY

1.2.1 The Rural Energy Problem and the Possible Role of Mini-Micro-Hydro Energy

In the beginning ......

> *" and God said ' Let there be light' and there was light. God saw that the light was good and he separated light from darkness. God called the light 'day' and the darkness he called 'night'. And there was evening and there was morning - the first day. ..... (Genesis 1: 3-5)*

For the past several decades .....

> *" and the Utility said, 'Let there be electricity' and there was electricity. The utility saw that the electricity was good and it separated electrified*

areas from the non-electrified areas. The Utility called the electrified areas 'urban' and the unelectrified areas it called 'rural'. And there was industry and there was affluence - development......"

(Ramani et al, 1995)

Rural Energy

Irreverent as the analogy may be, it is uncomfortably close to the reality experienced by most developing countries. For example, even 100 years after the establishment of the first power plants in Sri-Lanka and India, 82 percent of rural households in Sri Lanka and 75 percent in India still remain without access to electricity (*Foley, 1990*). The picture is just as dismal in Nepal and Bangladesh: about 89 percent of the people in Nepal (*CBS, 1998*) and 90 percent in Bangladesh (*Ramani, et al, 1993*) are still without electricity.

The role of rural energy has in recent years received much attention from academics as well as policy-makers as the critical means of achieving the target - sustainable development. Energy has been described (*Smil and Knowland 1980*) as the prime mover of economic development. It is well recognised that energy is a factor central to the well-being of both the developed and the developing countries. Observers such as Rosenberg (*1994*) state that the central feature of industrialisation has been the utilisation of increasing quantities of energy. Further, historical as well as cross-sectional inter-country studies have indicated a close and long-term correlation between energy consumption and economic growth as measured by national accounts (*Erik, B. 1990; Bhaktavalsalam, 1991; Naidu, 1997*). Foley (*1992, p145*) states that electricity is the key which opens the door into the modern world. Without it communities and individuals are denied access to a high proportion of the benefits and amenities which people in the industrial countries take completely for granted.
The classic reason for taking electricity to rural areas is that its availability promotes rural development (*Foley, 1992, p 145*). The Zambian Third National Development Plan put it thus:

> *The direct and indirect benefits of a rural electrification programme can be summed up as increasing agricultural production, promoting rural industries, effecting improvements in the field of health, education, training and the standard of living in general and generating employment opportunities which will reduce migration from the countryside to the town (Quoted in Foley 1992, p.1460).*

Likewise, a review of a programme which brought an electricity supply to villages in Bangladesh concluded :

> *These results show a clear correlation between the supply of electricity and significant growth of commercial enterprises in rural markets. Though other factors such as population, construction of roads, improvement in communication, accessibility to market, proximity to larger cities etc. may also contribute to this growth, there is no doubt that electrification of these markets is the most important intervention that has stimulated this growth in economic activity with a concomitant increase in employment, (Rahman et al,1983)*[1]

Though the focus in these passages is on electricity alone, the argument can be extended to the provision of energy in general when considering the rural areas of Nepal. The argument for the utilisation of renewable sources of energy has gathered new impetus due to two global trends (*Ramani et al, 1995*). One consideration is that the oil price shocks of the 1970s have raised the costs of generating electricity from large thermal power plants and made diesel fuel too expensive to use in providing power supplies to rural communities. Another influence is the growing concern with conservation of resources and the increasing emphasis being laid on the use of renewable sources of energy. As a result small communities are beginning to turn to the possibility of providing at least part of their electricity requirements from renewable resources. Small hydro power stations can make an important contribution

1. Quoted in Foley, G. (1992)

in this area; their success, however, hinges on the availability of technically and economically viable decentralised energy-generating technologies (*Bhadra and Ramani, 1995*).

Energy Availability and Usage in Nepal

Nepal as a whole and the countryside in particular are still heavily reliant on traditional sources of energy. It is estimated that total energy consumption in 1995/96 was about 292 million GJ (*Table 1.1*). Per capita energy consumption in 1995/96, estimated to have been about 13.7 GJ, comprised of 12.3 GJ (90 percent) of bio-mass fuels such as fuelwood, agriculture residue and dung and 1.4 GJ (10 percent) of commercial fuels such as fossil fuels and electricity. Fuelwood is the major source of energy in Nepal which accounts for over 80 percent of total energy generated. The predominance of fuelwood stems from its overwhelming usage in the residential sector - the sector which is responsible for over 91 percent of the total energy consumption. As mentioned commercial sources of energy accounted for a little less than 10 percent in 1995/96. The contributions of some of the major commercial sources towards the total energy consumed in 1995/96 are as follows: dièsel - 3.4 percent; kerosene - 2.6 percent; coal - 1.1 percent; electricity - 1 percent; petrol - 0.5 percent and aviation turbine fuel - 0.4 percent.

National-grid electricity reaches only 11 percent of the total population. The rural people who comprise 89 percent of the population have limited access to grid electricity - no more than 4 percent enjoying that benefit (*ICIMOD, 1997)*. The rural/urban energy consumption split of the residential sector (the largest consumer of energy) is presented in *Table 1.2*. It is evident that the rural areas are highly dependent on traditional animal and bio-mass sources of energy; in fact only 22 percent of the national-grid electricity consumers are in these areas.

Table 1. 1: Energy Consumption in Nepal for the Year 1995/96 ('000 GJ)

Description	Residential			Comm.	Indust.	Agricul.	Transport	Total
	Rural	Urban	Total					
Traditional	246503	12524	259027	973	3635			263635
Fuel-wood	220682	10427	231109	956	3430			235495
Agro-Residue	8964	1385	10349	17	205			10571
Animal Dung	16857	711	17568					17568
Conventional	4365	3756	8120	2136	8535	582	8710	28084
Coal/coke	11	4	15	366	2600		103	3084
Kerosene	4078	2005	6083	1096	384			7563
LPG	1	789	790	119				909
Diesel					3418	577	5862	9857
A. T. Fuel							1287	1287
Petrol					15		1439	1454
Other Oil Prod.				89	841			930
Grid Electricity	274	958	1232	467	1277	5	19	3000
Non-Conventional	563		563					563
Gaseous Fuel	563		563					563
Total	251431	16280	267710	3110	12169	582	8710	292282
%	86.0	5.6	91.6	1.1	4.2	0.2	3.0	100.0

Note: Comm.- Commercial Sector; Indust. - Industrial Sector; Agricul. - Agricultural Sector; A. T. - Aviation Turbine Fuel

Source: WECS, 1997

Table 1. 2: Rural/Urban Split of Residential Energy Consumption, Nepal, 1995/96 ('000 GJ)

Description	Rural		Urban		Total
	Total	Percent	Total	Percent	
Traditional	246503	95.2	12524	4.8	259027
Fuel-wood	220682	95.5	10427	4.5	231109
Agro-Residue	8964	86.6	1385	13.4	10349
Animal Dung	16857	96.0	711	4.0	17568
Conventional Energy	4365	53.8	3756	46.2	8120
Coal/coke	11	72.2	4	27.8	15
Kerosene	4078	67.0	2005	33.0	6083
LPG	1	0.2	789	99.8	790
Grid Electricity	274	22.3	958	77.7	1232
Non-Conventional Energy	563	100.0			563
Gaseous Fuel	563	100.0			563
Total	251431	93.9	16280	6.1	267710

Source: WECS, 1997

Against this background the country is presently applying the remedial measure of promoting decentralised energy sources. Of the several renewable technologies, MMHP has been used in Nepal since the 1960s and is today a major source of energy in the rural and remote areas of the country. Currently more than 1000 MMHP installations exist in the private sector; these operate in 59 of the country's 75 districts (*See Map 1.1*). The total capacity of installed MMHP is about 9 MW.

For most the rural areas alternative sources of energy appear to be the answer to their energy problem, a problem characterised, on one hand, by the rapid depletion of the forests and, on the other, by the absence of national grid connection. (*See Map 1.2)* Of the various alternative/renewable sources of energy mini-micro-hydro scores well in terms of capacity already installed and existence of domestic manufacturing facilities. Furthermore, it is dependent on one of the widely available resources of the country. Nepal possesses about 2.27 percent of the world's water resources, most of which yet remain unexploited (WECS, *1994/95*). There are over 6000 streams, rivers, rivulets and lakes which cover more than 4000 sq. km; 93 percent of such areas fall under the four big river basins Kosi, Gandaki, Karnali and Mahakali. (*See Map 1.3*) It is estimated that Nepal possesses a theoretical hydropower potential of 83,000 MW, out of which 42,000 MW seems economically viable. The large scale[2] hydro plants are responsible for about 95 percent of the national production of electricity, with 1.58 percent coming from small-scale plants, 2.72 percent from mini plants and 1.15 percent from micro-scale operation. However the development of this resource is inhibited by the heavy initial cost of large hydro plants and also by the high cost of transmission and distribution[3] in the hilly regions. The comparative costs of the hydro-projects of varying scales will be discussed in Chapter 4.

Mini-micro-hydro has been used in Nepal for many centuries in the form of "water-wheels" commonly known as "*Pani-Ghattas*". Currently, several modern forms of mini-micro-hydro turbines - cross-flow, multi-purpose power unit (improved "*Pani-Ghattas*"), modified pelton and propeller - which have been used in the country since the 1960s constitute a major source of energy in the rural and remote areas.

2 Classification of Hydro Plants: Large and Medium Scale - above 10 MW; Small Scale - upto 10 MW; Mini Scale - 101 kW to 1000 kW; Micro Scale - upto 100 kW

3 studies carried out for the hilly regions in India indicate a rise in transmission and distribution cost by 40 percent as compared to that in the flat land (TERI, 1994)

Renewable energy sources derived from bio-mass is also widely utilised in the low-lying areas favourable to anaerobic digestion. Solar photovoltaic (354 kW) and wind energy (20 kW) are so far being employed mainly for experimental and demonstration purposes (*WECS, 1994/95*).

1.2.2 Escaping Technological Backwardness

Presently, there are more than 4000 industrial units in Nepal employing about 2,25,000 persons (*CBS, 1991/92*). Capital goods production is extremely limited. The industrial sector is comprised 90 percent of consumer- goods producers[4], 7 percent of intermediate-goods producers[5] and only 3 percent of capital- goods producers[6]. The contribution of the industrial sector (excluding mining and electricity) to national GDP has increased from a mere 3.84 percent in 1980/81 to 9.3 in 1995/96. Detailed statistical information on the machinery manufacturing sector is not however available.

The Key Role of Machinery Manufacturing in Development

MMHP turbine manufacturing is the principal machinery producing sector in the country. The argument for promoting this sector stems from the fact that the activity of machinery production is recognised to be of key importance in the process of technology transfer and diffusion *(See e.g. Fransman and King, 1984, Huq and Pendergast, 1983, Huq et al, 1993*). Forsyth (*1987)* argues the case for promoting local production of plant and machinery, emphasising that the development of this sector is imperative in gaining mastery over new technology. A capital goods industry can play a dynamic role in building up indigenous technological capability, in respect both of products and processes, through absorption of technological know-how and

4 The consumer goods industries represent industries producing processed and canned food, oil, bakery, grain mills, confectioneries beverage and textile

5 Intermediate industries producing jute, paper and printing, rubber and plastics

6 Capital goods sector represents industries producing non-metallic goods, cement and lime, metal works, iron and steel and electrical goods

by raising of the engineering skills of the workforce. Local technological effort directed to the adaptation of imported technology to local conditions is another important element in the process of developing indigenous technological capability.

Governments of newly industrialised and semi-industrialised countries such as South Korea, China, Argentina, Taiwan and India have made it a priority to promote the growth of the machinery producing sector. Home production of machinery and equipment not only serves to advance domestic technological capability; it also helps to offset the import constraint on the availability of such producer goods.

The MMHP equipment manufacturers of Nepal not only constitute a machinery manufacturing sector - being for the past several years the main suppliers of MMH turbines for domestic installation - but are the suppliers also of most of the end-use equipment and other ancillary parts, as well as being involved in turbine site feasibility studies, plant installation and the training of the plant operators. From this it is evident that the MMHP turbine manufacturers play a pivotal role in the rural energy programmes. Judging by the experiences of other developing countries, development of this sector will go a along way in fostering the growth of technological capability in the country, not only as regards urban manufacturing activity, but also with respect to the transfer of new energy technology to rural operators and users.

A Question of Capabilities

A departure from the analytical tradition of relegating the sources of technical progress to an unexplained 'black box', a 'residual factor' or 'exogenous factor' has occurred in the development literature since the 1980s[7]. Questions on achievement of technical progress and 'why growth rates differ' have been addressed in recent empirical studies in terms of 'catching-up', 'overtaking', 'falling behind' and the convergence or otherwise of levels of competence in the countries considered (*Bhalla, 1995*). Recent investigations are no longer based on the neo-classical

7 See Rosenberg, 1976, Solow, 1957, Malecki, 1997, Lall 1987

approach which neglects all historical dimensions, concentrating only on the investment and labour requirements and completely ignoring other aspects such as scale of output, nature of product, skilled labour requirements, inputs, infrastructural requirements etc. The new analysis moves away from this static approach focuses more on dynamic issues of adaptation, assimilation, mastery and diffusion of imported technology (*Dahlman, 1987; Lall, 1987; Rosenberg and Fristak, 1985*) - on matters, that is to say, of technological capability (TC).

LDCs use imported technologies rather than being initial innovators. Taking into account the peculiarities of their technological development, the concept of TCs has been used in the development literature to analyse both how such imported technologies are used at different levels of technological assimilation, adaptation and improvement, and whether these stages progress into a more independent technological competence. The path towards achieving TCs comes only through continuous learning for developing technological capability at firm-level and at national level (*Lall 1990; Bell, 1984; Stiglitz, 1987*).

At the firm level, empirical evidence reveals that a common characteristic in the process of assimilation, adaptation and minor innovation is the explicit effort to carry out technological changes. In doing so, some firms (*See Park, 1983; Katz, 1984; Katz et al, 1987 and Teitel 1984)* - initially dependent on imported technology - develop enhanced capabilities with time and effort, and achieve higher standards of efficiency and international competitiveness. In cases of LDC firms that have developed technologies transcending technological frontiers, it has been found that the progress they have achieved does not involve major breakthroughs. The changes that have occurred are manifested in increases in productivity brought about by product-modification, process-modification and changes in inputs (*Lall, 1984*). In the analysis of the ways in which TCs are developed, Katz (*1984*) indicates the possibilities of the exposure of the firms to general science and technological developments in universities, R&D organisations and consultancies working in related technologies.

At national-level these capabilities have been perceived in various ways. Lall (*1990*) uses a combination of measures - such as industrial growth, competitiveness, total factor productivity change and export diversification - to assess the relative levels of national technological capabilities. From a study of ten nations,[8] Lall concludes that:

> *It is evident that TCs at the national level vary significantly, not only between developed and developing countries, but also within each group. Even if the motivations and determinants of firm-level behaviour were essentially similar between developing countries, the end result in terms of national capabilities would differ. Firms could be starting from different levels of development and working with different endowments of skill and within different market and demand structures. The structure of incentives, factor-markets, policies, institutions and infrastructure would differ. And of course, social, economic, political and cultural traditions would be different, each casting its own influence on the direction and pace of capability development. (Lall 1990, p. 15)*

A number of economic and non-economic variables influence the development of national technological capability. Case studies which concentrate on single countries can take into consideration country-specific circumstances contributing to TC development. The present study, focusing on one country, examines TCs in a particular capital-goods industry.

For skill formation, education becomes important as it helps in imparting technical knowledge, thus allowing more workers to enter the labour market. Scholars such as Meir *(1970)*, Mincer *(1962)*, Becker *(1962)*, and among others, the World Bank *(1987)* have underlined the importance of investment in education and suggested that, along with the lack of physical assets, lack of education is also a great obstacle to industrialisation. The importance of technical skill - and the constraint imposed by want of skill - is evident when making decisions on the selection and import of technology intended to be suitable to local conditions.

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8 Korea, Taiwan, Brazil, Mexico, India, Hong Kong, Singapore, Malaysia, Thailand and Kenya

If choices are made efficiently, taking local conditions into consideration, the gains from imported technology will be much greater. Together with these variables affecting the development of TCs, the role of government has received special consideration from authors like Amsden *(1989),* Chang *(1993),* Huff *(1995)* and Shapiro and Taylor *(1990).* Evidence from these studies postulate the need for supportive government intervention. These aspects of skill development will be discussed in more detail in Chapter 5.

Basic Education and Technical Training in Nepal

Table 1.3 presents data on enrolment in primary and secondary education in Nepal. Primary education figures reveal that in 1991 only 88 percent of the school-age population was receiving basic education - the education which provides the fundamental skills which a country needs to establish a modern manufacturing sector.

In considering the determinants of technological capability it is relevant to take into account the technical orientation of students as indicated by the proportion studying science and technology subjects at the higher education level. Data available for 1995 indicate the following percentage of enrolment in science and technology: 15.70 percent of Nepalese students were engaged in technical studies, 15.50 percent were on vocational courses and 68.80 percent were in general education *(CSB, 1998).* These figures postulate the need to strengthen and build up a technically skilled workforce for Nepal.

Table 1. 3: Education Enrolment in Nepal (Number Enrolled in Schools as Percentage of Age Group)

Education Level	*1981*	*1991*
Primary	52.20%	88.70%
Lower Secondary	37.90%	44.90%
Secondary	37.85%	37.50%

Note: Primary -Ages 5 to 10; Lower Secondary - Ages 11-12;
Higher Secondary - Ages 13-15
Source: CBS,1991, 1994 &1996; Ministry of Education,1993;

Table 1.4 presents a scenario of the growth of science and technology manpower over the period, with data for selected years (1977-1995). The figures computed with 1977 as base-year actually indicate a slowing down of the rate of growth of numbers of S&T personnel. The yearly growth rate for the whole period (1977-1995) was only 7.15 percent - as compared to 11.69 percent for (1977-1982) and 10.86 percent in (1982-1987); over the later years 1987-95 the rate was no more than 3.5 percent. For the period 1985-90 a shortage of 7, 000 technical personnel was estimated to exist *(NPC, 1985, Shakya, 1993)*.

Table 1. 4: Numbers and Growth Rate of Science and Technology Personnel (1977-1995)

Discipline	1977 *(base - year)*	1982		1987		1995	
	Number	*Number*	*Yearly Growth Rate %*	*Number*	*Yearly Growth Rate %*	*Number*	*Yearly Growth Rate %*
Agriculture	527	839	9.75	1607	11.79	1395	5.56
Engineering	803	1467	12.81	2263	12.74	2554	6.64
Forestry	155	175	2.46	267	5.59	718	8.84
Medicine	442	624	7.14	1031	8.84	1663	7.64
N. Science	450	1027	17.94	1351	11.62	1906	8.35
Total	2377	4132	11.69	6919	11.28	8236	7.15

Source: RONAST, 1987; Adhikari et.al 1995 (Draft)

1.3 OBJECTIVES OF THE STUDY

Having reviewed the context in which this study is set, we now return to the objectives of the study, which concern the contribution - actual and possible - of the MMHP sector. (the term "MMHP sector" has been used in this study to denote both MMHP energy generation in rural areas and the manufacture of the required generating equipment). The two principal purposes of the exercise, given the existing situation in Nepal as regards to rural energy and manufacturing capability are to assess (1) the potential of the MMHP sector to supply a solution to the rural energy problem and to assess 2) its potential to form, at the same time through the manufacture of generating equipment, a vehicle for the transmission of technical expertise to Nepal. In fact, with respect to technology transfer, there is a dual objective: to find out not only if producing MMHP equipment can develop manufacturing capabilities but also to see whether their installation, operation and maintenance of generating units is leading to a transfer of skills and knowledge to the rural areas - a transfer of technology which not only permits the efficient operation of the MMHP units but also facilitates the introduction of new, technology-based activities to these areas.

The MMHP sector was chosen for study for two reasons: 1) with a considerable amount of MMHP development having already taken place in Nepal, MMHP has been credited with the potential to provide a solution to the rural energy problem; 2) the manufacture of turbines and other related equipment has already found a firm foothold in Nepal, and is the only existing manufacturing activity in the country which may perhaps form the nucleus of a more highly-developed machinery manufacturing sector.

A further, third objective of the study is to assess the effectiveness of the support given by the government and other institutions both to potential users and to the manufacturers of MMHP equipment. We wish to identify the nature of the difficulties or problems faced by both sets of parties and consider whether, if it should emerge that the promotion of MMHP is a desirable strategy for Nepal, any improvement in policies or in the existing institutional structure can be recommended.

As the proximate means of achieving the study's objectives, information has been sought on the following issues:

1) Problems and Profitability in the Use of MMHP Installations:

The aim here is to identify factors inducing or deterring the establishment and affecting the operation of MMHP units. An attempt is made to estimate returns on MMHP investments. For the successful promotion of MMHP installations their financial profitability is essential to induce investment by possible entrepreneurs; as degree of plant utilisation determines the profitability of an energy project, the type and volume of end-use are critical. Such matters are investigated. The operations of the MMHP plants are also appraised with respect to their wider economic and social efficiency in terms of generating benefits to the rural communities. Finally, an analysis is made of how the MMHP installations compare in terms of private and social costs and benefits with solar photovoltaic and diesel-powered installations.

2) *The Technological Capabilities of the MMH Turbine Manufacturing Firms:* We investigate, with reference to the literature on developing technological capability, the progress of the MMHP manufacturing sector in Nepal, and seek to determine the potential of the sector to provide a core centre of technological expertise and technical experience within Nepal. Various indicators and measures of technological capability are applied to the operations of the mini-micro-hydro turbine manufacturers. Strengths and weaknesses of the manufacturers are then identified on the basis of these criteria. Furthermore, investigation of the operation of MMHP units in the field should yield information on the extent of technology transfer to the rural areas.

3) *The Policy and Institutional Environment in Nepal as It Affects the MMHP Sector*
Various measures have been introduced in order to promote MMHP in Nepal; direct and indirect policy enactments have sought to nurture technological progress in the country. In appraising these efforts, the study attempts to evaluate:

a) overall industrial policies with specific emphasis on policies related to technology transfer;
b) policies intended to promote the use of the technology in the rural areas of the country;
c) the financial incentives offered for the purpose of promoting technological progress;

d) the contribution of the various institutions, governmental and otherwise, involved in the areas of technology transfer and development

To summarise regarding the aims of this study; the probing questions are - does the promotion of MMHP turbine production as a manufacturing activity, and, the use of MMHP installations as an energy source, constitute an effective way, at one and the same time, of meeting a need (demand) in the rural areas for access to an alternative energy source, and of filling a technological gap on the production (supply) side within the economy? The study therefore seeks to identify the outcome of MMHP installation and the possible impediments to exploitation of this energy source by potential users. The study also seeks to identify the actual capabilities of the manufacturers and the path by which they may be able to advance, with appropriate support, to higher technological competence. Finally, it seeks to reach a verdict on the strengths and weaknesses of the policy/institutional context in which MMHP development is taking place. It is hoped that this study will generate clues as to critical factors involved in the successful transfer of technology in the case of a small-scale industry manufacturing equipment principally to meet the demands of domestic investors.

1.4 METHODOLOGY

1.4.1 Methods Employed

The study is exploratory as well as analytical. Two sets of surveys were carried out for this study: one of the manufacturers of the MMHP equipment, and the other of the operators and users of the MMHP installations.

A. The Survey of Users - Rural Enterprises

The survey of users was conducted using a set of questionnaires which was used to guide the enumerators in collecting the data. Information was sought under two headings:

1) with respect to the general environment under which the technology was operating;

2) as regards the financial and the economic viability of the plants.

Under the first heading information was collected on technical matters relating to operation, end-use and constraints encountered in the efficient performance of the plants. Under the second, financial and other information was gathered in order to estimate the commercial and social returns deriving from investment in MMHP plants. This allowed comparison of the MMHP technology with other energy sources - solar and diesel - and enabled assessment of the appropriateness of the technology choice.

The survey sample consists of 90 MMHP plants installed in the hilly and mountainous regions of 17 districts in Nepal. The sample consists of plants whose installed capacity ranges between 1kW and 50 kW and which are used for agro-processing as well as for electricity generation. The turbines for all the sample plants had been supplied and installed by the Nepalese manufacturers.

B. The Survey of Manufacturers

The survey was independently carried out by the author for the purpose of assessing technological capabilities of the firms engaged in the production of MMHP equipment. Eleven manufacturers were identified as having recently operated in this field. However, as three had diverted to other lines of production, only eight firms were included in the survey. These eight firms comprise the total currently engaged in the manufacture of MMHP turbines. Attempts were also made to contact the other three firms, with the objective of determining the reasons for their giving up MMHP activities; only one of the three proved difficult to contact.

The field survey was complemented by interviews with experts in this technology - research organisations as well as national and international organisations involved in the promotion of the technology. The interviews focused on the measures of technological capability. (These measures are discussed in detail in Chapter 5).

1.4.2 Data Sources

The data for the micro-hydro turbine manufacturers are derived from primary as well as secondary sources. Several micro-hydro plants in different parts of the country as well as the manufacturers, were also visited for first-hand information. Micro-hydro plants were visited in order to get an experience of the environment under which these plants thrive.

Amongst the secondary sources used were: *Census of Manufacturing Establishments* (CME) of various years, published by Central Bureau of Statistics and National Planning Commission, Government of Nepal. The coverage of the census is restricted to manufacturing establishments engaging ten or more persons. These censuses provide information about organised manufacturing units only; no reliable data for unorganised, small scale manufacturing firms are available. *The Annual Survey of Manufacturing Establishments* (ASME), which was published for the first time in 1987-1988 has also been used. The CME is however, the most exhaustive source of industrial statistics in Nepal; its coverage extends to the entire factory sector and provides disaggregated data at the individual firm level. The Census is generally undertaken every five years. Data regarding the energy scenario in Nepal have been extracted exclusively from the *Energy Synopsis Reports* published by the Water and Energy Commission Secretariat.

The *World Development Report,* World Bank Reports, various UNESCO reports and publications, and books by experts in the field of S&T were consulted and used. Similarly, data pertinent to Human Resource Development (HRD) and Human Development Capital have also been used.

1.4.3 Limitations

The MMHP sector is a 'non-organised' sector, and hence, is not listed in the CME and ASME. This has made it essential to visit the manufacturers individually to collect data related to investment, output and employment, thus making the exercise time consuming and also limiting the sample size. Further, the owners had reservations about providing certain information with respect to profit and actual investment details, indicators which could have helped in determining the output-efficiency with respect to resources. The production of multiple products by all the firms creates difficulties in estimating value of the profits made through the manufacture of the mini-micro-hydro turbines alone.

1.5 STUDY PRESENTATION

The study is presented in eight chapters. A brief outline of their content is given below:

Following this initial chapter, Chapter 2 focuses on mini-micro-hydro technologies used in Nepal and other developing countries. This chapter provides an insight into the comparable advantages and disadvantages of various types of turbine technologies. The discussion extends to some essential civil constructions as well as electricity generating components in a MMHP installation. Comparison between mini-micro- hydro technologies and selected renewable energy technologies with respect to applicability and efficiency, the status of MMHP technology as used in selected developing countries and the measures adopted by some of these countries for promoting this technology are also discussed here. A description of the commonly-used production process in the manufacture of turbines provides the background necessary for understanding the nature of technological capabilities required in this area and for appreciating the reasons for selecting this technology in the Nepali context.

In Chapters 3 and 4 the MMHP technology is examined from the perspective of the users. These chapters report on operational matters in the rural context, and on the viability of the MMHP installations in financial and in wider socio-economic terms. Chapter 3 presents the findings of the MMHP users survey, giving attention to the nature of the environment in which MMHP plants are required to operate. Light is shed on the factors which make for successful operation, or otherwise, of these plants. Chapter 4 reports on the assessment made of the financial and economic viability of MMHP plants. It is noted that while investment in MMHP installations by potential entrepreneurs will depend on the prospects of the profit that they foresee, wider considerations of economic benefits - benefits both tangible and intangible - are appropriate for the justification of such investment as a mode of national resource allocation. Chapters 3 and 4 jointly provide a picture of the effectiveness of MMHP as a provider of energy in the rural context. If MMHP was not a viable performer in the rural areas, the case for promoting in the country the manufacture of MMHP turbines and other equipment would be gravely - indeed fatally - weakened.

In Chapters 5 and 6 the focus changes and the study concentrates on the production side - on MMHP manufacturing as a vehicle of technological capability building in Nepal. Chapter 5 reviews the theoretical background, examining relevant ideas in the current literature on development which emphasise the importance for a country's economic progress of building up technological capability, thereby enabling advanced technologies from abroad to be successfully absorbed and mastered. The part which the government may play in promoting technology transfer and absorption is considered. Criteria by which a country's degree of technological capability may be judged are highlighted: these criteria or indicators provide a basis for the analysis in the following chapter of the technological status of the mini-micro-hydro manufacturing sector in Nepal.

Chapter 6 reviews the current status of the Nepali manufacturers against the technological capability indicators outlined in Chapter 5 and identifies the major strengths and weaknesses of the firms. This chapter addresses the hypothesis that experience in the use of imported technology alone does not automatically lead to higher levels of technological capability.

Chapter 7 is devoted to the role of the government and other institutions in promoting MMHP development. The policies that have been applied in Nepal are reviewed to determine whether there exist any major gaps such as may inhibit the development of

MMHP. The existing institutional arrangements for the promotion of this sector are also analysed with due acknowledgement of the role played by various international organisations. The institutional arrangements in selected countries of the region are also assessed in order to asses the strengths and weaknesses of the situation in Nepal.

Finally Chapter 8 presents the findings of the study and addresses some issues of policy which emerge. Concern is with the development of a dynamic process of building up technological capability in manufacturing and for the development of sustainable rural energy supplies through the use of mini-micro-hydro.

CHAPTER - 2

MINI-MICRO-HYDRO TURBINES USED IN DEVELOPING COUNTRIES

2.1 INTRODUCTION

The aim of this chapter is to highlight the mini-micro-hydro power (MMHP) technology as used in developing countries. The second part following this introductory section describes the various types of mini-micro-hydro technology in use and the technology upgrading that has taken place over the years. The third section compares the features of the different turbine technologies with respect to their advantages, disadvantages, performance and efficiency. The fourth section discusses the various accessories used in MMHP. The fifth section deals with the several components of MMHP turbine installations. The sixth section focuses on plant costs, the end-uses of MMHP and future prospects. The seventh section compares the status of the technology in selected countries with respect to manufacturing capability, and use of the technology. The eighth and the last section draws some conclusions regarding the MMHP technology used in the developing countries at large.

2.2 TURBINE TECHNOLOGIES USED IN MMHP APPLICATIONS

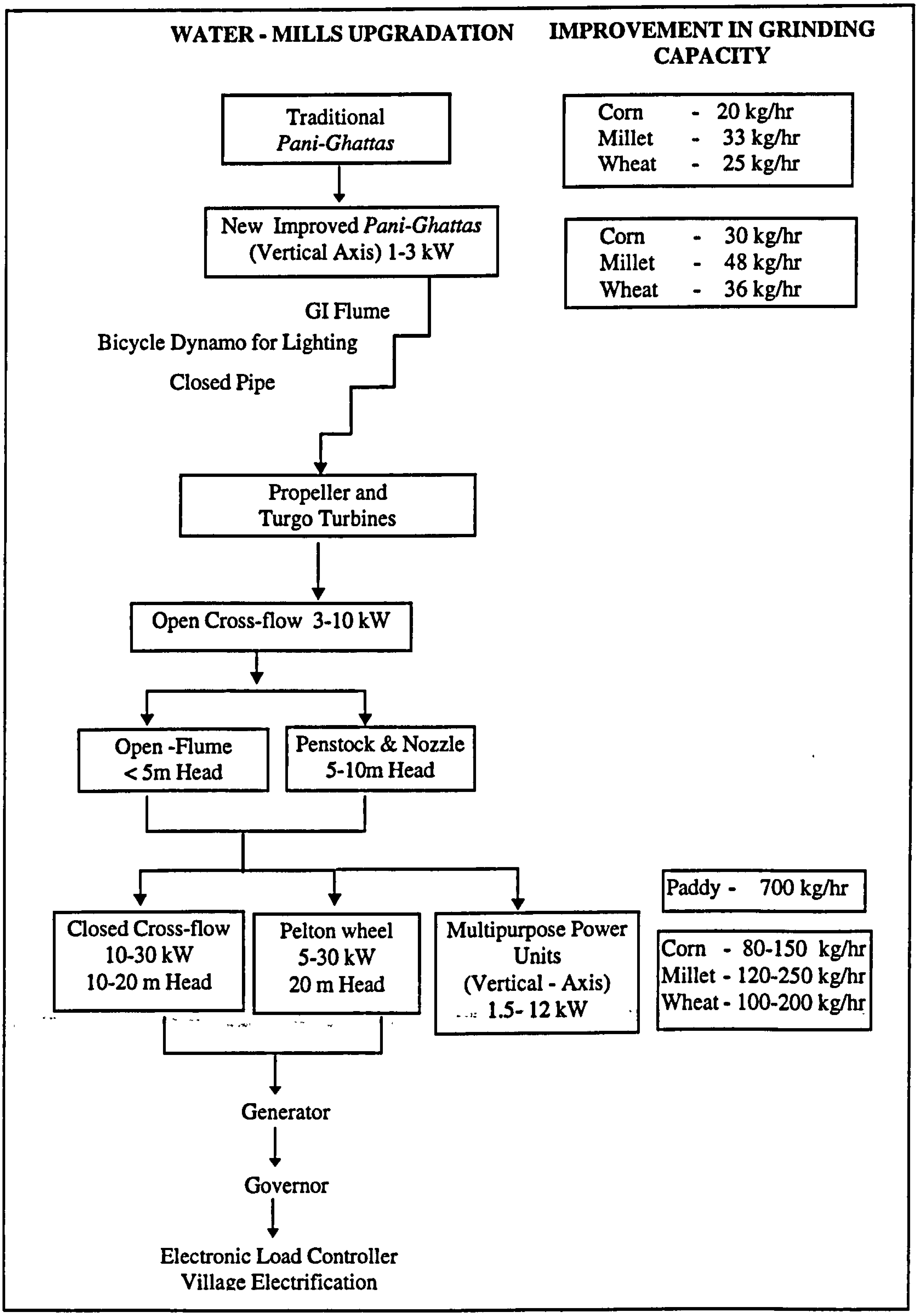
Hydro-power technology is a mature technology which has been well applied world-wide at a large number of sites. Mini-micro-hydro turbines are turbines of lesser capacity but not necessarily scaled-down versions of the larger turbines. They are widely used for providing decentralised energy sources and are one of the most environmentally benign energy conversion options available. Compared to large scale hydro power, MMHP can be much more easily implemented without significantly interfering the natural flow of the river (*SEI, 1991*).

In most developing countries the mini and micro hydro turbines locally produced are based on the concept of using simple equipment and reducing capital costs as far as possible, rather than scaling down large-scale hydro-technology for small installations. Harnessing of small hydro resources lends itself to decentralised utilisation and local implementation and management. This supports rural development based on self-reliance and local natural resources (*Meier, 1981*). The energy of micro-hydro units is best used when the larger part is consumed on the spot as mechanical energy, without the intermediary of electricity. Such units are called mechanical drive units. They can be used for decentralised agro-processing like grinding, rice-hulling and oil-pressing, sawing and water-lifting for irrigation. Micro units solely for electricity generation are often not economical because of high unit costs (*Blankenberg and Hulscher, 1990*).

These MMHP plants, unlike the large plants, do not require elaborate construction works in reinforced concrete, nor expensive power houses and highly optimised electro-mechanical equipment. Thus high safety standards associated with large-scale construction works are often not necessary. The standards of voltage and frequency of regeneration of electricity are modest, thus implying considerable savings, without substantially reducing the benefits of a small hydro-scheme.(*Meier, 1981*). Over the years several innovative developments have taken place to arrive at the present day technical-status. *Chart 2.1* presents the upgrade path of the mini-micro-hydro technology since the use of water-wheel or the traditional water-mill - "*Pani-Ghatta*".

Different terms have been used for different sizes of hydropower plants in various countries. UNIDO has categorised the sizes in the following manner: micro-hydro (MHP) up to 100kW capacity, mini-hydro between 101- 1000 kW capacity, and small hydro between 1001 - 10,000 kW capacity. Other countries have allocated other size ranges to each of these categories. In India, for example, plant sizes between 101-2,000 kW are defined as mini-hydro and those between 2,001 to 15,000 kW are designated as small, whereas in China mini plants have a size range of 101-500 kW and small have a range of 501-25,000 kW. For this study, the UNIDO definitions have been followed, unless otherwise stated.

Chart 2. 1:Technology Upgrading Path



Source: IT,1997; Survey of Manufacturers

2.2.1 Hydro Turbines Manufactured in Developing Countries

A turbine converts energy in the form of falling water into rotating shaft power. Turbines run most efficiently at a particular speed, head and flow. Turbines can be crudely classified as high-head, medium-head or low head machines. There are two distinct types of turbines, the impulse and the reaction turbine. The impulse turbine is driven by jets of water impinging onto the runner whereas the reaction turbine is submerged in water and is driven by the angular and linear movement of the water. Several other characteristics of the two types of turbines are compared in *Table 2.1.* Impulse turbines are easier to manufacture and hence most often attempted by new ventures in turbine production. The main difficulty encountered in the manufacture of reaction turbines is achieving the accuracy of machining required in order to produce the appropriate casing profile to accommodate the turbine runner; hence this production is seldom undertaken in developing countries. Furthermore, as reaction turbines rely more upon a uniform supply of water, their part-flow efficiencies are lower. This makes them less suitable for rural areas where there are large variations in the seasonal flow of the streams. Such areas would require a water storage system thus escalating the cost of the project.

Table 2. 1: Comparison of Various Types of Turbines

	Reaction Turbine	*Impulse Turbine*
Tailrace	Submerged	Open
Specific speed	High	Low
Speed efficiencies	High	Low
Part-flow efficiencies	Poor	Better
Runaway speed	High	Lower
Cavitation	Difficult to reduce	Reduction possible
Effect of sand and particles in the water	Higher	Greater tolerance
Maintenance requirements more complex	Complex	Easier
Casings required	Requires stronger and more accurately cast	Less critical
Suitability	Low-head schemes	High-head schemes

Source: Frankeil, 1991; SEI 1991 and various Editions of Hydronet

Although there are several differences in the efficiency and applicability of turbines, the selection of a turbine remains to be determined by the project site, available head of the water resource and the expected power output.

2.2.2 Water wheels and "*Pani-Ghattas*"

Traditional waterwheels are made of wood and are quite heavy. They are constructed with several flat paddles which are powered by a swift-flowing stream. Also known as under-shot, over-shot or breast-shot wheels, they can be made more efficient when built in combination with weirs. The water is banked behind the wheel and is admitted through a control gate at a fair velocity. The life span of water-wheels can be anything between 6 and 30 years (*Blankenberg and Hulscher, 1990*). In Nepal the most popularly used traditional mills have vertical shafts and are commonly known as "*Pani-Ghattas*". The vertical shaft of the mill is fixed to the upper grinding stone, and the mill is used for grinding grain (*See Fig.2.1*).

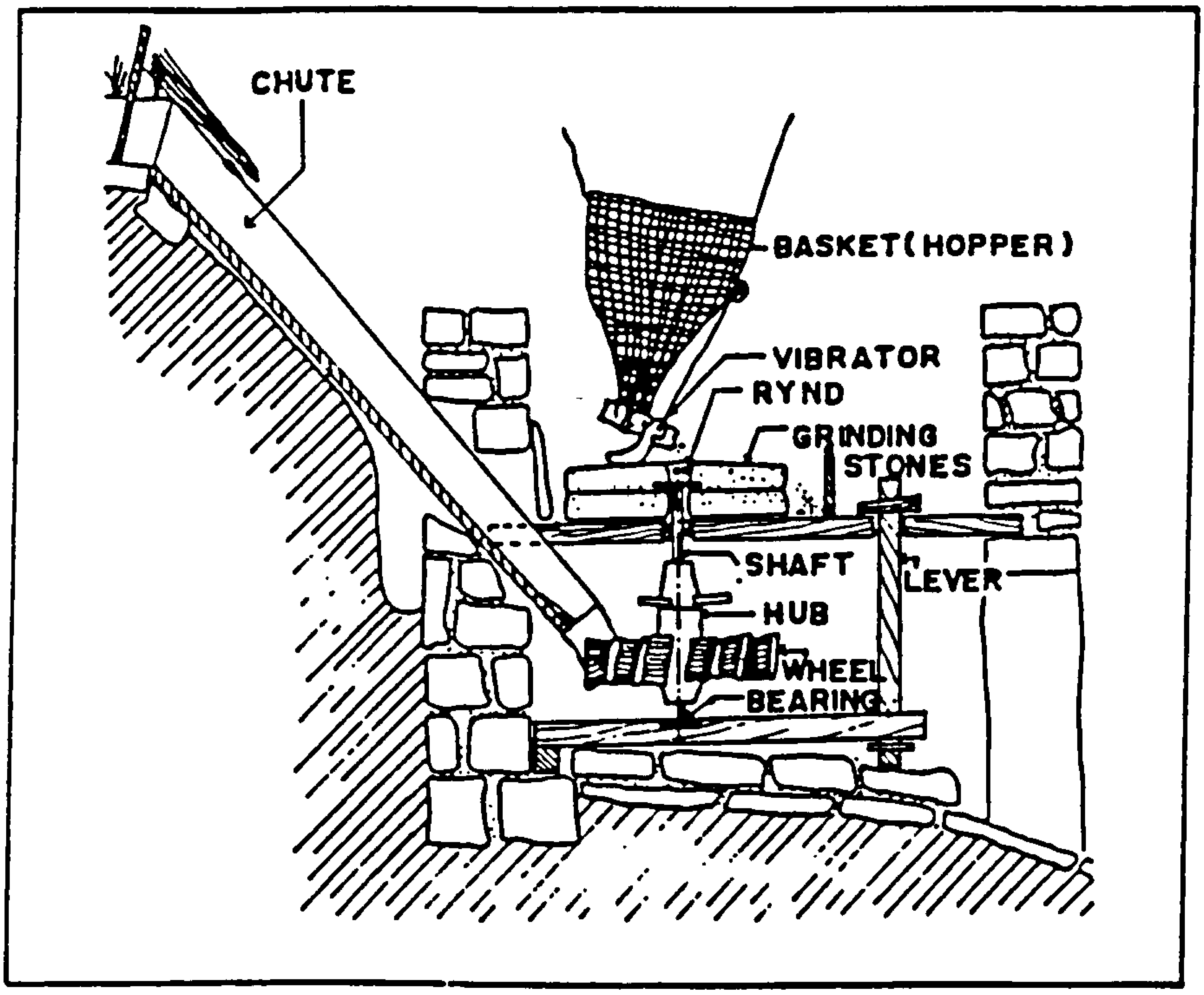
2.2.3 Multi Purpose Power Units (MPPU)

Fitting in somewhere in between the Pelton wheel and the traditional "*Pani-Ghatta*", is a design from Nepal called MPPU (*See Fig.2.2*). Like the Pelton turbine, it has a runner with spoon-shaped buckets and a penstock pipe with a nozzle. The whole construction is simple and cheap; it consists of large hammered steel buckets, standardised welded steel supports, and a non-adjustable nozzle. The design is also cheap because no painstaking efforts are made for optimisation. Nevertheless, compared to waterwheels, efficiency and speed are doubled.

The MPPU is a small unit designed for local agro-processing. The shaft is vertical which is directly fit into one of the mill-stones. Pulley drives are included for power take-off to agro-processing machinery. Likewise a generator or dynamo can be connected to produce electricity.

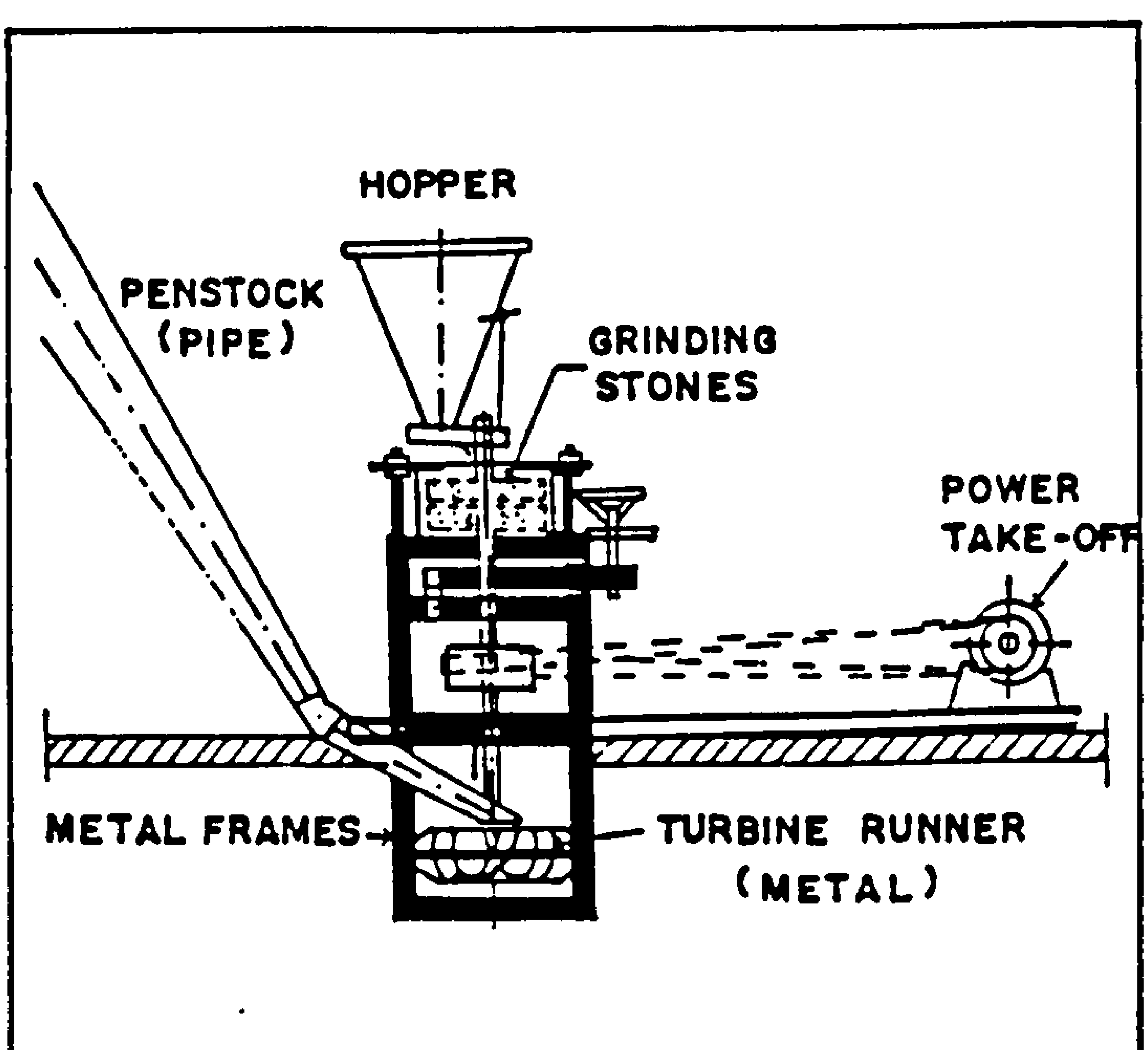
MPPUs are of modular construction, and are assembled on the site of the installation (*Blankenberg and Hulscher, 1990*). As the MPPU is a modern version of the traditional "*Pani-Ghatta*", a technology well understood by the local people, it is relatively easy for them to adopt this technology.

Fig. 2.1: Traditional Water Mill - "*Pani Ghatta*"



Source: Bachmann, 1981

Fig. 2.2: Multi-Purpose Power Unit (MPPU)



Source: Nakarmi and Bachmann, 1981

2.2.4 Pelton Turbines

The principal of the old water-wheel is embodied in the modern Pelton wheel (*See Fig. 2.3*), which consists of a wheel provided with spoon-shaped double buckets around the periphery. A jet of water emerging from a nozzle[1] impinges on a set of specially shaped buckets mounted on the periphery of a circular disc, thus setting the wheel in motion.

Pelton turbines are manufactured with cast steel or brass rotors. They are not difficult to construct as they require only casting facilities along with cutting and welding equipment and basic machinery for turning, planing and drilling. Runners may be cast in mild steel, stainless steel, bronze, cast iron and even in scrap metal for low capacity turbines. The runners are either cast as a single unit or else the buckets are cast individually and then welded or bolted to the central shaft. The individual buckets are cast using the sand casting method. The advantages of individual casting of buckets are several: a small cast furnace can be used, a smaller working area suffices and it is easier to machine/finish the buckets; individually bolted buckets also make it possible for a bucket rather than the whole turbine to be replaced when a bucket is damaged. The system of individual buckets has though the disadvantage of creating increased stress upon the bolts and a reduction of the overall strength of the runner. Bolted turbines are used only for small micro-hydro turbines (*Green, 1994*).

As the Pelton turbine manufacturers do not publicise their bucket design, designing of the buckets by preparing a pattern from an existing runner is commonly practised in Nepal (*Shakya, 1997*). Casings for the turbine require only cutting and welding facilities. However, the rotor shaft and spear valve controlling the water flow require accurate machining. Nozzles and spear valve, spindle and curved deflector are also cast, although they need not be. The spear valve is quite expensive. In case of run-off-

1 The number of nozzles may be more than one. The number depends on the energy required and the availability of water.

the-river schemes it is advantageous to have more than one nozzle so as to generate efficient power even at low flow rates. Provisions such as fixed nozzles, with holes drilled through a sheet of metal have led to reduction in the cost of nozzles (*Inversin 1986*). This adaptation permits the elimination of the spear valve and operates a plant at a more steady rate.

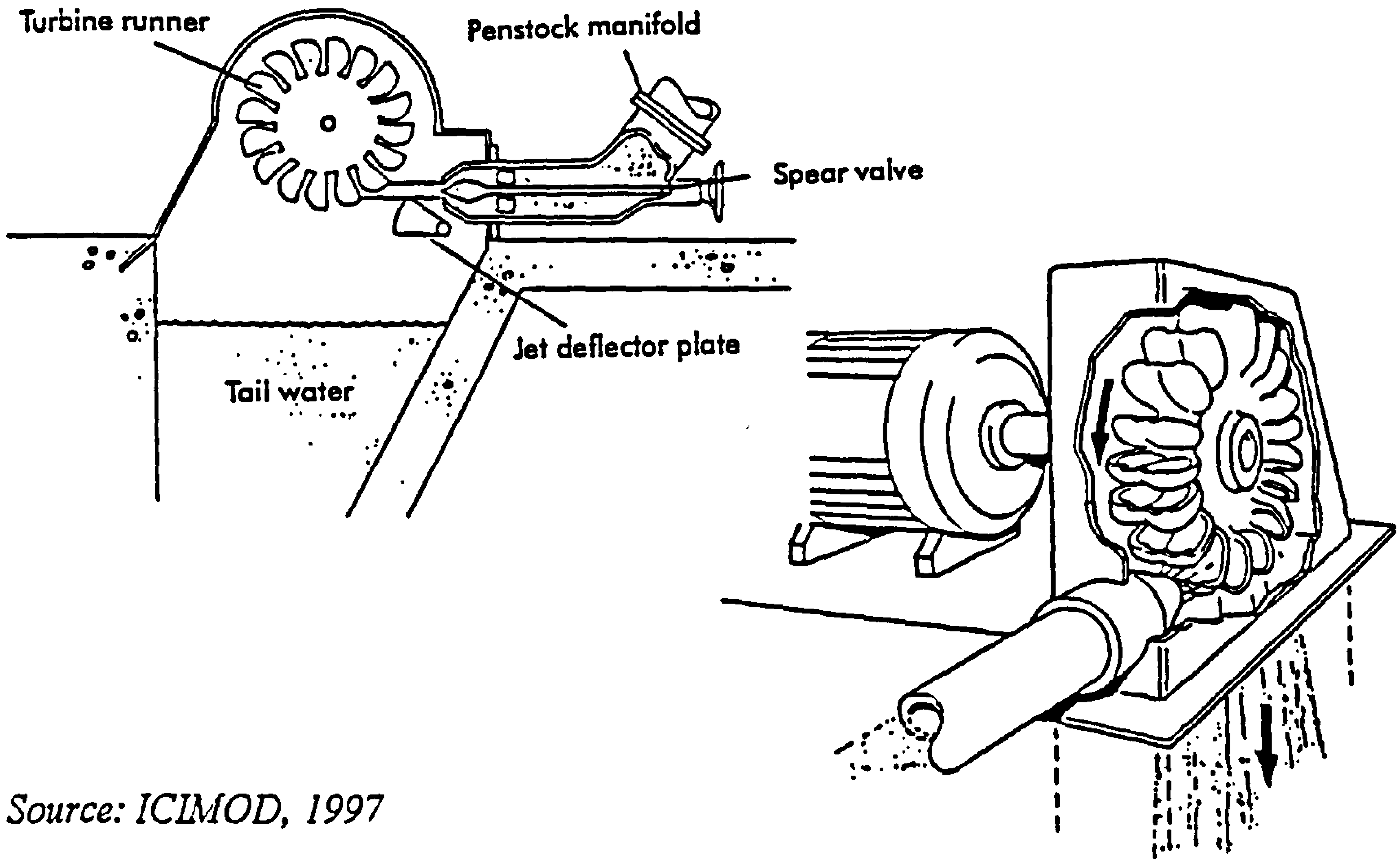
2.2.5 Cross-Flow Turbines

The cross-flow turbine, also known as the *Michell, Banki* or *Ossberger* turbine (*See Fig. 2.4*), was developed to combine ease of manufacture with considerable adaptability to different situations. The main characteristic of the cross-flow turbine is that a water jet of a rectangular cross-section passes through the blades of a cylindrical rotor, perpendicular to the rotor shaft. A single vane is used to provide flow control. A large variety of flow rates can be accommodated with a constant diameter runner, by varying the inlet and runner width. This form of construction reduces considerably the need for tooling, jigs and fixtures in manufacturing. Cross-flow turbines, being cheaper, are popular for generating both motive-power and electricity in rural areas.

Workshops with basic facilities[2] are sufficient for the manufacture of cross-flow turbines as casting is not necessary. In areas where the equipment has to be carried by porters and there is no welding facility, as in many parts of rural Nepal, cross-flow turbines have been designed in such a way that the parts are bolted together and taper pins are used to keep them in position. This makes the turbine lighter and easier for transportation by porters.

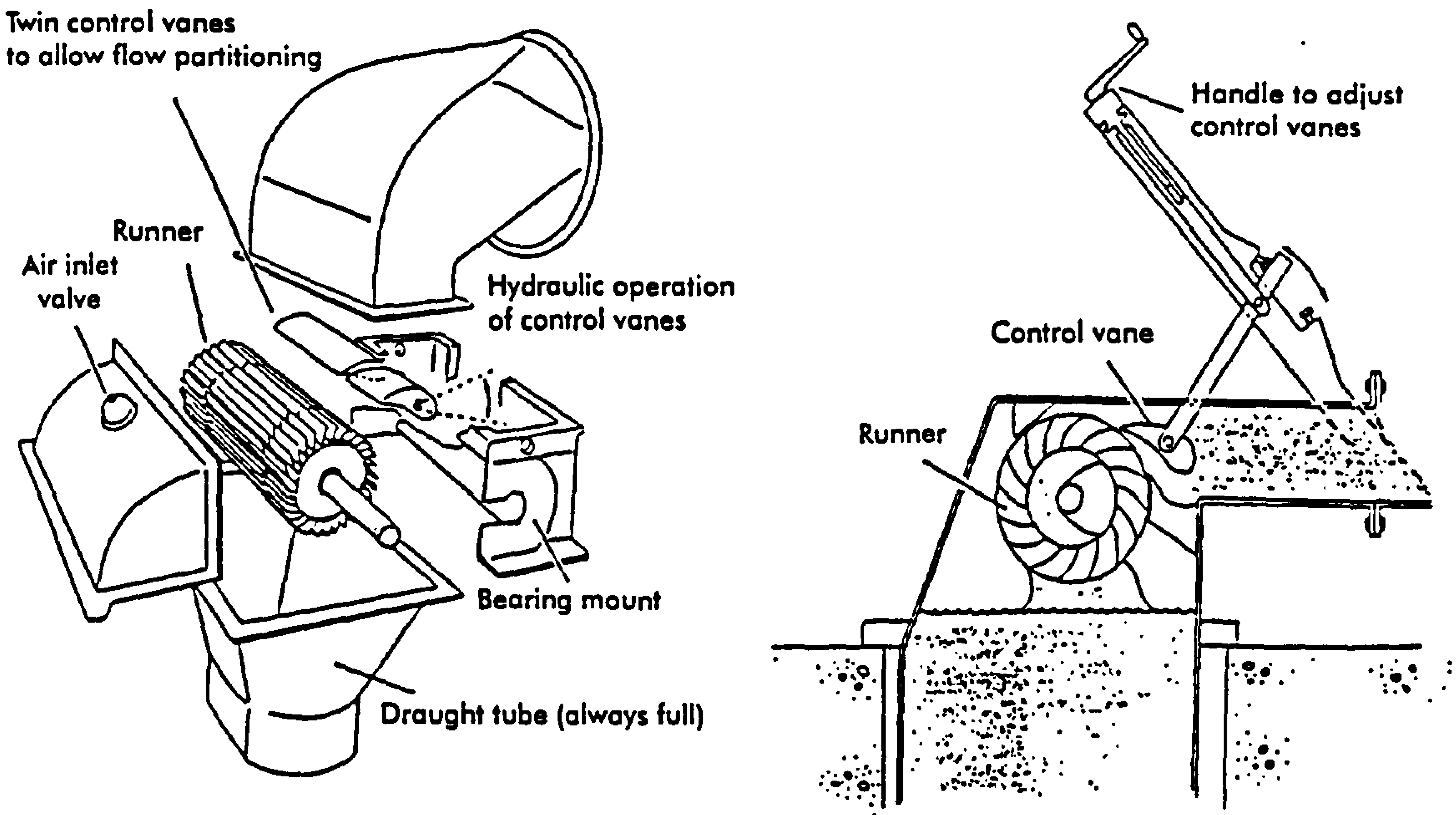
2 According to Meier, 1985, a basic workshop consists of the following machinery; a drilling machine with a boring attachment, a turning lathe, a milling machine, or shaper, an acetylene cutting torch, plate shear, arc welding equipment, specific jigs and fixtures and general hand tools; rolling and forging equipment are optional

Fig. 2.3: Pelton Turbine



Source: ICIMOD, 1997

Fig. 2.4: Cross-flow Turbine



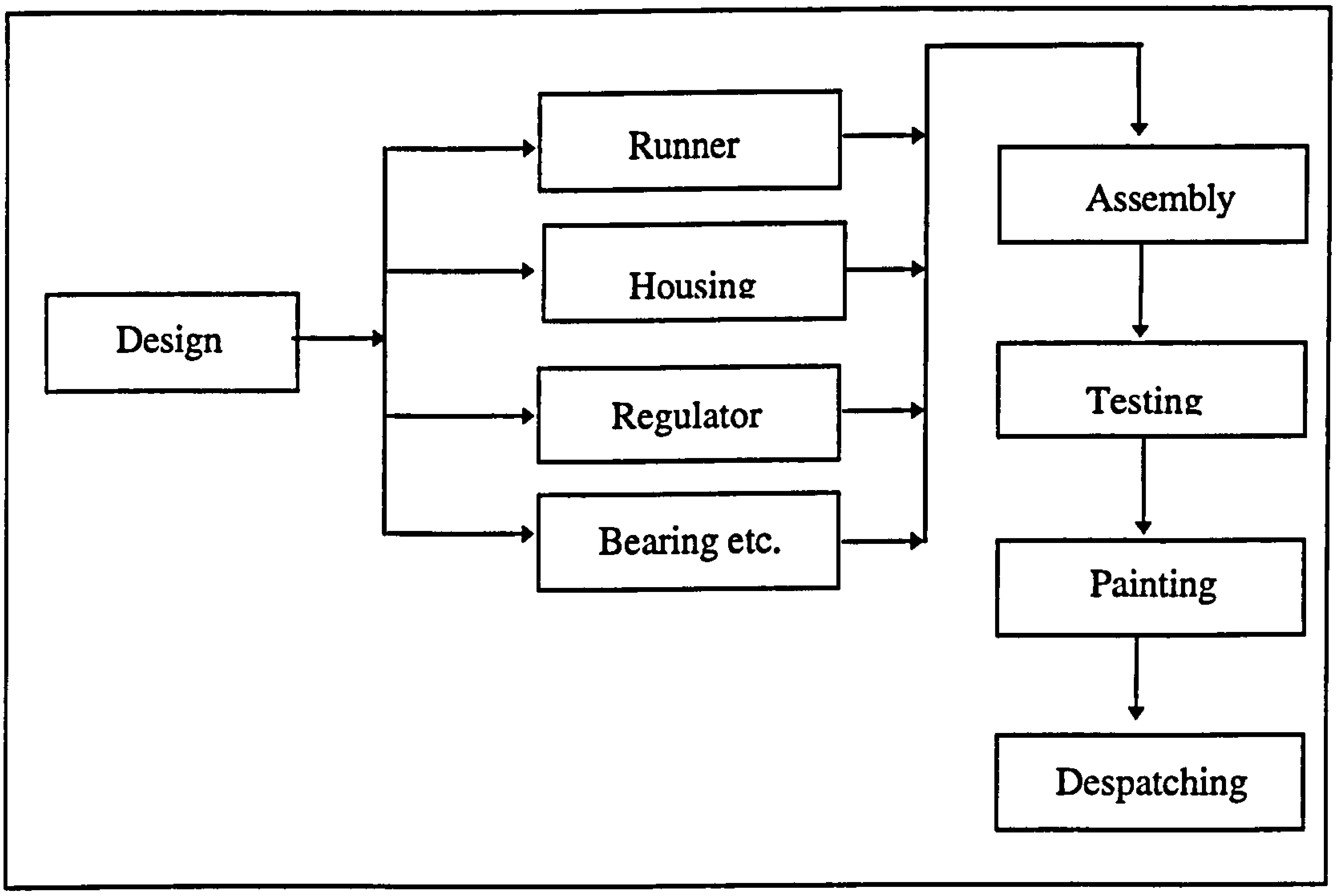
Source: ICIMOD. 1997

Being one of the easiest turbines to produce, there are about 25 major manufacturers of cross-flow turbines in the world (*Arter 1992*). Most of the manufacturers in the developing countries, with the exception of China and Vietnam, mainly make cross-flow turbines (*Green,1994*). Several construction manuals have been produced (*Nakarmi,1992; Inversin, 1980*), but the designs prepared from these published guidelines generally achieve efficiencies only up to 72 percent (*Arter, 1992*) in comparison with the 80 percent achieved by Ossberger (*Meir, 1981*), a German manufacturer, one of the few manufacturers possessing the design knowledge as well. Problems with these turbines, according to Green *(1994)*, are: inefficient draft tube arrangements, blockage of water at the first stage, shock losses at the second stage or structural failure of the runner blades.

Although the blades are made individually from mild steel and welded into slots in supporting discs, whole runners can also be cast in order to increase the strength. Other methods adopted in the fabrication involve cutting the pipe length-wise, as well as using a stamping press or bending machines. Only the width of cross-flow turbines has to be altered in order to produce machines of different capacities. But as the length of the blade increases problems due to metal fatigue may arise; this can however, be encountered with the use of supports at periodic intervals along the blade. Usually the casing is made of mild steel sheet whereas the rotor shaft is made of steel either drawn or machined from a steel block, a common practice in Nepal.

The production of a cross-flow turbine involves the design and manufacture of components as well as the preparation of all necessary items previously purchased. The assembly is done by fixing the runner shaft to the housing and assembling to it the regulating valve. The bearings, waterproof seals, nuts and bolts etc. are fixed as per the requirement during assembly. The assembled turbine is then tested and forwarded for despatch. Usually an identification number and specification are fixed on each turbine (*See Chart 2.2*).

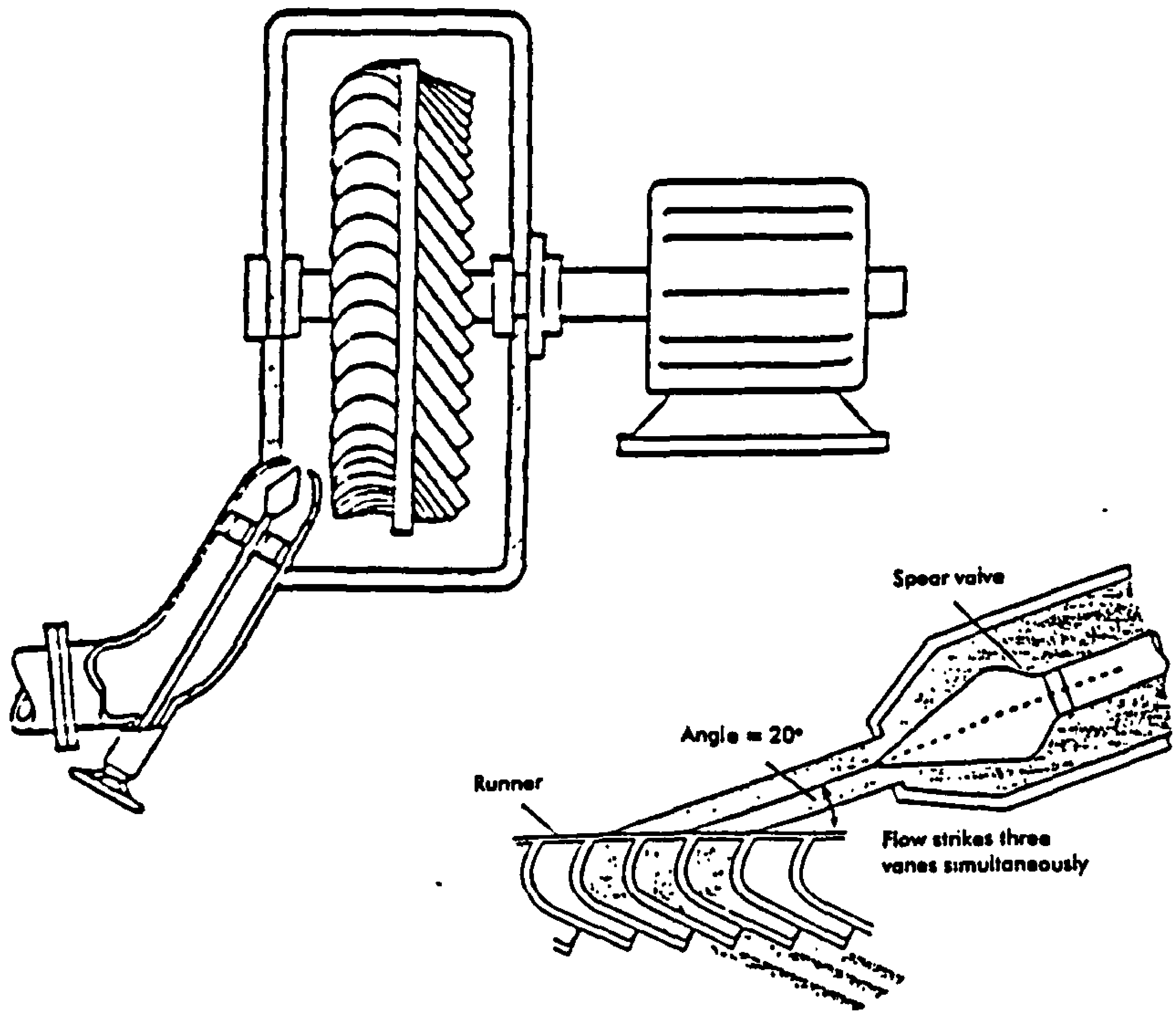
Chart 2. 2: Production Process of Mini-Micro-Hydro Set



2.2.6 Turgo Turbines

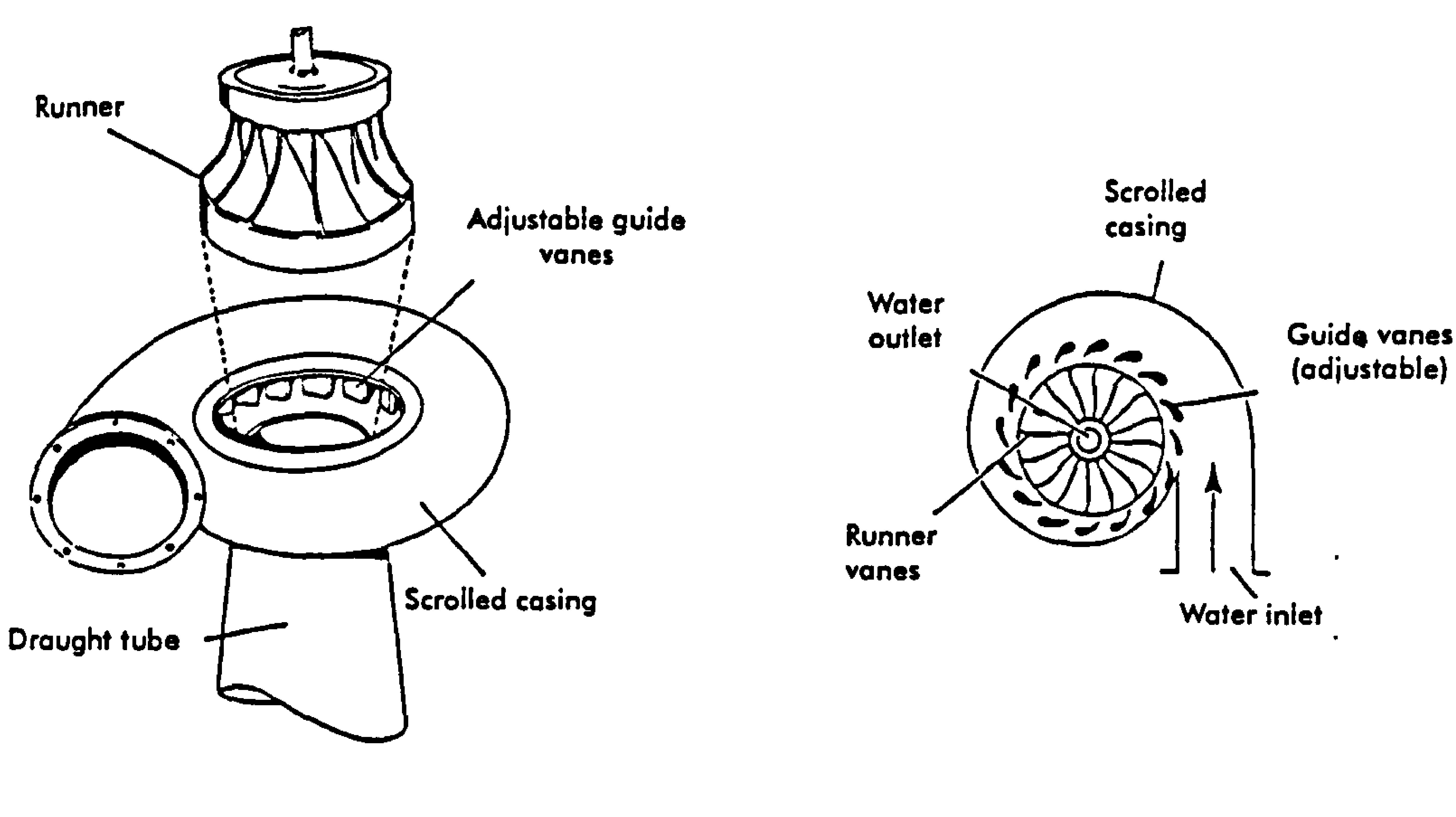
The Turgo turbine (*See Fig. 2.5*) is manufactured only in the UK and China. Very few countries have attempted to manufacture the Turgo turbine, for the simple reasons that the complexity of the blade design makes fabrication difficult and that proper design information is lacking *(Nakarmi, (c))*. Only one such turbine, made in China, has been installed in Nepal for agro-processing and electricity generation as well as irrigation activity. The design details of Turgo turbines will not be described here, as we are focusing only on turbines which are commonly manufactured in Nepal as well as in other developing countries.

Fig. 2.5: Turgo Turbine



Source: SEI, 1991, ICIMOD,1997

Fig. 2.6: Francis Turbine



Source: ICIMOD, 1997

2.2.7 Francis turbines

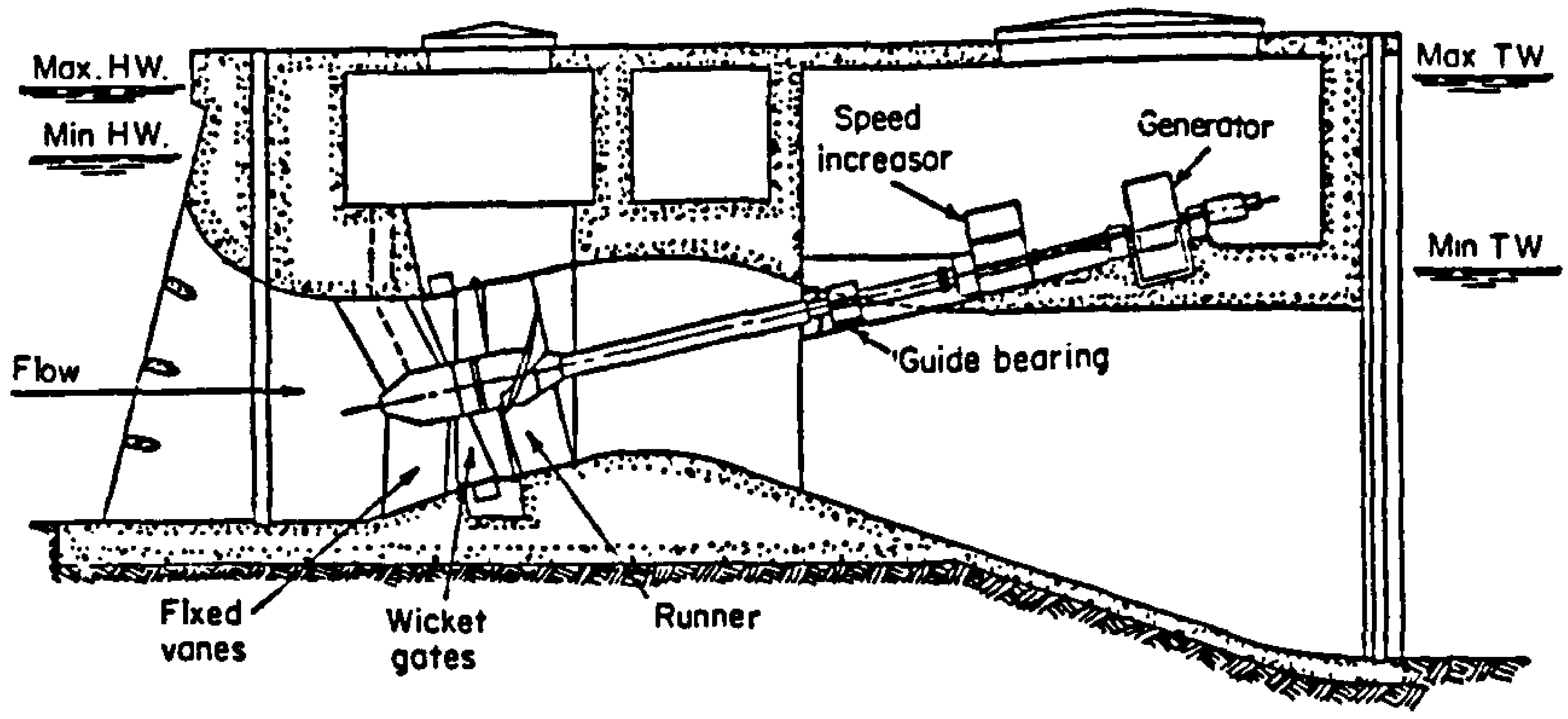
The Francis turbine is a reaction turbine (*See Fig. 2.6*). Although this turbine can be mounted vertically as well as horizontally, in practice, for mini-micro-hydropower, it is mounted horizontally. The Francis turbine is complex to manufacture due to the difficult shape of casting required (*SEI, 1991*). Both the runner and the casing require accurate casting. The runner is usually cast as a single piece. The materials used are steel, bronze and cast-iron as well as chrome-nickel stainless steel. The turbine housing consists of a split casing which permits seal replacement with ease. As in all reaction turbines the draft tube is an important part and this can be cast or fabricated from steel. The Francis turbine is popular despite the fact that it tends to be more expensive, and has a poor part-flow efficiency. The reason for its popularity is that it is the only turbine suitable for operation within a certain range of specific speeds. The Francis turbines installed in Nepal are mainly imported.

2.2.8 Propeller Turbines

The propeller turbine is also called the axial turbine (*See Fig. 2.7*). It is suitable for low heads and high flow rates, e.g. in barrages in rivers. The water enters the turbine laterally, where it is deflected by guide vanes. The rate of flow can be controlled by adjusting the guide vanes. There are two types of propeller turbines, one with fixed blades and the other with adjustable vanes or Kaplan turbines (*See Fig. 2.8*). The fixed blade turbines have less efficiency with reduced flow rates. The turbines with adjustable blades and variable pitch have higher efficiency, but are more costly thus making them very expensive for micro-hydro schemes.

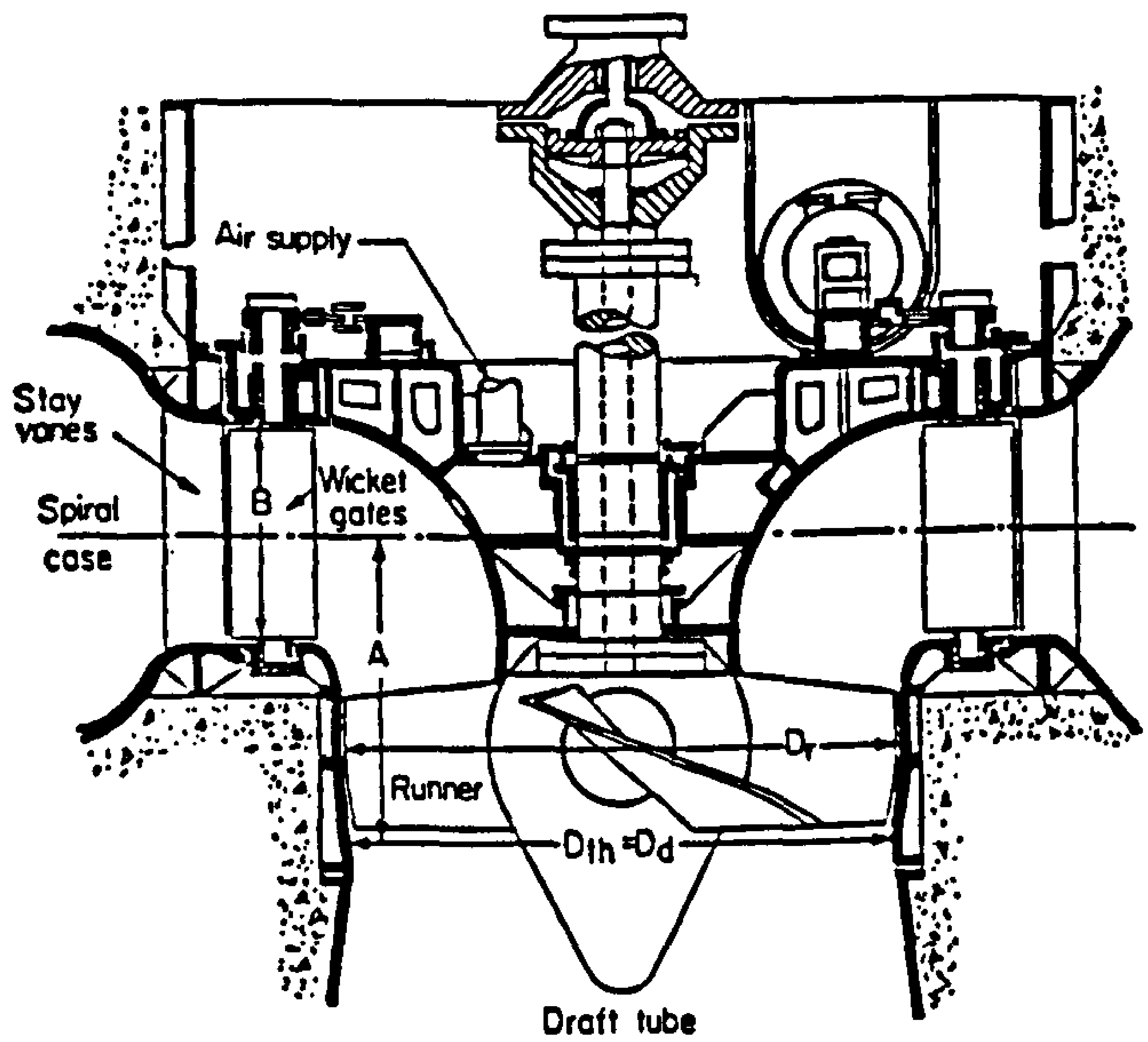
The blades of the Propeller turbine and the Kaplan turbine can be cast as well as formed from steel plates. Blade profiles need to be well-designed so as to reduce cavitation and obtain high efficiency. The casing, guide-vane assembly, and draft-tube can be fabricated from steel sheet (*Inversin, 1986*). The need for a mechanism to

Fig. 2.7: Propeller Turbine



Source: Considine, 1977

Fig. 2.8: Kaplan Turbine



Source: Baumeister and Marks, 1967

adjust the pitch of the blades makes a relatively sophisticated manufacturing unit necessary for the production of Kaplan turbines.

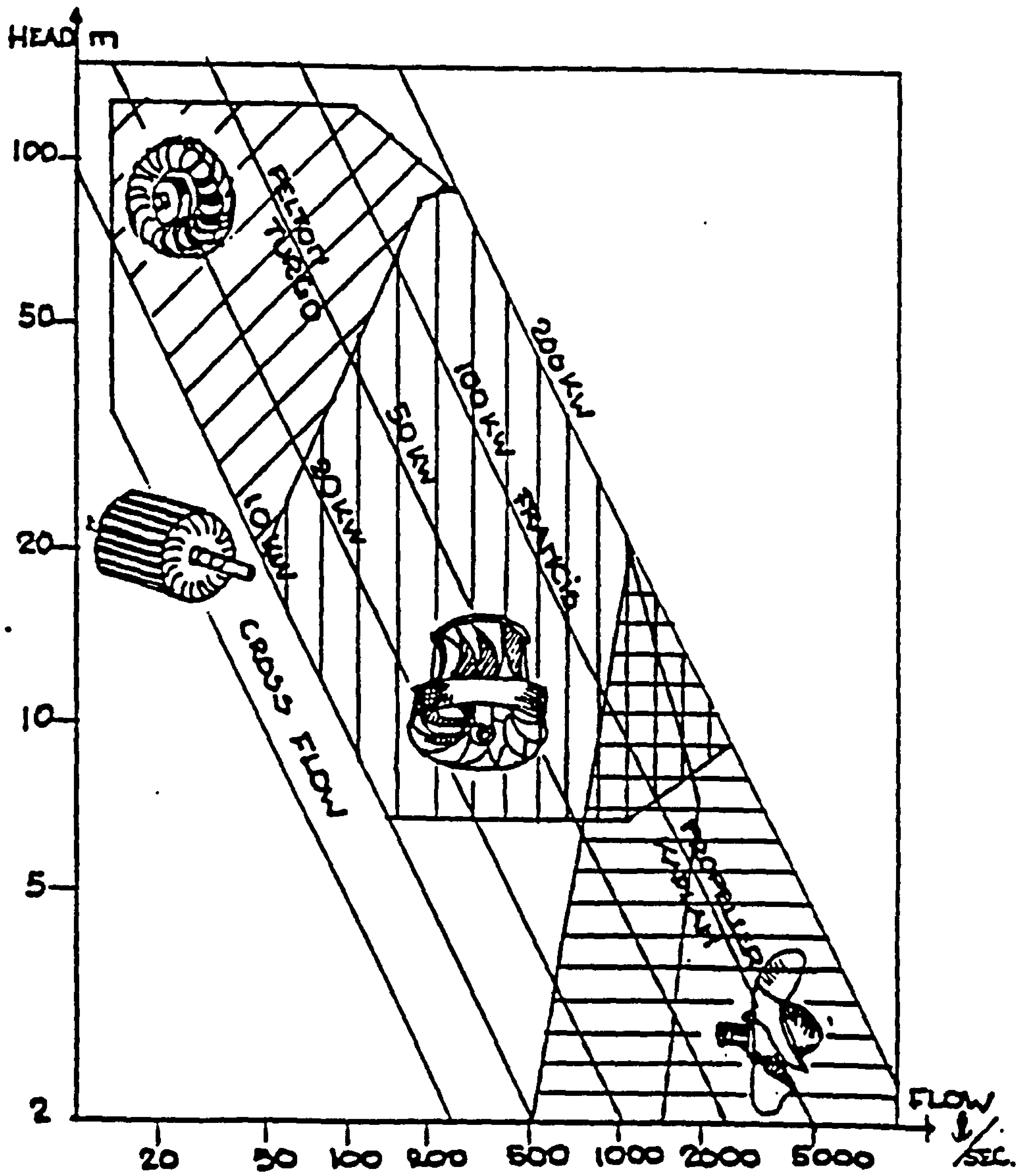
2.3 SALIENT FEATURES OF DIFFERENT MINI-MICRO-HYDRO TURBINES

2.3.1 Application, Advantages and Disadvantages of the Turbines

The technical features of the turbines described above determine their utility ranges as well as their efficiencies. The application ranges of the various types of turbines are listed in *Table 2.2* together with their advantages and disadvantages; *Fig. 2.9.* depicts head-flow ranges for different types of turbine.

Water-wheels are suited for site conditions having heads ranging between 3-6 meters, whereas the MPPU can be used for a head as low as 3m and as high as 20 meters. The Pelton-wheels can be used at medium to high-heads for schemes throughout the micro-hydropower range. The power range of the Pelton turbines manufactured in the developing countries is in the range of 1 kW to 200 kW for electricity generation. They are generally used for heads higher than 40-1000 meters (*Kristoferson and Bokalders, 1986*). The cross-flow turbines can be used for mini-micro-hydro capacities in either low-head or medium-head sites. Turgo turbines are used for the mini-hydropower schemes of medium-head range. The Francis turbine is well suited for a medium-head with a high-flow rate. The application range of propeller turbines is up to a head of 30 meters. A relatively larger flow, as compared to high head turbines, is required for propellor turbines for a given power output; these turbines are therefore comparatively larger. A propeller pump can sometimes be inverted to act as a propeller turbine.

Fig. 2.9: Application Ranges of Various Turbines



Source: Kristoferson and Bokalders, 1986

Table 2. 2: Applications, Advantages and Disadvantages of Various Turbines for Mini-Micro-Hydropower Schemes

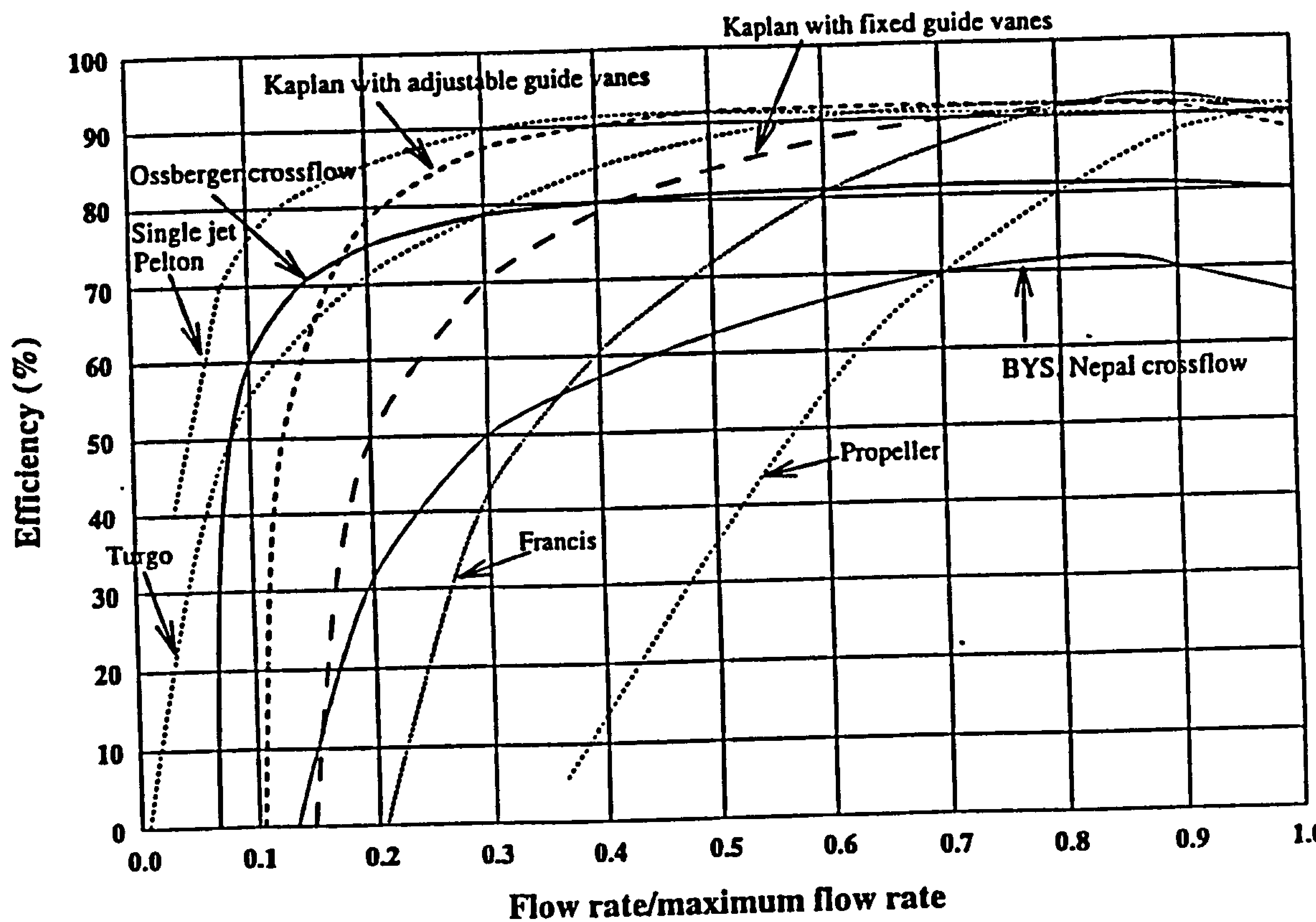
Type	*Head (m)*	*Flow (l/s)*	*Power (kW)*	*Efficiency (%)*	*Advantages*	*Disadvantages*
Pelton	20-1400	20-1500	50-5000	>90	Erosion damages can easily be repaired, high efficiency even at low flow	Casting is required
Cross-flow	3-200	100-7000	7-100	>75	High efficiency even at low flow, designs are easily available and is simple to manufacture casting is not necessary, favourable especially for hills	Low peak efficiency The runner is structurally weak
Propeller	1-30	300-70000	100-50000	>90	Easier to manufacture	Cavitation problems
Water-wheel	3-6	>30	0.3-1.5	20	Simple to manufacture, Cheap	Low efficiency
MPPU	3-20	60	1.5-12	50	constructed in modular structure, assembled at the installation site, Cheap	Low efficiency

Source: Fraenkel, 1991; Green 1994; Blankenberg and Hulscher 1990, Shakya and Shakya, 1997

2.3.2 Efficiency and Performance

Efficiency is the key factor by which to judge the performance of a technology. Efficiency indicates the quantity of final or useful energy obtained from a given energy input and is expressed in terms of the input-output ratio of gross energy consumed to net energy delivered. In recent years efficiency is becoming an increasingly important technology choice criterion, specially with respect to demand-side end-use technologies. All turbines have a characteristic power-speed and efficiency-speed. *Fig. 2.10* presents the efficiency curves of some of the turbines described above. The efficiency of the technology can vary due to load level. In general the technology

Fig. 2.10: Efficiency Curves for Selected Types of Turbines



Source: Meier, 1985

performs at its optimum level of efficiency when operated at its specified nominal capacity.

The efficiency of the water wheels is as low as 20 percent and the power output may range from a few hundred watts to 3 kW. With the same head and the same water flow, the MPPU can grind 4-8 times more than traditional water wheels.

The advantage of the Pelton system lies in its peak efficiency, higher than the cross-flow turbine, as well as in its reliability due to reduced operational vibration *(Blankenberg and Hulscher, 1990)*. Although runner efficiencies of 90 percent can be achieved with skilled casting and a well-profiled bucket pattern, efficiencies of up to 80 percent, suitable for small hydro schemes, are possible with basic design (*Waltham, 1992*).

The cross-flow turbine has lower peak efficiencies than other turbines but a valuable feature of the cross-flow turbine is its relatively flat efficiency curve, at about 83 percent. Often, this is a more important criterion than the higher efficiency point of other turbines: it means that at a reduced water flow efficiency is not much affected. The same is true of the dependency of speed variations: this means that in an agro-processing installation, standard pulley diameters can be used. In such simple units there is no governing of the speed.

The Turgo turbines have a specific speed between that of Pelton and Francis turbines. The efficiency is lower than that of the Francis turbine but part-load efficiency is higher, thus making them suitable for a wider range of flow rates. An additional advantage is that the efficiency of the Francis turbine is very sensitive to the available flow-rate; a flow rate 20 percent lower than maximum flow will cease to produce effective power. Turgo turbines have lower peak efficiency than the Francis turbine but a higher part-load efficiency, thus making them suitable for a wide range of low flow rates. An additional advantage is that the Turgo turbine does not suffer from cavitation.

Achieving higher efficiency of the products is an area to which the turbine manufacturers in Nepal should give attention. In recent years there has been a progressive introduction of various alternative energy sources into the rural areas. The efficiencies, capacity ranges and end-use activities of selected sources of decentralised energy are tabulated in *Table 2.3.*

Table 2. 3: Typical Efficiencies and Capacity Ranges of Decentralised Energy Technologies

Energy Source	*Conversion Technology*	*Typical Efficiency*	*Capacity Range*	*End-Use Activity*
Biomass	Combustion Improved Stove Furnace	 30 20-75	 5-20 kW 500 kW-30 MW	cooking drying of agro - products, brick-firing, baking etc.,
Solar	Solar Dryer PV	50-60 10	up to 1500 MJ/hr 20 W - 40 kW (off-grid) 1-80 kW (hybrid for mini utility)	drying of agro-products, lighting, water-pumping, refrigeration
Wind-power	Windmill Wind Generator	 30-35	50 W- 2 kW (off-grid)1-150 kW(hybrid for mini utility)	water-pumping, milling, etc., lighting, water-pumping, battery charging
Hydro-power	Micro-hydro Turbine	80-90	3-500 kW	lighting, water-pumping, milling, grinding, etc.

Source: Leslie, 1985; Thielhiem, 1982; Sodha, 1987; Hurst & Bernett, 1990, Kristoferson and Bokalders, 1986

MMHP comes out very well from these comparisons. It is evident that, in comparison with other energy sources, MMHP can be used over a wider capacity range and with higher efficiency.

2.4 ACCESSORIES FOR MMHP APPLICATIONS

2.4.1 Governors

The governor is a mechanism for keeping the speed of the turbine constant when the load varies. There are two types of governors; the flow control and the load control.

The flow control comes in many forms for adjusting the flow of the water in order to adapt to variations of the load on the system; this however requires a complicated mechanism, which may cost nearly as much as the turbine. For micro-units the adjustments can be made by hand operation of the nozzle.

In recent years cheaper governors have come into use for smaller turbines. These have been developed for controlling the load on the turbine rather than the water flow.

2.4.1.1 Mechanical Governors

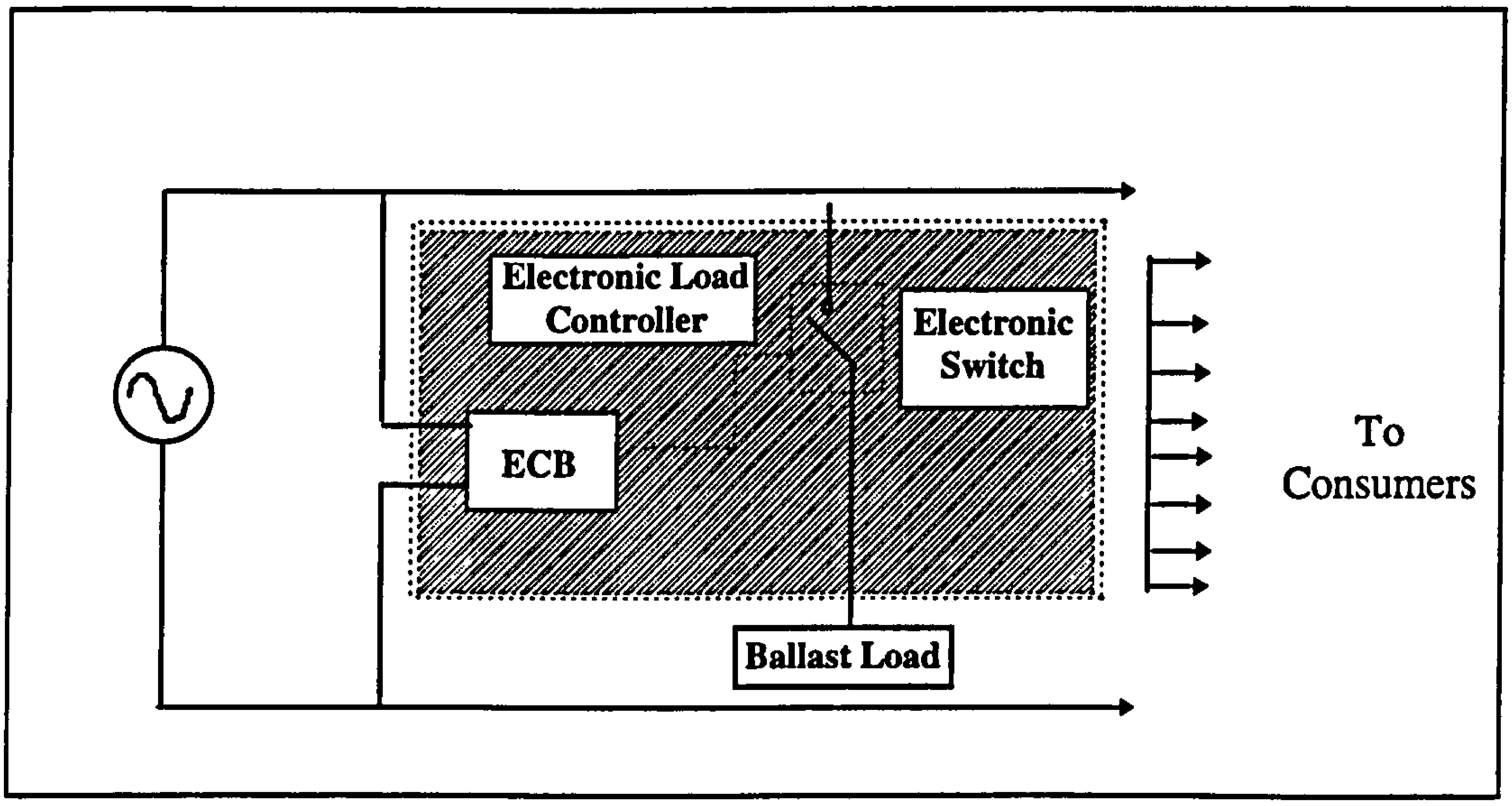
For several years mechanical governors were widely used to adjust the turbine power to match the load imposed. Mechanical governors require regular maintenance and are expensive, with the cost rising even above the cost of the turbine and the generator (*Smith and Harvey, 1994*). Besides the expense, response time of these governors is slow. Thus the use of mechanical governors for micro-hydro schemes in developing countries is highly discouraged. This has forced micro-hydro designers to look for alternatives.

2.4.1.2 Electronic Load Controllers

With the growing interest in 'stand - alone' systems and use of electricity for a large range of applications, the assurance of a reliable control system is necessary. This problem, to an extent, has been solved with the use of automatic load control systems. With automatic control systems such as the electronic system used in synchronous generators, the generated frequency is controlled by maintaining a near constant load on the turbine, (*See Chart 2.3)*. The electronic load controller compensates for variations in the main load by varying the amount of power dissipated in the resistive ballast load (*Henderson and MacPherson, 1988; ADB/N and ITDG, 1989*).

These electronic load controllers (ELCs) switch on or off a ballast load. The ballast helps in keeping the load on the generator constant. This is achieved by adjusting the resistance in the ballast load either by varying the number of active resistive components or by phase control using a single resistive load. Most developing countries import this component. Until recently, Nepal too imported the main electronic board (*black-box of the ELC*) and assembled the connection unit; but manufacture of the ELC[3] as well has now started in Nepal.

Chart 2. 3: Schematic Operation Diagram of an Electronic Load Controller



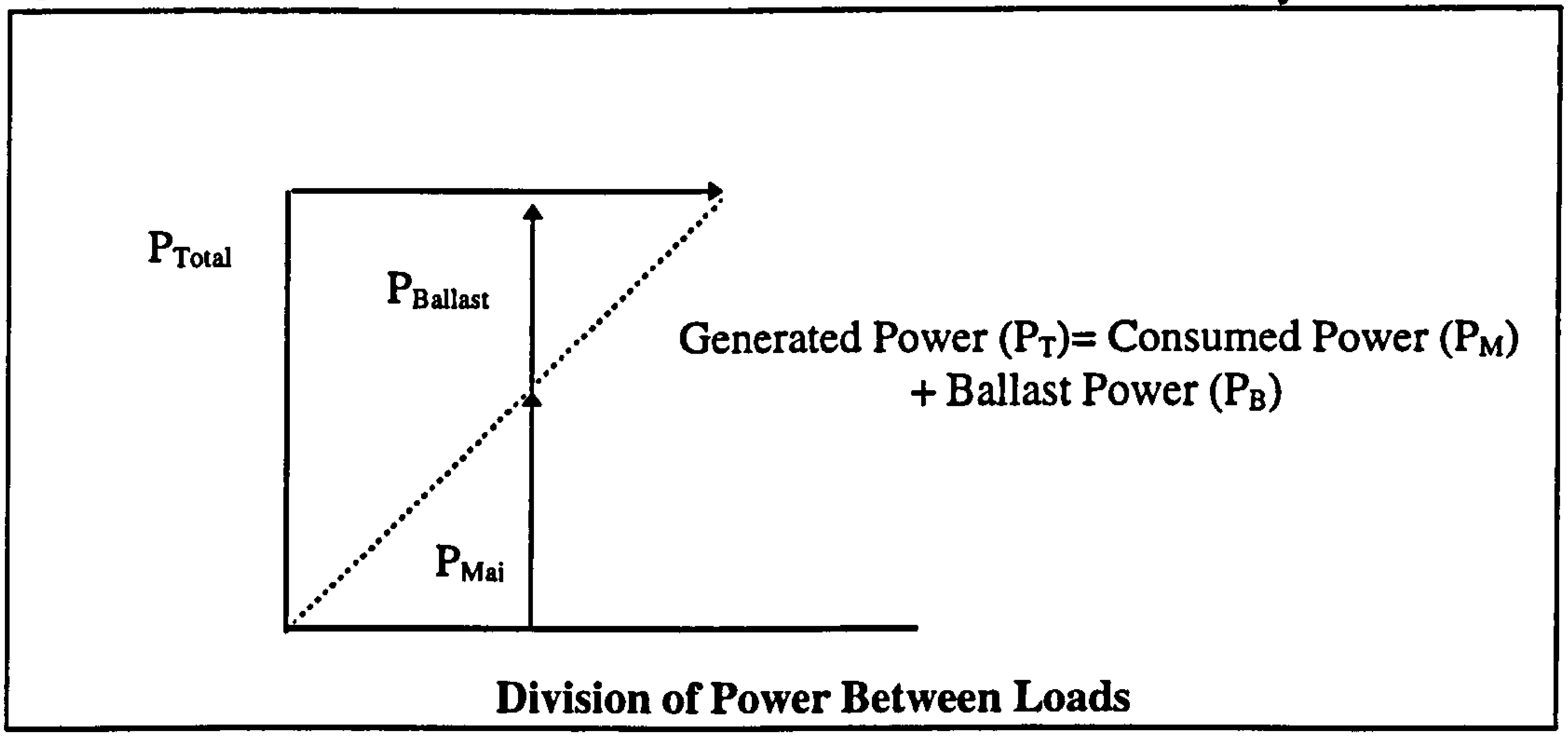
To keep the speed of a water-turbine driven generator constant, generated power and consumed power have to be matched. Turbine speed changes as electric appliances are switched ON and OFF; the same happens when the water flow entering the turbine varies. The Electronic Load Controller keeps generated frequency constant by diverting any excess power to the ballast load (*ADB/N, ITDG/UK, 1989*). ***(See Chart.2.4)***

The Electronic Load Control (ELC) senses the generated frequency. When the generated frequency falls below the set value of 50 Hz, the voltage falls and hence the

3 For details on ELC technology and the transfer of this technology to Nepal see Shakya, I., (1997): **"Promotion of Electronic Load Controllers in Nepal",**

controller will reduce the power dissipated in the ballast load. This reduction in resistive loading causes the turbine to speed up and thereby increases the generated frequency. On the other hand when the generated frequency rises above the rated value voltage rises, the system is connected to the additional load, the ballast load. This reduces the speed of the turbine and thereby the frequency. In both cases the purpose is to maintain consistency of the frequency generated by the turbine (*See Chart 2.4*).

Chart 2. 4: Power Distribution in an Electronic Load Controller System



Note: P_T - P_{Total}; P_M - P_{Main}; P_B - $P_{Ballast}$

With the addition of load controllers flow through the turbine is set at a constant level and all the water is used for power generation. Maximum use can be made of the energy generated in a load controller system as the "ballast load" can be used to heat water or for space heating. Eminent experts such as A. Smith[4] and A. Harvey[5] have strongly advocated the use of ELC for remote communities in the developing countries. Their experience shows that if properly designed and installed ELC is more reliable than mechanical governors and is considerably cheaper.

4 Consultant for micro-hydro Centre in the department of electrical engineering at the Nottingham Trent University

5 Micro-hydro Project Manager at ITDG

The most important advantages of electronic load control are better quality of electricity, possibility of running the hydro plant without operators, ease of transportation, reliability and less maintenance required, relative simplicity and hence reduced cost of the turbine unit. ELCs are also easy to install, give good response to load change and minimise surge in the penstock. But they are suitable only for run-off-the-river schemes, below 50 kW; furthermore, repair is difficult and requires electronic manufacturing capabilities. With an increase in 'electricity only' schemes the use of ELCs has increased. Attention has to be given to ease of use and reliability, since in remote villages, electrical knowledge is limited and the controllers are often used in quite arduous environments.

2.4.2 Generators

A generator can be connected to a turbine to produce electricity. This is usually alternating current (AC) suitable for transmission, and generators producing AC current are called alternators. Most hydro power stations have synchronous generators which can operate either alone or feeding into an electrical network of generators.

An asynchronous generator also called an induction generator. Such generators are generally cheap, and are principally used in grid-connected schemes. The speed of the induction generator is influenced by the frequency of the network into which it is feeding and is difficult to control. Such generators used to be considered inappropriate for use at isolated sites. However, the recent development of a governor to control small induction generators with a varying load has made it possible to use such generators for low-capacity rural electrification projects (*Smith, 1990*); their use in these situations is still however, in a state of development. Their application is restricted as they can be used only up to 40 kW, and in most cases the use of electronic load governors is required. However, within their limitations, induction generators turn out, in comparison with synchronous generators, to be less expensive, to have greater reliability, to be virtually maintenance free, more robust and more resilient to prolonged over-speed.

With micro turbine direct-current (DC) generators are sometimes used for low outputs. These can be standard car-type generators to provide electricity for lights in the vicinity of the turbine. They are less expensive but prone to brush and commuter wear problems, as well as being less efficient.

A large number of induction generators have been installed in micro hydro schemes over the last few years. They are generally installed in sites where the turbine is used for agro-processing during the day and to provide light in the evening. The main disadvantage of these installations is that large changes in electrical load cannot be allowed because there is no automatic voltage control. In order to reduce load variations, all the users are connected by means of single contactor mounted near the generator; no switches are installed in the houses. Despite this measure the load does change as the villagers remove the bulbs from the socket when they go to bed. In order to overcome this problem the voltage is set below the rated voltage of the loads and the flow of the water into the turbines is manually reduced if the lights are observed to be too bright (*Smith et. Al, 1990*). The main disadvantage is that expensive items such as household appliances are rarely put to use for fear of damage. Furthermore, the system is neither operated nor used efficiently.

Table 2.4 lists some of the characteristics of induction generators.

Table 2. 4: Characteristics of Induction Generators

Advantages of Induction Generators
Less expensive than the synchronous generators
Is much more reliable that the other generators
More Robust
Is cost effective for loads upto 40 kW
More resilient to prolonged overspeed

Source: Green, 1994

2.4.3 Drive Mechanisms

Drive mechanisms transmit power from the turbine shaft to the generator shaft. They also have the function of changing the rotational speed from one shaft to the other when the turbine speed is different from the required synchronous speed of the generator. This helps in eliminating the use of very low speed generators which tend to be large and expensive as well as not available in the range suited to micro and mini hydropower. Low capacity impulse turbines are often fitted with mechanisms to induce increased speed to a generator.

Although there are several types of drive systems, most of the small-scale hydro plants use a flat-belt drive system, V-belt or gear box. All of these are imported from India. *Table 2.5* lists the various features of the drive mechanisms used in Nepal.

Table 2. 5: Comparison of Various Types of Drive Mechanisms

Drive Mechanism	*Efficiency*	*Advantages*	*Disadvantages*
V-belt	85 - 95%	Widely Available Tolerates misalignment Most common up-to 100 kW	Less powers require multiple belts Less tension than with flat belts Lower efficiencies than other drive mechanisms
Flat Belt	95 - 97%	Low cost easy to produce Readily available Less rubber dust than V-belt	Operates under high-tension High Loads upon bearings Requires careful alignment Less available than V-belts
Gear box		High power transmission capacities	Difficult to manufacture High Cost Alignment problems Requires lubrication

Source: Nakarmi, BYS; Nakarmi, KMI

2.5 COMPONENTS OF MMHP INSTALLATION

Broadly speaking MMHP installations have two components: civil engineering work and electro-mechanical works. The electro-mechanical elements have already been described above. The civil works consist of the diversion structure, the water conductor system, the penstock pipe and the power house. A typical installation scheme with its various parts is presented in *Fig 2.11.* These parts are discussed briefly below.

2.5.1 Diversion Structure

The diversion structure is generally a trench weir[6], or any obstruction constructed at the head of the stream such that the required amount of water is diverted for power generation in a controlled manner. The water diverted into the channel must be regulated during high and low river flows. Depending upon whether the weir is temporary or permanent, the structures are made of metal cages fabricated from galvanised steel wire and filled with rocks or are built of sound rocks and concrete[7].

2.5.2 Intake Structure

This structure is designed to admit water into the power channel and is located beside the diversion structure at the entrance to the power channel. A suitable regulatory mechanism is usually provided at the intake by means of which the flow of water into the power channel can be controlled or completely shut off. It is important to ensure that the intake is designed to avoid silt deposition around it: avoidance of silting prevents blockage of the flow which would lead to diversion of the stream as well as inducing erosion and wear of the penstock, valves, sluice-gates and turbine runners.

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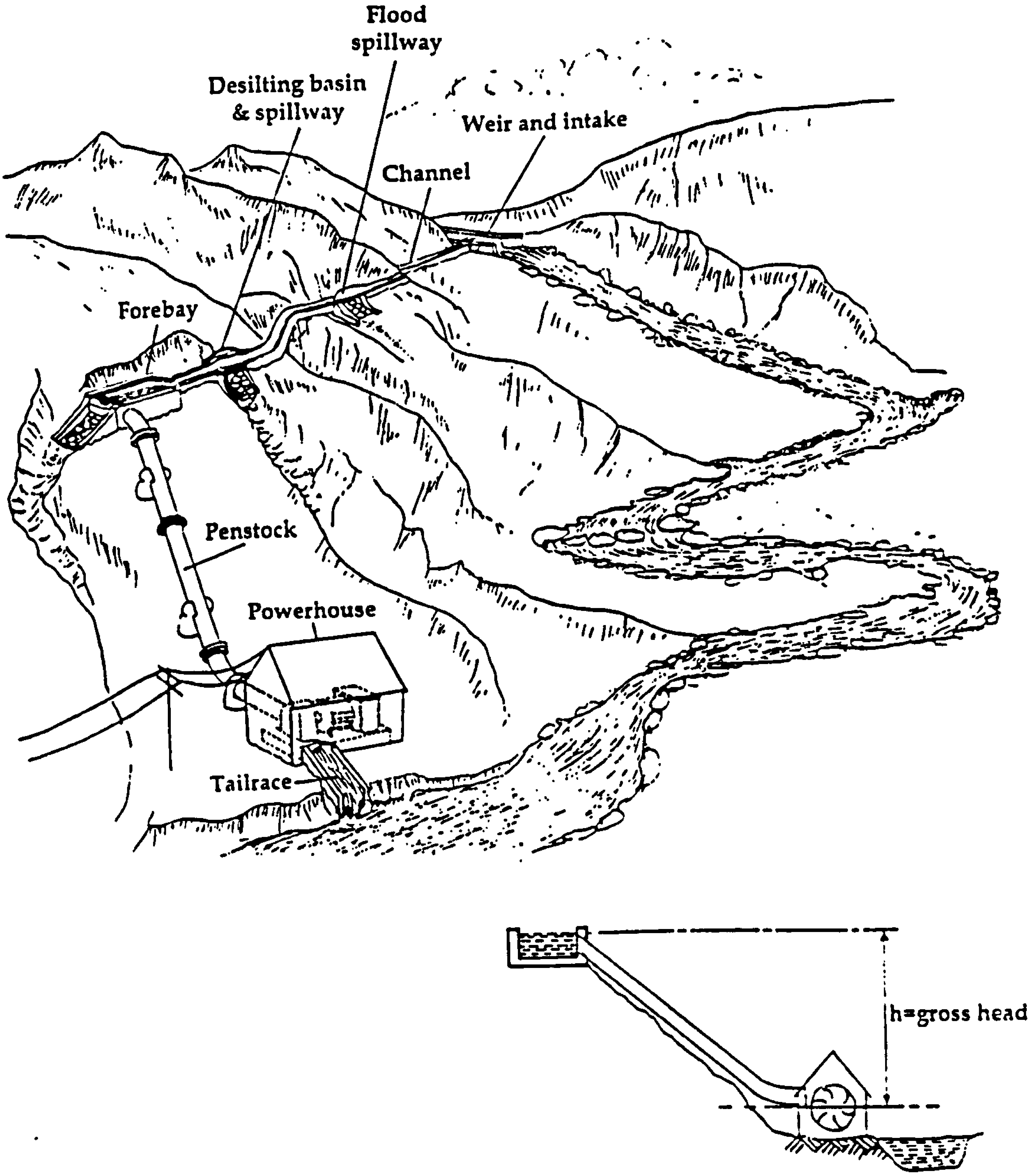
6 consisting of a trapezoidal trough located below the bed of the river. Trash racks are put on the river bed to stop the boulders falling into the trench.

7 Sound rock - free from fissures or cracks and impervious to the action of water. For details concerning various criteria for the construction of weir see books on Civil Construction

Fig. 2.11: Components of Mini-Micro Hydro Installation Schemes



Source: ICIMOD, 1997

2.5.3 Flow Channel

The flow channel is designed to carry water from the head-works to the forebay or reservoir situated above the powerhouse. At a number of locations along the course of the channel, strainers are installed to catch floating debris; also at appropriate distances the channel is provided with outlets which can be useful for emptying a particular reach of the channel during maintenance.

2.5.4 Spillways

The spillway is a flow regulator designed to permit controlled overflow at certain points along the channel. It is used to divert the water when the water is not in use. The spillway can also be combined with control gates to provide a means of emptying the channel. The spill-flow must be led back to the river in a controlled way so that it does not damage the foundation of the channel.

2.5.5 Forebay Reservoir

The forebay is the final settling area before the water is led into the penstock. The reservoir capacity is designed to provide for any sudden increase in turbine demand and has a spillway to reject excess water in the event of sudden decrease in turbine demand. The primary purpose of a forebay or reservoir is to provide the required amount of water to run the machinery for a given time even when the water supply in the channel is cut-off for whatever reason. This is known as the balancing capacity. Usually there is a valve to control the flow of water at the entrance to the penstock. The orifice at the entrance to the penstock is guarded by a mesh or strainer.

2.5.6 Penstock

The penstock is the pipe which conveys water under pressure to the turbine. Penstock pipes are usually made from rolled steel, welded longitudinally; polythelene pipes are sometimes used. The selection of penstock diameters involves a compromise between higher costs for larger diameters, and higher friction losses for smaller diameters. As the penstock often constitutes a major expense in the total equipment cost, care has to be taken in its design to minimise the friction loss. *Table 2.6* gives a comparison of the penstock materials most commonly employed in developing countries. Wooden staves are used only in the *'Pani-Ghattas'* while the use of polythene has recently been introduced for mountainous/remote areas of the country. In most cases the penstock pipes are made of mild-steel.

Table 2. 6: Comparison of Penstock Materials

Material	*Advantage*	*Disadvantage*
Mild-steel	Durable Long life expectancy	Very Heavy Expensive, Very difficult to repair Brittle surface Smoothness reduces with time Difficult to make bends
Concrete	Durable Cheap in some places Can be made locally Easily repaired	Heavy to transport Poor hydraulic performance Difficult to make bends
High Density Polythene	Light weight Rapid installation Smooth finish Easily repaired Good impact resistance Easily bent Corrosion resistant	Relatively high Cost Requires specialised joining techniques
Wood stave	Smooth surface finish Cheap in some places Can be built at site	Short life depending upon material used

Source: ITDG, 1987

2.5.7 Tailrace

The tailrace is a channel through which the water, after passing through the turbine, flows back into the river. This channel is similar in construction to the headrace. Site permitting, the water in the tailrace can be used for irrigation purposes as well. In the case of Nepal there are plants which are being operated in the downstream of another's tailrace using that water to run the turbine.

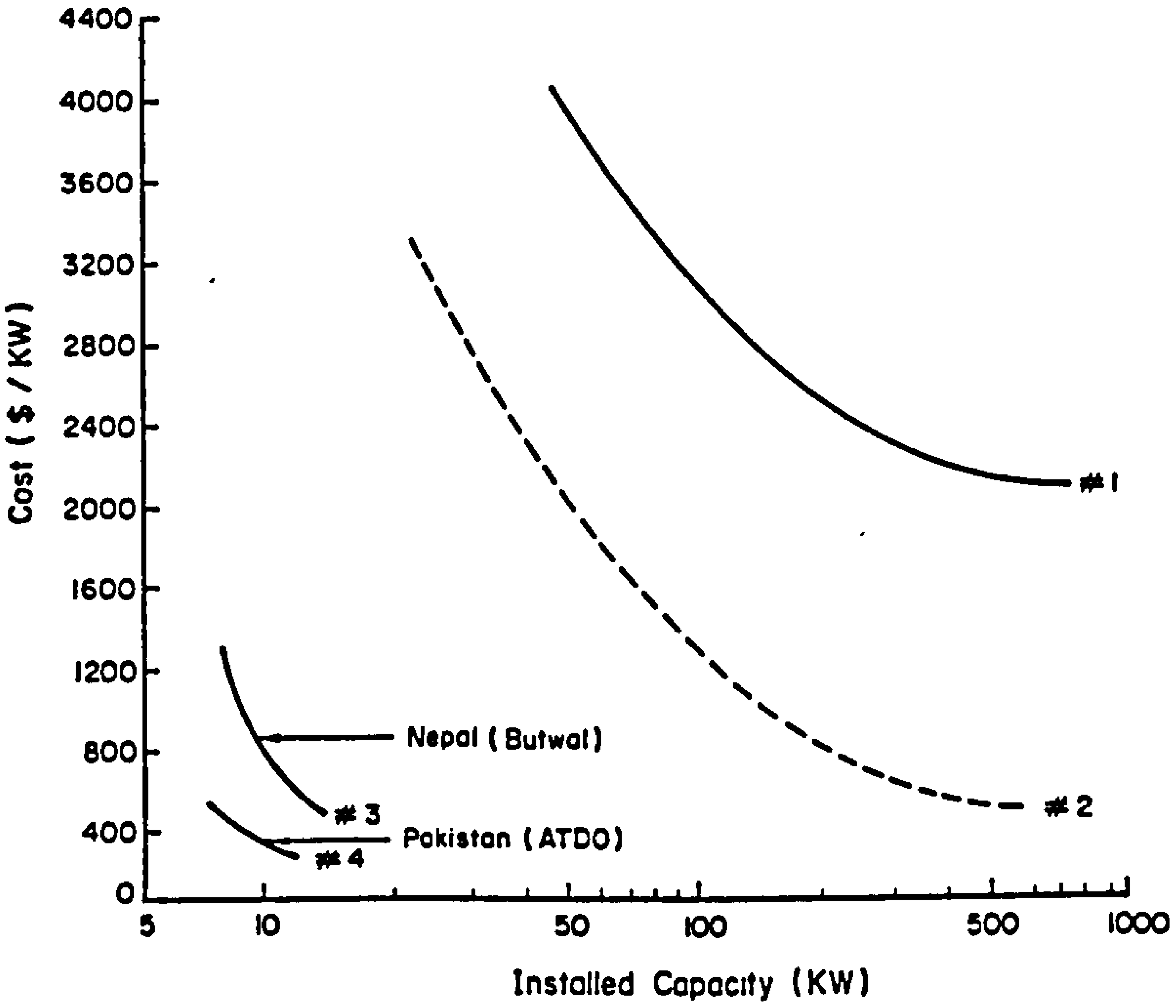
2.6 PLANT COST, END-USES AND PLANT CAPACITY

2.6.1 Plant Cost

In theory, the costs per kW of a hydro power installation should decrease in proportion to the installed capacity, due to economies of scale. However, in practice this theory does not always apply and large cost variations are observed. For instance, high heads and small flows may give the same power as low heads and large flows. In the latter case the turbine will have to be larger and hence generally more expensive. Furthermore, the costs can vary greatly depending on local site conditions. If the conventional technology for the big turbines were to be scaled down to mini-micro range, the unit costs would generally be unacceptably high. However, the new mini-micro-hydro technology gives a reduction in cost (*See Fig.2.12*). *Table 2.7* presents the typical costs of different types of turbines.

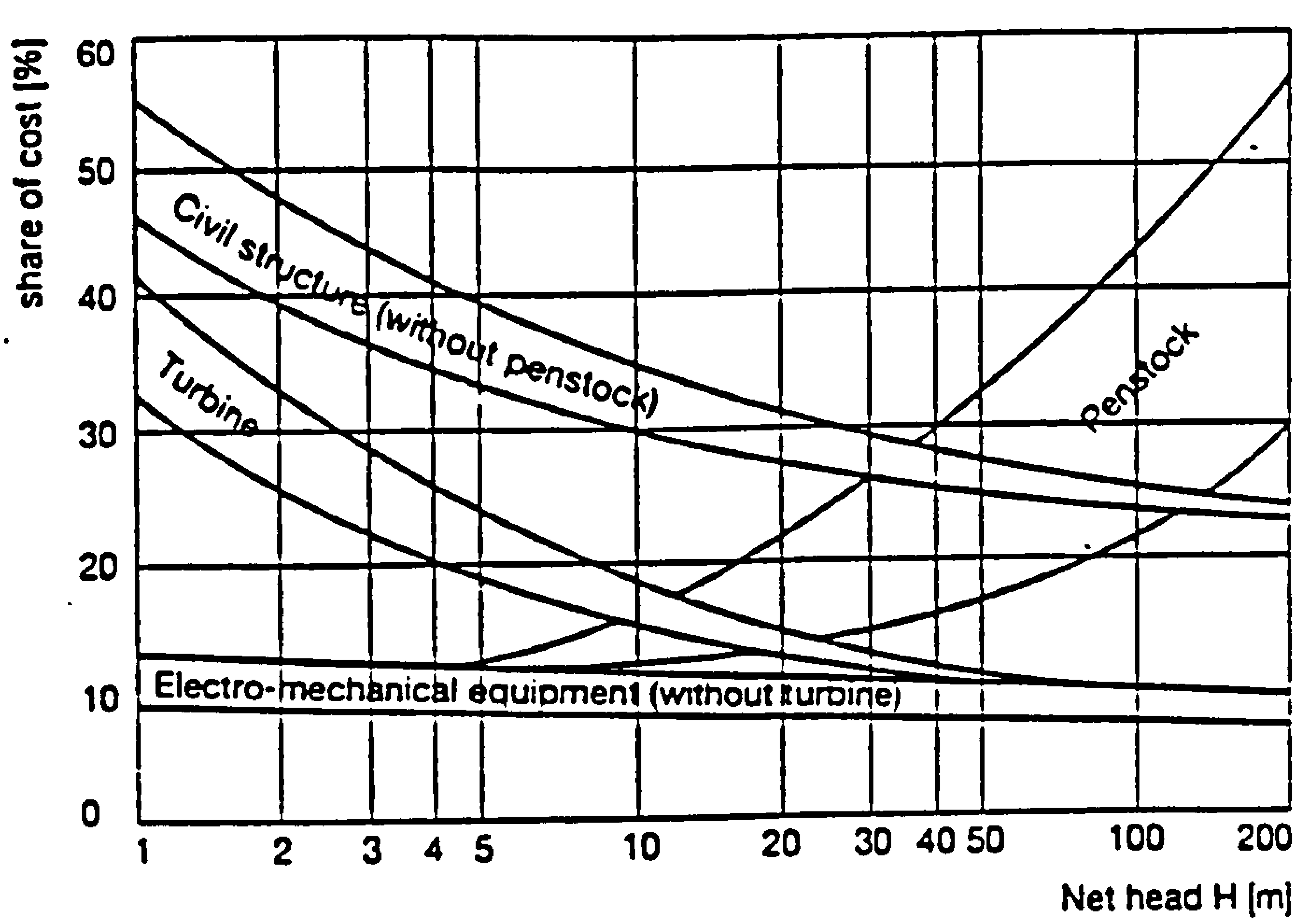
Fig. 2.13 gives a picture of costs of various components as a percentage of the total project cost. The cost of the components per installed kW is presented with reference to head height. In case of high-head systems, 50 percent of the equipment costs may comprise of the cost of the penstock. In case of low-head systems the cost of the turbine and civil structures may well be higher. This implies that the equipment costs can vary quite a lot within the same power range. For instance, for the same type of turbine, produced and installed by the same manufacturer in one country in the same year, the equipment price per installed kW can vary by a factor of 4 (*Blankenberg and Hulscher. 1990*). The difference is mainly due to the difference in head and difference

Fig. 2.12: Typical Costs of MMHP Schemes as a Function of Power Output



Source: Kristoferson and Bokalders, 1986

Fig. 2.13: Cost of Various Components of MMHP as a Function of Head



Source: Arter. 1992

in capacity. Obviously lower equipment prices per unit capacity relate to high heads and higher output capacity.

Table 2. 7: Typical Costs of Mini-Micro-Hydro Turbines (US $/kW)

Capacity (kW)	*2*	*5*	*10*	*20*	*50*	*100*	*150*
Cross-flow	500-1000	400-1200	200-1000	150-700	100-600	300-500	300-530
Francis	2000-3000	1600-2000	1500-2000	1000-1500	500-1400	400-1000	400-800
Single-jet Pelton	1000-2000	600-1600	500-1500	400-1000	400-1000	400-800	400-670
Multi-jet Pelton	500-1500	600-1200	400-1000	300-750	300-600	300-600	300-530
Turgo	1000-2000	1000-1600	800-1400	600-1000	700-1000	550-800	530-670
Propeller	2000-3000	1600-2000	1500-2000	1000-1500	500-1400	400-1000	40-800

Source: Fraenkel, 1991

Table 2. 8: Typical Project Costs for Low-Head and High-Head Schemes

Type	*Cost %*
Low Head	
Weir and Intake	35
Powerhouse	15
Turbine, alternator & control system	35
200 m Transmission line	5
Delivery and installation	5
Sundries	5
High -Head	
Intake, de silting and screening	12
Penstock and installation	32
Powerhouse	9
Turbine, alternator, controls	24
200m Transmission line	5
Delivery and installation	5
Sundries	9

Source: SEI, 1991

Typical project costs for low-head and high -head schemes are listed in *Table 2.8.* The major cost components of a mini-micro-hydro scheme are civil works construction on the one hand and mechanical and electrical equipment on the other. Both can vary between 30 percent to 70 percent of the total costs, mainly depending on the gradient of the stream to be used, the soil conditions, and the way the works are constructed (*Blankenberg and Hulscher, 1990*).

2.6.2 End-uses of Mini-Micro-Hydro Plants

Turbines are being put to various end-uses. These tend to differ with the ownership of the power plant. It has been observed from field studies as well as from secondary data that private plants usually concentrate on agro-processing, whilst public plants focus upon electrification of their areas, whereas community plants show varied uses including irrigation of farmland. Agro-processing is a proven and popular end use. Lighting is an upcoming use and cooking has been promoted in recent years. Other existing end-uses include battery charging, paper making, saw-milling, alcohol distillation, bakery-working, water heating, ice-making, cardamom drying and the operation of domestic electrical and electronic appliances.

Chart 2.5 presents a model of an MMHP plant with various civil components and the mechanisms for its utilisation i.e. motive power using mechanical drive or electricity using a generator. As seen from the chart plants are sometimes designed for agro-processing alone or solely for generating electricity, or in other cases, a generator is connected to a plant in order to provide both agro-processing services and electricity. In the first and the second cases the schemes are known as 'stand-alone' systems while the third is known as an 'add-on system'.

Chart 2.6 presents the project design for using mini-micro-hydro turbines for agro-processing as well as electricity. The chart also includes the types of agro-processing activities and uses to which electricity can be put in rural areas. The common applications in case of agro-processing are the operations of grinding, rice-hulling, oil-expelling, shelling, polishing, beaten/flattened rice "*Chiura*"-making and pulp-pounding. Activities such as ice-making, drying, "*Lokta*" boiling, saw-mill operation and nitrogen-fertiliser production have been practised in limited areas. In case of electricity the common use is for lighting and entertainment. In case of Nepal, the use of electricity for cooking is currently being promoted; use is made of electricity for heating in the Himalayan tourist regions.

Chart 2. 5: System Design for Mini-Micro-Hydro Plants

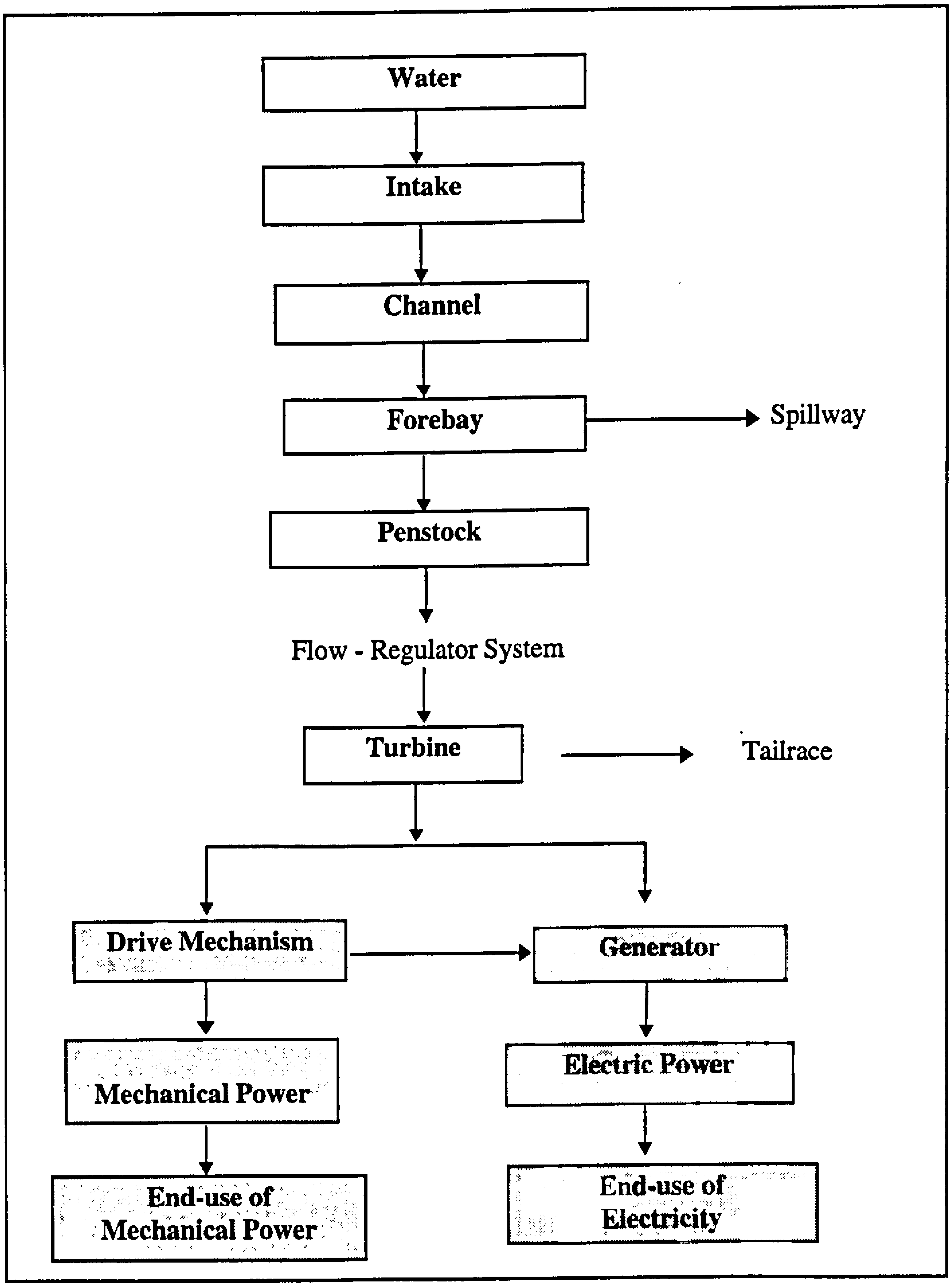
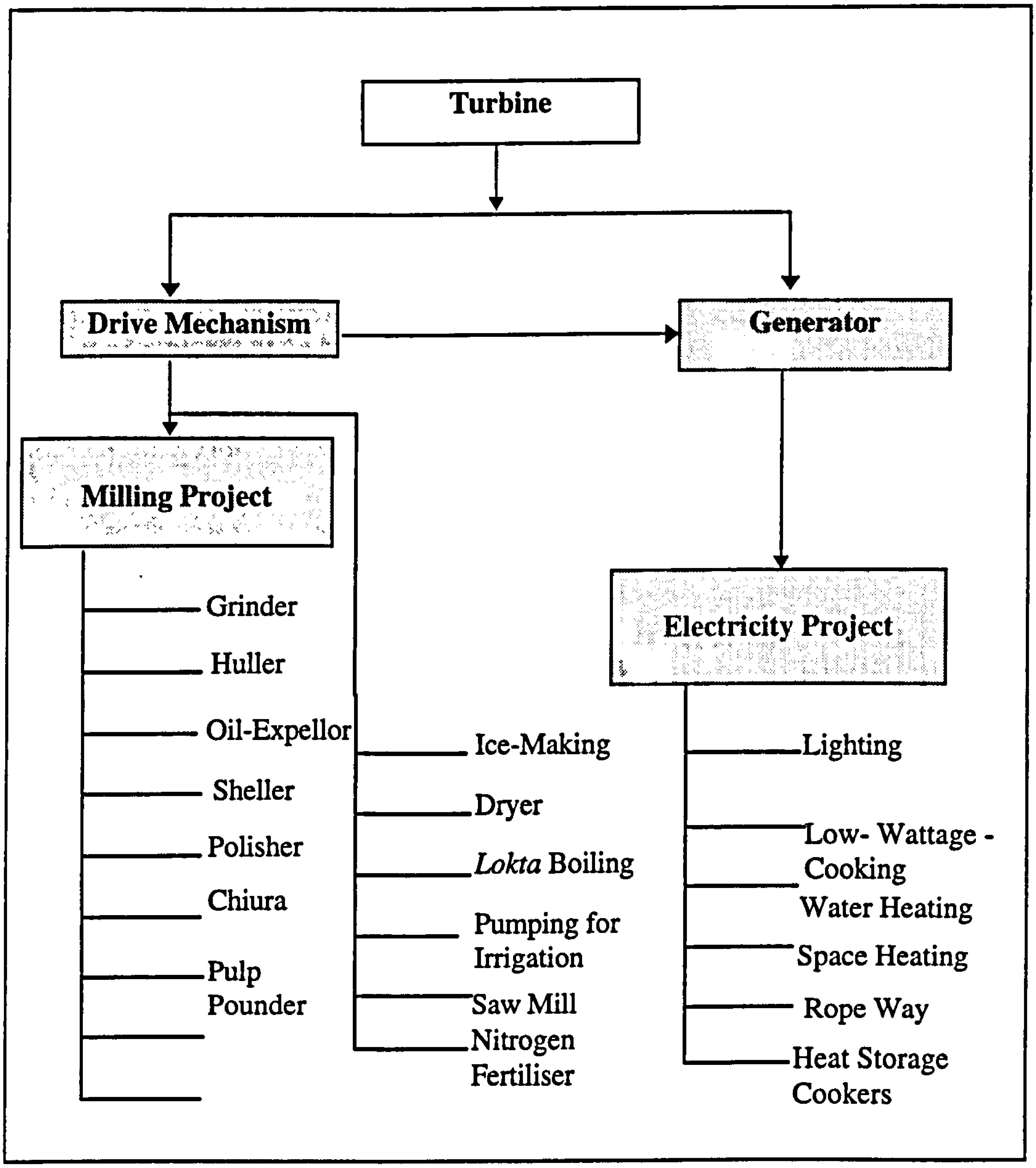


Chart 2. 6: Application of Mini-Micro-Hydro Turbines for Various End-Uses



2.6.3 Plant Capacity Utilisation

MMHP is apparently one of the most successful forms of alternative energy technology in the developing countries. However, available country-specific studies on the profitability of MMHP plants report low level capacity utilisation due to low plant load factors. This problem arises especially in the case of plants being used for electricity generation alone: a case study on India found that the actual plant load factor of MMHP hydro-electricity stations is on an average of the order of 10 to 20percent (*Dutta, 1997*); a similar study of such operations in Nepal and Pakistan reported that the plant factor of MMHP in general to be less than 30 percent (*Junejo, 1994*). Major reasons for poor plant-factor are: limited use of electricity i.e. only for 3-4 hours in the evenings for lighting; with milling plants operation is typically around 6-7 hours per day. In the case of MMHP plants powering agro-processing units, the reasons for a low plant utilisation factor include insufficient business, inadequate capabilities or skills of operators unable to connect various processing units simultaneously, or poor performance due to plants running at much less than the rated power output (*Bajracharya, Nakarmi and Singh, 1991*).

2.7 STATUS OF MINI-MICRO-HYDRO IN SELECTED COUNTRIES

The small-scale turbines are produced in several Asian countries. They are widely used for providing motive force as well as electricity for rural areas. The equipment is locally fabricated, and is cheaper than imported equipment (*Green, 1994*). In most cases the aim is to provide energy for the deprived population at the cheapest possible price. A trade-off has often had to be made between the price and the efficiency of the equipment on account of the manufacturing and operating conditions in developing countries (*See Table 2.9*).

The operations required for the production of mini-micro-hydro turbines include machining, welding, sheet metal fabrication, heat treatment, forging, casting, carpentry and the assembling of electrical and electronic parts. The skills to undertake these activities/equipment are available in most developing countries (*Meier, 1985*). The manufacture of more efficient MMHP systems is however limited by the lack of adequate test equipment, poor quality of raw material, lack of adequate machinery, lack of know-how and the lack of quality control measures (*Green, 1994*).

Table 2. 9: Conditions Affecting Local Manufacturers of Mini-Micro-Hydro Equipment in Industrialised and Developing Countries

Industrialised Countries	*Developing Countries*
Low Price appreciated but not essential	Low Price essential
Efficiency is important	Efficiency has often lower priority
Connected to the grid	Isolated sites more common
Wide availability of materials	Design restricted by non-availability of materials
Wide range of machinery available	Few machinery tools
Maintenance and repair easily possible	Maintenance and repair-free design as far as possible
Easy access to site	Difficult access to site, often restricting equipment size and weight

Source: Metzler, 1979

Vietnam, Thailand, India, China and Nepal have been producing equipment on a regular on-going basis. Lao PDR manufacturers have attempted production, but this has not been firmly established *(Green, 1994). Table 2.10* presents the manufacturing capabilities of selected countries in Asia.

Table 2. 10: Comparison of Local Manufacturing Capabilities of Selected Countries

Countries	*Turbines*		*Penstock*	*Electrical Components*	*No. of Manufacturers*
	Type	*Capacity*			
Vietnam	Cross-flow Pelton Francis Kaplan	5-600 kW 20-800 kW 30 kW-2.1 MW 5-1000 kW	Yes	Yes	5, recently only 3 are manufacturing
Lao PDR	Cross-flow	5 - 40 kW	Yes	No	no formal manufacturers
Thailand	Cross- flow	5-100 kW	Yes	Yes	1
India	Francis Pelton Kaplan Cross-flow	upto 3000 kW above 1000 kW upto 3000 kW only demo units upto 100 kW	Yes	Yes	9
Pakistan	Cross-flow	5-45 kW			no established firms
Nepal	Cross-flow MPPU Pelton Peltric	upto 250 kW upto 12 kW upto 50 kW upto 5 kW	Yes	Yes	11

Source: Vietnam, Laos PDR and Thailand - Green 1994; India- TERI, 1997; Pakistan- ATDO, Pakistan,1997; Nepal. Field Survey

All the countries listed above have the capability to manufacture cross-flow turbines. The Kaplan and Francis turbines have been produced in Thailand and India whereas the Pelton has been manufactured in both these countries as well as in Nepal. The penstock pipe is manufactured in all these countries. The electric components for transmission and distribution are manufactured in all the countries except for Laos.

In Vietnam, Thailand and India, more organised manufacturing sectors than in Nepal, are producing the turbines. In Nepal ten manufacturers are working in this sector; based on information available Thailand has one manufacturer, Vietnam has three while India (*AHEC, 1997*) has nine manufacturers working in this sector. In Pakistan and Laos, turbine manufacturing is undertaken by the local metal-smith.

2.7.1 Mini-Micro-Hydro Turbine Installation in Selected Countries

There has been considerable progress in the installation of MMHP plants in a number of countries of Asia, as shown in Table 2.12, although their actual contribution to the energy requirements of the rural areas is difficult to determine[8]. Nepal has a long history of hydro-power utilisation. Hydro-power has been used to drive traditional wooden turbines which provide the energy to turn the traditional grinders which were earlier manually operated, known as "*Janto*" and used everyday for processing cereals in rural areas of the country. A station consisting of a water-turbine and grinder[9] is known as "*Pani-Ghatta.*" This technology is popular in most areas of the country due to the fact that it is simple and very familiar to the users. Its popularity is emphasised by the existence of more than 25000 such sets are still operating in remote rural villages. The "*Pani-Ghattas*" have occupied an important place in the socio-economic condition of the rural population, specially of the women,

8 The difficulty in estimation is due to the lack of information on the functional status of the turbines in these countries.

9 Grinders consist of a pair of circular stones held together at the Centre by a piece of wooden/metal arm. The cereal, which is fed from an opening on the upper stone, is ground when the upper stone is made to run over the lower stone.

through provision of a processing facility for grinding maize, millet, barley, buck-wheat and wheat (the staple food of the people). The have also created income for *"Pani-Ghatta"* owners through marketing of the products and generating employment opportunities.

MMHP plants were introduced in Nepal by the Electricity Department of the Government of Nepal. The first MMHP plant, of 500 kW capacity, was installed at Pharping in the Kathmandu Valley in 1911; another set up at Sundarijal (within the capital) in 1934, is still operational. MMHP installations were initiated between 1920 and 1930 with most of the equipment being imported. The new approach of installing micro-hydropower units in the private sector, owned by individual entrepreneurs or communities was introduced in Nepal in 1970. The main feature of this approach is indigenous development of the technology on a small scale, thus making it cheaper and simpler to install, operate and repair the plants.

While this activity continues, more attention is now being given to replacing the water wheels with new units - MPPU - which are at the same time deliver more power and require much less maintenance than the existing units. These new machines - turbines and multipurpose power units - are capable also of a wider range of operations, such as rice hulling, oil expelling, pounding and the generation of electricity. As well as the MPPU units, an indigenous combination of pelton and generator, known as peltric set, has been developed in Nepal for generating electricity alone.

Almost all the MMHP units established for electrification in Nepal before 1990 were installed as add-ons. Add-on plants dominated the MMHP utility scene for several years; but recently, stand-alone plants, mostly using the Peltric-sets are operating in several areas of the country. About 80 percent of the MMHP plants are employed for milling. *Table 2.11* presents the distribution of MMHP plants in various development regions of the country. There are more than 1000 plants in Nepal providing about 9 MW of hydro-energy to the rural population residing in scattered settlements (*See Map 2.1*).

This technology is used widely in India, China, Bhutan, Pakistan, Thailand, Laos and Vietnam. *Table 2.12* shows the general pattern of MMHP plants installed in selected countries.

Table 2. 11: Number of Mini-Micro-Hydropower Installations in Nepal (1995)

Development Regions	*Mountain*		*Hill*		*Tarai*		*Total*	
	No.	kW	No.	kW	No.	kW	No.	kW
Micro Hydro Plants								
Eastern	23	279	75	766	4	25	102	1070
Central	56	526	164	1453	11	105	231	2084
Western	14	178	358	3218	11	89	383	3485
Mid-Western	21	272	156	1247	14	94	191	1613
Far Western	14	162	26	218	0	0	40	379
Total	**128**	**1415**	**779**	**6902**	**40**	**313**	**947**	**8630**
Peltric Sets								
Eastern	23	30	81	98	0	0	104	128
Central	1	2	2	2	0	0	3	4
Western	1	5	35	81	1	3	37	89
Mid-Western	3	5	3	4	0	0	6	9
Far Western	1	2	0	0	0	0	1	2
Total	**29**	**44**	**121**	**185**	**1**	**3**	**149**	**231**
GRAND TOTAL	**157**	**1459**	**900**	**7087**	**41**	**316**	**1098**	**8862**

Source: WECS, 1995; ICIMOD, 1995

In practice, there seem to be more plant shutdowns in Nepal due to problems with the civil works than with the electro-mechanical equipment (*New Era , 1993*). Commonly, canals sustain considerable damage through landslides or heavy rains and this results in power disruptions. Sometimes, the damage may also be due to unstable soils or slopes. Usually, very cheap and traditional techniques are used in the construction of canals. Advocates of this type of construction argue that since very cheap and unemployed labour is easily available in most areas, there is no need to increase capital costs by using more expensive materials and equipment for canal construction. This argument may be valid in some cases. However, in many situations, it may be more productive to construct stronger canals especially when breakage of the canals might cause additional soil erosion, landslides or other environmental damage.

Table 2. 12: General Pattern of Mini-Micro-Hydro Plants Installed in Selected Countries

Name of Country	*Reference Year*	*No. Installed*	*Energy Generated MW*	*Remarks*	*Source of Technology*
Nepal	1995	1078	8659	96% in the private sector, 4% in the public sector	Swiss
India	1997	199	144.36	12% in private sector, 88% in public sector	NA
Bhutan	1997	19	3.40	All in public sector, technology provided from India, Japan	Japan, India
Pakistan	1993	254	19.72	35% in private sector, 65% in the public sector	NA
Thailand	1995	65	NA	Locally Produced	Replication of Chinese Technology
Lao PDR	1995	> 20	NA	Attempted to Produce Locally	Mostly imported from China, France, Nepal, Germany, Japan, Poland, Sweden, Thailand and Vietnam
Vietnam	1995	3000	NA	Locally Produced	Chines, Initially imported from China,
China	1993	45645	6003	Mainly in the private sector	NA

Source: Nepal: WECS, 1995; India, AHEC 1997, Roorkee; China, ICIMOD, 1998; Bhutan, Etho Metho Electric, 1994;

Similar failure problems were also reported of the earlier Chinese installations (*ICIMOD, 1994*), many of these were latter replaced. Some of the most commonly reported breakdowns are:

- damage to the intake / catchment system
- damage to the power channel due to rains, floods, landslides etc.
- improper alignment of the turbine shafts and foundations, resulting in frequent damage to turbine bearings as well as shafts;
- water leakage from joints, etc.
- damage to the turbine runners;
- bursting of penstock pipes;

- damage to the water regulating vane or valve;
- damage to the generator and control equipment;
- excessive voltage fluctuation which causes damage to bulbs and appliances;
- damage to the transmission lines, especially due to low quality wooden poles.

These are some of the major problems encountered in the MMHP plants. The extent of the damages with respect to number of plants facing the problems listed above and the period of down-time, in case of Nepal, will be discussed in Chapter 3. Other reasons leading to low performance include the poor quality of the equipment installed, improper installation, operation by untrained personnel, and inadequate maintenance. It has been observed that indigenous equipment requires more attention in terms of maintenance and repair, and its overall performance is not as good as that of the imported equipment. Overall, the quality, performance and life expectancy of indigenously designed and manufactured equipment is relatively lower than that imported from the industrialised countries. This is also reported to be the case with the Chinese equipment (*ICIMOD, 1994*). However, this should not be taken to imply that this situation will continue for ever, or that efforts to improve domestic products should not be undertaken. On the contrary, every effort should be made in order to catch up.

2.8 CONCLUSION

The use of water as a source of energy is not new. The development of the technology from the traditional water-wheel to the modern hydro turbine has seen significant improvements in the efficiency of the equipment. The Multi-Purpose-Power-Unit and the Peltric-sets for electricity generation have been developed in Nepal in addition to the more conventional hydro turbines.

There are several different types of turbine suitable for mini-micro-hydro scale operation in a number of developing countries. Of the available turbines, attempts have been made in the developing countries to manufacture Francis, Propeller, Turgo, Pelton and Cross-flow turbines. However, the most commonly manufactured type is the cross-flow turbine. In case of hilly territories like Nepal, site permitting, even the Pelton turbines have been locally manufactured and installed successfully. Although the imported cross-flow and Pelton turbines are more efficient the cost of such turbines is prohibitively high as indicated by sample studies undertaken in Thailand and Vietnam (*Green, 1994*). On the other hand the locally manufactured turbines, although less efficient (lower by about 10 percent in case of cross-flow), are lower in cost (as concluded in case study of Vietnam, Laos and Thailand, by Green, 1994).

Manufacture of mini-micro-hydro turbines has been undertaken in several developing countries with the objective of meeting the energy needs of the rural areas. Several factors determine the choice of turbines: the available head (difference in height between water intake and the turbine), the available flow of water and the power requirement (depending on the energy needs now and in the future). Accordingly, the turbines are divided broadly into three groups corresponding to high, medium and low heads. But the choice is also determined by the quantity of water available. Another important factor is the efficiency of the turbines. The cost of product and ease of manufacture are other determining factors in the choice of turbines.

Of the varieties of turbine available for application in mini-micro-hydro projects the cross-flow turbine is the easiest to manufacture, as it does not require any casting; the ready availability of designs is another major reason for this type being manufactured in most of the developing countries. Although the efficiency of the cross-flow turbine is less than that of the other turbines it is cheap, robust and can be manufactured locally. Compensating for its lower efficiency is the possibility of the turbine being used over a large variation in flow with very little change in efficiency. The cross-flow turbine has been described as the type most suitable to the environments and conditions of developing countries (*Kristerferson and Bokalders, 1986*). Although the Pelton has higher efficiency, its manufacture requires casting facilities and more precision work in the making of its buckets. Despite these difficulties, the pelton turbine has been indigenously developed to suit the local conditions in Nepal. Another successfully implemented technology is represented by the Multi-Purpose Power Unit (MPPU), a technology which is simple for the local people to understand as the design is similar to the traditional mill. The propeller turbine on the other hand suffers from cavitation problems and has already proved unsuitable to the hilly territories of Nepal.

All the countries whose MMHP activities have been examined in this study have relied on adapting foreign technology to the countries' own requirements. Except for Laos all the other countries have extended their production to manufacture the equipment required in the installation of the turbine and generation of electricity.

The mini-micro-hydro technology has been used primarily for agro-processing as well as for generating electricity. Country specific studies of Pakistan and Nepal show that its use has, however, been limited in terms of operating hours as well as in terms of applications. But there do exist examples of the plants being used for additional purposes, as seen in Nepal, thus indicating ways of increasing the load factor and the income of the entrepreneur. Evidence shows that there exists a large difference between the costs of using scaled-down conventional hydro-power technology and those of using locally constructed micro-hydro plants. Provided the site conditions and technical factors are within acceptable boundaries, and the units are used over a wide spectrum of end-uses, mini-micro-hydro technology can be both technically and economically acceptable for rural areas.

CHAPTER - 3

MINI-MICRO-HYDRO PLANTS IN NEPAL: SURVEY FINDINGS

3.1 INTRODUCTION

The objective of this chapter is to study the status of the mini-micro-hydro plants in the rural areas. The methodology of analysis is presented in section 3.2. The status of these plants with respect to location, year of installation, installation by manufacturers, etc. are presented in section 3.3. The functional aspects such as services rendered, operation measures practised by the entrepreneurs, prevailing plant load factor and repair/maintenance issues are discussed in section 3.4. Financial details of the sample plants are presented in section 3.5. Skill-level of the managers and operators, which affect plant performance, are highlighted in section 3.6. The major constraints encountered in running a plant are discussed in section 3.7 which is followed by conclusion of the chapter, section 3.8. This chapter is also a prelude to the next chapter on the financial and economic viability of the plants.

3.2 METHODOLOGY

Both primary as well as secondary sources of information have been used for the analysis. The data have been collected for two sets of plants which use turbines made in Nepal: those that provide a combination of end-uses for agro-processing as well as electricity and a separate set of plants providing electricity alone. The primary data has been collected from the sites through visits and interviews with people directly involved in the management, operation and financing of the MMHP plants. All the interviews were conducted personally and enumerators assisted in carrying out the survey with the help of structured questionnaires (*See Annex-3A*) as a survey instrument. The questionnaires were used for collecting the following information on the mini-micro-hydro plants:

a) installed capacity

b) cost of various components

- cost of turbine
- cost of civil works
- cost of transportation
- cost of electrical components
- cost of installation

c) annual working expenditure on

- salary
- repair and maintenance

d) source of technology

e) loan amount

f) repayment period

g) annual revenue from the project

h) impact of subsidy

i) measures undertaken for repair and maintenance of the plant

In the process of sample selection, the country was divided into three geographical regions, namely Eastern, Central and Western, each comprising several districts in which MMHP turbines were installed. Each geographical region was then categorised into a northern block and a southern block to represent the geo-climatological representation[1]. An attempt was made to survey 20 percent of the recorded plants running on cross-flow turbines. The sample selection was based on their accessibility from road-head and time required to reach them within a maximum of 2 days. For preliminary selection advice was sought from the manufacturers, ADBN and other personal working in this area. However, the sample size had to be reduced to 13.12 percent (*See Table 3.1*) coverage to compromise with available time, and cost. Table

1 *See Annex 3.B for classification of districts in geo-climatological representation*

3.1 also presents the percentage of plants selected from each district. There occurs a bias in the district-wise selection of sample plants which is, as mentioned above, dependent on the accessibility. This sample contributes about 15 percent of the energy supplied by the total number of MMHP plants installed in the country.

Table 3. 1: Composition of Sample Plants With Respect to National Distribution

District	National		Survey		Percentage	
	No. of Plants	*Capacity kW*	*No. of Plants*	*Capacity kW*	*No. of Plants*	*Capacity kW*
Achham	8	78.6	1	5.9	12.50%	7.51%
Arghakhanchi	49	417.1	4	33.9	8.16%	8.13%
Baglung	48	507.6	10	91.3	20.83%	17.99%
Baitadi	8	69.8	1	6.6	12.50%	9.46%
Bajhang	9	115.1	-	-	-	-
Bajura	2	32	-	-	-	-
Bhojpur	13	171	2	41	15.38%	23.98%
Chitawan	8	79	1	2	12.50%	2.53%
Dadeldhura	7	52.5	1	7.5	14.29%	14.29%
Dailekh	10	71	5	37.5	50.00%	52.82%
Dang	8	56.1	1	9	12.50%	16.04%
Darchula	5	46.5	1	10	20.00%	21.51%
Dhading	36	410.8	5	63	13.88%	15.33%
Dhankuta	7	58.6	1	5	14.29%	8.53%
Dolakha	14	125.9	1	7	7.14%	5.56%
Dolpa	1	20	-	-	-	-
Doti	7	61.2	1	12	14.29%	19.61%
Gorkha	21	205.2	7	101.4	33.33%	49.42%
Gulmi	48	415.4	6	51.4	12.50%	12.37%
Humla	3	55.5	-	-	-	-
Ilam	10	116.7	6	92.4	60.00%	79.18%
Jajarkot	10	96	2	26.3	20.00%	27.40%
Jumla	6	88.7	1	6	16.67%	6.76%
Kailali	1	6.8	-	-	-	-
Kalikot	2	20.6	-	-	-	-
Kaski	7	100	3	61	42.85%	61.00%
Kathmandu	2	12	-	-	-	-
Kavre	4	33	-	-	-	-
Khotang	6	85	-	-	-	-
Lalitpur	5	30.2	-	-	-	-
Lamjung	13	156.9	2	11	15.38%	7.00%
Makawanpur	6	48	1	7.5	16.67%	15.63%
Mustang	9	92.6	-	-	-	-
Myagdi	11	116.4	-	-	-	-
Nawalparasi	9	73.8	-	-	-	-
Nuwakot	22	227.4	1	10	4.55%	4.40%
Okhaldhunga	8	88.4	-	-	-	-
Palpa	33	294.7	4	30.7	12.12%	10.42%
Panchthar	4	40	-	-	-	-

Table3.1 Composition of Sample Plants With Respect to National Distribution *(continued.)*

District	National		Survey		Percentage	
	No. of Plants	*Capacity kW*	*No. of Plants*	*Capacity kW*	*No. of Plants*	*Capacity kW*
Parbat	10	72.4	2	11.6	20.00%	16.00%
Parsa	1	10	-	-	-	-
Pyuthan	41	350.7	5	66.5	12.20%	18.96%
Ramechap	13	127	5	51	38.46%	40.15%
Rasuwa	1	20	-	-	-	-
Rolpa	19	145.5	-	-	-	-
Rukum	12	124.1	2	20.2	16.67%	16.13%
Sindhupalchok	20	202.5	2	11	10.00%	5.43%
Solukhumbu	4	56	2	25	50.00%	44.64%
Surkhet	20	143.1	4	27	20.00%	18.87%
Syangja	20	158.2	2	17	10.00%	10.75%
Tanahu	14	112.4	1	18.5	7.14%	16.46%
Tehrathum	2	17.5	-	-	-	-
Udaypur	4	39	-	-	-	-
	686	6604.8	90	1005.9	13.12%	15.23%

Source: Field Survey

At the stage of data processing, the collected information was re-arranged according to Eastern Mountain, Eastern Hill, Central Mountain, Central Hill, Western Mountain and Western Hill categories, adopting the standard geographical division of the country as employed by the Central Bureau of Statistics (CBS). In order to avoid an excessive number of divisions, the Central and Western Regions were combined and sub-divided into hill and mountain districts *(See Annex-3B).* Similar combination and subdivision was done for the Mid-Western and Far-Western Regions. The combination of the regions was appropriate since the conditions of the combined regions and their respective divisions are similar in geographical and socio-economic terms.

An orientation session with respect to understanding the questions and the selection of plants was held prior to conducting the survey. The survey was conducted mainly in 1994/95 and in 1996/97 subsequent visits were made to fill in the data gaps.

The present study relies on data collected on the basis of field visits and interviews with relevant persons working in this area. The data for the financial performance have been provided by both the plant owner as well as the operators and customers. Other data regarding construction details, staff employment and investment have been re-confirmed through interviews with key personnel working in the development and promotion of mini-micro-hydro programmes in the country such as members of the Water and Energy Commission of Nepal, the Intermediate Technology Development Group in Nepal and Rugby, UK, as well as the manufacturers.

3.2.1 Limitations of the Study

The limitations encountered were mainly due to

1. Inaccessibility of the MMHP plants
2. Time constraint, which did not permit the actual physical measurement of certain technical parameters, and hence the study had to depend on the response from the interviewees.
3. Due to lack of record-keeping practices on the part of plant operators information required for further analysis was highly dependent on the approximate values provided.
4. The reluctance of the owners to respond, in some cases, to certain queries.

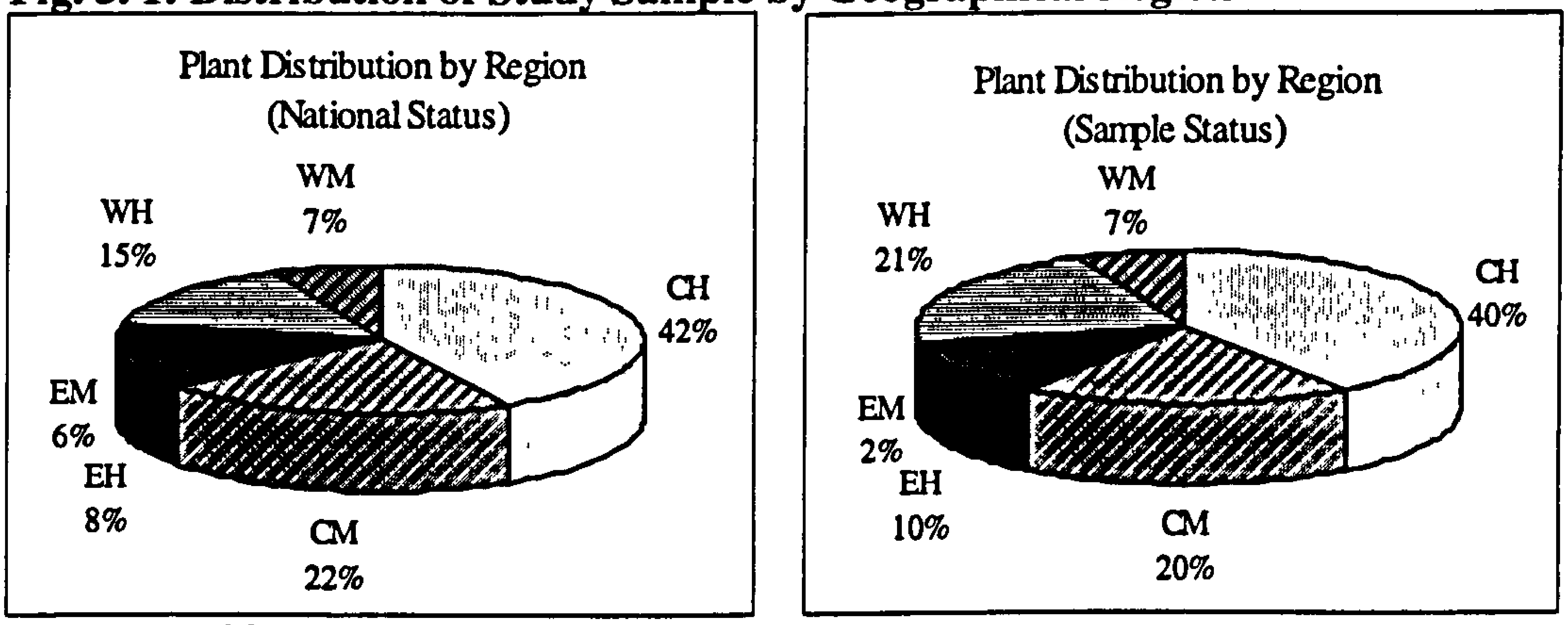
The data for stand-alone electricity generating plants were obtained from a WECS study which commenced in 1994/95. The study is being carried out for site feasibility analysis for the use mini-micro-hydro for rural electrification. The data for stand-alone electricity generating plants was obtained for 79 plants and when analysed provides an insight into factors affecting their performance.

3.3 PLANT LOCATIONS AND RELATED PARAMETERS

3.3.1 Geographical Distribution of the Sample Plants

The study sample in this group includes plants installed in 34 of the 59 districts in the country. The 90 sample installations considered in the study give a picture of 13 percent of the total number of plants using cross-flow turbines. *Fig. 3.1* presents the distribution of the 90 plants by geographical region; 40 percent in the Central Hills; 20 percent in the Central Mountains; 10 percent in the Eastern Hills; 2 percent in the Eastern Mountains; Western Hills 21 percent and 7 percent in the Western Mountains. The national status of the plant distribution is also presented in *Fig. 3.1.* indicating a similar proportion in the regional distribution of the plants.

Fig. 3. 1: Distribution of Study Sample by Geographical Region

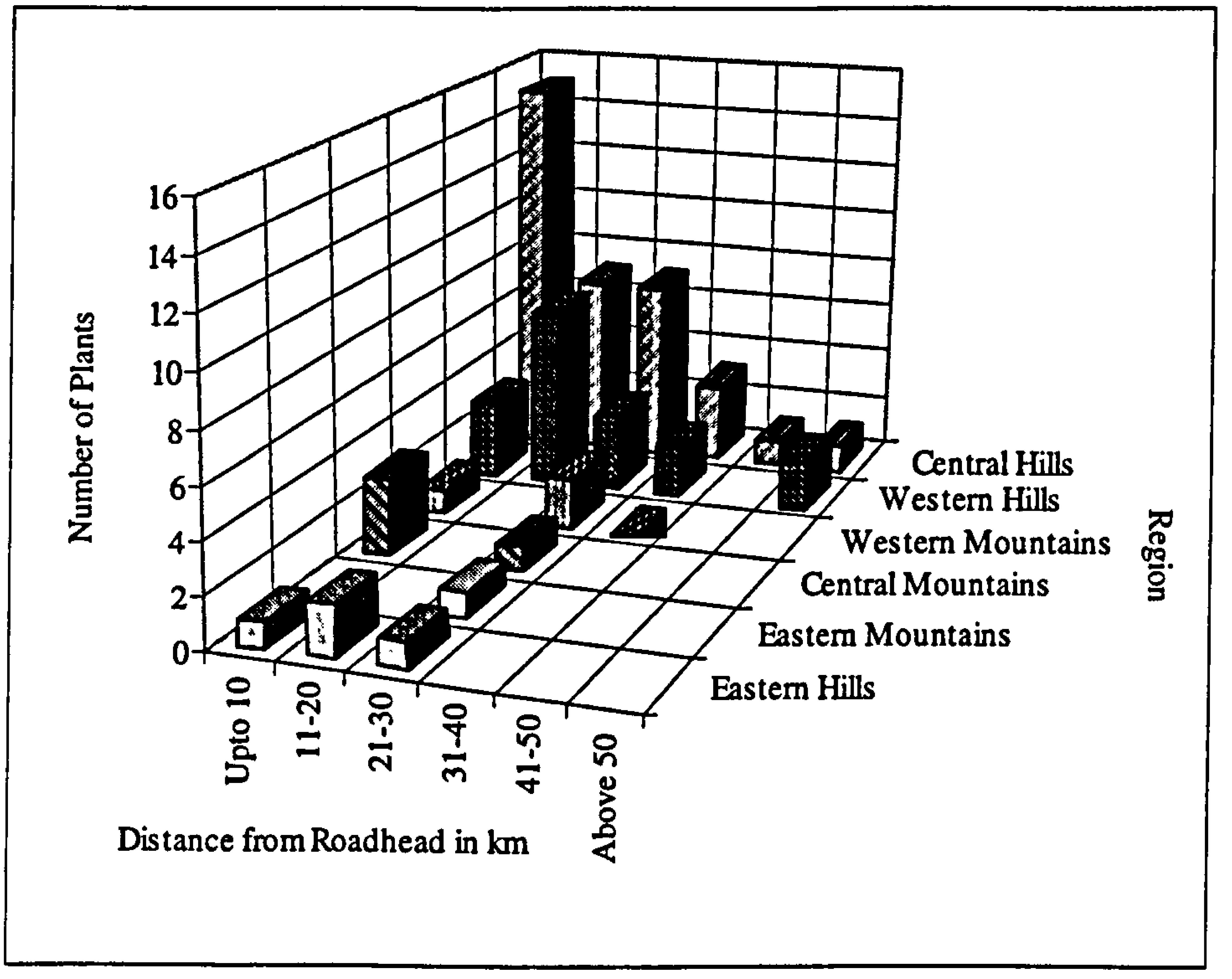


Source: Field Survey

3.3.2 Distribution of Plant Sites According to Accessibility

Micro-hydro power is more beneficial in isolated areas where the possibility of grid-connection is very low in the near future. The road network covers only a small part of the country and many places are still inaccessible by road or rail. This accessibility factor highly influences both the capital and the operation costs. The indicator is the nearest distance from a road. Of the 63 plants responding to this query, it is observed that 84 percent are within 30 km distance and 36.5 percent lie within 10 km distance from a road-head *(See Fig. 3.2)*. The accessibility in terms of kilometres does not mean much in a country like Nepal due to lack of proper vehicular roads. The distance measured in terms of number of hours of travel is more relevant in practice.

Fig. 3. 2: Distribution of Sample Plants by Accessibility to Plant Sites

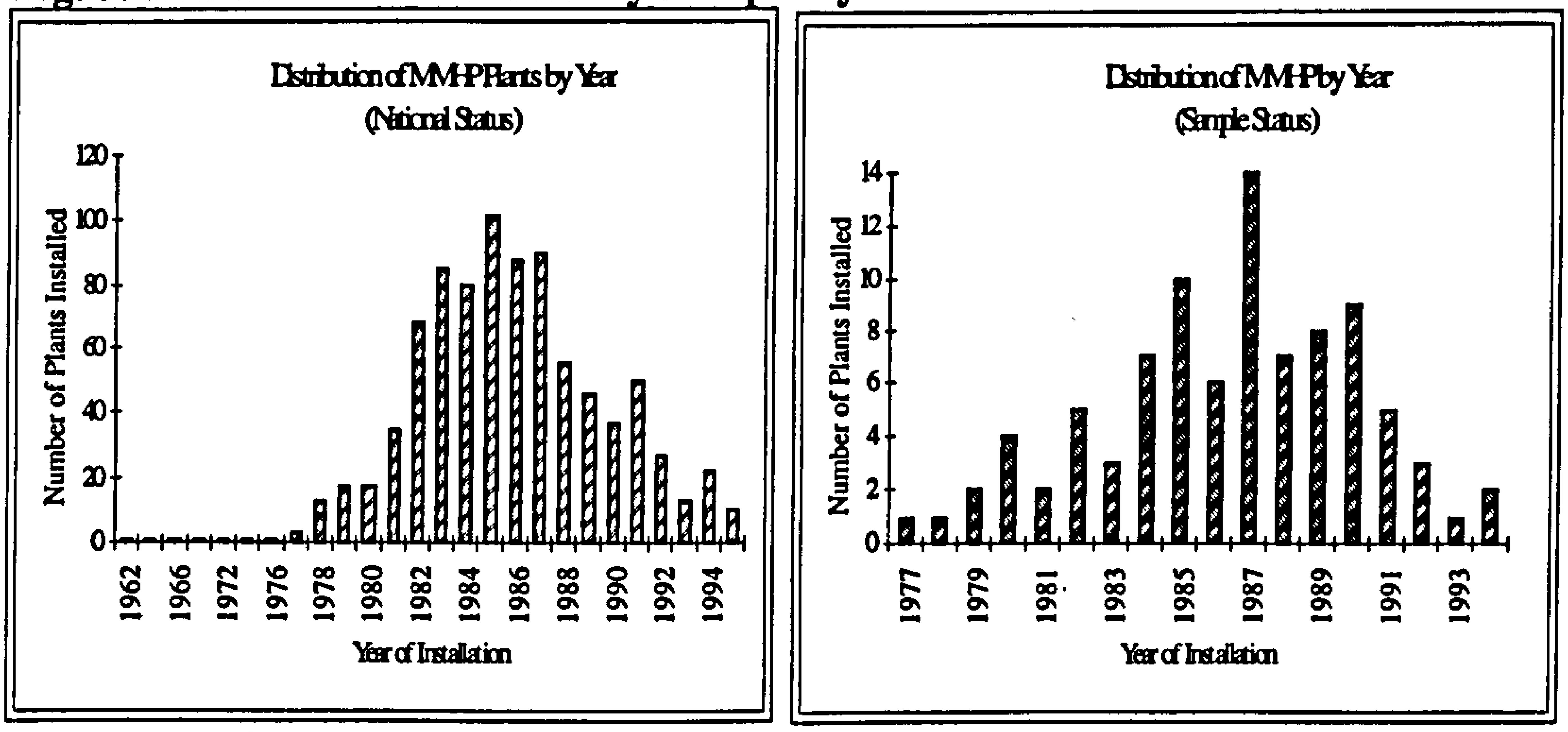


Source: Field Survey

3.3.3 Year of Installation of the Plants

The use of conventional mini-micro-hydro turbines was initiated in Nepal with the establishment of Balaju Yantra Shala in 1960s. This company started with the installation of propeller turbines which did not prove to be successful. In the 1970s an attempt to design, manufacture and install cross-flow turbines proved a more successful endeavour. The survey sample covers plants established from 1977 to 1995. *Fig 3.3* presents their distribution by year of installation. 15 percent were established in 1987, followed by 11 percent in 1985 and 10 percent in 1990.

Fig. 3. 3Distribution of the Study Sample by Year of Installation



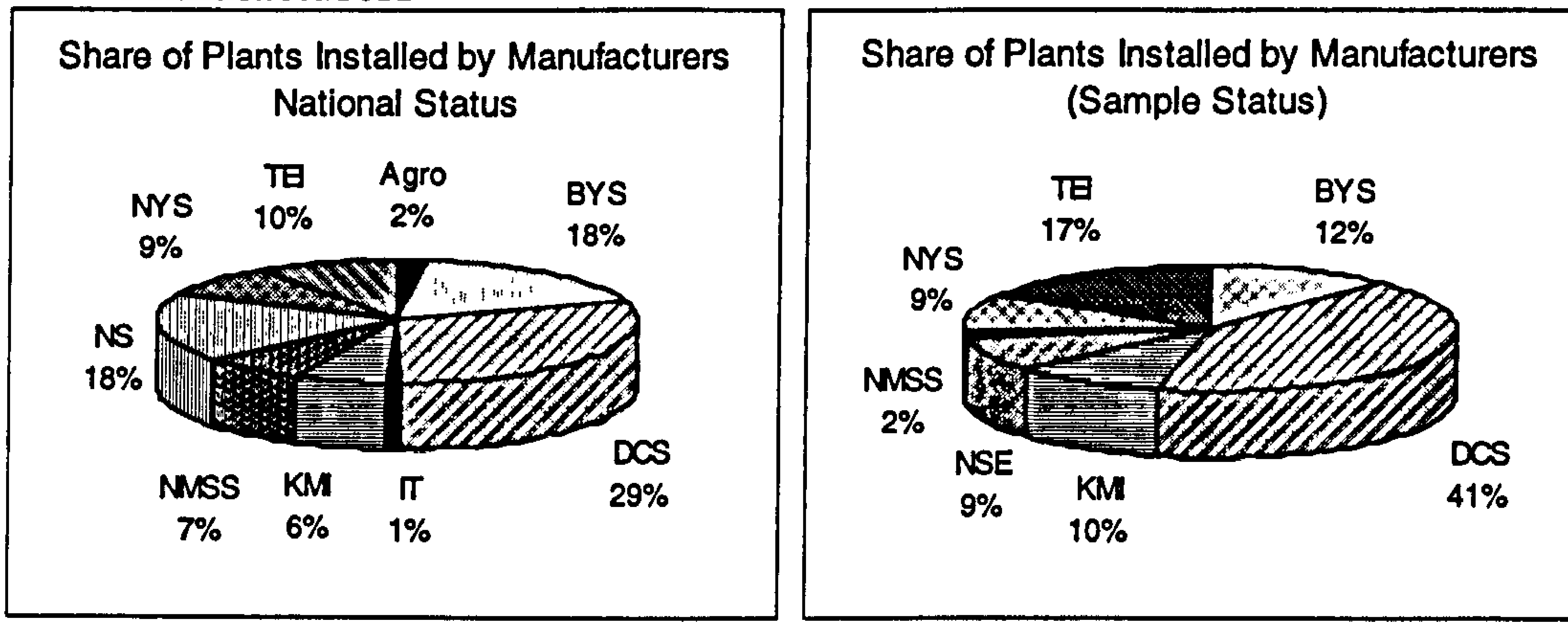
Source: Field Survey

3.3.4 Plant Distribution with Respect to Manufacturers

The sample covers a range of plants that have used turbines manufactured by the following firms: Butwal Engineering Works (Manufacturers for Development Consulting Services, DCS), 41 percent; Thapa Engineering Industry (TEI), 17 percent; Kathmandu Metal Industries (KMI) 10 percent; Nepal Yantra Shala (NYS) 9 percent; Balaju Yantra Shala (BYS) 12 percent; National Metal and Steel Structures (NMSS), 2 percent and National Structure Engineering Company (NSEC) 9 percent (*See Fig 3.4*). A general trend of the plant entrepreneurs is to select the manufacturers after having consulted the Agricultural Development Bank and entrepreneurs already conducting operations in the locality or neighbouring villages. The dominance of the manufacturers by region is difficult to establish due to the small size of the study sample.

The national distribution of cross-flow turbines by manufacturers indicates DCS to be the leading firm with 29 percent installation out of the total MMHP installed in the country. This is followed by BYS and NSE with 18 percent installations and TEI and NYS with 10 percent and 9 percent respectively. NMSS and KMI have the lowest shares of installations with 7 percent and 6 percent respectively.

Fig. 3. 4: Percentage Share of Sample Plants Installed by Various Manufacturers



Source: Field Survey

The largest percentage of plants has been set up in the Central Hill Region, followed by 20 percent in the Central Mountains, 15 percent in the Western Hills, 9 percent in the Eastern Hills, Eastern Mountains 8 percent and only 4 percent in the Western Mountains. In the Central Hills plants have been installed by seven manufacturers: DCS accounts for 21 percent, TEI has 6 percent, NSEC has 4 percent while BYS, NMSS and NYS have only 1 percent each. The sample in this region does not include any plants installed by KMI. In the Central Mountains BYS holds 7 percent, KMI has 1 percent, DCS and NYS have 4 percent each while NSEC and TEI have 2 percent each. In the Eastern Hills BYS has 3 percent; KMI has 5 percent and NSEC has 1 percent of the total installations. In case of Eastern Mountains, DCS has 4 percent of the installations, NSEC has 1 percent and NYS has 3 percent of the market. In the Western Hills, TEI has the highest share of installations - 7 percent, followed by DCS with 4 percent, KMI with 3 percent and NMS with 1 percent. DCS alone has installed 4 percent of the total installation in the Western Mountains. This indicates a pattern of neighbours influence on the entrepreneurs decision in the selection of the manufacturer for their turbines (*See Table 3.2*).

Table 3. 2: Percentage Share of Plants Installed by Firms and Regions

	Central Hills	*Central Mountains*	*Eastern Hills*	*Eastern Mountains*	*Western Hills*	*Western Mountains*	*% Installed by Each Firm (Sample)*
BYS	2.94%	35.00%	33.33%				12.2%
KMI		5.00%	55.56%		20.00%	25.0%	10.0%
DCS	61.76%	20.00%		50.0%	26.67%	75.0%	41.1%
NMS	2.94%				6.67%		2.2%
NSEC	11.76%	10.00%	11.11%	12.5%			8.9%
NYS	2.94%	20.00%		37.5%			8.9%
TEI	17.65%	10.00%			46.67%		16.7%
Turbines in Region (Sample)	37.78%	22.22%	10.00%	8.89%	16.67%	4.44%	100.0%

Source: Field Survey

3.4 FUNCTIONAL STATUS OF THE PLANTS

The production capacity depends to a large extent on the operational availability and the reliable performance of the plants. Plant availability depends on the design characteristics of the various components and inputs; these include: gross head, design flow, channel length, channel type, intake type, penstock diameter, length and thickness.

3.4.1 Gross Head and Design Flow

Details of the plants with respect to head and water-flow are based on information collected from the plant owners and confirmation from the manufacturers. As the plant managers did not have the technical and financial feasibility study report with them, reported design head and flow were in most cases based on memory recollection of the owners and hence may lack precision. This area has not been seriously pursued. However, from the response gathered from 75 of the cases it found that the head range varies from 5 m to 45m. Out of this total 45.33 percent of the plants had head ranging between 5-10m, 30.67 percent in the range between 11-

15 percent, 10.67 percent between 16-20 m while 13.33 percent had head exceeding above 20m.

3.4.2 Sample Distribution by Capacity

The sample includes plants having output capacity[2] ranging from 1 to 50 kW. The regional distribution of the plants with respect to capacity is presented in *Table 3.3.* More than 80 percent of the plants lie within the capacity range 1-10 kW and 42 percent of the total lie within >5-10 kW range. The same percentages apply in national terms.

Table 3. 3: Distribution of Plants in Various Regions by Capacity Range

Region	*Capacity (kW)*					
	<5	*>5-10*	*>10-15*	*>15-20*	*>20*	*Total in the Region*
Central Hills	10	11	12	1		34
Central Mountains	4	8	3	1	4	20
Eastern Hills	1	0	3	3	2	9
Eastern Mountains	1	4	1	1	1	8
Western Hills	1	13	1			15
Western Mountains	1	2	0	1		4
SAMPLE TOTAL	18	38	20	7	7	90
SAMPLE %	20	42.20	22.20	7.80	7.80	100
NATIONAL TOTAL	92	353	182	39	20	686
NATIONAL %	20.4	44.60	23.20	8.90	2.90	100

Source: Field Survey

The larger capacity plants, i.e. those above 20 kW, were installed between 1981-1990. Prior to and after this period more plants below 10 kW capacity were installed. *(See Table 3.4).* In the national context more than 50 percent of plants installed in 1977-80 were below the10 kW capacity; the same was true for the periods 1981-1985 and 1986-1990. However, plants with capacity between 10 and 15 kW, which constituted about 24 percent for all these periods, increased their share to more than 45 percent in the period 1990-1995. Nationally, 44 percent of turbines lie in the

2 The plants are referred to according to their capacity kW rating, i.e. installed capacity determined by a balance between the services to be provided by the plant and the available water resources on which the plant operates. The annual energy supplied by the plant of stipulated capacity is then computed according to the formula:
energy (kWh) = Installed Capacity X Number of Hours the Plant operates X Plant Factor

capacity range of between >5-10 kW, a similar situation is observed in the sample plant distribution. 47 percent were installed within the period 1986-90 with 42 percent in the capacity range of >5-10 kW (*See Table 3.5*).

Table 3. 4: Distribution of Turbine by Capacity and Period of Installation (*National*)

Period	*1977-80*		*1981-85*		*1986-90*		*1991-95*		*Total*	
Capacity	*No.*	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*
<5 kW	*6*	*12.00*	*49*	*21.49*	*70*	*26.42*	*14*	*14.00*	*150*	*21.52*
>5-10 kW	28	56.00	112	49.12	115	43.40	27	27.00	307	44.05
>10-15 kW	12	24.00	51	22.37	60	22.64	47	47.00	181	25.97
>15-20 kW	4	8.00	10	4.39	14	5.28	9	9.00	39	5.60
>20 kW		0.00	6	2.63	6	2.26	3	3.00	20	2.87
National Total	50	7.17	228	32.71	265	38.02	100	14.35	697	

Source: ICIMOD, 1995

Table 3. 5: Turbine Capacity by Period of Installation (*Sample*)

Period	*1977-80*		*1981-85*		*1986-90*		*1991-95*		*Sample Total*	
Capacity	No.	%	No.	%	No.	%	No.	%	No.	%
<5 kW	1	11.11	4	14.81	9	20.93	4	36.36	18	20.00
>5-10 kW	5	55.56	11	40.74	17	39.53	5	45.45	38	42.22
>10-15 kW	3	33.33	5	18.52	11	25.58	1	9.09	20	22.22
>15-20 kW			3	11.11	3	6.98	1	9.09	7	7.78
>20 kW			4	14.81	3	6.98			7	7.78
Sample Total	9	10.00	27	30.00	43	47.80	11	12.20	90	

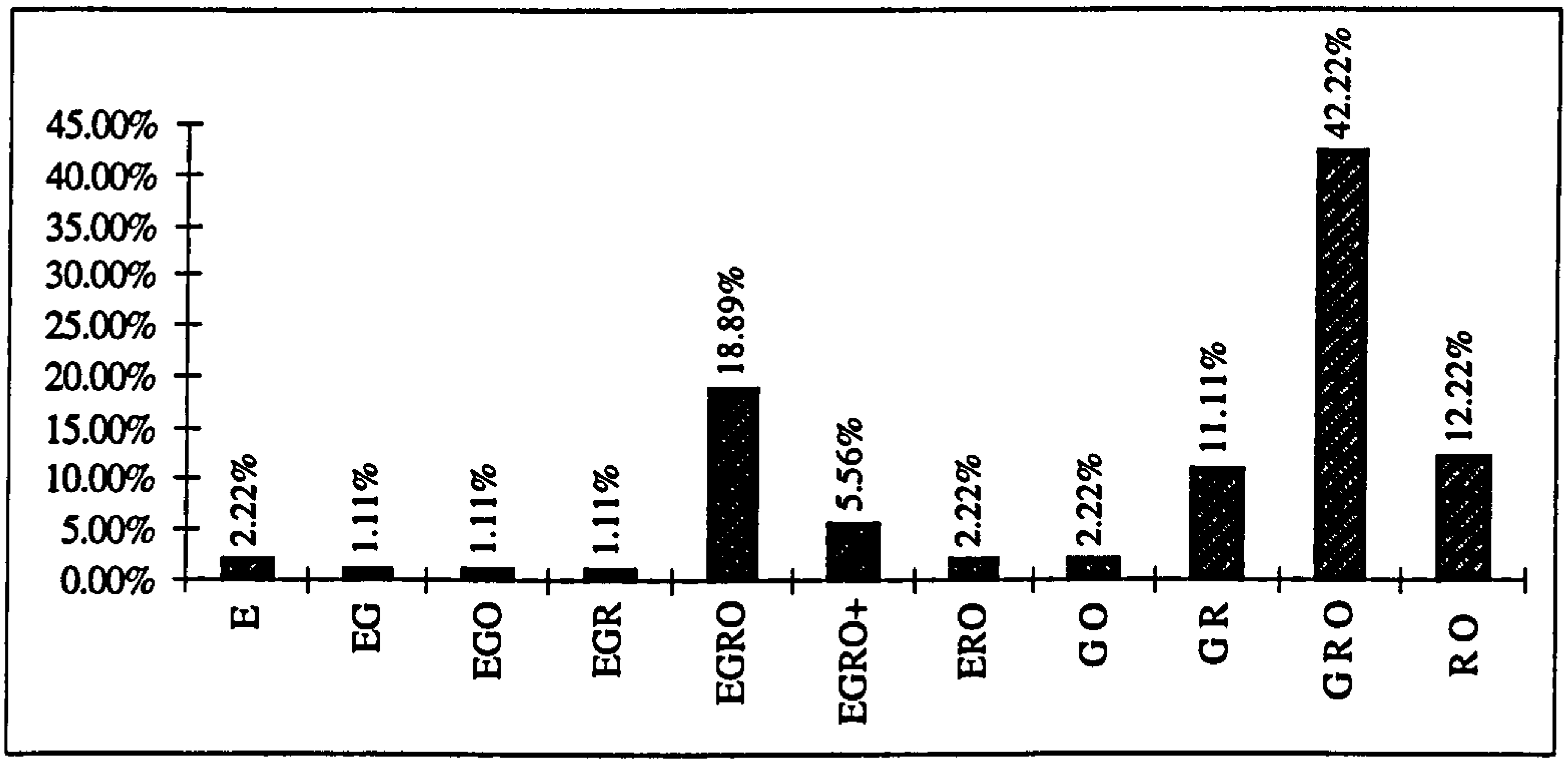
Source: Field Survey

3.4.3 Services Rendered

Milling and oil expelling applications were found to be more popular than generation of electricity. Electrification was introduced both as stand-alone as well as add-on projects. Besides agro-processing and generating electricity the turbine motive power were also found to be used for saw-mill operation, battery-charging, drier operation, paper and ice making. Two of the plants, Barpak and Ghandruk, were selling the downstream water for irrigation as well.

Electricity is used mostly for domestic lighting. However, use of electricity for cooking is found in the case of the Barpak and Ghandruk plants. Besides lighting, electric heating is also found in the Solukhumbu region where tourist service is the main source of income. Electricity is used also for battery charging and pulp-preparation in the making of paper.

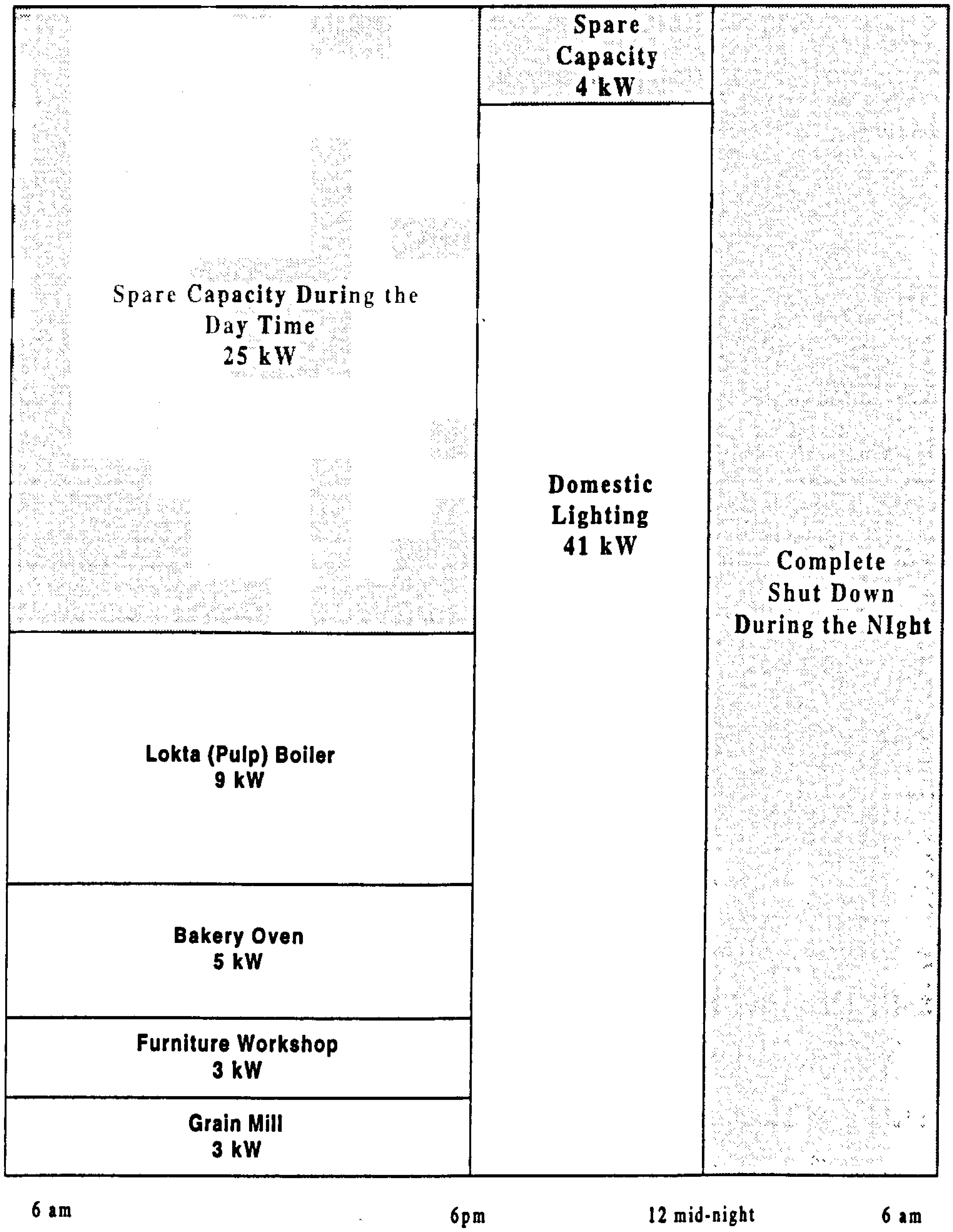
Fig. 3. 5: Percentage of Plants Delivering Services by Type



Note: E - Electricity; G- Grinding; O - Oil Expellor; R - Rice Huller
Source: Field Survey

All the plants providing agro-processing services engaged the huller, 89 percent had an expellor and 79 percent had a grinder as well. 30 percent of the plants had an add-on electrification system (*See Fig. 3.5*). The general practice was to operate the grinder and huller as well as the expellor in parallel (two units running together) when in demand rather than to operate them individually. 68 percent of the plants provided all of the agro-processing services. The plants with an add-on system generating electricity operated only in the early and late hours of the day for approximately six hours in total. The turbine mills were found to operate a range of agro-processing equipment such as rice-hullers, grinders, chiura machine, oil expellors and saw mills. Some of the milling-plants employed shellers. Besides these, five used the turbines for operating dryers and battery charging as well as making chiura (a local food of beaten rice).

Chart 3. 1:Typical Operation Cycle of the Hydro Plants (Barpak Plant ~ 45 kW)



Note: - Milling, furniture making, baking and pulp making are done from 6 am to 6 p.m.
- Lighting demands are from 6 p.m. to 12 (midnight)
- The plant remains shut down between 12 (midnight) to 6 am

The load distribution pattern for a 50kW MMHP at Barpak is replicated in *Chart 3.1*. The shaded sections indicate un-utilised energy which could be used for further end-use. The owner of this plant is keen to use the spare day-time capacity for activities such as welding and other metal-working services. The beneficial performance of the plants is associated with the end-use type of the various plants; in the plants providing agro-processing services, those having oil-expellor equipment have been found to be most successful.

All the plants were designed by the manufacturers. In studying the operating capacity it is observed that some of the plants have been over-designed, as the installed capacity is not able to provide the designated capacity, e.g. plants designated as 8 kW capacity have been found unable to operate more than a single load at a time; this is attributed either to problems at the design level or the end-use choice of the owners. On the other hand plants having 5-6 kW capacity are seen to operate multiple loads at a time. In the study sample about 70 percent of the plants were able to operate multiple loads. 23 percent operated two loads at a time and 7 percent operated only single loads (*See Annex-3C*).

3.4.4 Plant Factor[3]

A high plant factor means increased energy sales, hence higher income, which increases the possibility of the plant being financially viable. Since, with a MMHP

[3] ***Plant Factor*** is defined as the ratio of total actual energy produced by a plant in a year to its maximum energy production capacity.
Mathematically it is represented as:

$$PF = \frac{\text{Annual Energy Output}}{8760 \times P_{ins}} = \frac{\text{Energy Used over a Period}}{\text{Energy Available}}$$

where Pins is the installed capacity in kW; Period considered is usually a year

Energy available is computed as: E (kWh) = P x T

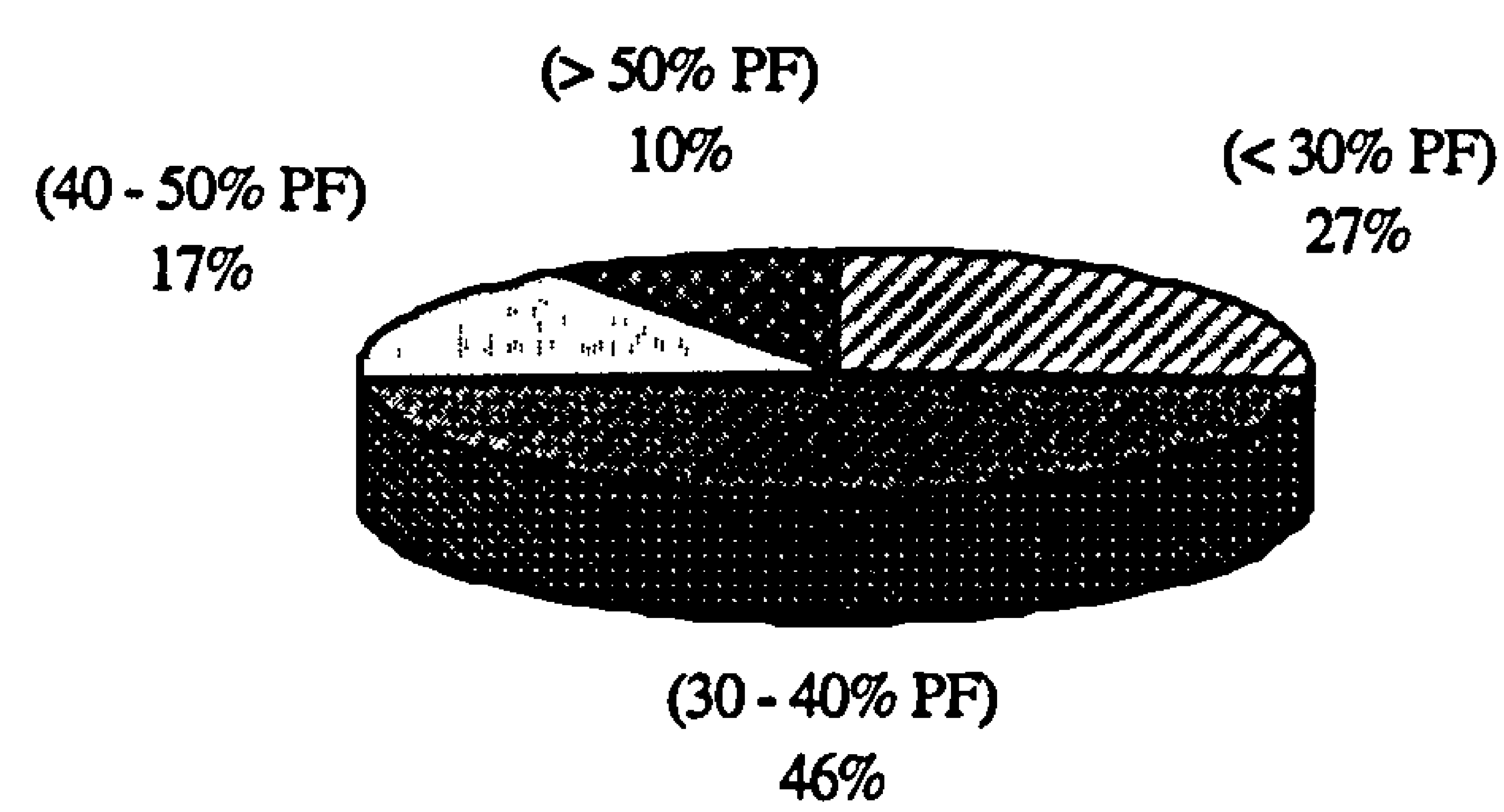
where E = Energy measured in kilo Watt hours (kWh)
P = Power measured in kilo Watts (kW) and is a function of water flow and available head as well as the efficiency of the turbine system
T = Time measured in hours (h)

plant unlike a diesel plant, there is very little additional cost incurred in generating power from an MMHP plant for additional hours, increasing the plant factor means a reduction in the unit energy cost. This makes energy more affordable and may lead to increased sales.

The plant factor, or the efficient use of available energy is a critical factor in respect of the profit incurred from a plant. A few reasons given for the occurrence of a relatively low PF are:

a) over-design of the project mainly for precaution against natural hazards;
b) low market for processing;
c) low demand for electricity in the area;
d) periodic change in the performance observed due to farm activities.

Fig. 3. 6: Plant Factor of the Sample Plants



Source:. Field Survey

Out of the 30 plants examined for this part of the analysis, all but four were found to be operating at below 50 percent plant capacity (PF). Only 10 percent of the plants operated with 50 percent PF, about 17 percent operated between 40 and 50 percent PF and 47 percent operated in the range 30 - 40 percent PF and 27 percent operated with less than 30 percent PF (*See Fig. 3.6).*

Table 3. 6: Installation and Energy Cost with Respect to Plant Factor

Plant Factor	Sample Size	Average Cost of Installation NRs./kW	Average Cost of Energy NRs./kWh	Increase in Energy Cost
<30%	27%	25608	9	
30-40%	50%	16572	6	33%
40-50%	13%	24497	5	44%
>50%	10%	27933	5	44%

Source: Field Survey

From Table 3.6 it is evident that the cost of energy generation decreases with increase in plant factor. With increase in plant factor the cost of energy (comparing with group having PF >30%) is seen to reduce by appreciable amounts: 33% in the 30-40% PF and 44% in the reaming groups. This picture strongly advocates the need to promote MMHP through increasing its end-use thereby increasing its plant-factor.

3.4.5 Repair and Maintenance

Not all respondents were able to provide a detailed breakdown of the repair and maintenance costs. One of the respondents claims that 50 to 70 percent of the R&M cost was incurred *(D. R. Regmi in Dailekh)* in the repair of mechanical parts such as bearings, worms, brass brushes, rollers and gaskets. Another respondent *(N. B. Shahi, Dailekh)* claims that 45 percent of the R&M cost goes for replacement of worn-out parts of the oil-expellor and another 25 percent for the canal replacement. The remainder is cost for travel to the city for purchase of the required spare-parts. Technical problems associated with most turbine plants are listed in *Table 3.7.*

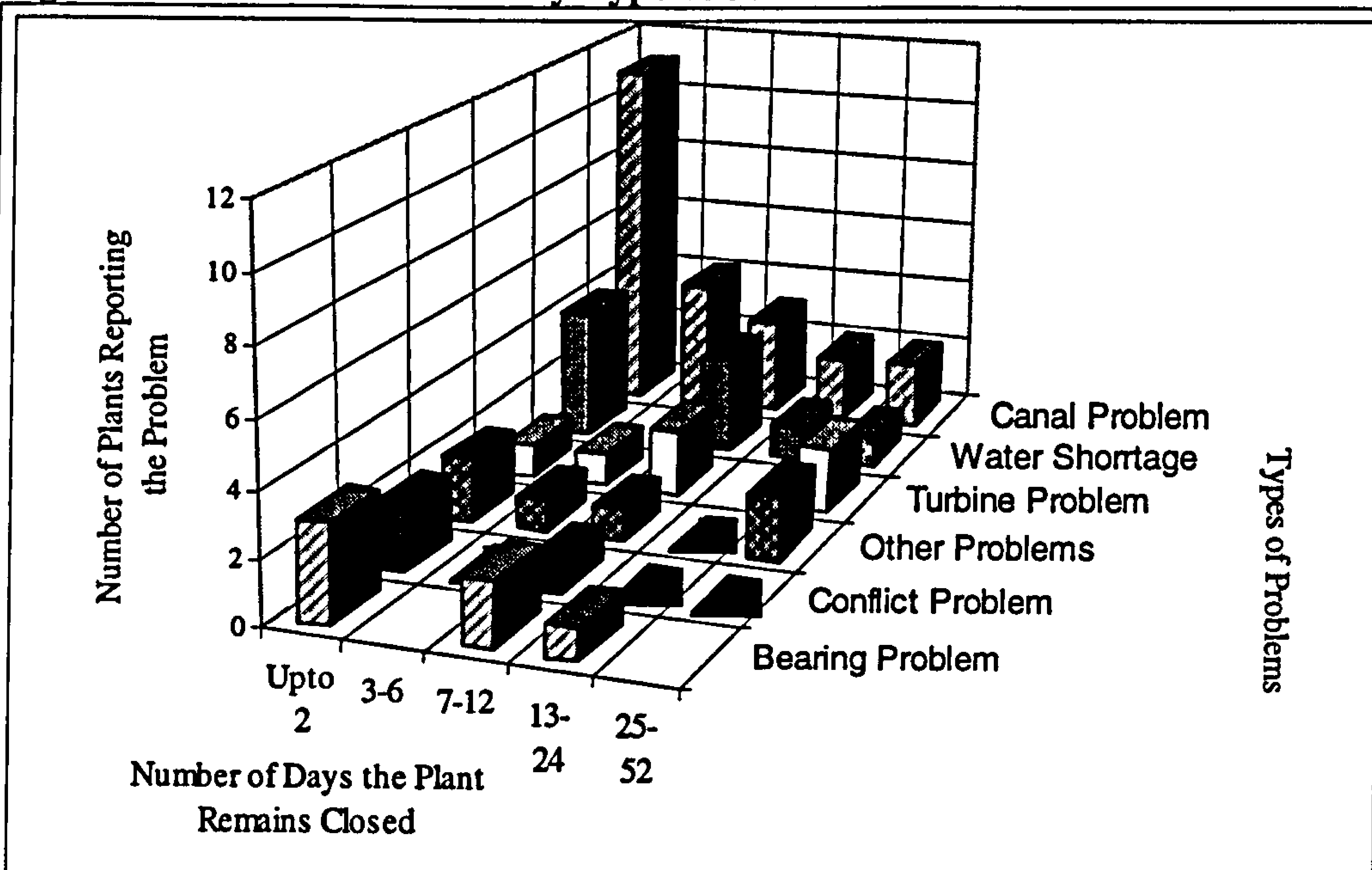
Canal breakdown and water shortage compels most of the plants to close for a day or two. On an average the plants are closed for more than a week for repair or maintenance of the bearings every time the problem occurs. The large number of days out-of-use is due to non-availability of these spare parts in the locality. Most operators have to go into the nearest town to purchase the parts. The number of days of closure of the plants at times of breakdown is presented *Fig.3.7.* The repair of turbines is most often referred to the manufacturers as local service for such repair is not available in most of these areas.

Table 3. 7: Areas Concerning Repair and Maintenance

Areas Requiring Repair and Maintenance	*No. of Mills*	*Percentage of the Sample*
Wearing of Bearings, Worms, Brushes, Roller and Gasket	25	83
Non-functioning of Turbine Valves	5	16
Breakdown of Driving Shaft	8	26
Wearing of Driving Shaft	18	60
Wearing of Pulleys	20	66
Damage of the Canal	16	53
Generator and Load Controller	2	7
Leakage in the Turbine Housing-Plate	3	10
Leakage in the Penstock Pipes	7	23
Turbine Breakdown	3	10

Source: Field Survey

Fig. 3. 7: Period of Shutdown by Type of Problem



Source: Field Survey

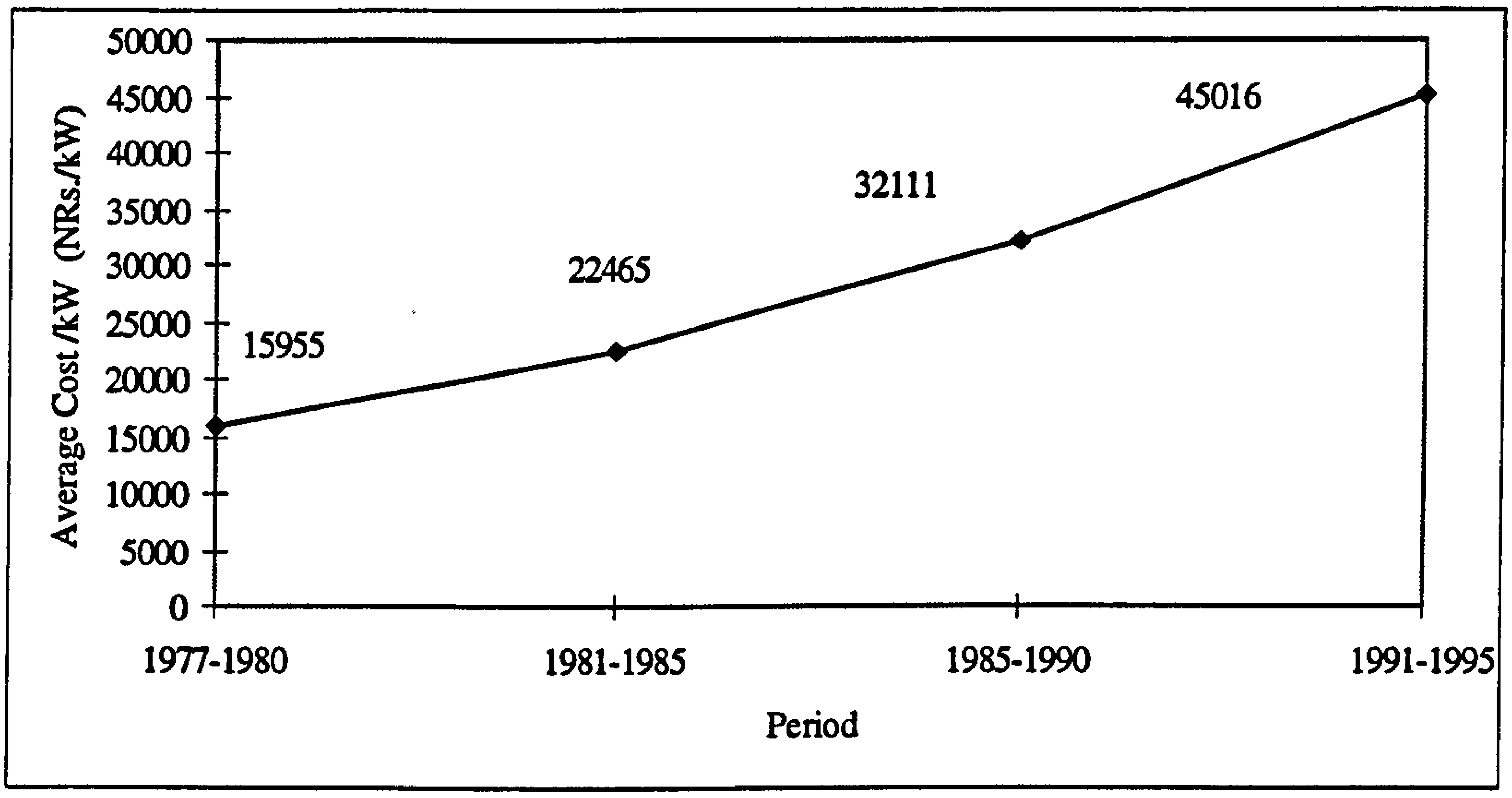
Some of the entrepreneurs in the study complained about the need to close the plant for a considerable period of the year due to lack of water availability. This chiefly reflects the lack of hydrological data for the area. Although flow measurement of the streams is carried out during the survey for plant installation, low flow measurements, derived from only a single day measurement, were often used. In some cases the experience of the local people were also utilised.

3.5 COST ELEMENTS

Entrepreneurs have been encouraged to establish MMHP plants by the soft-loan policy of the government. Except for the Bhadaure plant, all others were partly financed through loans taken from the Agricultural Development Bank. The loans reached as high as 80 percent of the total cost with a minimum of 17 percent. 30 percent of the plants had taken loans worth more than 70 percent of the plant cost, 15 percent had loans worth between 70-80 percent.

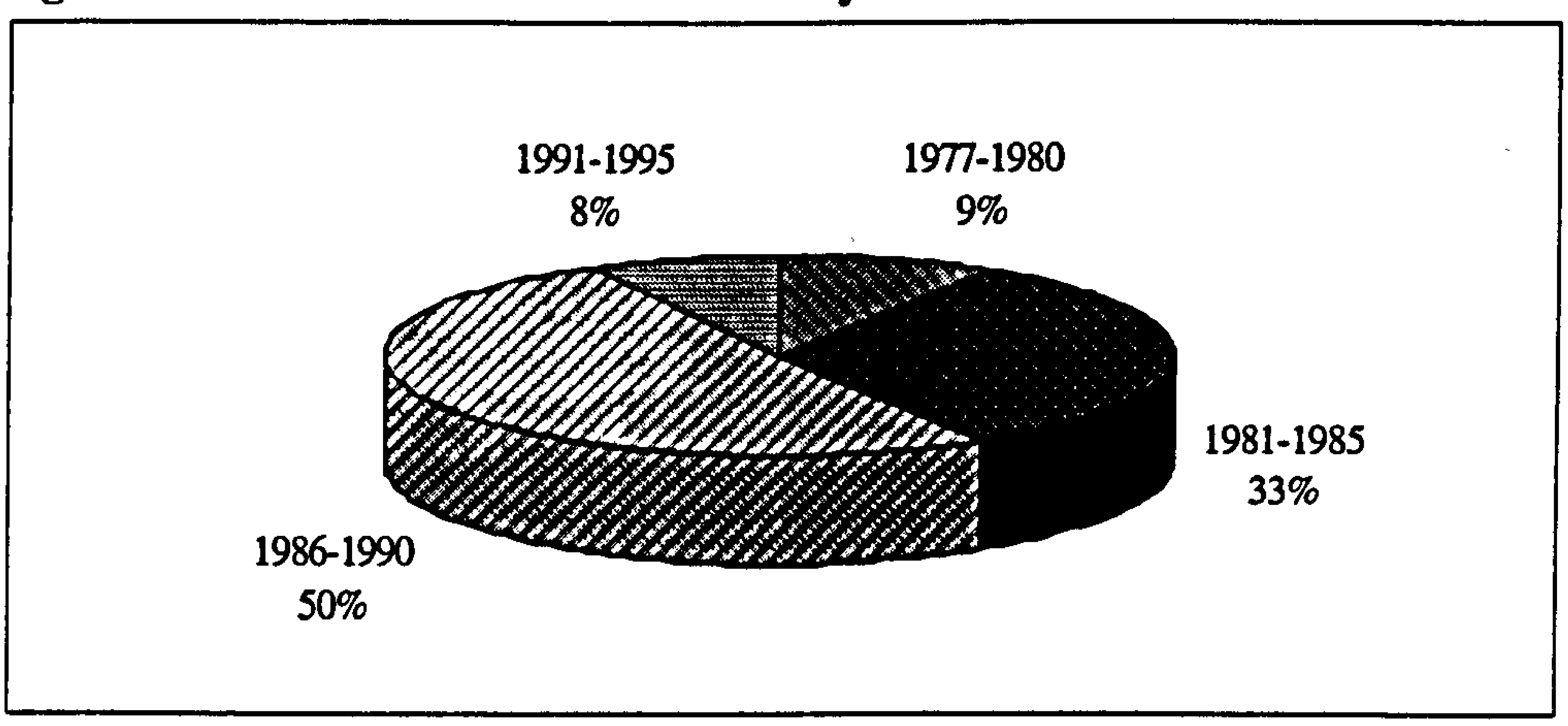
The cost of plant installation per capacity (kW) is seen to rise over the period since 1977. The graphic presentation in *Fig 3.8.* depicts a steady increase of plant cost per unit of capacity, with cost rising by 162 percent between the period 1977-1980 and 1991-1995. The incremental rise between each specified period is 41.32 percent. Over a period of time, the MMHP sector has attracted a considerable volume of investment expenditure. 58.60 percent investment was made during 1980s. It is evident from *Fig. 3.9* that almost 86.7 percent of this investment was made in the period 1981-1990. However, there has been a sharp drop with only 8 percent of the total in the period 1991-1995. This trend is explained by the increase in capital cost, the inconsistency of government policy and the extension of the grid to areas where MMHP were located.

Fig. 3. 8: Per kW Cost of Plant Installation by Period of Installation (*at 1995 prices*)



Source: Field Survey

Fig. 3. 9: Concentration of Investment by Time Period



Source: Field Data

3.5.1 Cost Distribution

The cost of MMHP is highly site-specific and influenced by the layout of the project. The design and cost estimation are based on discussions with people involved in

MMHP development and WECS. The percentage cost of machinery, electrical, transport and transmission/distribution component of cost with respect to total plant cost obtained from the field survey is shown in *Table 3.8.*

Table 3. 8: Cost Composition of Various Components of the Micro-Hydro Project

S. No.	*Percentage of Cost*					
	Mechanical	*Penstock*	*Civil*	*Electrical*	*Transportation*	*Labour*
Jajarkot	24.05	8.31	11.12	37.91	4.90	4.55
Doti	22.03	10.32	19.65	33.59	4.50	2.51
Dhankuta	19.23	9.07	25.76	24.71	6.71	5.50
Gulmi	20.91	6.43	25.32	30.54	1.16	6.42
Darchula	15.26	9.92	22.61	37.26	5.25	1.51
Lamjung	14.04	6.92	10.54	55.53	1.65	2.57

Source: WECS/UNDP, 1995

The percentage cost of the mechanical components in the total project varies from 14.04 percent to 24 percent and in some cases is as high as 42 percent. The civil-works construction cost varied between 10.55 percent to 25.76 percent of the total cost. The percentage electrical cost lies in the higher scale at about 55.53 percent, and a minimum of 24.71percent. The transport cost varies between 1.16 percent and 6.71 percent. The cost does not follow a rule which varies with the plant capacity; that is due to the site-specific nature of the plants. Added to this is the tendency of the manufacturers to over-design, or the effect of the high risk factor added in the designing of the turbines. The main factors which influence the plant installation cost are discussed below:

Mechanical Cost

The mechanical cost i.e. cost of the plant includes the cost of turbine and the penstock. This comprises of 15-24 percent of the total installation cost. As a breakdown by cost of these components was not available from the primary survey a typical breakdown of the mechanical costs was obtained from WECS/UNDP for selected areas: this indicates that the percentage cost of turbine to vary from 50 to 70 percent and that of the penstock pipes from 30 percent to 50 percent *(See Table 3.9).*

Table 3. 9: Composition of Mechanical Cost for Micro-Hydro Projects

S. No.	*% of Turbine Cost*	*% of Penstock Cost*
Jajarkot	65.14%	34.86%
Doti	55.33%	44.67%
Dhankuta	53.92%	46.08%
Gulmi	70.04%	29.96%
Darchula	50.17%	49.83%
Lamjung	50.17%	49.83%

Source: Field Survey

In the plants of earlier years the use of mild steel pipes as penstock pipes regardless of the head was common as this was the only available material. However, HDPE pipes are now more common because of lower cost as well as ease in transportation. There are cases of composite penstocks using both steel pipes and HDPE pipes as in the case of Ghandruk.

Turbine Cost

The turbine cost, ranging from 50 percent to 70 percent of the mechanical cost, includes the price of the turbine and base-plate. In case of plants generating electricity the cost includes the cost of base-plates for both the turbine and the generator. The shop price of these items listed in *Table 3.10* shows the cost variation with respect to the turbine used in different flow and head conditions. The similarity in the cost of the turbine for different conditions indicates the utility of that turbine for a range of flow and head variation.[4]

From the above Table it is evident that the cost of turbines decreases with increase in water head i.e. level of water from the water-intake to the turbine. This is due to the

4 This utility of the turbine has led to discussion regarding to the classification of the hydro-plants. For details see Naidu, B. S. K: "*Rethinking the Classification of Hydro Plants,*" Paper presented at Expert Groups' Meeting on Micro-Hydro Turbines, ICIMOD, Nepal, 1997

simplicity in the technology of the turbines that are used under high-head conditions (refer to Chapter 2).

Table 3. 10: Cost of Turbines *(1995 prices in NRs)*

	Head (m)	*Flow (lps)*	*Turbine Type*	*Cost of Turbine*	*Cost of Base -Frame*	*Total Cost*
1	17	1000	T12 series*	710,000	60,000	770,000
2	50	210	T12 series	445,000	50,000	495,000
3	47	250	T12 series	445,000	45,000	490,000
4	34	200	T12 series	440,000	40,000	480,000
5	28	190	T12 series	440,000	40,000	480,000
6	37	125	T7/360D/085W*	335,000	35,000	370,000
7	25	80	T7/360D/085W*	90,000	30,000	120,000
8	37	52	T7/360D/085W	90,000	30,000	120,000

Note: * identifies the turbine model
Source: Balaju Yantra Shala

3.5.2 Investment in Other Equipment

Other investments arise in the form of agro-processing equipment, saw mills, chiura-machines and other end use equipment. The agro -processing devices employed by the mills are found to be operated on the turbine motive power rather than on electricity generated from the plant. These items of end-use equipment have been supplied by the manufacturers in most cases: only one plant reported that their equipment had been bought from India. The cost structure of such equipment is as shown in *Table 3.11*

Table 3. 11: Details of Agro-machines Used

Machine	*Size*	*Capacity kg/hr*	*Cost*
Huller	4-12 No	150-500	NRs. 53000
Grinder	20 inch	140	NRs. 27600
Expellor	6 Bolt	50	NRs. 26200

Source: Nepal Agro Products, Kathmandu, Nepal

3.5.2.1 Electrical Components

The high cost of the electrical component, 24.71-53.53 percent, is attributed to the cost of transmission and distribution. These are the major items to be considered for cost reduction. Optimum voltage level selection, optimum conductor size selection and choice of the optimum line configurations should be considered for low cost design of transmission and distribution. The manufacturers need assistance for optimum design of transmission and distribution systems.

3.5.2.2 Transmission and Distribution

Most MMHP have the same transmission and distribution voltages. Single phase transmission is practised up to 5-10 kW. For power transmission/distribution of 1-3 kW range PVC insulated stranded copper wires are used. Many MMHP have the same transmission and distribution voltages. Single phase transmission is practised up to 5-10 kW. For power transmission/distribution of 1-3 kW range PVC insulated stranded copper wires are used. Such wires are in many cases supported by trees, bamboo and timber poles.

All MMHP except the one in Barpak use electricity generation voltage of 230 or 400 V for transmission/distribution of power to the load centre. The Barpak plant uses 11 kV transmission. The cost of transmission and distribution as a percentage of the total plant cost is presented in *Table 3.12.*

The average transmission and distribution costs of the above plants amount to around 24 percent of the total cost. Cost of transmission/distribution of similar plants in Pakistan is about 40 percent (*Appropriate Technology Development Organisation,, Pakistan, undated).* In case of India it has been reported that the cost for hilly regions is around 1.8 times the amount required in the plains (*TERI, 1994*), however, the actual figure is not available. Practically all MMHP of small and medium range use timber poles of soft wood found abundantly in the rural areas or else tie the wire to trees. The short life of the timber and poor alignment and poor workmanship are major problems.

Table 3. 12: Average Cost of Transmission and Distribution Component in the Total Plant Cost

Plant	*Capacity (kW)*	*Cost (%)*
Tehrathum	100	36
Okhaldhunga	125	16
Bhojpur	250	14
Khandbari	250	16
Ramechap	75	21
Syarpodaha	200	47
Bajhang	200	20
Manang	80	23
Chame	45	8
Bajura	200	15
Tatopani	1000	48

Source: WECS/UNDP 1995

3.5.2.3 Generators

As hydro plants are low-speed machines as compared to gas and steam turbines, low-speed salient pole synchronous generators are preferred. However, as micro range generators are not readily available in Nepal, micro hydro plants use high speed synchronous generators. These are coupled through belt drives with the water turbine. The major source of synchronous generators is the Kirloskar Company of India.

Induction generators are also found to be commonly used. They are converted from Chinese motors which are cheap and readily available in the local market. This is a relatively new technology, but its fast dissemination is an indication of a promising future. No major problems have been reported so far.

3.5.2.4 Electronic Load Controllers

Electronic Load Controllers (*ELC*) are fast replacing governors which are prohibitively expensive for MMHP plants. The cost of ELCs (*See Table 3.13)* manufactured in the country is reported to be at least 20 percent less than those imported from the UK.

Table 3. 13: Cost of Generators and Electronic Load Controllers in NRs.

Head (m)	*Flow (lps)*	*Generator Specifications*	*Generators*	*Electronic Load Controllers with Ballast*
17	1000	120 kW, 3-phase, 415V	400,000	200,000
50	210	86.5 kW, 3-phase, 415V	310,000	180,000
47	250	83 kW, 3-phase, 415V	300,000	180,000
34	200	48 kW, 3-phase, 415V	225,000	130,000
28	190	36 kW, 3-phase, 415V	210,000	130,000
37	125	33 kW, 3-phase, 415V	200,000	120,000
25	80	16 kW, 3-phase, 415V	140,000	100,000
37	52	13 kW, 3-phase, 415V	100,000	100,000

Source: Balaju Yantra Shala, Nepal

3.5.2.5 Transportation Cost

Transportation of materials, turbines and penstock pipes is included in the project package offered by the manufacturers. The means of transportation is a combination of vehicles and human/animal power. Transportation using vehicles is inhibited by the lack of motorable roads in most of study areas (*See Map 3.2*). In some cases, the materials have been air-lifted as well. In the study sample transport costs represent 1-7 percent of the total cost. (*See Table 3.14 for a typical transportation cost scenario*).

Due to the limited carrying capacity of the Twin Otter[5], the transportation may involve multiple trips. Thus in the remote areas not accessible by land the cost of the transportation needs special consideration.

Table 3. 14: Typical Transportation Costs

Means of Transport	*Unit*	*Rate*	*Remarks*
Road (Vehicle)	NRs./trip	5000	for a turbine of 2500 kg, other material 2800 kg
Road (Labour)	NRs/kg	5	rate varies depends on the terrain
Air Lifting	NRs/kg	30	Twin Otter Charter Flight
		40	Helicopter Total Charge
Total Cost	NRs.	159,000	Twin Otter
		212,000	Helicopter

Source: Royal Nepal Airlines Corporation, Nepal; KMI, Nepal

As most areas are inaccessible by vehicle and the cost of air transport is highly prohibitive, the major means of transportation is using porters. The rate charged for such transportation is at least NRs. 5 per kg. Due consideration is given to this factor in the manufacture of turbines thus limiting the weight of the unit to what can be carried by single porter.

3.5.3 Income Generation

Agro-processing was a major source of income generation. Electricity on the other hand was not found to be very popular. Many users had removed this facility after having operated it for a short time; others used it simply for their own consumption. Two of the sample plants were found to be distributing electricity free-of-charge.

[5] Calculation of a typical air transportation cost for turbines installation

Weight of 10 kW turbine & penstock material		≈ 4,500 kg
Electric wire (1- 2 km transmission wire used in rural areas)		≈ 800 kg
Total Load		≈ 5,300 kg
Transportation by air (Flight length)	≈ 1 hour	
a) Twin Otter Aircraft (Cargo charge NRs 30 per kg)	≈ 30 (NRs/kg) x 5,300 kg	≈ NRs.159,000
b) Helicopter (Cargo charge NRs 40 per kg)	≈ 40 (NRs/kg) x 5,300 kg	≈ NRs. 212,000

3.5.3.1 Agro-Processing

The processing charge for milling was found to vary between mills. In the absence of a detailed financial analysis of the project, entrepreneurs generally fix their own tariff rate by following the advice of the manufacturers/ installers or imitating the decisions of neighbouring MMHP entrepreneurs. However, the rate is not uniform in all MMHP plants as seen from *Table 3.15.* The tariff for the expellor was the highest in the case of all the plants. This was followed by the tariff for grinding. Some of the plants were charging for the services in kind: payment for a quantity of serviced-grain by volume of un-serviced grain. In these cases the value of the un-serviced grain in that locality has been has used as tariff.

Table 3. 15: Comparative Rates for Agro-processing Services by Region

Region	*Grinding Rate (NRs. per kg.)*	*Hulling Rate (NRs. per kg.)*	*Oil Expelling Rate (NRs. per kg.)*
Central Hills	0.50-0.75	0.30-0.40	-
Central Mountains	0.55-0.65	0.55-0.65	1.25-1.50
Eastern Hills	0.45-0.60	0.35-0.40	1.80-2.00
Eastern Mountains	0.65-0.85	-	-
Western Hills	0.50-0.75	0.40-0.60	1.6-2.00
Western Mountains	0.40-0.60	-	1.70-1.80

Note: The figures in bracket represent variation in the cost
Source: Field Study

3.5.3.2 Electricity Tariff

Electricity tariffs follow a mixed system. Plants having add-on systems had a tariff system based on the number and wattage of bulbs connected in the houses, while others had a tariff based on the energy consumed per house per month as well as number and wattage of bulbs connected. This discrepancy in the tariff system is mainly due to the absence of monitoring equipment (meters) in transmission/distribution units. This has been looked upon as an added cost, besides being complicated to handle for the entrepreneurs. The electricity tariff of some of the plants is listed in *Table 3.16.* It is evident that there is no consistency in the tariff rate which varies from NRs. 0.35 to NRs. 16.70 per kWh.

Table 3. 16: Micro-hydro Electricity Tariff of Selected Plants

Plant	*District*	*Plant Type*	*Monthly Tariff*	*NRs./ KWh*[6]	*Source*
Ishaneswar	*Lamjung*	*Add-on*	*NRs. 15/40 W Bulb*	*1.56*	*East Const. 1991*
Sundar Water Turbine	*Tanahu*	*Add-on*	*NRs. 60/40 W Bulb*	*6.25*	*East, 1990*
Yagya Rice Mill	*Gulmi*	*Add-on*	*NRs. 60/40 W Bulb* *NRs. 14/25 W Bulb*	*6.25* *2.33*	*East, 1990; Nafziger, 1992*
Lopra Project	*Jumla*	*Add-on*	*NRs. 7/60 W Bulb* *NRs. 4/50 W Bulb*	*0.49* *0.33*	*Bernard V.B, 1991*
Shaha S. P.	*Rukum*	*Add-on*	*NRs 20/ Bulb*		*NSEC*
Basnet T. B	*Dhading*	*Add-on*	*NRs. 25/ Bulb*		*Survey*
Lamad	*Ramechap*	*Add-on*	*NRs. 30/ Bulb*		*TEI*
Pinthali Community	*Kavre*	*Add-on*	*NRs. 1/W*	*4.17*	*KMI*
Milan M. B.	*Bajhang*	*Add-on*	*NRs. 1/W*	*4.17*	*TEI*
Budhathoki.D. B.	*Gulmi*	*Add-on*	*NRs. 25/ Bulb*		*TEI*
Angaha khola	*Palpa*	*Add-on*	*NRs. 0.75/ W*	*3.13*	*Survey*
Bhadaure	*Kaski*	*Stand Alone*	*NRs. 60/15 W Bulb* *NRs. 75/25 W Bulb* *NRs. 90/40 W Bulb*	*16.67* *12.50* *9.38*	*Survey*
Purang	*Mustang*	*Stand Alone*	*NRs. 25/ Bulb*		*Survey*
Barpak	*Gorkha*	*Stand Alone*	*NRs. 0.45/W* (200 W group) *NRs. 0.72/ W (25 W group)* *NRs. 4.50/kWh (metered)*	*1.88* *3.00* *4.50*	*Survey*
Ghandruk	Kaski	Stand Alone	*NRs.* 0.50/ W, (Domestic) *NRs.* 0.75/ W, (Hotel) *NRs.* 0.25/ W, (Daytime)	2.08 3.13 1.04	Survey

Instead of meters the householders choose the number of bulbs they wish to connect and pay a fixed amount accordingly. If they choose to pay a tariff for 50 watts, for instance, they are dissuaded from fitting bulbs or other appliances that consume more

6 This value has been computed with the available data by converting the prevailing tariff in each of the plants into available energy for the month when the plant operates for eight hours a day for a period of 30 days

than 50 watts by a special fuse which cuts off the supply when consumption increases beyond the designated amount. During this '*blackout*' the householder must turn the main switch off, reduce consumption again to the correct level, wait till the fuse resets (about two minutes) and switches the power back again[7].

Apart from buying bulbs and appliances the householders must also pay for wiring the house, usually NRs 400 to 1000 together with a connection fee of NRs. 10. These consumers are allowed to use electricity only at stipulated times - early morning and evening hours. The rules and tariff levels are decided through negotiations between the plant owner and the consumer without any outside guidance. In case of households having meters payment is determined according to the energy consumption per month. This is also true for electricity consumption for industries such as paper-making, baking and furniture-making as found in Barpak. This is an exceptional example of an ideal micro-hydro plant in Nepal.

Large differences exist between electricity tariffs implemented by various plants. The break-even tariff for stand-alone plants is higher than that of add-on plants. This is associated with the lower cost of add-on plants, about 50 percent less, and lower operating cost. In order to make stand-alone systems more attractive there is a need to set a code for bringing more uniformity. This will be possible through implementation of an acceptable flat rate based on energy consumption depending upon the end-use. This in itself requires a rigorous exercise.

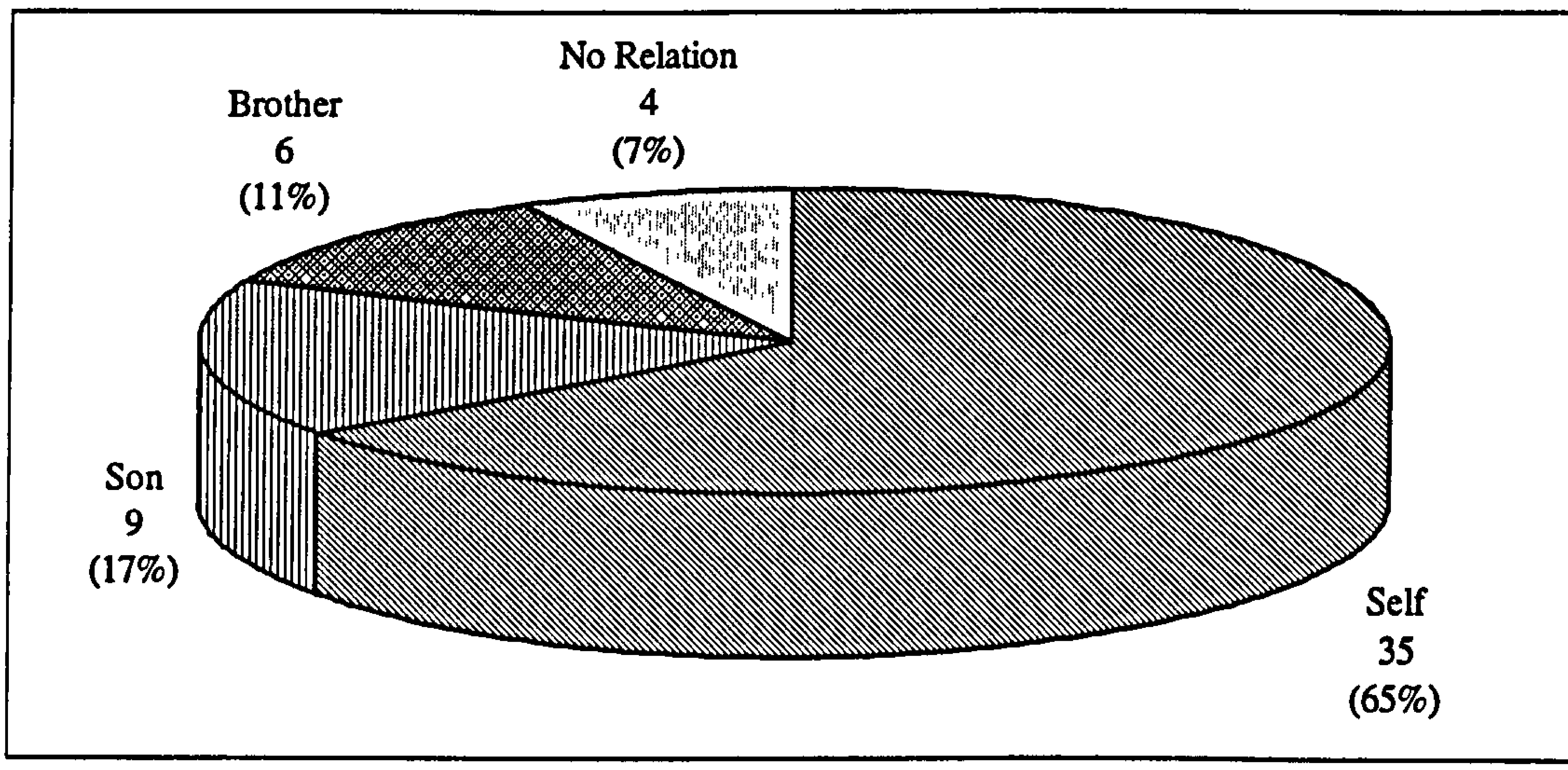
In the course of the survey complaints of inadequate profit were reported. Some of the reasons mentioned for poor results were competition from neighbouring plants, frequent plant breakdown and low plant factor specially for electricity generating plants, less water than expected, poor management and difficulties in repair and maintenance.

[7] The fuse known as a Positive Thermal Coefficient (PTC) switch, costs NRs. 200-400.

3.6 PLANT MANAGEMENT AND OPERATION

Management of the plants is often handled by the plant owners themselves. *Fig. 3.10* indicates that 65 percent of the plants are being managed by the owner himself and in case of the remaining 35 percent the job is assigned to others. Management is a separate activity requiring special knowledge and skill. The quality of the managers of the MMHP however, is apparently very poor *(See Fig. 11)* as they have neither obtained special management training nor have a clear ideas about their duties and responsibilities. Of the 28 owners responding to queries about their training status, 12 (42.95 percent) reported that they had one week's training. That training was probably operators' training as there is no information on institutions providing special managerial training.

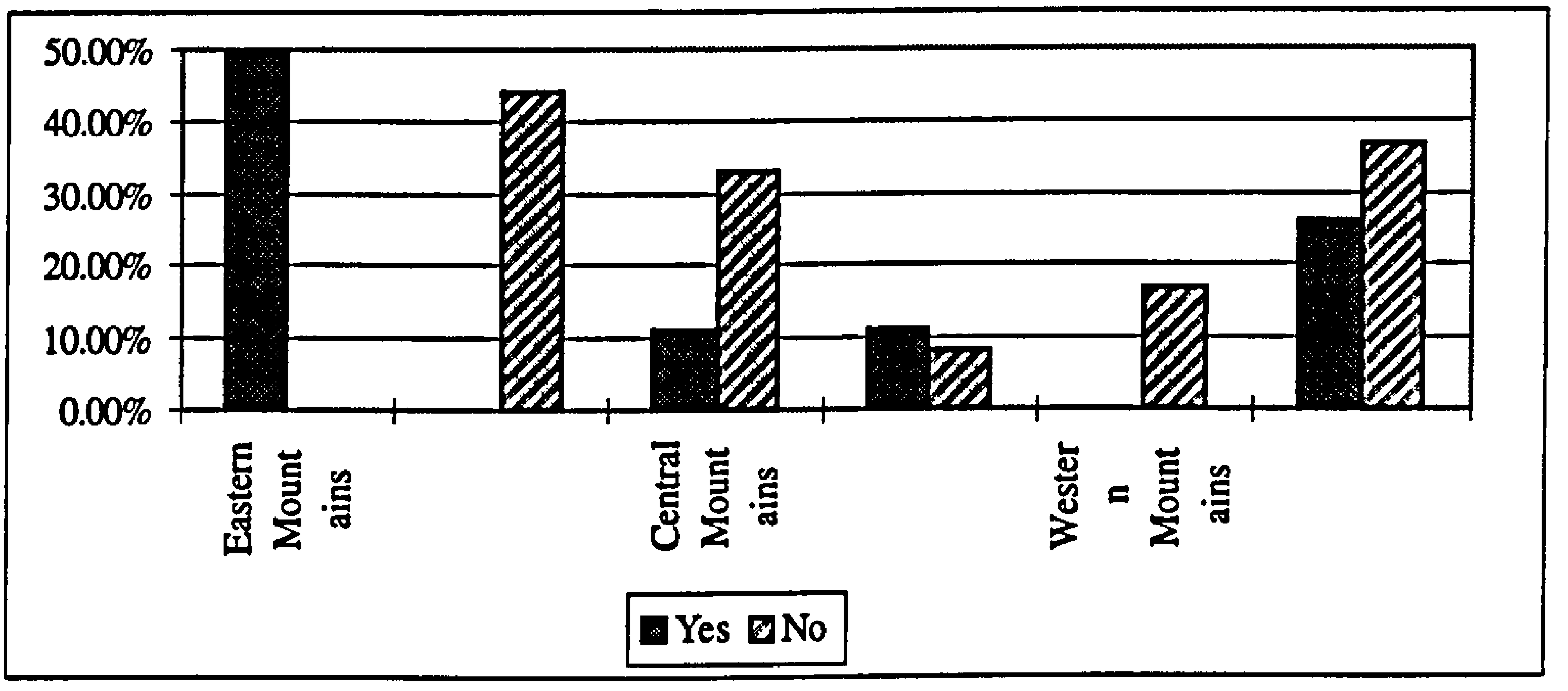
Fig. 3. 10: Management of Plants by Relation with the Manager



Source : Field Survey

The general qualification of the manpower engaged in the plants as well as that of the managers is presented in *Table 3.17.* It is evident from the study that the staff operating the plant do not have much training. The educational background of the plant operators varies considerably from plant to plant. Many of the operators of add-on plants, who also look after the mill operation, are illiterate or barely literate. Their competence seems to have developed, by and large, through instructions received from technicians installing the plant or attending it for repairs, from the owners, and mostly from experience of operating the plant itself. The capability to repair and maintain plants is generally poor.

Fig. 3. 11: Training of Managers



Source: Field Survey

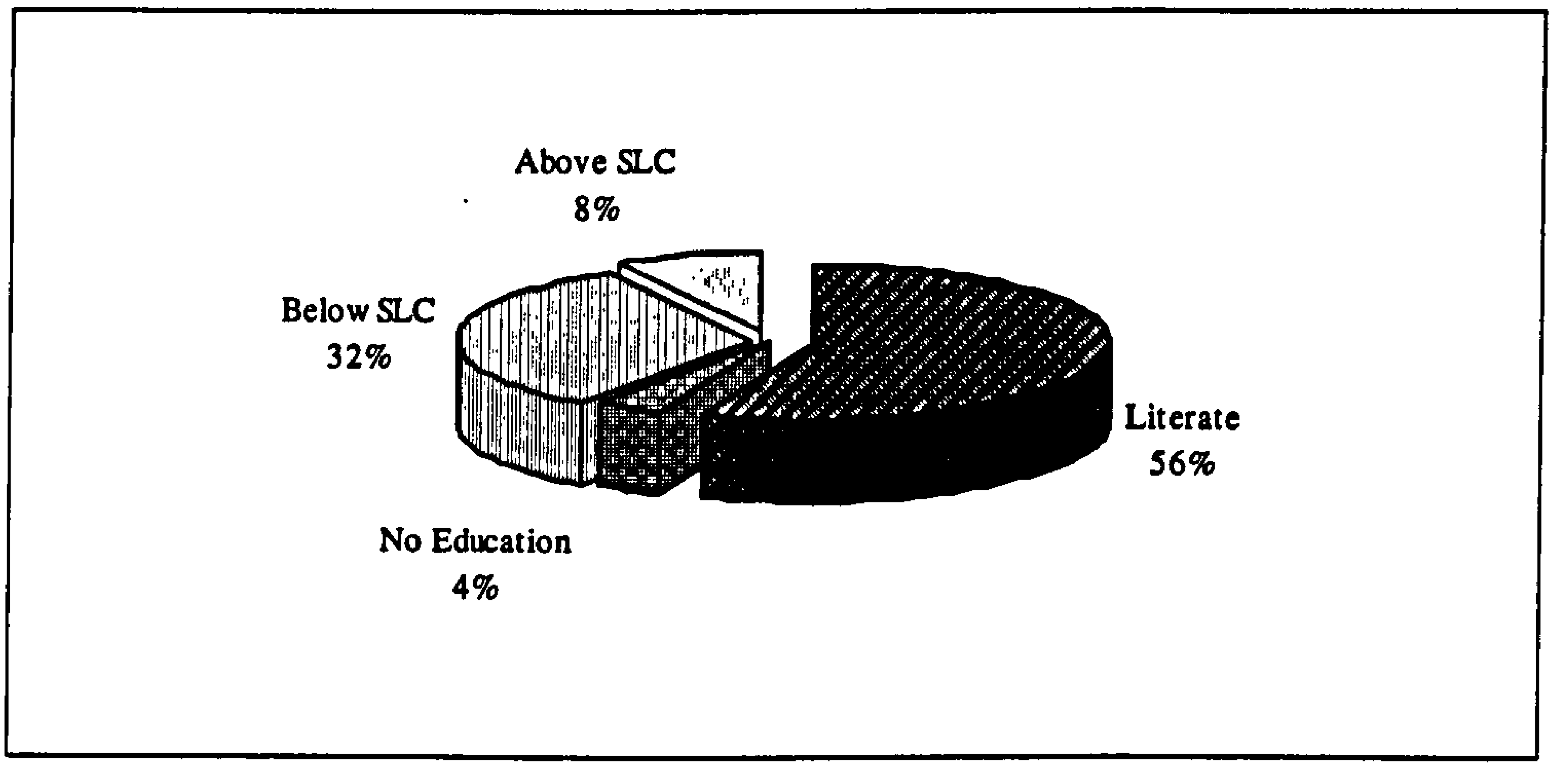
Table 3. 17: Characteristics of Plant Staff

Post	*Salary*	*Qualification*	*Duties*
Manager	-	School Leaving Certificate, SLC, (10 years of Schooling)	Plant Management, Administration, Financial and Technical
Operator	1200	Literate in Nepali, no formal training	Plant Operation and Minor Repairs
Lines-man	1050	Literate in Nepali, 1 months training	Supervision, Repair/Maintenance and Extension of Transmission and Distribution Line, New Consumer Connection
Helper	daily wages	Literate in Nepali, no formal training	New Consumer Connections, House Wiring, Maintenance and Repair, Services for Consumers, Distribution line Extension
Mill Operator	1200	Literate in Nepali, no formal training	Mill Operation
Accountant (part-time)	500	SLC	Book Keeping and Tariff Collection

Source: Field Survey

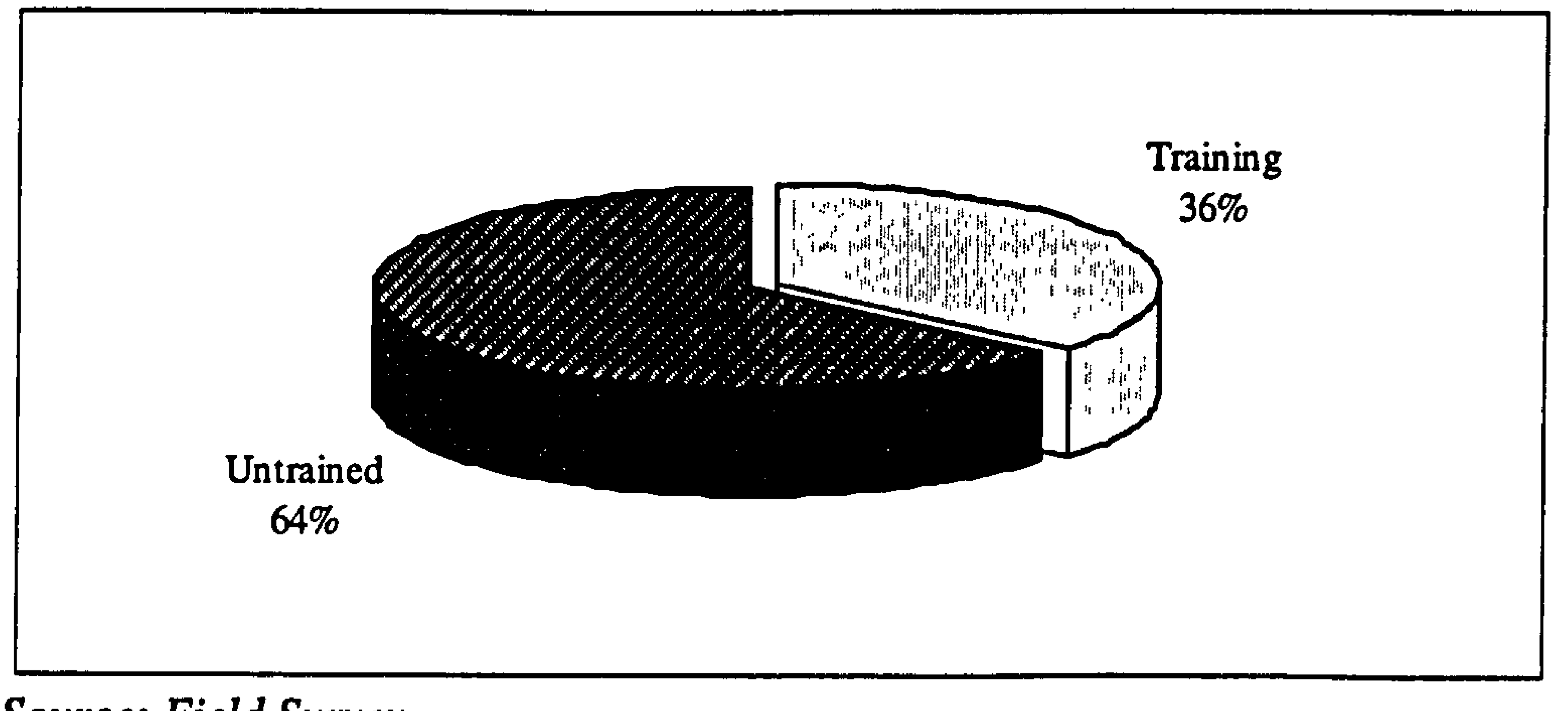
Fig. 3.12 presents the educational status of operators. The most qualified operator has completed only the School Leaving Certificate (SLC), a level of qualification found in only 8 percent of the plants. In most of the cases the only training acquired is through the manufacturer at the time of installation and this knowledge is passed on to succeeding operators. Entrepreneurs in Ghandruk, owned by retired British Gurkha Army personnel, have initiated training of the operators as well. However, the percentage of the trained operators is presently only 36 percent *(See Fig. 3.13)*.

Fig. 3. 12: Educational Status of Operators



Source: Field Survey

Fig. 3. 13: Training Status of Operators

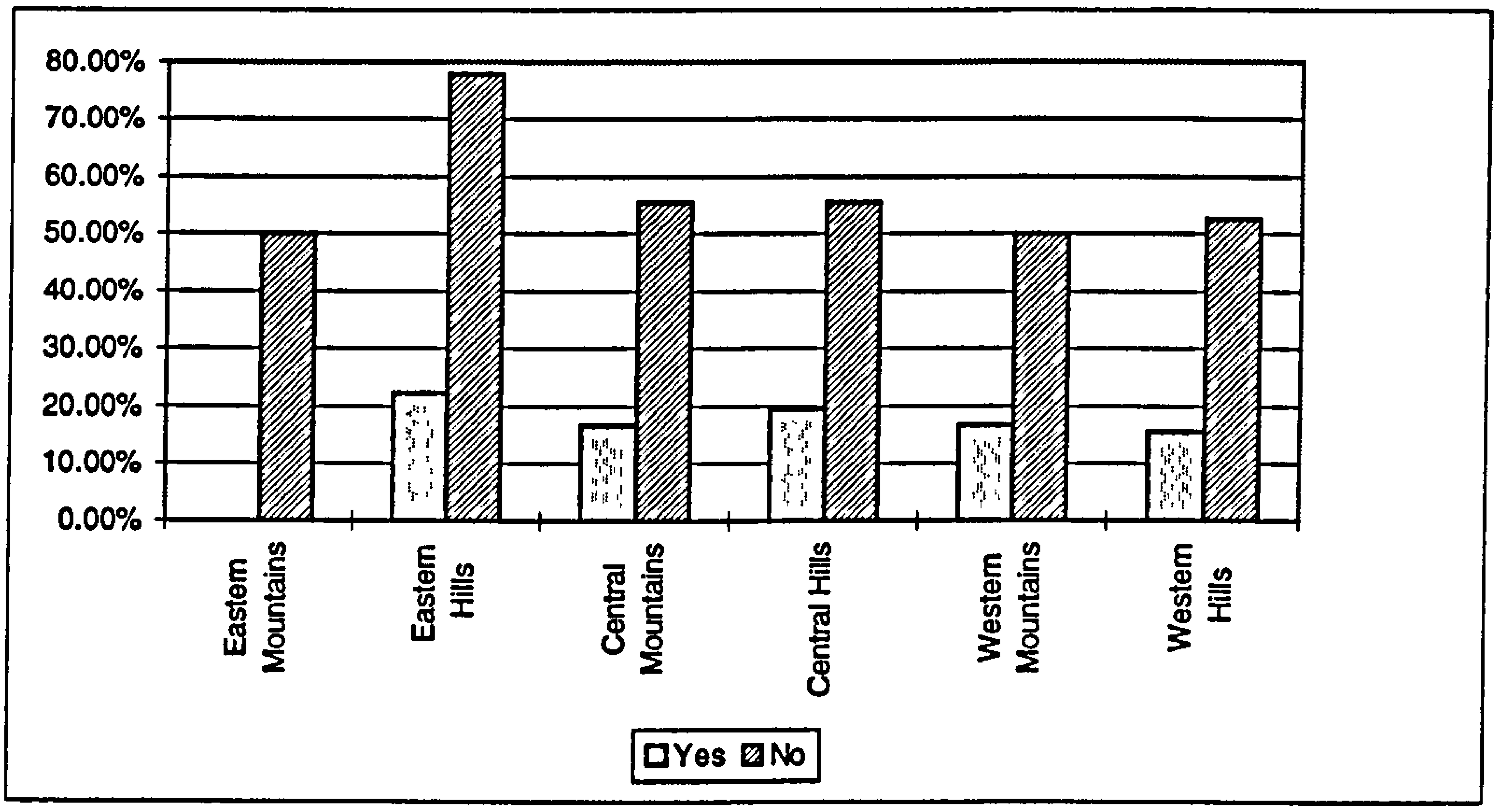


Source: Field Survey

78 percent of plants in the Eastern Region that were managed or run by hired operators has been described by their owners as satisfactory. This the owners have

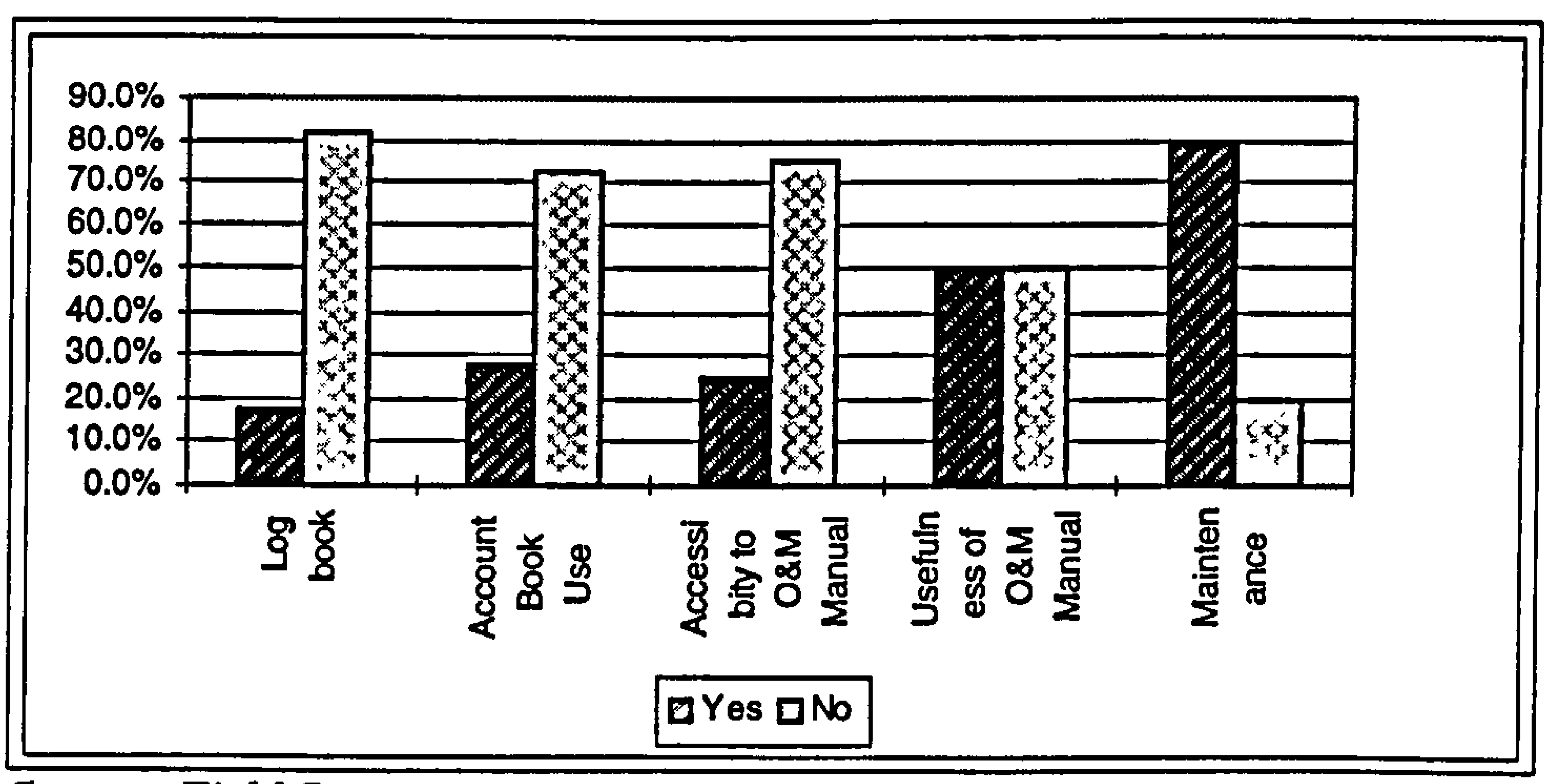
credited to the training imparted to them by the manufacturers at the time of installation. However, the field survey has found a larger percentage of dissatisfaction with the state of the plants.

Fig. 3. 14: Adequacy of Training of Operator by Region



Source: Field Study

Fig. 3. 15: Record Of Different Management Activities



Source: Field Survey

Of the 40 samples responding to this query only 15 percent maintained a log book for stock of the spare parts. The proportion of plants maintaining an account book was just 28 percent. Only 25 percent had access to the O&M manual although 50 percent regarded such information as useful. Regular maintenance was not regarded as of much importance; only 20 percent of plants actually carrying out a systematic maintenance program (*See Fig. 15).*

3.7 PROBLEMS AND CHALLENGES

The problems and challenges as encountered in mini-micro-hydro plant operations are discussed below under selected categories. The objective here is to analyse the nature and causes of problems experienced.

3.7.1 Competition

65 of the plants reported they were affected by competition from local ghattas, diesel mills or the national grid. The most severe competition is reported in the Central Hills and Western Hills regions. This has resulted in a decrease in market share leading to loss in income earnings; in some cases there has been complete closure.

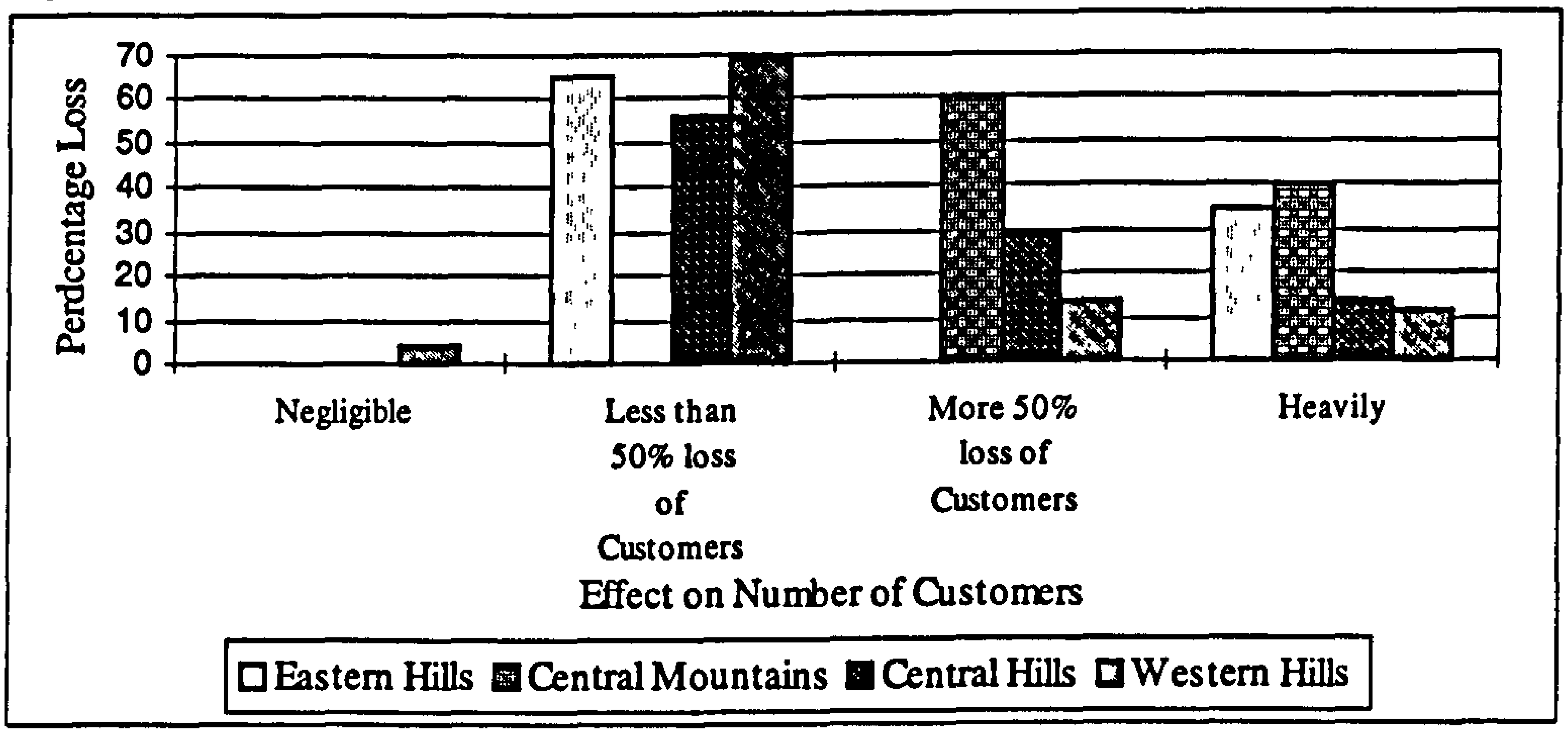
For this analysis plants whose operations are affected by the proximity of other plants in the neighbourhood are categorised in three groups according to the number of competing plants: less than four competitors, between four and eight competitors and more than eight competitors. Of the 65 MMHP plants, 23.08 percent of the plants had less than 4 competitors, 49.23 percent plants had between 4-8 competitors and 27.69 percent had more than eight competitors (*See Table 3.17).* The location of the competing plants varied from 2 to 3 hours walking distance. The impact is highest on the plants in the Central Hills where a loss of more than 50 percent has been encountered (*See Fig. 3.18*).

Table 3. 18: Status of Plants Facing Competition from Neighbouring Plants

Competitors	*< 4 Plants*	*>4 - 8 Plants*	*> 8 Plants*	*Total*
Eastern Mountains	1 (50%)	1 (50%)		2 (100%)
Eastern Hills	1 (33.33%)	2 (66.67%)		3 (100%)
Central Mountains	2 (40%)	1 (20%)	2 (40%)	5 (100%)
Central Hills	7 (21%)	18 (55%)	8 (24%)	33 (100%)
Western Mountains	2 (50%)	2 (50%)		4 (100%)
Western Hills	2 (11.12%)	8 (44.44%)	8 (44.44%)	18 (100%)
Total	15 (23.08%)	32 (49.23%)	18 (27.69%)	65 (100%)

Source: Field Survey

Fig. 3. 16: Extent of Effect by Existence of Other Mills



Source: Field Data

3.7.2 Technical

The technical problems identified are of two types, one related to lack of knowledge and the other to the hardware itself. The general problems in this category are:

1. shortage of water
2. bad installation
3. low-processing speed in the mills
4. generator problem
5. lack of technical knowledge, including inability to identify defects
6. damage of electrical components
7. leakage

More than 35 percent of respondents reported lack of technical knowledge as an impediment to their job, whereas 31 percent did not respond to the query on technical problems. The various types of technical problems revealed by the survey are presented in *Table 3.19.*

Table 3. 19: Types of Technical Problems Encountered

Types of Technical Problems	*Respondents*	
	Number	*Percentage*
Lack of Technical Knowledge	35	41.70
Water Shortage	5	5.95
Bad Installation	9	10.70
Defective machines	7	8.35
Lack of Technical Supervision	14	16.65
Others	4	4.75
No Problem	10	11.90
Total	84	100.00

Source: Field Survey

3.7.3 Management

Entrepreneurship and business management skills are obviously lacking in rural Nepal - a deficiency further compounded by the lack of technical knowledge. Very few managers have undergone any kind of training concerning business, management, supervision, operation, etc. Management is often not considered important by owners and is often confused with ownership. In the present survey, 36.67 percent (*See Table 3.20)* entrepreneurs felt that they have no managerial problems. For the rest, the following are some of the problems identified during the survey:

Table 3. 20: Managerial Problems

Description of Problem	*Respondent*	
	Number	Percentage
Lack of Managerial skill	23	25.55
Inadequate time for management	12	13.35
Lack of management guidelines/manuals	10	11.10
Lack of ability to deal with competitors	12	13.35
No Problem	33	36.65
Total	90	100.00

Source: Field Survey

3.7.4 Operation and Maintenance

Many MMHPs are facing operation and maintenance related problems, which have contributed to the increase in annual expenditure of MMHP and reduction in incomes. As reported by the respondents, the major problems are :

1. lack of training of operators
2. lack of ability to understand operating manual
3. low incentive to operators
4. frequent turnover of operators due to various reasons

Amongst these problems the lack of training has been reported by 42.85 percent of the plant owners (*See Table 3.21*). Similarly in the field of maintenance, problems encountered have been listed below:

Table 3. 21: Operations Problems

Description of Problem	*Respondent*	
	Number	*Percentage*
Lack of training to operators	36	42.85
Plant operation problem to damage of canal	8	9.50
Operation problems due to shortage of water in dry season	12	14.35
Others	5	5.95
No Problem	23	27.35
Total	84	100.0 0

Source: Field Survey

1. unavailability of repair workshop in the vicinity
2. lack of knowledge on minor repair activities
3. unavailability of skilled technicians
4. communication problem
5. lack of advice and training in the field of repair and maintenance
6. higher cost for repair and maintenance

Amongst these problems, the non-availability of a repair workshop in the vicinity was reported by more than 47.50 percent of the plant owners (*See Table 3.22*).

Table 3. 22: Repair Problems

Description of Problem	*Respondent*	
	Number	*Percentage*
Unavailability of repairing workshop in the vicinity	36	47.50
Lack of knowledge on repairing of the turbine	12	15.60
Need for Training on repair works	11	14.40
Others	9	11.30
No Problem	8	10.30
Total	76	100.00

Source: Field Survey

3.7.5 Financial

The major financial problems as identified by the entrepreneurs are as follows:

1. reduction in previous income due to competition
2. low tariff collection thereby leading to low income
3. lack of funds for repairs, business expansion, loan repayment etc.
4. very high interest rate for burrowing from private sector
5. lack of knowledge and difficulty in obtaining institutional loan
6. low risk bearing capacity of entrepreneurs

Amongst these, lack of funds for repairs and plant expansion was reported as the major problem by 45 percent and low earnings from plants was reported by 16.65 percent (*See Table 3.23*). The problem due to competition has not been highlighted here as it has already been dealt with separately earlier in the chapter.

Table 3. 23: Financial Problems

Description of Problem	*Respondent*	
	Number	*Percentage*
Lack of fund for repair and plant expansion	40	44.45
High rate of interest	5	5.55
Low earning from the plant	15	16.65
Problems associated with institutional loans	5	5.55
Problem of repayment	8	8.90
Others	6	6.65
No Problem	11	12.20
Total	90	100.00

Source: Field Survey

On the basis of information provided by the respondents and the observation of the field surveys, the problems identified have been selected according to the maximum percentage reported in each of the groups under which the specific problem is categorised for the survey. These problems have further been ranked (ascending order) according to the percentage recorded and presented below:

1. Loss of up to 50% customers due to competition form neighbouring plants;
2. Non-availability of repair and maintenance workshop and spare parts in the vicinity
3. Lack of fund for repair and plant expansion
4. Lack of operation and maintenance training to operators;
5. Lack of technical knowledge
6. Lack of managerial skill

3.8 CONCLUSION

The national scenario shows that there are more than 600 plants in the hilly and mountainous regions using cross-flow turbines. The sample plants, covering a wide area of the country and mostly located in isolated hill and mountain areas, indicate that more than 63 percent of plants are below the 10 kW capacity range. The 1980s witnessed widespread growth in the installation of the plants. This period also saw the installation of turbines of larger capacity. Plants providing agro-processing services are highly popular in these rural areas where the economy is mainly based on subsistence agriculture. The investment for these projects is dependent upon loans which run as high as 80 percent. The expansion of MMH plants in Nepal has been possible through the co-ordinated efforts of three main players, the manufacturers, rural entrepreneurs and the bank.

The supervision and management of the project is carried out by the entrepreneurs and the manufacturer. Site work and management is done by the entrepreneur. Construction of the foundation of the turbine and forebay tanks is supervised by the manufacturer. In the case of electrical schemes, setting up of the electrical portion is supervised by the manufacturer as well. The entrepreneurs are also engaged in arranging for the transportation of the equipment from the road-head. The feasibility test in most cases has been conducted by ADB/N with co-operation with the manufacturers, while the installation is carried out solely by the manufacturers.

The plants typically show low performance which is attributed to over-sized plant capacity, due to inflated estimation of demand for powering various services. The poor performance has obstructed the ability of the managers to convert potential demand into real end-uses and caused delays in repair and maintenance. The plants are operated mainly by staff who generally do not have much technical background and have only minimum education. Training at the time of installation is the only source of knowledge of the technology. The profitability of the plants has in some cases been seriously been affected by competing mills.

Factors which might affect the plants, such as water availability, have been neglected at the initial stage of development. Load survey, a critical part of MMHP survey, has not received due importance in current MMHP development. Assessment of possible end-uses, so that there are enough end-uses for diversification as well as high plant factor, has not been given sufficient attention at the planning stage.

It has been observed that some of the components which lead to added life of the plant and increased efficiency, such as the de-sanding basin and forebay, have in some places been either neglected or not given their due importance; although engineered structures such as these incur added cost they must be given due consideration. Reducing the cost of the structures should be measured against their necessity with respect to the size of the plant. Questions concerning use of traditional methods or the use of new techniques and their cost effectiveness and importance with respect to the size of the plant need more in-depth study; such considerations should be incorporated in the guidelines.

The de-sanding basin is an integral part of all run-off the river type of hydro-power plants and all MMHP belong to this type. However, none of the plants have a de-sanding basin. According to *Mr. A.M. Nakarmi*, the lack of a de-sanding basin in turbine mills has caused major erosion damage to penstock sand turbines. There are cases when penstock had to be changed within three years of their installation because of erosion. Likewise erosion of the turbine runner has resulted in a severe drop in efficiency.

The design practices followed for various civil structures require compilation and standardisation. The design practices vary from manufacturer to manufacturer and exact account of design methods currently adopted for MMHP is not available. Uniformity in design will facilitate project appraisal. The use of new materials in the canal lining and penstock, as well as for the turbine itself, needs immediate study in terms of cost and effectiveness.

Training is an important but neglected aspect of MMHP operations. Most of the training provided to the plant owner/operators is "on-the-job" training. In turbine mills, the installer demonstrates to the owner once the installation is completed how the turbine and milling machines work. In case of electrification schemes, the manufacturer demonstrates how the plant operates and points out the safety aspects of running the plant before handing over to the user.

With the prevailing level of competence of the operators it is difficult to expect the development of MMHP as a reliable source of energy such as to attract entrepreneurs to invest in different end-uses of electricity. The qualification requirements of the operators should be specified and even differentiated with respect to size of the plants. Further, the existence of the large number of plants justifies training being conducted on a regular basis. Preparation and introduction of operation manuals would make a valuable contribution.

The management, operation and maintenance have been weak links in the use of MMHP plants. The management has largely been *ad hoc*, unsystematic and inadequate thus leading to problems such as:

- waste of resources: loans, subsidy, effort and time
- inconvenience to users: could also mean customers going back to manual processing or travelling further to another mill. In cases of electricity generation, it might mean users returning to kerosene or even resinous wood for lighting as well as damage of the electrical fittings
- over and above these problems a bad name is earned for the technology

The ability to carry out major repair of the MMHP plants, especially in remote areas, is severely limited due to lack of workshop facilities, skilled personnel and transportation problems. This means that when a major repair is required, a plant has to refer to workshops in the major cities (Kathmandu and Butwal) which are far distant and may involve several days of walking to a main road for proper transportation. This means prolonged plant closure i.e. high downtime.

To enhance maintenance capability of plant staff and entrepreneurs, regular training ought to be supplemented by the preparation of manuals and guides to instruct in the repair of minor breakdowns. A commendable effort made by DCS in this sector has been the establishment of service centres in remote areas. This move has been ugmented through inputs from various parties concerned in setting up a national network of service centres equipped with expertise and spare parts.

CHAPTER - 4

MINI-MICRO-HYDRO PLANTS: FINANCIAL AND ECONOMIC VIABILITY

4.1 INTRODUCTION

This chapter focuses on the financial and economic (private and social) viability of mini-micro-hydro plants installed in various regions[1] of the country. Section 4.2 describes a financial appraisal made of the viability of mini-micro-hydro installations in Nepal. The financial returns yielded by these plants are reported with respect to location, end-use, capacity utilisation and the existence of competing plants. The next section, 4.3, highlighting the distinction between financial (private or commercial) returns, identifies intangible and external benefits and provides an analysis of the economic viability of the mini-micro-hydro plants. A comparison is made of the financial and economic returns these plants yield. Section 4.4 compares, in respect of costs and returns, the mini-micro hydro plants against larger scale hydro-installations and other alternative energy technologies. A summing-up in section 4.5 concludes the chapter.

4.2 FINANCIAL APPRAISAL

The assessment of financial viability has been conducted using a simple discount cash flow method. Using the information on financial analysis as a basis the economic analysis has been carried out with reference to works of *Little and Mirrlees* (1974), *Squire and Van der Tak* (1975), UNIDO (1972), *Sell* (1991), *Curry and Weiss*

1 The regions here follows the same categorisation as in the field survey, Chapter 5

(1993) and *Clunies-Ross and Huq* (*1997*). All calculations concerning financial and economic assessment have been made using constant prices (1995/96 prices).

4.2.1 Methodology

The discount cash flow method is a common technique employed to take account, in the evaluation of costs and benefits, of the time dimension. All expenditures and receipts which occur at different times throughout the life of the project are all re-valued to make them comparable to present expenditure and receipts. The analysis can be carried out using three main decision rules: net present value criterion (NPV); internal rate of return criterion (IRR) and benefit - cost ratio criterion (B/C). The NPV takes a sum receivable in the future and looks backwards, discounted to the present time to ascertain how the original sum would have grown to the future value. The difference between discounted benefit and discounted cost is known as the Net Present Value of a project.[2] It is formally represented as

$$NPV = \sum_{t=0}^{n} \frac{B(t)}{(1+d)(t)} - \sum_{t=0}^{n} \frac{C(t)}{(1+d)(t)} - I \quad \text{.........} \quad (1)$$

$$NPV = \sum_{t=0}^{n} \frac{B(t)-C(t)}{(1+d)(t)} - I \quad \text{.........} \quad (2)$$

Where:

NPV = Net Present Value of the mini-micro-hydro plant

$\sum_{t=0}^{n}$ = Summation over the years

$B_{(t)}$ = Total Benefits in year t

$C_{(t)}$ = Total Costs in year t

d = Discount Rate

n = Life of the project in years

2. See Curry, S. and J. Weiss (1993), "Project Analysis in Developing Countries" for details. Also see M. G. Wight (1973).

I = Initial cost of the investment and is discounted where appropriate

NPV analysis is the most commonly used method of appraisal of investment in physical assets. It is easy to understand and to apply, is convincing and practical, and easily supports discussions even among those with little background in investment analysis. On the other hand it is weak in its treatment of information, uncertainties and risk involved due to the deterministic nature of cash-flow, assumed for simplicity. This later difficulty can however, be overcome through the use of sensitivity analysis (*Sugden and Williams, 1978*) which identifies and evaluates as far as possible the relative importance of the various items entering the cost-benefit system (*ODA, 1988, pp.76*). Accounting for risks due to unforeseen technical or operational causes on the other hand is normally done by adding a "risk premium" to the discount rate (*Sugden and Williams, 1978, pp.60*).

Assumptions Used

For computations of financial feasibility the following assumptions have been used:

1. discount rate is taken as - 10 percent
2. life span of the plants - 15 years has been used for the analysis of mini-micro-hydro plants
3. in case of comparisons carried out with diesel and solar photovoltaic technologies too the life span considered is 15 years; the effect of overhauls and major replacements have been considered as and when required

The financial appraisal parameters for this study are represented as:

FNPV - Financial Net Present Value
FIRR - Financial Internal rate of Return
FB/C - Financial Benefit - Cost Ratio

4.2.2 Financial Analysis: Costs and Returns

The data for these costs have been collected through interview and using the questionnaire described in Chapter 3 (also *See Annex-3A*). As noted in Chapter 3, the lack of record-keeping by the plant operators made it necessary in most cases to accept only approximate values as provided by the plant owners or managers.

Fixed Costs

The fixed cost includes the cost of equipment and cost of construction. The equipment cost was re-confirmed with the manufacturers as and where possible. The equipment cost is inclusive of the penstock pipe and the primary spares, engineering design, supervision and commissioning. However, as disaggregated information is not available, the cost as presented in this study reflects all the above costs as lump sum. Most of the plants constructed an open intake channel using locally available stones on mud-mortar. A more permanent section of the structure was found at the turbine end for its foundation as well as for the prevention of debris from flowing into the turbine. Local labour, mainly unskilled, was engaged for this work. The cost of this labour in some cases was not available as the mode of payment in these rural areas rests on payment-in-kind as well as a combination of kind and money, which is un-quantifiable. In these cases the cost in other plants in the same area had to be used instead.

Land used for the plant installation has often been recorded as private land and the service-station, the station for providing various agro-processing services, forms a part of the residence. It is land which would have remained idle or might have been used for seasonal storage of agricultural goods or for cattle-stables. In some cases the land was provided by the village community. In the present study, following the discussions with relevant persons working in this area, ITDG/N, ICIMOD, WECS, as well as the owners themselves, the cost of land has been neglected[3]. *Table 4.2* presents the installation scenario of the plants with respect to the period of installation.

Table 4. 1: Installation Scenario

Year	*Average Capacity*	*Average Installation Cost*	*Average Loan*	*Range of Investment*	
	kW	NRs	%	Lowest	Highest
1977-1980	10.14	157178.75	66.68%	54.85%	75.00%
1981-1985	11.60	220252.67	68.35%	29.59%	94.46%
1986-1990	11.19	297527.92	68.35%	38.04%	90.00%
1991-1995	7.25	351164.73	60.31%	0.00%	91.45%

Source: Computed from Survey Data

Subsidy on the cost of electricity generating components of MMHP projects has been included in the financial appraisal. In accounting for this subsidy the analysis has adhered to the existing subsidy policy of the government, which is: 50% subsidy on electrical components for projects in rural areas and 75% subsidy on electrical components for areas in remote areas.

Operating Costs

The operating cost is comprised mainly of the operators' salary, administrative overheads and items required for repair and maintenance. The operators' salary on an average is about NRs. 1000 per month, although there are some disparities from plant to plant. This is due to the fact that the operators are in some cases living with the owner who is providing for their lodging and food as well.

As observed from the survey there is typically a failure to maintain an inventory of spare parts. This affects the cost of repair and maintenance. In this study the repair and maintenance cost includes the cost of travel to the nearest town, often a day or two away. This forms a substantial element of the repair and maintenance cost.

3 This also follows the assumptions made in the development of national conversion factors by National Planning Commission, Nepal for energy technologies such as mini-micro hydro, solar photovoltaic, diesel and bio-gas.

Project Revenues

The source of annual revenues is from the sale of the motive-power from MMHP for agro-processing services, the operation of small scale industrial activities such as saw-milling, paper-making, bakery, ice-making, battery charging and from the sales of electricity generated from the plants for operating domestic appliance. To maintain comparability in the results, only the revenue earned in the past 12 months prior to the date of interview has been used. Results arising due to exceptional conditions in the season, creating either soaring benefits or otherwise, have been neglected.

Income from agro-processing forms a major source of revenue. Grinders and rice-hullers were found very popular with the entrepreneurs included in the sample study. Providing electricity for domestic lighting alone, was however, not a favourable proposition for most of the plants. The cost of the project, along with the revenues are presented in *Annex -4A*.

4.2.3 Financial Analysis: Result of Plants Providing Multiple Services

Analysis with Respect to Location

The inaccessibility of different parts of the country forms a major problem in programme implementation. In case of mini-micro-hydro projects it is realised that the cost of the plants is high due to cost of transportation in terms of time consumed in transporting the goods required for the project. One measurement is the distance from the supplier-point to the site. This forms the bench-mark for the study. The suppliers in our study are the manufacturers themselves. As stated earlier, the manufacturers are established in two major cities of the country, Kathmandu and Butwal, which are situated in the central region.

The results thus obtained have been ranked - grading rising with profitability - as shown in *Table 4.3* The ranking with respect to NPV alone is not deterministic and hence a cumulative ranking using IRR and benefit cost ratios has been used in this study. The results of the analysis is presented in *Table 4.4*

Table 4. 2: Ranking of the Results of Plants by Location

Regions	*FNPV*	*FIRR*	*FB/C*	*Ranking*
Eastern Mountains	1	1	1	1
Western Mountains	1	2	2	2
Western Hills	2	4	4	3
Central Mountains	3	3	3	3
Central Hills	4	5	5	5
Eastern Hills	5	6	6	6

Source: Field Survey

The ranking obtained from FNPV, FIRR and FB/C indicate the plants in the Eastern Hills, with a positive average FNPV and average FIRR of 14.21 percent, to be the most profitable. These are followed by the plants in the Central Hills with a positive average FNPV and average FIRR of 13.53 percent. The plants in the Central Mountains and Western Hills also have positive average FNPV and FIRR of 10.95 percent and 12.08 percent respectively. Only the plants in the Western and Eastern Mountains show negative FNPV; but the plants in the Western Mountains have average FIRR of 6.8 percent, whereas the plants in the Eastern Mountains have (minus) 3.34 percent. Only the plants in these two regions have FB/C lower than the acceptable value of 1, while all the others have average FB/C above 1. Road network is concentrated only in the south and mid-belt of the country (*See Map 3.1*), whereas most rural areas are accessed by foot-trail although considerable part of the rural areas are covered by STOL[4] airports (*See Map 4.1*). In contrast to this infrastructure, the plants on the mountain regions, where the sites are accessible only on foot are less profitable than those in the hills.

4 STOL is the term used for airports providing short take-off and landing facilities.

Table 4. 3: Results of Analysis of the Plants with Respect to Location

	Average FNPV in NRs.	*Average FIRR in %*	*Average FB/C*
Eastern Mountains	-405623	-3.34%	0.61
Western Mountains	-263739	6.80%	0.92
Western Hills	13272	12.08%	1.06
Central Mountains	32495	10.95%	1.04
Central Hills	47247	13.53%	1.09
Eastern Hills	103424	14.21%	1.11

Source: Computed from Survey Data

Analysis with Respect to End Uses

The performance of the plants with respect to end-uses is ranked and presented below in *Table 4.5*. Providing multiple services is observed to be a common practice. In regions where mustard is grown, there is a major contribution to the revenue from the use of oil-expellors; these are very popular in the regions growing a large quantity of mustard. The job which otherwise depended exclusively on manual labour is now eased by the availability of motive power.

Table 4. 4: Ranking of Plants By Services Provided

End Use	*FNPV.*	*FIRR*	*FB/C*	*Ranking*
GR	6	10	11	9
GRE	4	9	10	8
G ROE	5	8	9	7
ROE	3	5	6	5
GO	1	7	7	5
GRO	2	6	8	5
RO	1	5	5	4
GOE	1	4	4	3
GROE+	1	3	2	2
E	1	2	3	2
GE	1	1	1	1

NOTE: G - Grinder; R - Rice-Huller; O - Oil Expeller; E - Electricity; + - additional services

Source: Computed From Field Survey

Table 4. 5: NPV Results of Plants Providing Different Services

End-Use	*Average FNPV in NRs.*	*Average FIRR in %*	*Average FB/C*	*Ranking*
GR	181325.08	23.09%	1.35	9
GRE	49580.75	15.18%	1.16	8
G ROE	106707.93	13.58%	1.08	7
GO	-159056.69	12.82%	1.04	5
GRO	22189.76	11.93%	1.05	5
R OE	31065.01	10.21%	1.03	5
RO	-15407.39	10.19%	1.02	4
GOE	-34340.70	8.12%	0.94	3
GROE+	-194150.13	6.59%	0.89	2
E	-24388.43	4.41%	0.91	2
GE	-945656.12	1.94%	0.79	1

Source: Computed From Field Survey

The plants operating grinding mills and rice-hullers prove to be the most profitable installations, yielding a FIRR of 23.09 percent; this reflects the fact that these plants are operating in rice-growing areas in which rice is the staple food and these equipment also incur comparatively low initial investment. The combination of grinding and rice-huller with electricity generation proves feasible and has a positive average FNPV and a FIRR of 15.18 percent. Oil-expelling with grinding, rice-huller and electricity also proves to be a good business with a positive average FNPV and average FIRR of 13.58 percent. Similar is the case with plants providing oil-expelling together with grinder and rice-huller service with positive average FNPV and average FIRR of 11.93 percent. The performance of plants providing electricity with oil-expellor and rice-huller service also have positive average FNPV and average FIRR of 10.21 percent. The negative average FNPV of plants providing grinding and oil-expelling service is difficult to explain due to the small number of samples in the study. These plants have an average FIRR of 12.82 percent.

The low returns from plants providing electricity alone is attributed to three major reasons: (i) the number of customers is less than had been expected or estimated for the plant, (ii) the introduction of the national grid has led customers to switch over to the grid, as is the case with several plants in Dhading district, and (iii) limited use is made of electricity i.e. for domestic lighting only. The low performance of the plants providing electricity with grinding, electricity with grinding, rice-hulling, oil-expelling as well as other additional services and electricity with grinding and oil-expelling is mainly due to the high initial investment in the installation of the service equipment and an inability to perform multiple services simultaneously. These plants not only have negative average FNPV but also have average FIRR less than 10 percent and average FB/C less than the acceptable value of 1. *(See Table 4.6)*

Besides the services provided, the operating practices[5] also influence the rate of success of the plants. The rate of return for those plants which operate only one equipment at a time is evidently relatively low; an ability to operate several devices at one time is also seen to increase benefits from the plants.

The success of the mills operating only two agro-processing devices *(See Table 4.7)* supports the thesis that the lower rate of revenue in the plants having larger number of end-use devices is due to the initial high investment. The inability of the large size plants to operate larger number of devices is attributed to mis-planning as well as faults at the design stage.

Table 4. 6: Financial Performance with Respect to Type of Operation

Operating Practice	*Services Rendered*	*FNPV in NRs.*	*FIRR in %*
Double Load	R, G	306248.18	13.34
	R, O	75880.62	14.22
Multiple Load		21753.90	7.02
	R, G, O	255131.77	12.45
	R, G, O,E	216743.30	10.45
	R, O, E	18758.46	12.35
Single Load		-590.88	10.98

NOTE: G - Grinder; R - Rice-Huller; O - Oil Expeller; E - Electricity;
Source: Computed From Field Survey

Successes and failures of the plants with respect to services and location are reported in *Annex 4.D* . Analysed on the basis of FNPV, FIRR and FB/C, it is obvious that the plants providing only electricity are not profitable in either the Central Hills or the

5 Operation practices here is defined as the operation of number of end-use equipment in combination at one time.

Central Mountains. The plants providing electricity with grinding and with grinding and rice-huller fail to perform profitably in the Western Mountains. Providing electricity with oil-expellor and agro-processing equipment proved successful in Western Hills, Central Hills and Eastern Hills but not so in the case of Central Mountains and Western Hills. The provision of additional services in all three regions i.e. Central Mountains, Eastern Hills and Eastern Mountains does not meet the required profitability target. The reasons for failure have already been discussed earlier on in this chapter.

Analysis with Respect to Presence of Other Plants in the Vicinity

The presence of other plants in the vicinity creates competition with customers moving from one plant to another. 65 plants responded to questions regarding the influence from competing plants. The analysis of the effects of competing plants is presented in *Table 4.8.*

The situation with respect to the number of competing plants has been categorised into three groups according to presence of <4, 4-8 and >8 competitors. It is obvious that the degree of competition rises with the number of plants in the vicinity. In the Central Hills there is a drop in the average FNPV, although it is positive, for the plants having eight competitors. The average FIRR is 16.02 percent for plants having less than four competitors, 14.96 percent for plants having between four to eight competitors and 11.95 percent for plants having more than eight competitors. In this region the average benefit-cost ratio of all these plants remains above unity. Similarly in the Central Mountains, the average FNPV is positive for plants facing competition from less than four plants but is negative for both remaining categories. The average FIRR drops from 12.94 percent to 4.32 percent and 1.85 percent as the number of competing plants increases from less than four to between four and eight plants and more than eight plants respectively. Here the benefit-cost ratio is above unity only for plants having less than four competitors. For the remaining two categories the benefit-cost ratio drops to below unity.

Table 4. 7: NPV Analysis with Respect to Competing Plants in the Vicinity

Regions	*Number of Competing Plants*		
	<4	4-8	>8
Central Hills			
FNPV in NRs.	124455.29	59922.29	30837.45
FIRR in %	16.02%	14.96%	11.95%
FB/C	1.15	1.11	1.05
Central Mountains			
FNPV in NRs.	30770.61	-54719.97	-293281.24
FIRR in %	12.94%	4.32%	1.85%
FB/C	1.07	0.88	0.84
Eastern Hills			
FNPV in NRs.	63520.39	13037.38	
FIRR in %	16.37%	9.82%	
FB/C	1.12	0.97	
Eastern Mountains			
FNPV in NRs.	-666454.19		
FIRR in %	-2.81%		
FB/C	0.66		
Western Hills			
FNPV in NRs.	77893.64.	5630.49	8883.75%
FIRR in %	16.04%	11.19%	10.66%
FB/C	1.17	1.03	1.02
Western Mountains			
FNPV in NRs.	-42014.49	-29343.25	
FIRR in %	8.54%	7.33%	
FB/C	0.96	0.92	

Source: Computed from Field Survey

In the Eastern Hills the average FNPV is positive for plants having less than four competitors as well as for those having between four and eight competitors. The average FIRR for plants having less than four competitors is 16.37 percent and the benefit-cost ratio is also above unity. The plants having between four and eight competitors have an average negative FNPV and an FIRR of 9.82 percent and the benefit-cost ratio remains less than unity. In the Eastern Mountains, however, the plants are not able to withstand any competition. The average FNPV is negative, FIRR is (minus) 2.81 percent and the benefit-cost ratio is also below unity.

The plants in the Western Hills indicate an ability to withstand competition in all three categories. They have an average positive FNPV and an average FIRR of 16.04 percent in the category of less than four competitors; an average positive FNPV and average FIRR of 11.19 percent in the category facing competition from between four and eight competitors; an average positive FNPV, an average FIRR of 10.66 percent and an average FB/C above 1, for plants competing with more than 8 plants. The plants in the Western Mountains are sensitive to competition from the neighbouring plants. Plants facing competition from less than four competitors as well as between four and eight plants have negative average FNPV, the average FIRR for these two categories are 8.54 percent and 7.33 percent respectively and the average FB/C is less than 1 in both the cases.

4.2.4 Financial Analysis: Stand - Alone Plants

A supplementary analysis of stand-alone electricity generating plants has been conducted using other data - secondary data provided by the Water and Energy Commission, Nepal (WEC) - relating to a different sample of plants. This sample is derived from a study carried out by the WEC and United Nations Development Programme (UNDP) to assess feasible sites in 25 districts of Nepal. The data was gathered by the WEC during the period 1991-1995.

Using this data, the cost of energy (NRs./kWh) with respect to various generating capacities and plant factors has been computed (*See Table 4.9*). The financial performance of plants at different plant factors has also been estimated (*See Table 4.10)*. A further calculation determines the tariffs which the several plants would each have to charge to make a return of around 17 percent on capital invested (*See Table 4.11*). A criterion of 17% has been selected so as to assess the plants' ability to meet the prevailing interest rates for these projects in Nepal. These investigations are discussed more fully in the following sections.

Stand-Alone Plants: Generating Costs

The costs of electricity generation of the WEC sample plants were calculated for different plant capacities and for operation at various levels of utilisation (plant factor).

The generation cost based on annual cost of the project is computed using the following equation:

$$C\,Energy = \frac{IA + (O\ \&\ M)}{C\ \ x\ T\ x\ PF} \qquad \text{..........} \qquad (3)$$

Where

C_{Energy} = Cost of generation energy measured in NRs. per kWh

I_A = Annuity cost of Initial Investment Measured in NRs.

O&M = Annual Operation and Maintenance cost measured in NRs.

T = Number of operating hours measured in NRs.

PF = Plant Factor

The annuity cost of investment in turn is computed from the following equation

$$Annual\ Cost\ of\ Investment\ = I\,x\,\frac{r(1+r)^{n}}{(1+r)^{n-1}} \qquad \text{..........} \qquad (4)$$

Where

I = Initial Investment

r = discount rate

n = number of years of operation

Table 4. 8: Generation Cost at Various Plant Factors in NRs.

Capacity kW	*Plant Factors* 10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
5	21.29	10.64	7.10	5.32	4.26	3.55	3.04	2.66	2.37	2.13
10	10.58	5.29	3.53	2.65	2.12	1.76	1.51	1.32	1.18	1.06
15	7.05	3.53	2.35	1.76	1.41	1.18	1.01	0.88	0.78	0.71
20	5.29	2.65	1.76	1.32	1.06	0.88	0.76	0.66	0.59	0.53
25	4.13	2.07	1.38	1.03	0.83	0.69	0.59	0.52	0.46	0.41
35	3.04	1.52	1.01	0.76	0.61	0.51	0.43	0.38	0.34	0.30
36	2.93	1.46	0.98	0.73	0.59	0.49	0.42	0.37	0.33	0.29
38	2.75	1.37	0.92	0.69	0.55	0.46	0.39	0.34	0.31	0.27
68	1.57	0.78	0.52	0.39	0.31	0.26	0.22	0.20	0.17	0.16
Average Cost NRs/kWh	6.51	3.26	2.17	1.63	1.30	1.09	0.93	0.81	0.73	0.65

Source: Computed from Secondary Data Provided by WECS, 1995

The results are shown in *Table 4.9.* In keeping with the assumptions made by the WEC in their study, a 60% plant factor is taken as the criterion of efficient capacity utilisation. It will be seen from the Table that the average cost of energy, across plants of different sizes, at this plant factor is NRs. 1.09 per kW. But for the purpose of the present study the actual cost of generation, allowing for inclusion of costs for transmission, electrical connections and overhead costs, is taken to be NRs. 2 per kW.

Stand-Alone Plants: Plant Factor And FIRR

On the basis of this estimate of energy cost of NRs. 2 per kWh distributed, the impact of plant factor on its profitability is determined using FIRR as the main criterion. The results are shown in *Table 4.10.*

Table 4. 9: Financial Performance of the Plants at Various Plant Factors

Location	*30%*	*40%*	*50%*	*60%*	*70%*	*80%*	*90%*	*100%*
	IRR %	IRR %	IRR %	IRR %	IRR %	IRR %	IRR %	IRR %
Baitadi	-8.82	-3.57	0.44	3.83	6.84	9.60	12.19	14.65
Bhojpur	-8.14	-2.92	1.11	4.52	7.57	10.38	13.02	15.53
Dadeldhura	-0.21	5.16	9.70	13.79	17.60	21.23	24.74	28.16
Dailekh	-7.94	-2.73	1.30	4.72	7.79	10.61	13.26	15.79
Darchula	4.04	9.84	14.92	19.60	24.06	28.37	32.58	36.73
Dhankuta	-	-4.30	-0.30	3.06	6.02	8.74	11.27	13.68
Gulmi	-1.06	4.26	8.71	12.70	16.40	19.92	23.30	26.59
Jajarkot	-	-7.05	-3.02	0.26	3.10	5.67	8.03	10.26
Khotang	-	-3.81	0.20	3.57	6.57	9.31	11.88	14.32
Lamjung	1.89	7.44	12.23	16.59	20.69	24.64	28.47	32.22
Okhaldhunga	-	-	-8.28	-4.94	-2.18	0.22	2.38	4.37
Palpa	-12.78	-7.11	-3.08	0.20	3.04	5.60	7.97	10.19
Panchthar	-4.65	0.52	4.69	8.34	11.65	14.75	17.70	20.55
Pyuthan	-3.47	1.73	5.98	9.72	13.15	16.37	19.45	22.43
Ramechap	-	-	-7.08	-3.78	-1.02	1.40	3.60	5.63
Sankhuwasabha	-	-	-5.80	-2.53	0.24	2.70	4.94	7.02
Sindhupalchowk	-	-7.65	-3.60	-0.33	2.49	5.03	7.37	9.56
Taplejung	-	-	-5.03	-1.76	1.02	3.51	5.78	7.89
Tehrathum	-	-5.34	-1.34	1.98	4.89	7.54	10.01	12.34

Source: Computed from Secondary Data Provided by WECS, 1995

It is clear from *Table* 4.10 that the plants providing electricity alone are not profitable when operating at 30 to 40 percent plant factor. A net gain emerges only when operating with a plant factor approaching 60 percent. Even at 60 percent PF only 20 percent of the plants have an acceptable FIRR above 10 percent; at 70 percent PF the proportion rises to 30 percent and at 80 percent PF to 40 percent. At 90 percent PF and 100 percent PF the proportion of plants yielding over 10 percent returns becomes 60 and 80 percent respectively. Even at 100 percent PF only 30 percent of the plants will be able to pay for a loan at 17 percent interest.

Stand-Alone Plants: Required Tariff Rates At 60 Percent Plant Factor

Having analysed the effect of PF variations on plant profitability, the optimum tariff of the plants when operating at 60 percent PF is now examined. The tariff rates that would have to be charged to cover costs at that PF are shown in *Table 4.11.* From the Table it is evident that the required tariff (NRs per kWh), differing from plant to plant, varies between NRs.1.25 and NRs 4.5. The selection criteria here is for plants yielding FIRR above 17 percent.

Table 4. 10: Estimated Tariff Rate per Energy at 60 Percent Plant Factor

Plant Location	*Assumed Cost NRs./kWh*	*FNPV in NRs.*	*FIRR in %*	*FB/C*
Baitadi	4.5	433693	17.59	1.52
Bhojpur	2.5	605957	17.45	1.75
Dadeldhura	1.5	323915	18.43	1.63
Dailekh	2.25	508858	18.82	1.59
Darchula	1.25	343138	18.74	1.71
Dhankuta	2.25	343043	16.54	1.46
Gulmi	1.5	291422	18.18	1.55
Jajarkot	2.25	473242	17.80	1.53
Khotang	2.25	398082	17.24	1.50
Lamjung	1.25	241992	17.63	1.52
Okhaldhunga	3.5	572800	16.56	1.46
Palpa	2.75	536732	17.72	1.53
Panchthar	1.75	355073	16.98	1.48
Pyuthan	1.75	391526	18.69	1.58
Ramechap	3.5	717176	18.23	1.56
Sankhuwasabha	3	415190	16.07	1.43
Sindhupalchowk	2.75	542696	16.96	1.48
Taplejung	3	525824	17.15	1.49
Tehrathum	2.5	485446	17.76	1.53

Source: Computed from Field Survey

The existing tariff rate of Nepal Electricity Authority, which is the sole distributor of national-grid electricity, varies from NRs. 3.00 to NRs. 7.75 per kWh[6] for domestic consumption. Comparison of the tariff rate of energy from these hydro plants of differing scales indicate that the tariff rate of MMHP is very competitive.

4.2.5 Results of Financial Analysis

The financial analysis of performance - actual and potential - of both sets of sample plants (the sample surveyed at first-hand for this study, and the sample of stand- alone plants from the WEC investigation) draw attention to several points of interest.
The financial performance of the plants is affected by their location as is indicated by the better results recorded for plants in hill areas as compared with those for plants in the mountain regions. Other factors affecting performance are the nature of operations carried out - whether or not more than one item of equipment is driven by the turbine; plants able to operate multiple services simultaneously are evidently more profitable. Grinding is apparently the most profitable end-use; to determine the optimal combination of end-uses however would require further study. The degree of utilisation of capacity - plant factor - has a highly important influence on unit costs and profitability of operations. The existence of neighbouring plants can adversely affect profitability; the impact of such competition is found to be greater in the mountain regions where plants are not to withstand competition even from four rivals.

A particularly significant finding is that stand-alone electricity generating plants fail to meet the required criteria. Of the 90 plants investigated at first-hand for this study, only two were stand-alone electricity generating units, and neither appeared to be commercially profitable. Likewise it seems that the stand-alone plants of the WEC

6 The large-scale hydro tariff rate since 1995/96 is as follows (*NEA*, A Year in Review, 1997/89) :

For Domestic Use:	upto 20 Units NRs. 3.00 per unit; 21-250 Units NRs. 5.00 per Unit; Over 251 Units NRs. 7.75 per unit.
For Commercial Use:	Rural and Cottage Industry NRs. 4.00 per Unit
	Small Scale Industry NRs. 4.90 per Unit
	For Industries Using Medium Voltage (11and 22 kV) NRs. 4.40 per Unit
	For Industries Using High Voltage (>66 kV) NRs. 3.5 per Unit

sample could yield a satisfactory rate of return only if operated at plant factors far higher than are observed in practice under current circumstances. It follows that rural electrification needs to be promoted from a different angle than that of utilising electricity merely for domestic lighting in rural areas; other applications need to be encouraged if higher plant factors are to be achieved.

4.3 ECONOMIC APPRAISAL

Having addressed, in the previous section, the issue of the private profitability of the MMHP plants, this section now turns to analysis of their economic (i.e. social) efficiency in terms of cost and benefit to the community and the nation as a whole. At this point it becomes necessary to highlight some of the major issues which help differentiate the concept of economic returns from financial returns.

1. Differences between Economic and Financial Costs: The economic costs measure the real, or resource cost to the economy from undertaking a particular activity. Where inputs are subsidised, financial costs will be below the economic costs. Where inputs are taxed, financial costs will exceed the economic costs.
2. Differences between Economic and Financial Benefits: The economic benefits do not always directly accrue in financial forms as in the financial benefits.
3. Accounting for Externalities: Unlike the financial appraisal external or spill-over-effects, i.e. side effects of unintended consequences from the project that may be advantageous or detrimental are accounted for in case they are measurable.

4.3.1 Methodology

Market prices in developing countries are generally unreliable indicators of the real worth of goods and services because of distortions in the markets where these goods are bought and sold (*Little and Mirrlees, 1974; Powers, 1981*); they are not necessarily the prices that ought to be used in public sector project evaluation

(*UNIDO, 1972).* Such evaluation exercises are governed by the objective of maximising social gains. The reasons for distortions in market prices are many; some important ones are:

1. The presence of taxes and subsidies on goods and of monopoly situations in productions and purchase of commodities.
2. Rigid control of foreign exchange rate and the supply of foreign exchange by the Government (local currencies over-valued in relation to foreign currencies), particularly under situations of adverse balance of payments.
3. Protection via domestic market tariffs, quotas and trade taxes.
4. Government legislation and union bargaining leading to a labour wage structure that is out of line with the true opportunity cost of labour.

The concern with social economic justification is therefore introduced into the appraisal by using special "accounting prices"[7], "shadow prices," or "social accounting prices" - values invented for the purpose of properly measuring project inputs and outputs. These are prices which also take into account the significance of resources that cannot be valued simply because they are not bought or sold and consequently have no market price (*Clunies-Ross and Huq, 1997*).

There are two popular guidelines adopted to estimate such values: one follows the Little and Mirrlees approach[8] - *OECD Manual of Industrial Project Analysis for Developing Countries (1968),* later modified by Squire and Van der Tak[9]- which is used by the World Bank and Regional Development Banks. The other is the *UNIDO Guidelines for Project Evaluation* (1972). Both these methods have been developed

7. "A price that has been calculated with certain objectives in mind, such as maximising economic growth, improving the balance of payment and promoting employment opportunities and that is consistent with a country's development policies and resource endowments. the accounting price of a good or service is thus a measure of its real worth to the economy as a whole in terms of these objectives" - UNIDO Guidelines.
8 The Little and Mirrlees method uses world price numeraire and expresses all costs and benefits in terms of foreign exchange equivalent values, OECD Manual of Industrial Project Analysis for Developing Countries
9. This method uses the unit of account (or numeraire) for adding up economic benefits and costs in "uncommitted public income measured in foreign exchange".

to take into account the matters which cannot be comprehended by simply using market prices as a base for analysis of projects. Thus they take account of the over-valuation of domestic currency against foreign exchange, lower labour wage-rates of unskilled labour as compared with market value and the lower value of available income for consumption as compared to income available for investment *(Clunies-Ross and Huq, 1997)*. There is, however, a difference between their approaches. The UNIDO method, which has a consumption based objective, converts the value of foreign exchange, and the goods bought or sold for foreign exchange, into domestic market-prices using "shadow-exchange rates". OECD method, which has a saving investment-based objective uses a "standard - conversion factor" to convert market prices into border prices.

The conversion factors for various parameters are expressed as ratios for the reasons that:

1. such presentation makes for ease in computation;
2. current prices can change rapidly whereas the ratios of shadow prices to market prices, on the assumption that actual and shadow prices alter at roughly the same rate, will remain relatively stable (UNIDO Guidelines for Ethiopia, *undated*).

Mathematically the conversion factor for Exchange Rates is expressed as:

$$CF = \frac{W_P}{D_P} \times OER \qquad \text{..........} \quad (5)$$

where:

CF . Conversion Factor

Wp - World Price

Dp - Domestic Price

OER - Official Exchange Rate

The conversion factor associated with labour is expressed as

$$CFul = \frac{SWulR}{MWulR} \qquad \text{..........} \qquad (6)$$

$$CFsl = \frac{SWslR}{MWslR} \qquad \text{..........} \qquad (7)$$

Where

CF_{ul} and CF_{sl} are conversion factors for unskilled and skilled labours respectively

$MW_{ul}R$ = Market wage of unskilled labour

$SW_{ul}R$ = Shadow wage of unskilled labour

$MW_{sl}R$ = Market wage of skilled labour

$SW_{ul}R$ = Shadow wage of skilled labour

The conversion factors for labour is calculated as:

$$CF = \frac{Opportunity\ Cost\ at\ Shadow\ \ Price}{Wage\ \ Rate} \qquad \text{..........} \qquad (8)$$

Separate conversion factors for skilled and unskilled labour, which along with materials are further classified into domestic and foreign inputs, are computed. Furthermore, the values depend upon the nature of the good i.e. whether it is tradable or non tradable[10]. Accounting prices for tradable goods are determined by the true values of imports and exports (e.g., the c.i.f. and f.o.b. prices respectively), the reference prices, which determine the domestic production decision[11]. These prices are a convenient reference for production decisions because often a large portion of domestic economic activity is subject to international trade (*Powers,1981, pp. 9*). A

10 Traded goods are those whose production or use by a project has an effect on the country's balance of payments, because either the goods are exported or imported or they are close substitutes for goods which are exported or imported. The extent to which the production or use of these goods affects the foreign exchange position of the economy is determined by their price on the world market.

11 The c.i.f. (cost insurance freight) price is the cost plus insurance and freight expense to port of destination. The f.o.b. (free on board) price is the cost at port of origin before insurance and freight charges to destination are incurred.

good is classified as "non-tradable" when its domestic price lies above the f.o.b. export price and below the c.i.f. import price of a similar good; a good is also non-tradable if it receives special protection from international competition in the form of quotas or prohibited tariffs. The accounting price for a non-traded commodity is generally measured by the cost of supply, with all inputs valued at their accounting prices (*Powers, 1981, pp. 2).*

The economic appraisal tests the project's profitability from a different point of view - not just the impact of the project on the financial profits of the investor - but for the utilisation of the country's resources, for the savings and consumption pattern of the country, for the distribution of income and for any other objectives the decision makers may wish to take into consideration (*UNIDO, 1978, pp. 3*)[12].

In order to differentiate between financial and economic analyses the following nomenclature has been used:

ENPV = Economic Net Present Value

EIRR = Economic Internal Rate of Return

E(B/C) = Economic Benefit Cost Ratio

Economic Discount Rate

The economic discount rate differs from a financial rate which is normally the rate that reflects the cost of funds to an enterprise. It is the "opportunity cost" of capital to the economy. The economic discount rate may differ from the financial rate. The financial or market discount rate is normally the rate that reflects the cost of funds to an enterprise, whereas the economic discount rate is the opportunity cost of capital within the economy. In the words of *Gittinger* (1984), the latter is the rate that will result in utilisation of all capital in the economy if all possible investments are

12. See UNIDO (1978), Guide to Practical Project Appraisal: Social Benefit- Cost Analysis in Developing Countries for further details.

undertaken such that they bring about a positive net yield; it will be the return on the last or marginal investment made that uses up the last of the available capital. For this study the economic discount rate is assumed to be 10 percent.

There are various approaches[13] to estimating the discount rate. It is difficult to estimate precisely the value of the economic opportunity cost of capital, but it is assumed to be somewhere between 8 and 12 percent (*Chitrakar, 1994*). The present study uses the concept of opportunity cost of capital as the basis for the discount rate. The rate used here is based on previous studies on Nepal which have used a discount rate ranging between 8-10 percent as shown below in *Table 4.1.* For simplicity and consistency to studies carried out for the industrial sector in the country, a discount rate of 10 percent has been used in this study.

Table 4. 11: Estimates of Discount Rate for Nepal

Studies	*Discount Rates*
ODA/UK (1975)	8%
Phillips (1979, 1986)	9%
Phillips (1989)	9%
Industrial Sector Plan Studies	10%
Adhikari (1981, 1986 & 1988)	9%
Various studies by Industrial Services Centre (ISC), Nepal	10%

Source: Chitrakar, 1994

Assumptions Used

National Accounting Rates as developed by the National Planning Commission for various energy technologies have been used for comparison between Financial and Economic Performance of the mini-micro-hydro plants. The conversion factors used are as follows:

Exchange rate - 1.11

13 The two approaches suggested regarding the discount rate are: external borrowing rate the nation has to pay for foreign exchange to finance a project; Social time preference rate- based on assumptions that the discount attached to future returns by society is different from and lower than the discount individuals use. The discount rate computed by social opportunity approach is normally reckoned to be higher than the social time preference approach and is hence adopted as the social discount rate.

Unskilled labour - 0.7

Skilled labour - 1

4.3.2 Benefits and Costs in Economic Appraisal

The establishment of MMHP in the rural areas has contributed to the local communities in different ways. Some of the benefits are listed in *Table 4.12* on the basis of interviews with plant owners, plant users and NGOs (both national and international) working on the development of this sector. Some of the activities bringing about economic benefits are illustrated in the photographs in the *Appendix*. The Table also lists some of the problems associated with the use of the MMHP, as presently experienced by the entrepreneurs.

Table 4. 12: Compatibility of Some End-uses with Mini-Micro-Hydro Energy

End Use	*Advantages*	*Limitations*
1. Rural Industries • Paper making • timber processing • agro-product drying • ice making • noodle making • village workshop (welding, drilling, grinding) • bakery • commercial laundry (ironing) • milk preservation (chilling)	⇒ utilisation/value adding of local raw material ⇒ electricity and motive-power useable ⇒ local employment ⇒ generation and economic growth	⇒ expensive ⇒ limited power capacity and seasonal fluctuations ⇒ unreliable supply
2. Cooking, domestic lighting	⇒ clean operation ⇒ no health hazards ⇒ bio-mass saving	⇒ low voltage devices are time consuming ⇒ very expensive ⇒ cooking clashes with peak load
3. Lift irrigation	⇒ clean operation	⇒ expensive irrigation time same as low water availability
4. Battery Charging	⇒ extended outreach of electricity	⇒ high investment ⇒ problematic transportation
5. Business (tourist lodge, eateries, shops)	⇒ improved atmosphere ⇒ enhanced business ⇒ utilisation for cooking/heating	⇒ limited power capacity ⇒ some contribution to peak load ⇒ unreliable supply

Source: Compiled from Field Survey; ICIMOD, 1997; Bhadra, 1997 and Shakya and Shakya, 1997

Benefits are classified as tangible or intangible according to whether they can be measured or not. The tangible benefits alone can be used for quantifying the returns on the plants. The tangible benefit of these plants is that they are installed and operated as commercial ventures yielding lucrative financial returns, especially those processing agro-products, thus providing a source of income for the entrepreneurs. In many areas oil-expelling operations are almost exclusively carried out now by oil expellors powered by MMHP plants, and in those areas *kols* (traditional manually operated expellors) are no longer used; this is because the oil yield from modern expellors is up to 15 percent higher than that from traditional *kols (Bhadra and Ramani, 1997).*

With the introduction of electrification schemes using mini-micro-hydro plants the benefits go beyond meeting the milling and lighting requirements. They play a major role in fuelwood substitution, saving foreign currency through kerosene substitution, rural industrialisation, irrigation (lift irrigation) programmes, tourism development and many more. Such benefits from fuelwood substitution, rural industrialisation, and irrigation have been considered in this study only as qualitative benefits. Besides these, there are qualitative advantages brought about in the daily life of the community. The most important contribution of the MMHP agro-processing plants is the alleviation of drudgery for women from tasks such as cereal grinding or dehusking of rice. The time saved from these tasks enable them to concentrate in off-farm activities for income-generation.

Furthermore, another favourable feature of mini-micro-hydro plants is that they do not require the construction of large dams leading to land-inundation, land slides, erosion and other environmental hazards. Thus in the case of mini-micro-hydro projects, the environment impact is negligible.

Only those benefits listed in *Table 4.12* which involve monetary transaction have been accounted for in the shadow pricing. The remaining are considered only as qualitative benefits.

External Effects of Technology Driven Projects

External effects or "unintended income or income equivalent welfare changes for others in the economy" (*Weiss and Curry, 1994, pp174-175)* from a project are a major concern in cost-benefit analysis. It has however been realised that both identification and quantification of externalities are difficult. Though *Cook and Mosley* (1989; 143-150) argue strongly for the explicit consideration of external effects as an integral component of the rate of return calculation process, they too admit the difficulties and agree with Little and Mirrless (*1974*) that these externalities may be accounted for in qualitative terms. Following Little and Mirrless and Cook and Mosley (*1989*), this study also treats the effects in terms of linkages, labour training, technical progress and impact on the environment in qualitative terms (*Weiss and Curry, 1994, pp. 175).*

The effects on labour training associated with MMHP development are two fold: training at the point of installation and training during the life-span of the project i.e. through experience at work. The learning gained through working with MMHP is unlimited; the value of this experience being applied in other activities of the community is unaccounted for in the labour shadow price. Such benefits can be envisaged as the possibility of establishing workshops, repair centres and inputs to industrial activities; these cannot readily be measured. The operation by DCS of nodal workshop centres for turbine repair using these labours is a good example. This indirectly initiates the training of a technical workforce in the rural areas. The external benefits from labour training are also realised in the use of this manpower in the industries connected with the mini-micro-hydro plants.

Technical progress from this project is realised in the experience gained by plant manufacturers. The feedback from the performance of the turbines at the site has enabled the manufacturers to improve upon the turbine technology so as to make it suitable to the rural settings of the country. Besides, there occurs an informal technology transfer while information is being transferred through the users of one technology to other manufacturers. The knowledge of installation and management of the technology forms a major source of external effect generated for the future plants in the community.

An important external effect are the linkages, backward and forward, in this sector. An observed backward linkage[14] developed in this sector is the growth of industries producing end-use equipment for the use with turbines in rural areas. These industries include those that manufacture equipment such as rice-hullers, grinders and electronic load controllers. The forward linkages are realised in the establishment of small scale industries which manufacture low-wattage cookers and saw-mill equipment for use with MMHP generated electricity.

Similar is the case in the turbine manufacturing sector. The introduction of new turbine technologies such as the Pelton turbine creates a source of jobs for existing foundries such as Dhalaut Karkhana in Kathmandu and Shrestha Metals in Butwal. This factor has also led to a new foundry owned by Kathmandu Metal Industries in Kathmandu.

4.3.3 Economic Analysis : Results

This section is concerned with analysing the economic effectiveness of installing mini-micro-hydro plants. It should be noted that, despite the discussions above regarding tangibles and external effects, the exercise conducted here is relatively limited in scope; no attempt has been made to attach values to what have been referred to as intangible or even to the external effects of mini-micro-hydro developments (that does not however, preclude account being taken, in qualitative terms, of the existence of such effects). The only quantitative modifications made to the figures used in calculating financial returns in order to estimate economic returns are to the values of labour and material inputs employed in setting up the mini-micro-hydro installations; allowances that is to say, is made for the difference between these costs at market values and the real social costs incurred in using resources, derived from domestic or foreign sources. These cost adjustments have been made using the conversion factors described above; the composition of material and labour costs, sub-divided as appropriate to the calculation of shadow prices, is given in *Table 4.13.*

Table 4. 13: Cost Distribution for Labour and Material

	Cost in %		*Cost in %*		*Cost in %*
CAPITAL COST					
Material		Labour		Transport	
Material (Foreign)	21.40%	Labour - Skilled (Local)	31.91%	Truck	80.38%
Material (Local)	78.60%	Labour - Unskilled (Local)	68.09%	Air	0.00%
		Labour - Skilled (Foreign)	0.00%	Labour	19.62%
OPERATIONAL					
Material		Labour			
Material (Local)	15%	Labour - Unskilled (Local)	85%		

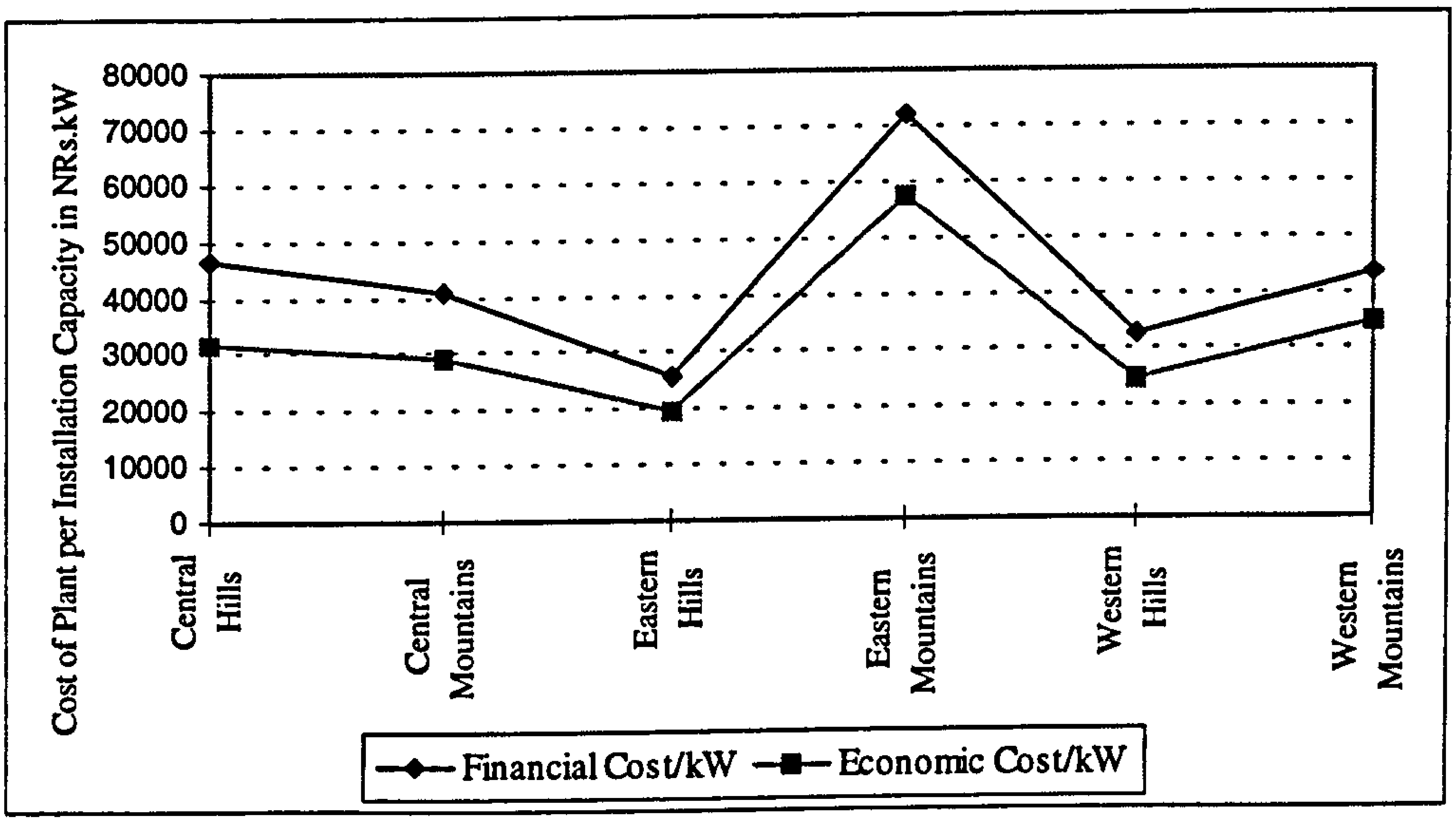
Source: WECS, Nepal, 1995

The mode which has been adopted of illustrating the disparity between the financial and economic results of MMHP investments is to calculate the difference between financial costs (in terms of market prices) and economic costs (in terms of shadow prices estimated by application of the conversion factors described above). In this study we make two cost comparisons: (i) of the financial and economic costs of plant installation (NRs/kW of installed plant capacity) and (ii) of the financial and economic costs of generating energy (NRs/kWh of energy produced). The results of these comparative exercises are shown in *Figures 4.1 and 4.2* respectively.

The graph plotted in *Fig. 4.1* for the financial and economic costs of mini-micro-hydro plant installations show the latter cost to be considerably lower, in all regions, than the former. The cost differences are substantial, with financial cost per unit of capacity installed typically exceeding economic cost by around 29.00% (*See Table 4.14*), with economic returns of the plants highest in the Central Hills and lowest in the eastern Mountains.

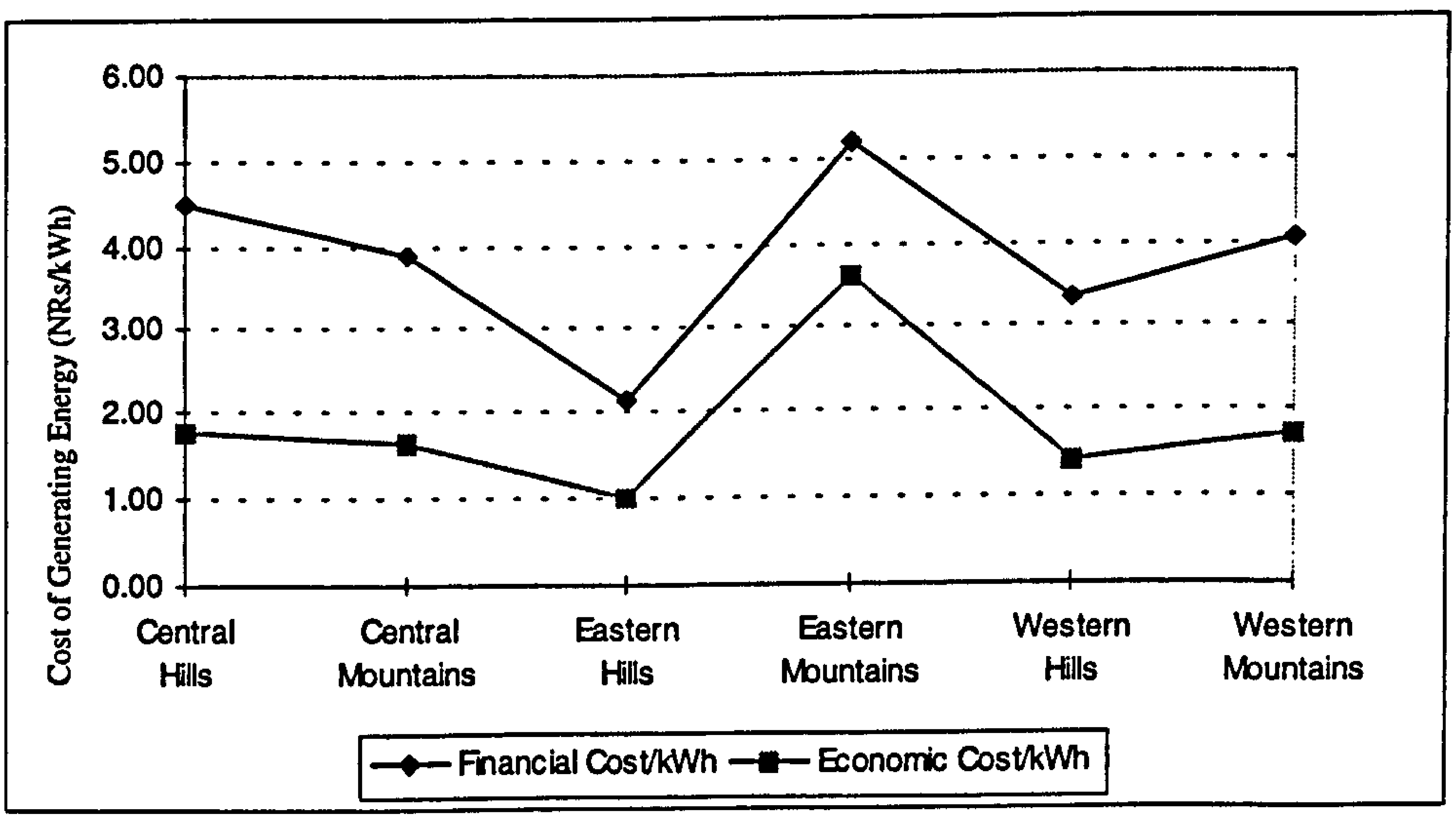
14 Backward linkage as the project will then purchase these equipment as an input for the operation of these turbines

Fig. 4. 1: Comparison Of Financial And Economic Cost of Installation (NRs./kW)



Source: Computed from Field Survey

Fig. 4. 2: Comparison Of Financial And Economic Cost of Energy Generated (NRs./kWh)



Source: Computed from Survey Data

Table 4. 14: Result of Financial and Economic Cost of Plant Installation (NRs/kW) and Energy Generation (NRs/kWh)

Region	*Financial*		*Economic*		*Percentage Difference w.r.t. Financial Cost*	
	Cost/kW	*Cost/kWh*	*Cost/kW*	*Cost/kWh*	*Cost/kWh*	*Cost/kW*
Central Hills	46110	4.49	31820	1.77	30.99%	60.68%
Central Mountains	40763	3.89	29062	1.65	28.71%	57.54%
Eastern Hills	25497	2.15	19436	1.00	23.77%	53.36%
Eastern Mountains	72168	5.21	57586	3.62	20.21%	30.61%
Western Hills	32685	3.34	24445	1.41	25.21%	57.71%
Western Mountains	43132	4.04	34534	1.71	19.93%	57.59%
Average Difference in %	43392	3.85	32813	1.86	24.80%	52.92%

Source: Computed from Field Data

These findings regarding set-up costs are complemented by the evidence on generating costs. The graphs in Fig. 4.2 indicate that financial costs per unit of electricity generated exceed, in all regions, the economic costs of generation by a significant margin ranging from 31.00 percent in the Western Mountains to 60.68 percent in the Central Mountains, with economic returns highest in the Central Hills and lowest in the Eastern Mountains.

From *Table 4.15*, compares the economic and financial returns on mini-micro operations in the different regions. It is evident that, on this calculation of economic returns , the mini-micro-hydro plants are economically worthwhile when installed in all three Hill Regions and in the Central Mountain Region. The plants in the Central Mountains, which in financial terms, were not profitable, prove to be economically acceptable with an average EIRR of 17.5 percent. For the Western Mountains, the result is less clear-cut. The average EIRR of the plants in that region is an acceptable 11.08 percent, but at the same time, their average ENPV is negative. The rise in the EIRR can be explained to be due to the cumulative effect of the rise in EIRR of the other sample plants in the region. The Eastern Mountain Region shows the weakest results: the average EIRR for plants installed there is only 9.41 percent and an average ENPV is negative. The Eastern Mountain Region is also the only area for which the average economic benefit-cost ratio (EB/C) is less than unity.

Table 4. 15: Results of Economic Analysis

Regions	*ENPV in NRs.*	*EIRR in %*	*EB/C*
Eastern Mountains	-66595	9.41%	0.98
Western Mountains	-180581	11.08%	1.06
Western Hills	42520	14.22%	1.17
Central Mountains	166814	15.75%	1.18
Eastern Hills	15477	15.16%	1.14
Central Hills	107085	16.12%	1.22

Source: Computed from Field Survey

Notwithstanding the relatively poor economic outcomes for the Western and Eastern Mountain regions as reported in the previous paragraph, it does not necessarily follow that mini-micro-hydro installation in these regions is economically not justified. For one thing, the average rates of return are in the one case above the critical 10 percent level and, in the other, only just below it. But the further consideration of which account must be taken, is that the estimated economic returns, as actually calculated, make no allowances for what were described above as "intangible" and "external" benefits. There can be no doubt that such benefits are yielded by the mini-micro-hydro plants and - unquantified though they may be - are economically and socially significant. It would be worthwhile working out what national value would have to be placed on such benefits to produce - by enhancing the returns from plant operation - a positive ENPV for the plants in the Western and Eastern Mountain Regions.

Table 4. 16: Result of Economic Analysis with Respect to End-uses

End Uses	*ENPV in NRs.*	*EIRR in %*	*EB/C*
GR	114498	22.48%	1.44
GO	68127	21.75%	1.25
RO	60815	17.07%	1.31
GRO	110880	16.43%	1.25
ROE	34211	12.02%	1.06
GROE	79067	11.47%	1.09
GROE+	7472	10.99%	1.06
E	-220	9.85%	1.00
GOE	-12761	9.18%	0.96
GRE	-25698	7.91%	0.94
GE	-986476	0.91%	0.61

Source: Computed from Field Survey

Table 4. 17: Result of Economic Analysis with Respect to Competing Plants in the Vicinity

Regions	*Number of Competing Plants*		
	<4	*4-8*	*>8*
Central Hills			
ENPV in NRs.	144419.69	44102.98	48028.64
EIRR in %	18.29%	13.73%	14.91%
EB/C	1.27	1.15	1.17
Central Mountains			
ENPV in NRs.	114398.31	28990.31	-98561.42
EIRR in %	18.90%	13.99%	7.66%
EB/C	1.40	1.08	0.90
Eastern Hills			
ENPV in NRs.	74700.29	86020.58	
EIRR in %	18.84%	15.43%	
EB/C	1.19	1.18	
Eastern Mountains			
ENPV in NRs.	-183830.04		
EIRR in %	6.84%		
EB/C	0.88		
Western Hills			
ENPV in NRs.	100096.70	66634.54	7119.84
EIRR in %	25.64%	14.99%	10.82%
EB/C	1.42	1.25	1.05
Western Mountains			
ENPV in NRs.	-37154.98	-25698.21	
EIRR in %	8.28%	7.9%	
EB/C	0.96	0.94	

Source: Computed from Field Survey

Comparison of economic with financial results was also made in respect of end-uses and competition from neighbouring plants. These comparisons are reported in *Table 4.16 and 4.17.* The analysis with respect to end-use indicates that the plants with grinding and rice -hulling is the best business. Stand-alone electricity generation rises in the ranking but fails to meet the required criterion of having an EIRR greater than 10 percent (*See Table 4.16*).

Comparison of economic viability of the plants facing competition from neighbouring plants also indicate the plants to be economically more beneficial than they were in financial terms: these values are higher than FIRR. Plants in the Eastern and Western Mountains still fail to meet the criterion of 10 percent rate of return, with less than four competitors (*See Table 4.17*).

The economic analysis indicates the cost of installation as well as the cost of energy generation to be highest in the Eastern Mountain Region while it is lowest in the Central Hill Region. The economic performance of the plants with respect to location, services provided and the existence of competing plants is better than their financial profitability. This difference between economic and financial profitability suggests one for the introduction of further subsidy support for the promotion of MMHP in these areas.

4.4 COMPARISON OF MMHP WITH OTHER ENERGY SOURCES

Here the feasibility of MMHP installations of various capacities is compared with that of hydro plants larger than MMHP, as well as with diesel generators and solar photovoltaic power generation. In Nepal, as in several other developing countries, solar and wind energy, as well as hydropower, have been tested for feasibility as a source of energy for rural development. The technologies for the conversion of energy are checked for their appropriateness in the rural areas of Nepal. In the present study comparison of MMHP with medium and small scale hydro plants is based on information collected from *Nepal Electricity Authority* (NEA)[15]. The comparison with diesel generators and solar photovoltaic technologies is also based on data provided by NEA for Simikot, a remote rural area in Nepal. The comparison is made in terms of financial and economic feasibility.

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15 The feasibility analysis of the large, medium and small scale hydro projects have been carried out by NEA and these values have been used for comparison with selected MMHP plants in this study.

4.4.1 Medium and Small Scale Hydro Plants

The medium and small scale hydro plants included in this analysis have mostly been installed with foreign support. This includes finance as well as technical support. The local involvement ranges from 20 to 30 percent of the total cost. This contribution is mostly in the form of unskilled manpower. The machine components too are not new in these projects: they are refurbished and or used equipment.

As the data for FNPV of the plants of the medium scale was not given the comparison is carried out only with respect to FIRR, Cost-Benefit Ratio, cost of installation and generation of energy. *Table 4.18, 4.19 and 4.20* present the details of plant capacity, cost of the plant, FIRR, FB/C, generation cost and installation cost as provided by Nepal Electricity Authority (NEA).

Table 4. 18: Financial Feasibility Test Details of Medium Scale Hydro Power Plants

Name of Plant	*Units*	*Modi*	*Upper Modi*	*Bhote Kosi*	*Ilam*	*Chilime*
Plant Capacity	MW	14	14	36	6.2	17
Cost of Plant	10^6 NRs.	1,360.72	1,513.50	3,442.00	601.00	1,401.00
IRR		19.80%	19.90%	19.50%	22.00%	24.53%
B/C		1.87	1.94	1.92	2.18	2.45
Generation Cost	NRs./kWh	2.00	2.36	2.06	1.85	2.03
Installation Cost	10^3 NRs/kW	97,194.71	108,107.86	95,611.11	96,935.48	82,411.76

Note: These computations have also been provided by NEA
Source: NEA, 1995

Table 4. 19: Financial Feasibility Test Details of Small Scale Hydro Power Plants

Name of Plant	*Units*	*Langtang Khola*	*Indrawati Khola*	*Piluwa Khola*	*Gandi Khola*	*Daram Khola*	*Dudh Khola*	*Tadi Khola*
Capacity	kW	4600	5100	500	1500	3000	6000	2000
Cost of Plant	'000 NRs.	535,550	511,000	85,450	183,250	271,500	544,050	221,500
NPV	'000 NRs.	511,250	553,250	22,400	142,950	522,150	863,950	3,550,517
IRR		13.30%	14.10%	7.40%	12.10%	19.3	17.30%	21.74%
B/C		1.85	2.01	1.15	1.73	2.8	2.41	3.56
Energy Cost	NRs. /kWh	1.63	1.49	2.60	1.73	1.07	1.25	3.94
Installation Cost	'000 NRs/kW	109.15	91.20	159.85	98.55	81.30	75.50	125.12

Note: These computations have also been provided by NEA
Source: NEA, 1995

From *Tables* 4.18, *4.19 and 4.20* it is apparent that the Benefit Cost ratios of the MMHP projects ranging from 0.62 to 1.06 are lower than those of the small and medium scale plants, with Benefit - Cost as high as 2.5 for medium scale and 3.5 for small scale plants. The energy generation cost of MMHP, ranges from NRs 1.90 to NRs 10 per kW while that of the medium scale plants ranges between NRs. 1.85 to NRs. 2.36. The cost of generation reduces with increase in plant capacity except for the mini-micro-hydro plant in Darchula.

Table 4. 20: Data for Mini-Micro-Hydropower Plants

Name of Plant	*Units*	*Bhadaure*	*Angaha*	*Khimti**	*Barpak*	*Darchula*	*Khandbari*
Plant Capacity	kW	1	3.2	30	50	300	250
Cost of Plant	NRs.	89944	99860	1770717	1796842	31878000	10625000
O&M	NRs.	32000	26600	28000	138780	566060	793721
Benefits	NRs.	30200	30890	160910	410400	3894978	2084233
Life Span	Years	15	15	15	15	15	15
NPV	NRs.	-37370	-61588	1010924	239824	25320014	9815736
IRR		-6.77%	-3.07%	1.52%	13.55%	6.22%	8.64%
B/C		0.873	0.818	0.62	1.06	0.82	0.95
Generation Cost	NRs./kWh	10.00	3.10	1.94	1.90	3.53	1.97
Installation Cost	NRs/kW	89944	31206	59957	35936	108146	45674

Note: The information for plants marked * have been provided by NEA
Source: NEA, 1995

4.4.2 Other Renewable Energy Sources (Diesel-mills and Solar Photo-Voltaic (SPV))

Solar (together with batteries for storage) and diesel as sources of energy are at present highly import-oriented. Solar photo-voltaic technology used in Nepal has been installed mainly for experimentation and demonstration programmes. These installations are used for preliminary studies for the collection of data regarding the availability of useful solar radiation with respect to various topographical zones of the country. Solar photovoltaic systems do not involve significant maintenance costs and have a life-span of over 20 years; but this technology is largely imported and even for operation and maintenance there is high dependence upon skilled labour and imported materials. Labour utilised in solar photovoltaic operations requires more skilled manpower at installation, as well as for repair and maintenance of the system, as compared to mini-micro-hydro plants.

Diesel equipment too is imported into the country. As the country depends on imports for petroleum products, the use of plants operating on diesel is a strain on the national foreign currency reserves. The equipment, as in the case of hydro plants, depends on skilled manpower for major repairs, although minor repairs are easily undertaken by the operators themselves. *Table 4.21* presents the data and results for each of these technologies for generating electricity. It is apparent that both MMHP and SPV do not involve any overhaul costs over a period of 15 years. Diesel on the other hand incurs a larger operating cost for fuel as well as overhaul after every five years.

Table 4. 21: Result of Financial Analysis of Selected Renewable Energy Technologies in Nepal

Result Financial Analysis of Selected Renewable Energy Technologies in Nepal

	Units	Micro-hydro	Diesel	Solar PV
Total Capital Cost	NRs	5277778	3290543	27027029
Discount Rate	%	10	10	10
Installed Capacity	kW	50	50	50
Average Operating Hours	hrs./day	7	5	5
Plant Factor	%	60%	60%	80%
Annual Energy Production	kWh	76650	54750	73000
Cost of Energy Generation	NRs.	7.12	5.54	34.27
Cost of Plant per kW	NRs	105555	65811	540540
Cost of Diesel	NRs/kWh		2.8	
Annual Price of Fuel	NRs		191406	
Annual O&M Cost	NRs	158333	230338	551000
Tariff	NRs/kWh	11.25	18.5	57
Benefits	NRs	862312.5	1012875	4161000
Overhaul Price	NRs		987163	

SOURCE: WECS, 1998

The Net Present Value and IRR have been used to compare the acceptability of the technologies. The analysis is carried out to fix a tariff so as to make the plants acceptable at a discount rate of 10 percent. The economic analysis too has been employed to compute a tariff for the plants so as to make them acceptable at a discount rate of 10 percent.

In order to make the projects acceptable with an discount rate of at least 10 percent, the tariff of electricity generated by these different technologies would have to be:

Micro -hydro	NRs. 11.25/kWh
Diesel plant	NRs. 18.5/kWh
Solar Photovoltaic	NRs. 57/kWh

4.4.3 Comparison of Renewable Energy Technologies

Table 4. 22 below shows the comparison between the four popular options: MMHP for agro-processing and electricity; MMHP for electricity only; Diesel for electricity only; and photovoltaic (PV) for electricity only.

Table 4. 22: Ranking Various Benefits and Costs of Alternative Energy Technologies

Scoring	Benefits	*Option*			
		MMHP (cross-flow)		Diesel	PV
		AP + El	EL	El	El
0 - 5	Initial cost per kW	2	3	5	1
0 - 4	Running cost per kW & frequency of repair	3	3	1	4
0 - 5	Employment and income generation	5	3	2	1
0 - 5	Drudgery	5	1	3	1
0 - 3	Foreign exchange saving	3	3	2	1
0 - 4	Education and adult Literacy	3	3	1	2
0 - 3	Standard of living	3	2	1	2
0 - 2	Cooking - low wattage	2	1	0	0
0 - 5	Environment mitigation and health	4	4	0	5
0 - 5	Use of local capability, energy source & skill	5	5	1	2
0 - 4	Life of the plant	3	3	1	4
0 - 4	Site specificity	1	1	3	2
0 - 4	No. of hours of service	4	3	3	1
	TOTAL	43	35	23	26

Note: Agro-processing - AP; Electrification - EL

Source: Compiled from Field Survey; ICIMOD 1997; Shakya 1997

The scoring of 1-5 has been assigned with respect to benefits and costs associated with each of the technologies. The scoring is as follows: 5 for the highest benefits and

1 for the lowest. The listed criteria are again ranked amongst themselves, hence their ranking also varies 5-1. From this analysis it is evident that diesel option is not suitable. PV is most popular for solar home systems which provide light and power for entertainment as well as educational purposes. Diesel sets are mainly employed for agro-processing and not much used for the supply of electricity. Hydro plants are more popularly used for agro-processing (AP) and electricity supply.

The analysis indicates a comparable reduction in the capital cost of mini-micro-hydro plants whereas it is not so in the case of diesel and solar photovoltaic system (*See Table 4.23*).

Table 4. 23: Results of Economic Analysis of Selected Alternative Sources of Energy

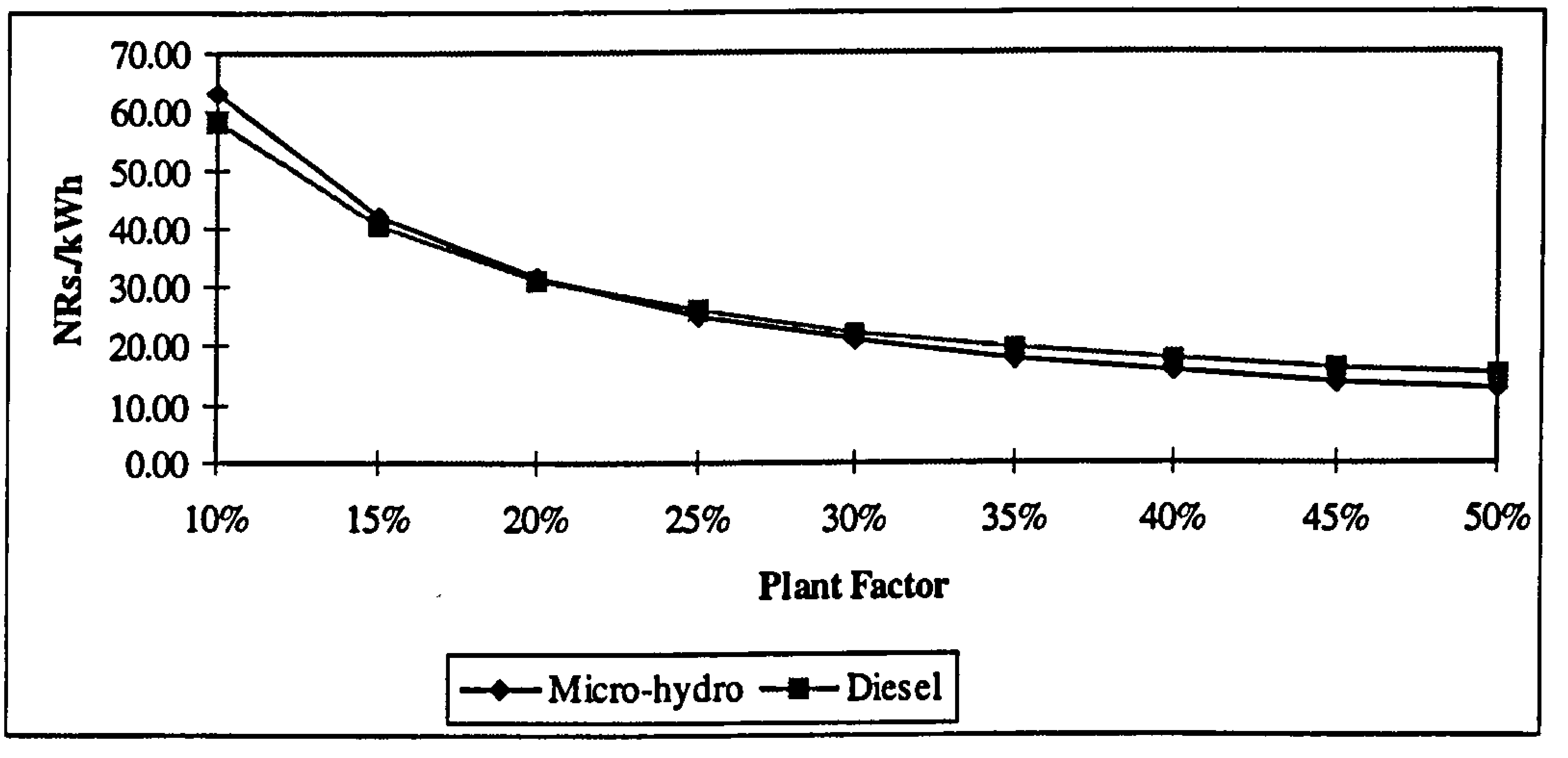
Result Financial Analysis of Selected Renewable Energy Technologies in Nepal				
	Units	Micro-hydro	Diesel	Solar PV
NPV	NRs	76746.05	19337.50	430918.02
IRR	%	10.25%	10.12%	10.28%
B/C		1.01	1.00	1.01
Result of Economic Analysis of Selected Renewable Energy Technologies in Nepal				
	Units	Micro-hydro	Diesel	Solar PV
Total Capital Cost	NRs.	4463288	3108054	21492096
Cost of Energy Generation	NRs.	6.20	10.40	29.60
Cost of Plant per kW	NRs	89265	62161	429842.
Cost of Diesel	NRs/kWh		3.12	
Annual Fuel Cost (Diesel)	NRs		212460	
Annual O&M Cost	NRs	152787	1642	4519
Tariff	NRs/kWh	8.75	12.75	35.50
Benefits	NRs	744463	774849	2836050
Overhaul Price	NRs		894095	
NPV		37041	58541	44752
IRR		10.15%	10.39%	10.04%
B/C		1.01	1.01	1.00

Source: Computed from Survey Data, NEA, 1995

In case of economic analysis the acceptability of the projects at 10 percent discount is obtained only at a tariff of NRs 8.75 for mini-micro-hydro, NRs. 12.75 for diesel and above NRs. 35 for solar photovoltaic.

The high tariff of diesel at NRs. 12.75 per kWh is computed for 50 percent plant factor. The cost of diesel is expected to rise with increase in plant factor as seen from *Fig. 4.3*. The initial cost of diesel at 10 percent plant factor is low but at 25 percent plant factor, which is a common plant factor in rural areas of Nepal (*Junejo, 1997*); also reported as 24 percent in Peru, (*Viani, 1997, pp. 94*), 36 to 44 percent in Sri Lanka (*Hislop, 1986, pp.38-47*), the cost begins to rise. The economic comparison indicates that MMHP is the best choice for the rural areas of Nepal.

Fig. 4. 3: Effect of Plant Factor on Average Energy Cost (Micro-Hydro Versus Diesel)



Sensitivity Analysis

The sensitivity analysis has been carried out for all three different types of technologies to analyse the effect of varying the fixed cost, operating cost and the profits by +20 and -20 percent at the discount rate of 10 percent.

The analysis was applied to the same data as for financial appraisal of the plants earlier in the study. In the given condition and accepting only technologies with IRR higher than 10 percent, mini-micro-hydro is able to meet this criterion with an increase of 20 percent in its benefits as well as 20 percent reduction in the installation or operating costs. The solar and diesel are able to meet the required criteria only with 20% reduction in the fixed cost and operating costs as well as with 20% increase in the existing profit margin. The results are presented in the *Table 4.24.*

Table 4. 24: Impact of Variations in Selected Parameters of Alternative Technologies

Parameters	*Variations*		*Units*	*Micro-hydro*	*Diesel*	*Solar PV*
		NPV	NRs/kWh	76746	19337	391744
		IRR	%	10.25%	10.12%	10.28%
		B/C		1.01	1.00	1.01
Fixed Cost	20% Increase	NPV	NRs	-978810	-750217	-4522262
		IRR	%	7.20%	5.89%	7.22%
		B/C		0.87	0.91	0.86
	20% Decrease	NPV	NRs	1132302	788892	5305749
		IRR	%	14.48%	16.06%	14.51%
		B/C		1.21	1.11	1.23
Benefit	20% Increase	NPV	NRs	1388510	1560139	6146089
		IRR	%	14.40%	18.89%	14.19%
		B/C		1.21	1.20	1.22
	20% Decrease	NPV	NRs	-1235017	-1521464	-5362601
		IRR	%	5.66%	-2.21%	5.97%
		B/C		0.81	0.80	0.81
Operating Cost	20% Increase	NPV	NRs	-164113	-331056	-370247
		IRR	%	9.45%	7.81%	9.74%
		B/C		0.98	0.96	0.99
	20% Decrease	NPV	NRs	317605	369731	1153735
		IRR	%	11.04%	12.28%	10.81%
		B/C		1.05	1.05	1.04

Source: Computed from Field Data

4.6 CONCLUSION

The financial analysis has been carried out using the conventional discounted cash-flow method to assess the relationship between costs and benefits measured at market prices, while the economic analysis, also carried out using the discounting procedure, has employed standard conversion ratios to estimate shadow prices for certain cost items. No formal quantification of benefit items falling into the categories of "intangible benefits" or "external benefits" has been attempted in estimating economic returns.

The financial appraisal carried out for 90 plants indicates variation in plant profitability according to region of operation: plants in the Hill Regions are more profitable than plants in Mountain Regions. The lowest rates of commercial return are shown by plants in the Western and Eastern Mountain Regions. It appears therefore that the distance from the operating site to the location of the plant supplier is an important factor affecting profitability; in remote areas which are inaccessible by motorable roads, necessary recourse to alternative modes of transport - air, or foot - implies longer transport times, higher costs and lower profitability.

The financial analysis with respect to different types of end-uses shows that plants providing only electricity are least viable. Both the plants of the 90 plant sample which are used solely for electricity generation had negative NPVs; analysis of profitability of the plants of the plants of the WEC sample indicate that profitability can be achieved only through operation at very high plant factors. The rate of return improves as the number of end-uses to which the plant is put increases; that result of the present study accords with recent reports from ICIMOD and ITDG. In the case of plants providing multiple services, grinding, rice-hulling and oil-expelling are the most profitable operations. An ability to run several items of end-use equipment simultaneously is seen to have a favourable effect on profitability.

The relatively poor returns from electricity generation alone suggest a need for some re-thinking of policy. On the perception that electricity symbolises modernisation and progress, MMHP is currently being promoted as a means of meeting the electrical energy requirements of the rural and remote areas. The electricity generated is however predominantly used merely for domestic lighting, implying low demand relative to production capacity and consequently low plant factors in operation. The effect of a low plant factor is to cause high unit costs of electricity generation; from the WEC data it is clear that there exits a systematic inverse relationship between the value of the plant factor and the cost of electricity. It would appear, in order to achieve operation at higher plant factors, that attention should be given to encouraging the use of electricity for further purposes in addition to domestic lighting. An appropriate model might be found in Chinese practice; in China electricity generated by small-scale plants is applied to substantial use in productive activities (*Dutta, 1997*).

Even with employing relatively restrictive measure of economic returns, there seems to a substantial disparity between economic and financial returns. This possibly suggests that there exists a case for further subsidisation of MMHP developments, with subsidies being used to bring about greater correspondence between commercial returns as perceived by entrepreneurs and the potential economic or social returns which the community could enjoy.

The effect of the plant factor on various electricity generating plants shows a reduction in the cost of energy generation with rise in plant factor. In general, an accepted value would be for a plant to work at least 60 percent plant capacity in order to sell electricity at NRs. 2 per kWh. The existence of a low system load factor is due to the fact that more than 90 percent of the energy is used merely for domestic lighting. Practically, there is none or very little energy-use in productive activities either in industrial or agricultural sector. Very few of the sample plants report its use in commercial sectors (hotels, tea-stalls and other shops). The performance shown by the Barpak plant which is a 50 kW plant and operating for industrial use as well, has to be accepted as an exclusive case, as there are external factors such as higher income level and more technical experience of the local people in that village. Most families there have served in the British Gurkha Army and their income from that source accounts for the success of the plants in this area. This is a situation which cannot be replicated in most areas of the country.

As seen from the study, the installation cost and the cost of energy are both high at the mini-micro scale when compared with large, medium and small scale hydro plants. This is largely due to the fact that the mini-micro plants are not being used to full capacity. The plants have been installed in the hope of putting them into intensive use, but these hopes have not been realised in practice. As remarked above, this situation - rather than implying that the technology is inappropriate - calls for the introduction of more end-uses for the hydro-plants.

Comparative study indicates that the mini-micro-hydro plants offer better returns than the diesel powered or solar photovoltaic plants. Micro hydro has advantages in terms of diversity of use, cost of operation and environment friendly. A further important consideration is that all the mini-micro-hydro plants are operating turbines which have been manufactured in Nepal. In meeting the demand for such equipment, Nepal has become a producer of mini-micro-hydro turbines - turbines that the smallest scale of 1 to 200 kW. The technological capability of the turbine manufacturers in Nepal will be examined in subsequent chapters of this study. It may be noted that the wide use of mini-micro-hydro plants has led also to the establishment of enterprises producing equipment for use with the mini-micro-hydro turbines - items such as grinders, hullers, the oil-expelling machine, low wattage cookers and, most recently, electronic load controllers.

CHAPTER-5

TECHNOLOGICAL CAPABILITY BUILDING IN DEVELOPING COUNTRIES

5.1 INTRODUCTION

The examination of factors leading to the successful economic development of newly-industrialised countries, all of which have been heavily dependent on access to foreign technology for their initial start, ushered in a new dimension in development literature. It calls for emphasis on the management of technological development as a process of combining local and foreign technological elements to develop a range of local technological capabilities (*Choi, 1989; Habibie, 1990).* Though controversial, some economists like Choi, *(1989)* and Sharif *(1986, 87)* argue that that exporting raw materials and primary goods for imported machinery and process know-how is a loosing strategy, as purchasing power of such commodities has steadily fallen, while the price of machinery has continuously risen. On the other hand a strong conviction of the need to build technological capability (TC) and to develop the ability to transform raw materials into high value-added goods is gaining ground amongst the developing countries (*Choi, 1989; Habibie, 1990; Enos, 1987; Lall, 1990, 1996).* Developing countries have for a long time given high priority to promoting and developing small scale industries for income generation as well as for making income distribution more equitable (*McPherson, 1995*), but the technological aspects have received very little attention (*Shariff, 1989*). Accepting the critical role of accumulating technological capabilities to master imported technology and to keep pace with global technological changes, this chapter deals with technological capability building in developing countries. A brief survey of the relevant theoretical approach towards economic development through technological capability building is provided in section two. No clear definition of technological capability (TC) has been established in related literature. Terms such as "technological capacity", "indigenous capability" and "technological mastery" are used to refer to the same concept. Some authors are found to refer to TC as synonymous with technological changes, while others make a clear distinction. Section three provides the definition used in this study. TC in the development literature is analysed with emphasis on various determinants, whose identification and understanding are necessary to arrive at policy recommendations to provide or consolidate variables that effect the development of TCs. Given that there is no common definition for TC, it is necessary to analyse the various forms of TC as addressed in the available literature. Section four provides a classification of the various forms of TC. The major source of acquiring TC in the developing countries is associated with various forms of learning as postulated by Bell and Lall. Section five discusses about some of the common forms of learning. Section six discusses the embedded difficulties encountered by LDCs in the acquisition of capabilities and the measures required to overcome them. Section seven presents the conclusion of the chapter.

5.2 TECHNOLOGICAL CAPABILITY AND ECONOMIC DEVELOPMENT

The prospects of technological capability building can only be enhanced with a proper understanding of the role of technology and the impact of technological change on economic development. Technology, perceived as a set of techniques or ways of producing "useful things" (*Stewart, 1977*) by enterprises, has two dimensions: the first is equipment and the second is knowledge. From the technical aspect it is defined as the "application of scientific knowledge and skills to the setting up, operating, improving and expanding of productive facilities" (*Lall, 1987:1*). The second definition is somewhat broader than the first. This sees technology not only in terms of knowledge of the "hardware" of production (engineering goods, intermediate goods, raw materials etc.) but also as "software" (*UNCTAD, 1987; Stewart, 1977*), -

extending to all skills, knowledge and procedures for making, using and doing useful things, including those techniques directly involved in production, services such as administration, education, banking, law and so on, and comprehending also the nature and specification of the products. In addition to this Fransman and King (*1984, p. 9*) include the "social organisation of production and the labour process". Technology does not equate with machinery alone; to comprehend it adequately, it becomes necessary to decompose a technology into four embodiment forms (*APCTT, 1988; Sharif, 1997, 1988a*), which are: object-embodied physical facilities or the "Technoware"; person-embodied human abilities or the "Humanware"; record-embodied document facts or the "Infoware"; and institution-embodied organisational framework or the "Orga-ware". It is the unique combination of these four components' productivity which determines the market value of the ouputs of the enterprises. Chaisnais (*1986*) calls productivity gains, a "chronic disturber" of comparative advantage, providing the principal source of change for firms, regions and nations, the obvious cause and effect of cumulative wealth of rich nations (*Rosenberg, Landau and Mowery, 1992*).

Researchers have approached the question of why some countries have a higher growth rate as compared to others. The role of technology in determining this differential growth has been recognised for sometime. The contribution of technology has been approached in very different ways by various schools of economists. These differences will be dealt with the use of the classical productivity equation:

5.2.1 The Neo-Classical Approach

The neo-classical theory of growth translated mathematically is represented as

$$O = f(L, K)$$

where:

O = output

L = Labour

Q = Capital stock

This function treats output as a function of capital and labour.

It is assumed by the Neo-classicals that the production function is "well-behaved". Implicit in the "well-behaved production-function" assumptions is the understanding that capital and labour are perfectly substitutable and that factors of production are paid according to the value of their marginal products, that there are constant returns to scale and no technical progress, and that capital is malleable (*Archibughi and Michie, 1998:9; Fagerberg, 1994, 1149, Malecki, 1997: 37)*. The neo-classicals also assume that technology is freely available to all countries, sharing the same pool of technology, but fail to address the actual mechanisms of technical changes (*Fagerberg, 1994:1147*). In explaining the economic growth of the United States, Abramovitz (*1956*) and Solow (*1956*) added an exogenous term labelled as "residual" component or "technological progress" to this production function. Technology was still treated as a "free good" readily available to all. These researchers found the role of the residual to be as high as 90 percent; an attempt was made to "squeeze the residual" (account for this residual) with the inclusion of factors such as education (*Nelson, 1981*), quality of inputs (*Jorgenson, 1996*) and employment mix (*Denison, 1967*).

5.2.2 New Growth Theories

The new growth theories have concentrated on technological advances as more of an endogenous phenomena. Working on this line, economists (*Nelson, 1994; Pack 1994*) have included investments in R&D, infrastructure and human capital in the conventional production function, giving the representation:

$$O = f(L, K, R)$$

where:

O = output

L = Labour

Q = Capital stock

R = "Residual Factor", taking care of investment in R&D, Infrastructure and Human capital

Attention is seen to be directed more and more to the process of how imported technology is assimilated, adapted and mastered to undertake innovation in production, processes and products. The focus shifts from the consequences of technical change to its causes (*Kharbanda and Jain,1997*). It is also seen to shift from the forms in which technical change is manifested to the agents of change i.e. from processes and products to persons and institutions (*Nelson, 1995*). This approach to the understanding of economic development sees technology and the environment in which it is nourished as important variables.

Unlike the neo-classical approach which disregards the actual mechanisms of technical changes and postulates increases in capital and labour to generate economic growth, the new growth theory takes technological difference as the prime cause for economic difference across countries (*Fagerberg, 1994*). It envisages the existence of a technological gap which is reflected in the differences in growth rates.

5.2.3 Evolutionary Theories

Joseph Schumpeter attached particular importance to the contribution of the innovating entrepreneur: he makes "innovation" the mainspring of autonomous investment. Innovation takes the form of technical progress or resource discovery, or other new development. He thought of innovation in general as any change in the production function which would bring an increase in output. "Any doing things differently", which increases the productivity of the bundle of factors of production available is he said , an innovation (*Schumpeter, 1934*). He listed five major forms of innovation:

* Introduction of a new good, that is one with which consumers are not yet familiar, or of a new quality of good;

* Introduction of a new method of production, not yet tested by experience in the branch of manufacture concerned, which need by no means be founded upon a discovery scientifically new and also exists in a new way of handling a commodity commercially;
* The opening of a new market, that is a market into which the particular branch of manufacture of the country in question has not previously entered, whether or not this market has existed before;
* The conquest of a new source of supply of raw materials or part manufactured goods, again irrespective of whether it has first to be created;
* The carrying out of the re-organisation of an industry, like the creation or the breaking up of a monopoly position.

The stress on the leading role of the entrepreneur in economic development under capitalism is the main feature of the Schumpeterian system.

Schumpeter views the entrepreneur as a man "who sees the economic potential of an invention or resource discovery and brings it into use". Although Schumpeter's entrepreneur is the agent of technological development, the capability of those actually working with the technology once installed, and their role in bringing about innovation, is not emphasised.

As expressed by Antonelli (*1995*), the evolutionary theory explicitly observes the variety of product, processes, economic agents and institutions as the key to economic development. The strength of this theory lies in the fact that the idea of a "well-behaved" production function especially in the context of developing countries is rejected. The arguments against the neo-classical model can be categorised under four main lines of attack questioning the effectiveness of the market mechanism [1]:

1 For details see Myint, H. (1971), "Economic Theory and the Underdeveloped Countries", where this argument has been made with respect to the suitability of applying development models used developed countries in the study of developing countries

* The market mechanism works more imperfectly in under-developed countries than in advanced countries for various reasons, such as greater degree of immobility, indivisibility of resources, and imperfect knowledge;
* The surplus of labour in under-developed countries and shortage of other factors e.g. capital and natural resources, creates a dis-equilibrium. This fundamental dis-equilibrium cannot be corrected by merely improving the allocative efficiency of the market mechanism on the basis of given resources, techniques and patterns of consumer demand;
* the market mechanism can only make one-at-a-time marginal adjustments whereas an effective development programme requires large structural changes introduced by a simultaneous expansion of a wide range of complementary industries.
* free markets tend to fossilise or exaggerate existing market imperfections and the inequalities in income and bargaining power that are to be found in many underdeveloped countries.

5.2.4 Technological Capability Building in the Developing Countries

In the course of time opinions regarding technology and development have come through a steady change. The need for technical learning began to be emphasised. Several factors contributed to this development. Innovation activities in developed countries, according to Dosi (*1984*), Freeman (*1982*), Rosenberg (*1976*) and Pavitt (*1984*); technological transformations in the newly developing countries and their ability to export goods and services of high technology content (*Lall, 1982, 1984b*) have placed technology in the forefront of economic growth and focused on it as the key to maintaining international levels of competitiveness. Over the decades technology has become a prominent topic of analysis amongst scholars, incorporating technological elements such as skill and R&D. The attempt to address the technological gap (*Krugman, 1990: Dosi, Pavitt and Soet, 1991*) has been made by treating these elements in the analysis of technological change. The empirical evidence from studies on India,[2] Korea[3], Japan[4] and Latin America[5], carried out by various economists and the World Bank indicate that amongst the factors determining productivity the quality of "labour" and "environment" (*Malecki, 1997*) have much influence on economic development. The ILO (*1981*[6]) defines Technological Capability as : ".... ability of a given country to choose, acquire. generate and apply technologies which contribute to its development objectives". An instrumental definition is provided by Fransman (*1986a*). He expresses TC as ".... a general set of abilities to conduct in the activities of buying, producing and selling". This definition is common with that of Enos (*1990*) who also includes activities other than production, activities which may have just as much of a technological content. Buying and selling require knowledge, constantly accumulated and purposefully applied, if they too are to be carried out efficiently.

In the 1960s and 1970s research on technology in poor countries was directed to the question of appropriate labour or capital intensity of production technique. The neo-classical theory was concerned with choice of technique from a given set of technical alternatives to produce a given product. The aim was to identify the optimum technique to meet a country's (developing country) objectives, especially those of employment creation and economic growth. Until the late 1970s, the implicit assumption was that Third World Countries should import technologies from abroad instead of focusing on local technological capability as it was believed that "Third World Countries possessed extremely weak technological capabilities" (*Fransman, 1986a*). Rosenberg was of the opinion that the Third World Countries were technically dormant in many important respects as:

> *" Many of the major innovations in Western technology have emerged in the capital goods sector of the economy. But under-developed countries with little or no organised domestic capital goods sector*

2 Study carried out by S. Lall,1982, 1987
3 Study Carried Out by C. Dahlman et al, 1987
4 Study carried out by P. Franks
5 Study carried out by Lall,. Enos and W. H. Park (1988) and A.H. Amsden
6 cited in Enos, 1991, p 4.

simply have not had the opportunity to make capital-saving innovations because they have not had the capital goods industry necessary for them. Under these circumstances, such countries have typically imported their capital goods from abroad, but this has meant that they have not developed the technological base of skills, knowledge, facilities and organisation upon which further technical progress so largely depends" (Rosenberg 1976 pp 146-7)

With a relative absence of technological innovations in developing countries, it is not surprising that discussions revolved around acquiring technology from abroad and discouraged significant national R&D efforts. Industrialised countries were viewed as the main source of technology and the trans-national enterprises as a means for transferring technologies. The technology transfer process was not seen as free of imperfections. Questions as to the suitability of the imported technology, with respect to factor endowments, and scale, and basic needs of the population in the Third World were raised and the need to choose suitable production techniques was emphasised (*Fransman 1984*). This static approach to technology was eventually challenged: a new set of directions developed in research - concerned with technology in a dynamic setting with attention on how technology changes over time, whereas previously the major concern was with the static question of choice out of a given set of techniques (*Stewart and James, 1982*)[7]. Expanding upon this, various experts (*Fransman and King 1984; Enos and Park 1987: Forsyth 1990 and Lall 1987, 1990, 1996*) stress the importance of being able to handle imported technology rather than the matter choosing an appropriate technology. The ability to increase the productivity of the installed technology through incremental innovations thus appears to be to be of utmost importance.

7 For Details see *Stewart and James, 1982,* Economics of New Technology in Developing Countries

5.3 DEFINITION OF TECHNOLOGICAL CAPABILITY BUILDING

The definition of the concept of technological capability depends on whether it refers to TC at the firm level or at the national level. In general, different kinds of technological capabilities are distinguished as corresponding to different technologically related activities:

1) the search for available alternative technologies
2) the selection of appropriate technologies
3) the mastering of technology
4) its adaptation in order to suit specific production conditions
5) the further development of the technology through minor innovations
6) the carrying out of R&D

At the firm level technological capability can be defined as the ability to select, assimilate, adapt and improve existing or imported technology or to create new technology. The development of technological capability is viewed as a process of learning taking place in a sequential manner. Sharif *(1997)* divides the technological capabilities into two distinct components, the "technological " and "managerial."

The mastery of technology is charted through four phases - acquisition, utilisation, absorption and innovation (*Amsden, 1989*). This process of technological development consists of either building indigenous capabilities within a producing unit or in developing them through linkages between a given producing unit and public sector bodies, industry associations, universities, R&D institutions or other producing units (*Malecki, 1997*).

The definition of TC may be extrapolated to the national level in the following ways. National TC refers to the ability of the country to use knowledge effectively to select, assimilate, adapt, improve, diffuse and/or create technology. Such capability is reflected in industrial dynamism, diversification and competitiveness, It is important to stress, as Lall (*1990*) points out, that because of externalities and inter-linkages, national TC is not simply a sum of individual TC.

Efforts have been made to derive a general model of the process of TC building in LDC's by identifying various stages in the acquisition of TCs (*Lall, 1982; Dore, 1984; Fransman 1984, 1985, James 1988*). The sequence defined by James (*1988*) consists of the following steps:

1. Identification of opportunities, the reaping of which - or a problem, the amelioration of which - involves a technological dimension;
2. Searching the existing technological shelf, screening and selecting the appropriate technologies and, if property considerations are involved, bargaining effectively for the acquisition of the new knowledge;
3. Operating the technology;
4. Adapting technology to local conditions, according to local factor prices, range of skills available, consumer tastes, local inputs, climate etc.;
5. Modification of the technology in response to a changing economic environment;
6. Producing and acting upon designs leading to major equipment modification or new or sustainably modified products;
7. Conducting enterprise-based R&D in an organised, systematic way;
8. Setting up a new plant or undertaking a major expansion of an existing one.

The various stages are further distinguished by the qualitative depth of knowledge required in the activity. An extraordinary amount of effort - calling for a conscious strategic decision by the firm - is required to achieve this set of capabilities.

5.4 VARIOUS FORMS OF TECHNOLOGICAL CAPABILITY

It is difficult to apply any conceptual differentiation of the forms of TC in practice. Efforts have been made to classify them in order to understand and identify the kind of skills, amount of effort and other implications for each type. A treatment based on the works of a number of writers such as Fransman (*1984*), Dahlman *et al (1987)*, Lall (*1987*) and James (*1988*) gives the broad division discussed below:

5.4.1 Acquisition Capability

Acquisition capability refers to the ability to search for, assess, negotiate, procure and transfer technology. What Dahlman (*1990*) identifies as acquisition capability is described by Lall (*1987*) as investment capability. This capacity to search and select technology, is according to Dore (*1984*), attributed to the technological information base which allows a firm to survey what exists and is available in the world, to detect new developments and to judge their appropriateness and to learn the details. The capacity to acquire technologies includes the capacity to identify the technology sources - an important aspect of which is the knowledge and information about existing range of choices and the costs involved in the alternative ways of obtaining the knowledge (*See Malecki, 1997; Lall 1990)*. In the context of LDCs, Ranis (*1990*) describes Stewart's (*1977*) "technology shelf" as a mistaken concept as these countries have little or no information on what is available in the world or even in their own country; this implying a high search cost for the LDCs.

Pavitt (*1984*) aptly states that the decisions firms make regarding the choice of technology, innovations and product development are constrained by the existing range of knowledge and skills. This level of skill also determines what they can realistically try to do technically in the future. Generally the search is guided by two factors: the first is for techniques that are relatively more close to the technique already in use; the second involves judging the activities of competing firms, equipment suppliers or R&D institutes. If a newly found technique is more profitable than the prevailing one then the firm switches over to the new technique, thus establishing a new starting point for future local searches (*Nelson, 1987*). The lack of previous experience and limited contacts with the world technological frontiers hampers the ability of LDCs to exercise the second type of search.

Past experience is helpful in the selection of technologies. This search capability is supported by access to information, the ability to make evaluative judgement and the identification of parameters that are sensitive to local conditions. The so-called technology shelf is moving as technical change proceeds, and some parts of the shelf are moving faster than the others. An important aspect is being able to follow this change. This involves the ability to anticipate future technological developments and requires not only access to information network systems but also the ability to analyse these information and forecast the changes *(See Stewart 1977; Malecki 1997).*

The alternative source of new technologies may be local, public or private R&D centres. These sources are however, very much undermined in developing countries because of weak linkages between local research institutes and industrial firms *(Reddy 1979; Stewart, 1978; Desai, 1980).* Instead, as stated by Sagasti (*1979*), the private sector centres its technical activities on copying or importing technologies from abroad without considering local universities as a source of technologies. Types of decision-makers, government or multi-national corporations, the objectives of decision-makers, scale of firms, government policies, institutional behaviour and established relations are some of the non-technical factors influencing the selection of technologies (*Lall, 1996, Huq et al 1993, Chalise, 1997*).

The ability to make a purchase of most suitable technology (suited to the prevailing technical resources available in the country and purpose) comes through technological knowledge and experience. The ability to bargain allows the buyer to buy technologies suited to his needs on proper contract terms and to select suppliers on the best terms. In fact there is a direct relationship between the level of TC possessed by the buyer and his bargaining power. The higher the TC attained by the buyer the greater the bargaining power since he can evaluate more precisely the real value of different components of the technology he is to acquire. His knowledge base regarding various components re-enforces his ability to negotiate with the seller.

5.4.2 Design and Project Implementation Capability

To carry out an investment project means setting up new firms/plants or the subsequent expansion of existing firms. Here the project owner lays down detailed specifications for the project defining its layout, input requirements, product and product mix and the scale of production. A package is thus developed defining the main features of process and operation conditions, maintenance and repair for implementation in the subsequent stages of the project which include both technical as well as non-technical activities.

The actual setting up, plant/project implementation capability, involves engineering (mechanical and construction) and organisational capabilities. The main functions are detailed engineering design, equipment specification, procurement, testing, civil construction, mechanical erection, over-all project co-ordination and supervision, commissioning and usually training of operators (*Lall, 1987*).

LDC firms participate to a lesser extent in the definition and analysis of initial design conditions then on the implementation of the project as a result of ignorance or lack of concern and difficulties regarding access to information (*Sercovich, 1987*). Chudnovsky (*1986*) reckons that the design capability that has been developing in Brazil, India and Korea lies in the area of detail design rather than in the more fundamental area of basic design. More positively, Amsden and Kim (*1986*) argue that, in the case of Korea, TC has come to include basic design, at least for a limited sub-set of products. However, studies of TCs within the capital goods sector have found that developing countries like Brazil, India, Korea, Taiwan and Hong Kong are limited in their competence (*See Pack, 1982; Fransman, 1984; Chudnovsky, 1986; Amsden and Kim 1986; Fransman 1986 b*) due to an under-developed capital goods manufacturing sector which prevent synergies associated with local basic design activity, given that process and equipment design usually require collaboration with capital goods producers.

5.4.3 Assimilative Capability

The capacity to assimilate describes technological mastery or operational capability. It refers to the successful use of technology in transforming inputs into outputs. It implies successful operation and maintenance of the plant. It includes development of labour skills to meet standard specifications and training to upgrade technical competence. Technology mastery is not achieved merely by importing foreign technology. The extent of indigenous effort required for successful achievement of technological mastery is demonstrated in the technological changes processes or innovations (incremental or radical) taking place in a firm *(Dahlman and Westphal 1982)*. It is the initial effort aimed at "debugging plant, mastering production routines and skills, and achieving rated capacities and quality control" (*see Freeman 1984, Sagasti, 1979).* This is possible only when a firm has achieved a certain level of scientific and technological capability. i.e. it has, as expressed by *Sharif (1997),* the ability to use imported technologies more effectively through adaptation and improvement, to improve traditional technologies, to reduce dependence on advanced countries and to export some technologies for striking a better bargaining position for imported technologies. King (*1984*), characterises this ability as the confidence to analyse, un-package, modify and adapt imported technologies leading to proper understanding of the technological factors which affect the productivity of plants. This allows activities to be taken to optimise the use of resources, which in turn conditions the competitive characteristics of the final product. The task of learning to make effective use of existing knowledge requires technical effort (*Dahlman and Westphal, 1982*). Thus technical mastery of foreign technology or the process of assimilating it is itself difficult, long and uncertain (*Lall, 1987*).

In LDCs the effort required is even greater, when the technology itself is new to the country and complex in its characteristics. In the beginning it involves learning basic operating skills and routines, trouble shooting, achieving rated capacities, setting up suppliers, quality control, balancing different stages of the process etc. (*Lall, 1987*). These activities are characterised by an explicit assimilative effort which has to be internal to the firm. Technological knowledge that cannot be directly absorbed by the enterprise, or the absorption of which could be too expensive, can be acquired through developing consulting capability at national or regional level, together with the exploitation of information and technical extension services. The rate of technical absorption may be slowed down when reliance on foreign consultants is maintained and no explicit actions are taken to transfer technological knowledge and experience from foreign to local engineers.

5.4.4 Modifying Capability

Modifying capability refers to the ability to carry out modifications to existing technology. It involves the acquisition of additional knowledge to make minor products and process modifications. The imported technology is often best suited to the factor endowments of developed countries and adaptation is required to match the transferred technology to the prevailing conditions in the LDCs (*Katz 1987*). Adaptive changes may be made to the product to adjust it to local needs and preferences, or to the input requirements to permit the use of locally available material and resources. Adaptation may consist of adjustment to a smaller scale of production, adjustment of the quality or nature of the product, adjustment of ancillary processes to the lower cost of labour, use of local materials and so on. These adaptations involve a process of making existing technology more appropriate to local conditions.

Although it is easier to modify an existing technology than to create a new one, the technological efforts required for the modification of technology, to adapt it to local needs or to make minor improvements, are hindered by the lack of adequate technological infrastructure and the numerous imperfections in information and skill markets prevalent in the LDCs. Thus availability of different kinds of skilled labour supply and quality of local resources, the size and characteristics of local markets, degree of competition in protected markets, foreign exchange shortage etc. are factors that affect the degree and direction of adaptive activity and general technology activity.

Korea sets a good example of a country that has acquired the capacity to search and select the technologies to be imported. It has effectively assimilated various elements of foreign technology and it has implemented minor innovations that have been significant in increasing production efficiency, changing production design, upgrading quality and improving management practices (*Westphal et al, 1984b*). The creation of a technical infrastructure built into an institutional framework has supported such development. There is also a strong base of technical human capital and a high educational level of the population, as well as high expenditure on R&D as compared to other newly industrialised countries (*See Lall, 1990, Enos and Park, 1987, Westphal et al, 1984b*).

5.4.5 Innovative Capability

Innovation has been referred to as the activities related to improving existing technologies either through incremental and minor modifications or major changes. "Minor" changes are considered as important elements leading to technical progress (*Stewart, 1976; Teitel, 1984; Fransman, 1985; Lall, 1982, 1987; Dahlman, 1989*). Lall (*1987*) points out that major technological innovations are not the only ones, perhaps not even the main sources of productivity improvement in the history of industrial development. Accordingly minor changes in the given technologies - to equipment, materials, processes and design - are vital and a continuous source of productivity gain in practically all industries. Considering technological progress as a movement along the "frontier" only, according to Lall, is an over simplified neo-classical approach.

On the other hand, product engineering, production process engineering and industrial organisation and production planning activities generate a steady flow of new technical knowledge or information when changes are introduced in the engineering routine of any given plant, generating in this way an incremental flow of technical information useful within the firm (*Katz, 1987*). Innovation should, therefore, be defined broadly to cover all the activities involved in the technological capability described above.

In order to avoid confusion, the term innovative capability is restricted to the capacity to perform formally organised innovation activities within the firm or to the institutionalised research for more important innovation with developed forms of R&D facilities (*Fransman, 1984*). Innovation here involves the ability to carry out radical product or process modification, achieve major changes, or create new products and processes. It is also relevant for the absorption of advanced new technologies (*Dahlman, 1990*). Some necessary conditions wherein innovative capability can be developed as stipulated by Freeman (*1974*) are:

- Strong in--house professional R&D;
- Readiness to finance heavy R&D experiments over a long period and to take high risk;
- Ability to identify potential markets;
- Careful attention to potential markets and substantial efforts to effectively co-ordinate R&D, production and marketing;

The capacity to innovate relies on a series of functions such as:

- Technological forecasting: Definition of the future scenarios for technical and scientific achievements, location of the firm, competence and the technology suppliers within these scenarios;
- Technological planning: Identification of strengths, weaknesses, obstacles and limitations of the firm and proposals of actions and requirements of technological development by the firm;
- Technological development: Actual execution of experimental activities to support technological innovations and substantial modification of the technology in use;

- Information systematisation: Collection, strong analysis, bringing upto-date relevant technology information and observe selective dissemination of the information system;
- Allocation of funds for training and skill development;
- Allocation of funds and manpower for R&D: This depends on the role of R&D in the hierarchy of the firm, autonomy given to R&D manager and an accountability system;
- Design and implementation of incentive structure for innovation at the shop-floor, production engineering etc.;
- Other institutional linkages with the outside world.

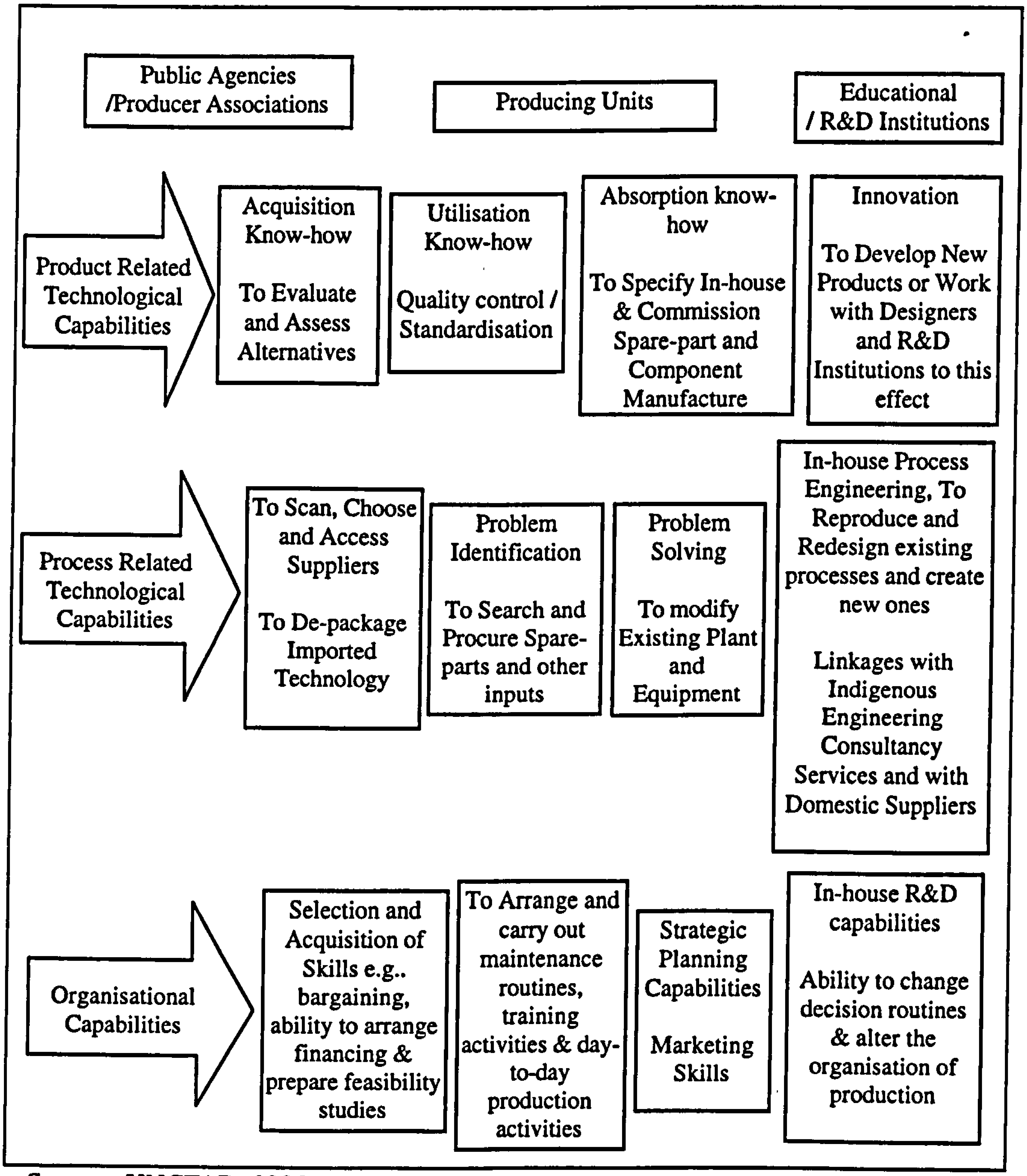
It is important to note that LDCs very rarely produce products and processes that are in a fundamental way new to the world (*Fransman, 1985*).

At the national level, the development of the new technology is an alternative to foreign technology and a way to reduce technological dependence. The capability to create technology is composed of a predetermined quality and quantity of scientific and technological manpower with which to conduct pure and applied R&D activities, physical facilities and other support facilities and services. The ability to create technology also depends on co-operation between government and industries, links between the educational and productive sectors, a sound financial base and the development of local human resources.

The encouragement and use of local technology to achieve economically justified national independence can be seen as a policy with realistic possibilities only for some countries since the expenditures involved are often beyond the means of individual low-income countries which lack technicians, engineers, scientists and could never achieve the necessary economies of scale (*Stewart, 1987*).

A study carried out by UNCTAD in 1990 presents a conceptual framework depicting an outline of many of the key technological capabilities required for sustained growth, structural transformation and continuous adjustment (*See Chart.5.1*). These capabilities are categorised along three dimensions - production related, process related and organisational technologies and are in agreement with the various kinds of activities involved in each of the forms of TC described by Lall (*1987*).

Chart 5. 1: A Matrix of Technological Capabilities



Source: UNCTAD, 1990

An additional form of capability is the linkages capability. This refers to the information and skills required to interact with entities outside the firm and becomes critical when any form of transfer of technology is carried out by the firm. The importance of being able to transfer out technological knowledge and the nature of such knowledge depends on the industrial sector in question. For example, the capital goods industry is probably the sector which most strongly develops linkages through sub-contracting and other means of local sources; for science-based industries, collaborative research with academic institutions deserves special attention.

Enos (*1988*) is of the opinion that developing countries should channel their technical skills into improving existing lines of activities, concentrating on the absorption of new technologies and their diffusion rather than attempting more ambitious ventures. In the developed countries technological change or technological development generally means the introduction of a new product or a superior process of production (*Lall, 1987*). However, these major innovations according to Rosenberg (*1974*) are not the main sources of industrial development. Minor changes in the given technologies - the equipment, raw material, process and design - are more vital. This comes through continuous learning-by-doing and may or may not require formal research and development (*Lall, 1987*).

5.5 SOURCES OF TECHNOLOGICAL CAPABILITY BUILDING

The four categories of TC discussed above are inter-linked at every stage contributing to mastery of the others. Sources of technology may be endogenous, generated primarily through research and development (R&D). Alternatively, technology can be obtained from exogenous sources - other people, other firms, other regions. However, if external sources are relied upon, the successful integration of new ideas and techniques demands an internal capability to assimilate external knowledge. The competence to discover, select, adapt, utilize, learn and improve new technology is a key determinant of economic success of firms, of employees and consequently of the regions in which they are located.

5.5.1 Learning

The success of the NICs has accentuated the need for development of technological capability and the significance of skill and knowledge acquisition which goes beyond reaching static efficiency. TC is also a major determinant of dynamic efficiency, i.e. of adaptation to change, of improved productivity performance and of innovation (*Enos and Park, 1987; Scitovsky, 1988; Hans Duller, 1992*). Their experience further highlights technological capability as a desirable attribute as it enables a developing country to exploit fully existing techniques as well as, ideally to improve upon those that are perfectly suited to the country involved (*Enos, 1991*).

The theory on development of indigenous technologies now believes that a shift towards sustainable industrialisation is possible only through the development of technological capability which comes through a sequential process of learning in various aspects (*Dahlman et al, 1987; Lall 1992*). The term "learning" is understood to mean "the acquisition of additional skill and knowledge by individuals and, through them, by organisations" (*Bell, 1984, pp.188).* Bell (*1984)* distinguishes "doing based" learning such as learning by operating and learning by changing from other mechanisms where learning depends on the allocation of resources such as learning by training, learning by hiring and learning by searching. In other words some activities are based on experience accumulation (doing-based activities) and others involve explicit effort and investment.

The process of technological learning itself may not be known to LDC firms. Thus "learning to learn " may be a by-product of learning in the same way that learning by doing is a by-product of producing. In other words, the ability to learn, like the ability to produce can be improved (*Stiglitz, 1987*).

5.5.1.1 Learning by Doing

"Simple" learning by doing is an indispensable, but relatively minor, element in the acquisition of TC. It is characterised by three properties: it arises passively, it is virtually automatic and it is costless (*Bell, 1984*). The kind of addition to TC in the doing-based learning process comes through the acquisition of greater understanding of the particular form of technology, the acquisition of greater understanding of the principles involved and the acquisition of increased confidence in manipulating the technology.

In the process of learning by doing, a cause-consequence effect can be noticed. Various kinds of "doing" lead to augmented technological skills, but at the same time the learning which is thus achieved is a function of the prior existence of capacities to undertake such "doing" and acquire knowledge during the process.

5.5.1.2 Effort-Based Learning

Learning by doing is one mechanism of accumulating TC but at the same point explicit effort or investment becomes a necessary condition for any further progress. According to Bell's definition, technological effort is the conscious use of technological information and the accumulation of technological knowledge, together with resources, to choose, assimilate and adapt existing technology and/or to create new technology. This definition can be applied at the firm-level, where specific activity is taken or at the national level where legislation, administrative process and operations by special organisations promote the incorporation of efforts to attain economic and social goals.

Many authors point out the relevance of technological effort to achieve and reinforce indigenous TC (*Dahlman and Westphal 1982, Katz 1984a, Bell et al 1984)* and several case studies at the country level (*Westphal et al 1984a, 1984b for Korea, Lall 1984 for India*), at the industrial level (*Katz 1984b for metal working industries*) and at firm level (*Dahlman and Sercovich, 1984*). Lall (*1987*) thus describes the process of TC acquisition through effort based learning:

> *Assimilation tends to be an important component of technological activity in early stages, and constitutes the initial base for technological learning. But it becomes routine over time, as the focus shifts to adaptation, maintenance and improvement..... If the requisite technological capability exists, minor changes appear early in the firm's life, increasing in range and sophistication as its stock of knowledge increases. The process of "survival" type of adaptations (to local raw materials, climate, skills and scales) shades into adaptation made to lower costs or raise productivity..... Adaptation shades into more adventurous innovative activity as enterprises grow technologically mature.... In some activities, raw material prices, availabilities and quality change over time causing enterprises to alter and improve their processes accordingly. Major jumps in process technology are not usually developed locally and even mature enterprises tend to import these in the form of new equipment or license.... Nevertheless, the selection, implementation and improvement of such major technological jumps require substantial technological effort.* (pp. 235-36)

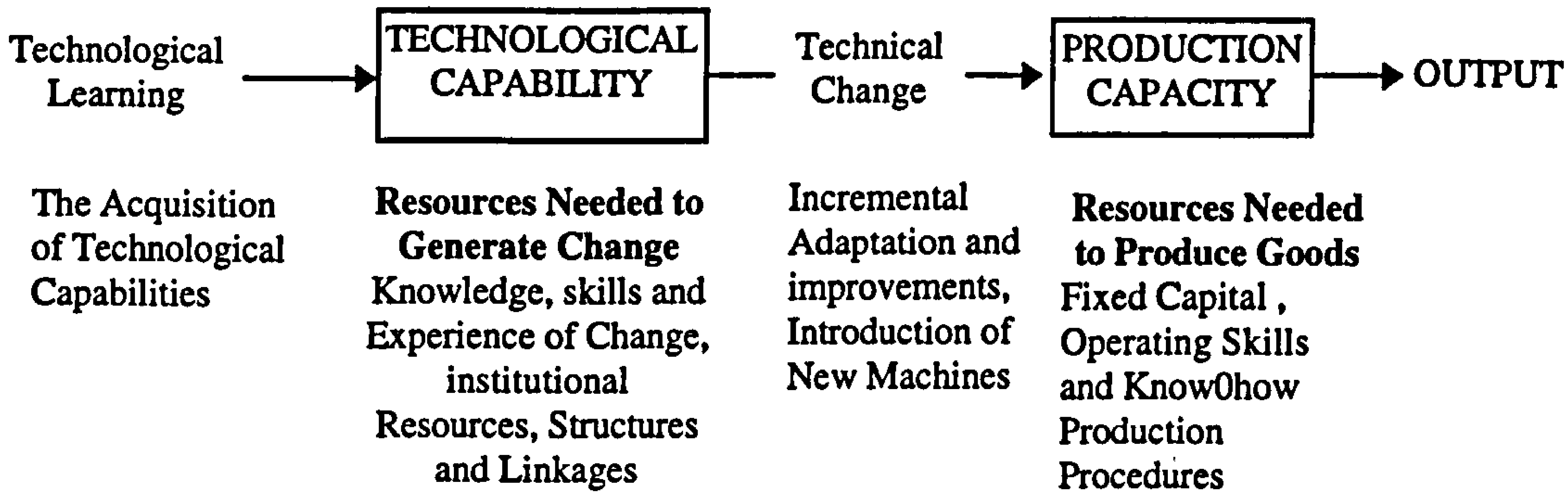
Learning is not automatic and simply a function of time of use of some particular technique. Other factors are also necessary. Two are noted by Bell et al (1984): first the firm needs to devote resources to the learning process; second, the external environment needs to be conducive to technical change. A framework provided for examining technical learning at the firm-level by Lall (*1987*) and Fransman (*1984*) is represented by a "learning ladder"; the first step is the elementary achievement of technological capability building; the second in the sequence is ability to recognise an opportunity or problem entailing a technological dimension, the capacity to search and select an appropriate technology and negotiate effectively for the technology; the third is the capacity to make minor innovations for adapting the technologies for local conditions; next is the capacity to conduct in-house R & D. In the case of machinery (capital goods) production, Fransman (*1986c*) suggests the need to produce "both pecuniary externalities in the form of machinery that has been adapted, modified and improved as well as non pecuniary externalities in the form of manpower which has been trained to bring about such changes in machinery".

There is a growing recognition that it is necessary for nations to develop their science and technology by introducing incentives as well as an atmosphere conducive for innovative activities, developing necessary human resources and providing appropriate institutions - infrastructural and support services so as to reap the total benefit from imported technology (*Lall, 1992*). There is also a growing consensus that the firms are the chief locus of accumulating technological capabilities in the developing countries. Expanding along this line Enos (*1991*) states that: ".... the producing firm is the most important creator of technological capability. If technical competence resides anywhere, it is within the producing firm". (*Enos 1991, pp. 85*).

Bell and Pavitt call the learning process involved in building the underlying dynamic resources "technological accumulation" (*Bell and Pavitt 1993, pp. 164*). The relationship between these different terms and concepts is represented schematically below in *Chart 5.2*.

The process of technological learning so defined indicates how a firm with fixed set of technological capabilities might generate a stream of improvements in production capacity over time. Such improvements may be important for enabling the firm to modify or scale-up production, unlike a firm which lacks in technological capabilities at all. Such a firm would be rigid and unable to adapt to any changes in the environment. This model reflects the most important task facing any firm in the long run is technological learning: the acquisition and strengthening of their technological capabilities.

Chart 5. 2: Technological Capabilities Basic Concepts and Terms



Source: Bell and Pavitt 1993

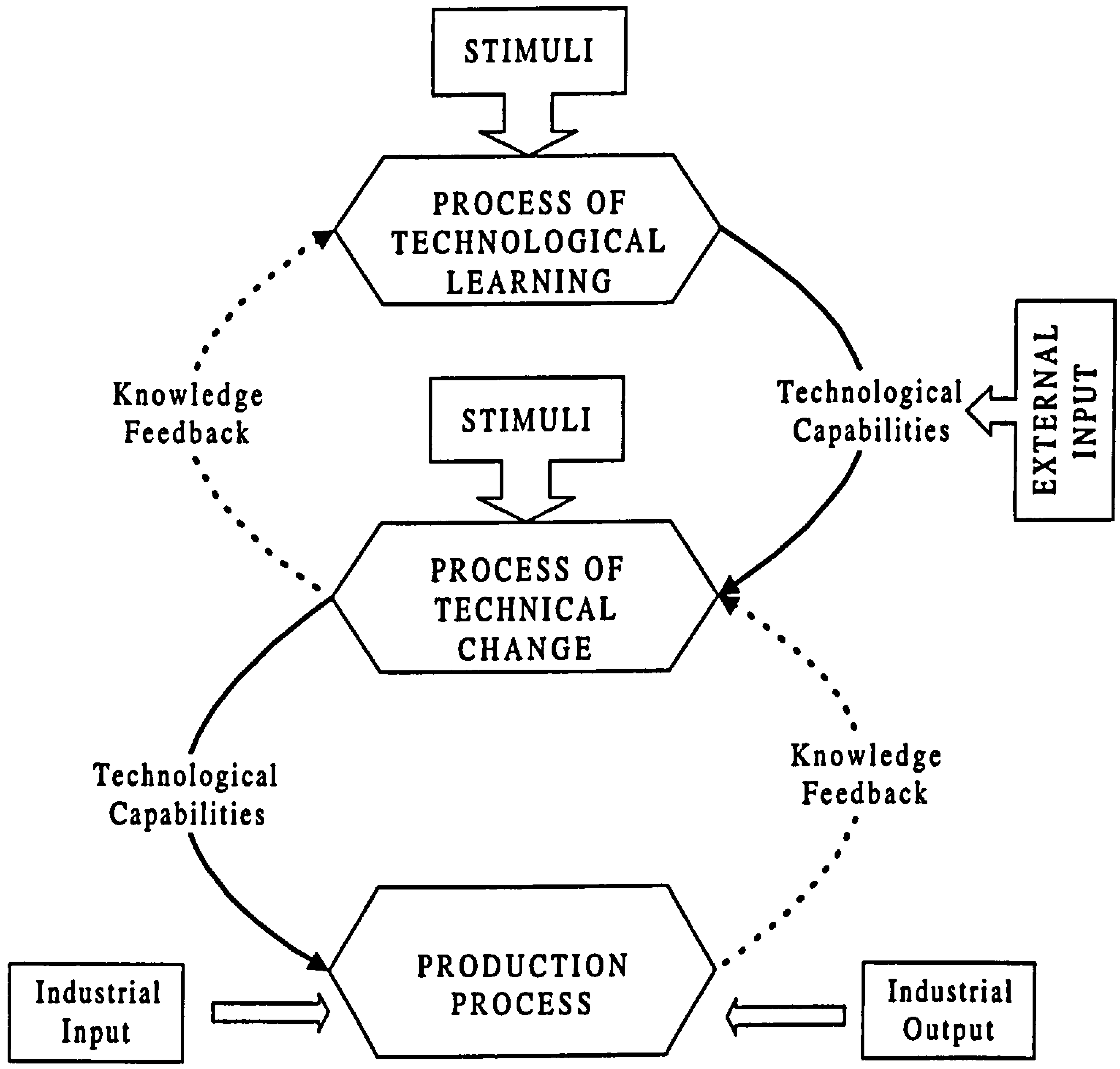
The above model represents a linear relation between technological learning, technological capabilities, technical change and production capacity. In reality it is represented by cycles where learning involves a moving back and forth between doing (action) and thinking (theory). While learning individuals build up on the theories that provide coherence to a complex world of experiences which are continuously put to test in the realm of action. Using the knowledge gained from this action is then used for further improvement of the theoretical understanding. Thus indicating that learning requires some degree of systematic feedback. Firms that monitor their performance, analyses their strengths and weaknesses, plan strategically are more likely to learn and improve than ones which are in fire-fighting mode, reacting to external events (*Albu, 1997*).

Chart 5.2 represents the relationship between technological learning, technological capabilities, technical change and production capacity for simplicity as a linear process: It is widely accepted however, that learning processes are best represented by cycles. Jambekar and Pelc (*1996*) for example describe and compare four examples of learning cycles devised by Dewey, Deming, Kolb and Kofman. All these models share the idea that learning involves a moving back and forth between doing (action) and thinking (theory). The argument is that when individuals learn they build theories that provide coherence to a complex world of experience. These patterns of knowledge are then continuously tested in the realm of action. For learning to proceed however, it is essential that the learner reflects on the results of the action - using the knowledge gained to update and improve the theoretical understanding. As the output of this activity (knowledge building and action) results in changes in the existing stage i.e. stage of capability and state of the product, the learning process can be defined as defined as an "iterative" process rather than a "cyclic process" which requires at least some degree of systematic feedback. By analogy, the same cyclic process can be applied to learning in organisations and firms. Organisations which monitor their own performance, analyse their strengths and weaknesses, plan strategically and are more likely to learn and improve than those which are constantly in-fire-fighting mode, reacting to external events.

Combining this iterative view of learning with the system of technological learning terms as used in Bell and Pavitt' s linear model (Chart 5.2) gives a model of inter-locked learning cycles shown in Chart 5.3 where the main flow-lines of Bell and Pavitt's model is now supplemented by learning feedback loops. The upper zone presents the technical learning process. TCs are used to generate and manage a process of technical change whose product is production capability. A certain amount of knowledge feedback may be derived from the process of technical change in order to augment the process of technological learning whose outcome is improvements in technological capabilities.

The lower zone is the technical change process. The existence of production capacity is used to convert material inputs into goods. The experience from the production process helps in augmenting a process of technical changes leading to improvements in the production capacity. This is however, possible only with the existence of certain level of TC to generate and manage technical change.

Chart 5. 3: Firm Level knowledge Acquisition System



Besides there is a need for stimuli at the technical learning process and the technical changes process which may be internal or external to the firm. *Table 5.1* illustrates examples of stimuli, input and feedback relevant to each level of learning.

Table 5. 1: Illustrative Framework for Knowledge Acquisition System

	Process of Technical Learning	*Process of Technological learning*
Stimuli	Short term changes in demand Competitive threats and opportunities Demonstration Effects	Government policy encouraging innovation Culture and norms of social environment Strategic awareness of economic trends
Knowledge feedback	Skills and Knowledge gained from experience of production interaction between producers and users	Skills and Knowledge gained from investment projects Insights gained from effecting improvements and modifications
External inputs	training in Operating Skills Hiring Skilled Labour technical Advice Service	Training in Strategic Planning, Designs Management of technology Collaboration between Research and industry Consultancy Services

Source: Albu, 1997

5.5.2 Linkages

Lall in 1980 stipulated several different types of linkages amongst enterprises which form a key element in capacity building. According to Lall, manufacturing industries do not develop capabilities in isolation. They operate in a network of formal and informal relationships with suppliers, customers, competitors, consultants, R&D as well as educational institutions. These linkages help individual firms to access information, skills and facilities which, very often, are not available under a single roof. Although the extent of need of the linkage may differ, generally there is the requirement of a constant flow of information, skill, etc. for maintaining efficiency and to make decisions regarding investment and capability building. In developing countries, the institutions and the network between them are far from reaching maturity.

Ernst *et al* relates linkages capability to knowledge, skills and organisation competence associated with the transfer of technology at three different levels: within the firm, between firms and between firms and the domestic science, engineering and technological infrastructure. The effect of this linkage capability is to support in improving the effectiveness of firm-level innovation strategies.

5.5.3 Marketing Capability

This capability related to the knowledge and skills of the firms in collecting market intelligence, for developing new markets, establishment of distribution channels and provision of customer services. The ability to identify customer needs and the ability to translate this into successful products and services requires a strong in-house product and design systems, engineering capabilities and the ability to redefine their marketing into a strategic management function (*Clark, undated*).

5.6 TECHNOLOGICAL CAPABILITY BUILDING: GOVERNMENT AND INSTITUTIONS

There have been some attempts to systematise the study of factors acting upon the development of indigenous TC whether considered in general or in terms of its different forms (*Katz 1984b; Katz 1987; Ranis 1984; Bhalla and Fluitman 1985, OECD 1987; Lall 1990, 1992a).* Added to these are research works carried out on the topics of catch-up, forging-ahead and falling back (*Abramovitz, 1986*) with the suggestion that there is more at work in economic growth than what can be captured by capital and labour (*Baumol, Nelson and Wolff, 1994*). A strong emphasis in these studies is on the role of institutions (*Nelson, 1995*) which vary from country to country. According to Porter (*1990*), the large variations in a multitude of political, social, legal and institutional elements profoundly affects the competitiveness of various industries. Freeman (*1994*) strongly criticises the neo-classical model of development for its lack of attention to institutions and institutional changes, while Pack (*1994*) finds it ironic that the new growth theories focus on R&D and externalities rather than on organisations and institutions. Rosenberg (*1982*) on describing the difference in geographical variation in technological capabilities points out the misunderstanding of the complexities in the functioning of institutions besides social systems and incentive structures as one of the causes. The institutions related to industrial development comprise the governance system, rules and standards, sources of basic research, sources of human resources and finance and an instrumental sub-systems including suppliers of R&D, manufacturing, marketing and distribution.

Authors like Gerschenkron (*1962*) have expressed the view that backward countries are fortunate in that they have a backlog of technologies to draw upon. Although there are already technologies which the developing countries can draw upon, the question is - is their mere existence enough to ensure technology absorption and diffusion? According to Amsden (*1989, p 130*) "Gerschenkron failed to give equal weight to the proposition that the more backward the country, the harsher the justice meted out by market forces." Given the imperfections in the identification and purchase stages, the availability of technologies in the developed countries does not give any guarantee to the latecomers that, by depending on market forces, they will even be able to select the cost-minimising alternatives, far less achieve technology absorption and diffusion.

This is where the setting up of appropriate institutions, geared to the specific needs of industrial efficiency, becomes significant. The development of autonomous, specialised institutions with proper structures of control and incentives can be critical to the building and deployment of industrial capabilities through economic system. Government can play a central role in promoting, encouraging or directly setting up such institutions (*Malecki, 1992*). "As far as capabilities are concerned, there is perhaps more agreement on the need for policy interventions to promote physical and human capital development and technological effort. The interventions needed may be selective as well as functional if industrial strategy itself is geared to realising a specific form of comparative advantage." (*Lall, 1995*).

A variety of market imperfections can reduce the efficiency of private-market performance. The properties of efficiency in resource allocation and its optimal distribution, which characterise a competitive equilibrium, depend on the existence of a competitive set of markets. But the developing economy is to an extent characterised by an incomplete set of markets (*Meier, 1989*) deficient in provision of information, subject to lags in adjustment and insufficient competition among firms. Under these uncertainties it can then be argued that it is in the public interest to have the government correct these informational deficiencies.

Government can support co-ordination in the private sector without distorting incentives. Communication and transportation infrastructure facilitate the market's ability to direct resources into their highest and best use. Market information, including the support of research and design and liberal banking policies, can make market opportunities available to many potential entrepreneurs. These policies complement the market's ability to select the organisation or organisations best suited to exploit a particular market niche (*Kim and Ma, 1996*).

Other means of government involvement are reflected in various ways - tariff policy, technology transfer negotiations, aid negotiations, management of public sector projects, credit policy towards private sector, export policy, R&D support, manpower development (*Huq, 1995*). In order to sustain economic development "... state should not only maintain the macro-economic balance and supply of public goods and services, but it should also undertake direct responsibility both for augmenting the economic investible resources and for establishing a mechanism to transfer these resources into productive investment leading to capital accumulation".

Theoretically, government promotion of R&D activities is further justified by arguments related to spillover effects. R&D activities often produce knowledge that benefits not only the inventor but also others (*Minami et al, 1995*). Formal education, on-the job training and centralised technology information services are areas affected by lack of R&D activities. Private firms may under-invest in R&D activities when such activities require large amount of investment and involve extraordinary risks which they are not willing to bear (*Kim and Ma 1996*). Here arises a case for propounding strongly for government programmes to encourage private R&D activities, to improve education and vocational training as well as encourage centralised consultancy services (*Lall, 1996; Enos 1995 and Sakuma, 1995*).

Even classical economists saw that science has a function in relation to the development of production (*Fagerberg, 1994*). Works of Adam Smith and Karl Marx depict their keen interests in the origins of new technologies, sources of innovations and their effect on technological change. Science to them was more of an application of scientific principles to production than a specific search for new techniques in a research laboratory. For Smith "philosophers or men of speculation" *(Smith, 1964, pp. 9*) as well as workers and machine-makers were more responsible for many of the mechanical "improvements". Stressing upon the link between science and production, Marx (*1961, pp. 322*) deliberates that science lies at the origin of technological advance in the capitalist economy. He goes on to point out that technological advancement generates new specialised skills at the interface of science and production - i.e. various types of engineering. Analysing Marx's works, Cooper (*1973, pp. 3*) explains that these new specialists are then able to interpret the needs of the entrepreneur to the scientists and economic demands begin to affect the orientation of science. Schumpeter believed that the competitions in the market economy gives birth to demand for "innovations". Essentially he believed that new technologies were a source of advantage to the entrepreneur.

On the other hand, there are authors such as Bernal (*1970*), who rewriting the history of science, elucidates how research laboratories have become an important source of technological innovations. Besides accepting science as an integral part of production, there is an increase in the investment in scientific researches by the entrepreneurs as they see it as a potential source of profit. Despite these underlying problems, there is the transfer of these foreign technologies in the developing countries in profusion. Of the several explanations for this trend, some of them outlined by Cooper (*1973, pp 13*) are market imperfections i.e. distortion in relative factor prices. To counter the rising problems due to this technological dependence according to Cooper is to develop local innovative capacity including local R&D. However, it is obvious that scientific institutions in the under-developed countries have been alienated from production activities. On the other hand, here science is more like a consumption item lacking direct investment from their users. Research here is undertaken by individual research workers who have more or less very little links with the economic and social realities surrounding them.

Finally it is not enough to say that "developing countries cannot leave it to market forces", it is necessary to create a right, supportive environment: create the supply of technical manpower to assimilate technological development and set the right environment for their industries to develop the requisite capabilities ... "specific policies have to be implemented on the extent of protection, domestic competition imports of technology, in-house R&D, the nature and amount of foreign investment, provision for a S&T system[8], and all other things that influence learning and production efficiency." (*Lall, 1987, pp. 240-41*).

Amsden (*1989*) is an ardent supporter of strong government intervention in the developing countries. Similarly in his studies of underdeveloped countries including Bangladesh and Ghana, Huq (*1996, 1989*) too stipulates not only the need for government intervention but a supportive government intervention in the economic activities of a country. Observations from the three industry studies from Bangladesh (*Huq, et al 1990, 1992, 1993*) and Ghana (*1989*) provide evidence of the lack of progress in technology promotion largely because of the absence of government commitment, whereas in the case of South Korea (*Enos and Park, 1987, Amsden 1989*) the government has played a beneficial role with the conclusion that "... there is no stage in the process of incorporating an imported technology that a conscientious and patriotic government should neglect," (*Enos and Park, 1987: 257*). In line with these observations Huq (*1994*) strongly emphasises "... for technology promotion the support of the state needs to be unwavering as in the case of South Korea. State commitment combined with policy constraints is likely to yield only partial success, as evidenced in the case of India, whereas an obstructionist policy regime as found in the

8 The science system or scientific infrastructure has been defined as institutions whose activities involve mainly the discovery, articulation and propagation of scientific and technological knowledge (*Clark, N 1987*). At the heart of it is research and development, "a creative work undertaken on a systematic as is to increase the stock of scientific and technological knowledge and to use this stock of knowledge to device new applications" (*Freeman, 1974*).

case of Bangladesh will lack state commitment and failure in technology promotion may be expected to result."

5.6.1 Education and Training

Knowledge in the industrial sector, conveyed through education and training, is a crucial determinant of the acquisition of TCs. Education and technological training (including in-firm training) are essential to the provision of skills required in all forms of TC, from the most basic engineering activities to the most advanced R&D. Therefore, the adequacy of national education and training systems appears to be a crucial factor in determining how effective a country's firms are in applying technological skills across the full range of their activities. It also determines the capacity of individuals and of the labour market as a whole to respond to changing circumstances, over a longer term (*Enos, 1990; Lall, 1990; OECD, 1987*).

The importance of the availability of S&T skills has been demonstrated in many empirical case studies dealing with TCs in developing countries. Katz, (*1984a*) points out the development of a wide spectrum of technological and engineering skills in Latin American countries, that permits these countries greater likelihood of successful manufacturing production. For East Asian countries, Pack (*1988*) argues that methods of production that would have been technologically infeasible become viable because of the presence of highly educated managers and technicians. In this line can be cited the case studies of Pack (*1983*) of petro-chemical, iron-steel and textile firms of Korea where emphasis was laid on the importance of personnel training.

The examples point to the importance for industrial performance, of availability of educated and trained people in the appropriate disciplines. The significance of the different kinds of education and training depends on the level of industrial development. Basic literacy and numeracy and low levels of education are sufficient for early stages of industrialisation - for the utilisation of simple machine embodied technologies. As the level of technical sophistication increases, so does the significance of vocational training and advanced technical education. The better educated the labour force is, the greater will be its capacity to adjust to sophisticated new technologies. High technologies enhance the need for basic science capabilities. Finally, in an environment of high technological change, in-firm training becomes indispensable to the continuous creation of new skills (*Teitel, 1982; King, 198; Lall, 1990).*

There has been a clear lesson from successful countries, both developing and industrialised. It is generally accepted that the successful industrialisation of the East Asian NICs was possible because of the availability of a sufficient number of educated and literate people. This favourable human environment has been largely the result of an early priority given to the development and upgrading of human resources. Important efforts were made not only to expand and improve secondary and higher education but also to organise an efficient country-wide vocational training system. The quality of this training is considered to be the decisive factor in dealing with technical change and in applying new technologies (*UNIDO, 1989*).

According to Caillods (*1984*), the middle-level skilled personnel are crucial for technological development of firms, but this is an element which is sometimes neglected in the planning of the educational system or employer training programmes. Enos (*1990*) concludes that in many LDCs, there is a shortage of graduate engineers and scientists, while in almost all there are shortages of technically trained persons of the lower ranks.

The institutions involved in providing skills, basic to high-level, are mainly technical schools, universities and research institutes. In addition, informal education or -"local knowledge -systems" form, in a many countries, a crucial input to TC development. These local knowledge systems, according to King (*1984*), are connected with the non-cognitive aspects of indigenous TC. They are particularly evident in the expanding activities of the informal sector of the economy. They are very widely disseminated and they are not necessarily unscientific and anti-modern.

5.7 CONCLUSION

Rapid technological change poses a major challenge to developing countries today. Most countries in the process of development through industrialisation seek to gain access to new technologies, as users if not producers. They are aware that the technologies will effect their ability to build modern industry and compete in the world markets. Recent literature on development has focused more explicitly upon concept of TCs, identifying stages or categories of technological development and stipulate a strong case for Third World countries to develop their own capacity *(Stewart, 1987)*. This is to enable them to use imported technology more efficiently, because imported technology is rarely adapted to Third World circumstances and its efficiency can often be markedly increased by local adaptation. Local technological capacity reduces dependence on advanced countries, permitting countries to strike a better bargain for imported technology, as well as contributing to objectives of independence and self- reliance. The development of local technological capacity can lead to comparative advantage in this area and significant export earnings.

Although various empirical case studies on TCs which have been carried out in LDCs lack an explicit theoretical framework (*Stewart, 1984, Enos and Park, 1987; Lall, 1987; Huq et al 1990, 1991*) they provide a valuable source of data for theoretical analysis. Different forms of TCs have been identified: search and selection, design and project implementation, assimilation, adaptation, improvement and major innovation. Empirical evidence shows how they grow in different degrees in different entities, each one having its own importance and implications. In each of the TC forms, a process of learning is acknowledged and demands an explicit technological effort. TC is a multivariable determined concept, and because of the nature of the variables involved, it is not possible to state them in exact order to measure or estimate their influence. A further complication arises from the fact that the variables identified as determinants of the development of TCs are dynamic and therefore the building up of TC will be affected by the direction and rate at which such variables change over time. Increasing degree of sophistication of the technology components demands increased capability of successful operation as well as the ability to undertake maintenance, to replicate and to make adaptation according to local conditions, and to successfully introduce TC which is either incremental or radical. Further, operational capability of these components is dependent on many micro and macro economic variables which are collectively conducive to and responsible for building up indigenous technological capability at the firm level. The spread, assimilation and further improvement of new technologies largely determine the patterns of consumption, growth and trade among developing countries and the world at large (*Malecki, 1997*). This is because technologies enable quantitative growth of any production function by improving the conversion efficiency of inputs to outputs. Also, qualitative improvement of any productive activity results from the use of new technologies (*Stewart and James,1982)*.

Developing countries have been users of imported foreign technologies rather than innovators and the process of technological improvements that occurs in these countries relies strongly on the use, assimilation and adaptation of such imported technologies. Literature analysing TCs in LDCs allows one to confer a corresponding degree of importance on various forms of TCs, as opposed to the emphasis given to aspects of innovation in the technological change literature. This is not to deny that major innovations cannot be carried out by developing country firms, but they have not contributed to this element in the process of building TCs in LDCs.

Enterprises in developing countries do not have the capabilities to create frontier technologies/innovations which require a well developed R&D infrastructure. This is true of most of the developing countries. These countries start off by implementing technologies from abroad, followed by incremental changes at the shop floor. This kind of technology change, although incremental, plays a very significant role in the overall technical advances of the firms. Experience is believed to be a major source of technological capability but not the only factor. It is also a matter of other conditions in the economy, the industry and the firm e.g. the extent of skill availability, the need for technology adaptation. The existence of technological capability as a significant phenomenon has a number of implications for choice of technique and choice of project, as well as for general economic policies.

There is the need to find a balance between the promotion of technological self-reliance and the introduction of the most advanced technologies from abroad. These aspects are not mutually exclusive and a compromise between importing technology and developing internal technologies can be found. Both activities, in the last instance, lead to the acquisition of TC in different forms. In general the understanding of how and under what circumstances local TCs develop is a very valuable contribution to the policy making process, if an adequate environment to promote and enhance the acquisition of an indigenous TC is considered as a means of achieving national level objectives.

An important conclusion at the national level is that education and training constitute a crucial determinant of TC formation and technological change. Investment in human capital development comes as a straight-forward policy recommendation for all LDCs. The levels and areas of education and training that need to be emphasised depend very much on the level of development and the TCs already attained by the country in question.

Finally the analysis of the relationships between technological variables and other developmental variables has to be adjusted to the peculiarities of each country. This is primarily because developing countries are at different stages of industrialisation, but have different development goals and economic policies and are different in terms of structures and sizes of their markets, resource endowments and socio-political conditions, all of which will influence and shape the development and form of national TC building.

In conclusion technological capability, just as capital goods, are accumulated over time. Both require the sort of resources that are most scarce in developing countries. Both yield a product that is not useful in itself but in the other products that its application permits; both take considerable time in their production and yield their flow of services over a period of time; and both can become obsolete with further advance in the state of the art. Yet they are different, capital goods being physical pieces of equipment, technological capability being embodied in a collection of technically skilled individuals moved by a common purpose. To the extent that they require the same resources, in limited supply, the creation of capital goods and the creation of technological capability compete with one another, either being generally absent, the developing countries must import the missing one or forgo production; in this sense the capital goods and technological capability are complements, whereas, endogenous capability and imported capability are substitutes.

CHAPTER - 6

MINI-MICRO-HYDRO TURBINE MANUFACTURERS IN NEPAL

6.1 INTRODUCTION

This chapter focuses on the assessment of technological capability of the mini-micro-hydro power (MMHP) turbine manufacturers in Nepal against the technological capability indicators as discussed in Chapter 5. The discussions of the interviews of the manufacturing firms conducted by the author is presented in section 6.2. Section 6.3 provides some background information on the firms on which this study is based. Technical background of turbine manufacturing is provided in section 6.4. The MMHP turbine manufacturing in Nepal is discussed in section 6.5. The assessment of the capabilities of the firms is presented in section 6.6. As is evident from case studies based on technological capability in developing countries, much of the technical effort is focused in the production process or modification of the product rather than on changing the core-technology. This section also focuses on the various activities undertaken by the firms as strategies for growth. Section 6.7 reflects on the implications of the case study analysis of MMHP firms, followed by conclusions in section 6.8.

6.2 THE SURVEY OF TURBINE MANUFACTURERS

For the overall objective of assessing the technological capability of the MMHP turbine manufacturing firms it was necessary to identify the firms manufacturing MMHP turbines. Having done so an interview was then conducted based on formatted questionnaires, to collect data with respect to size, structure, age, source of technology, product development activities, cost of product, sales and range of production activities. The information collected was complemented by interviews with concerned experts that were acquainted with this technology, scientific research institutions with alternative energy technology development and promotion, and government officials (*See Appendix*). 11 companies were identified as operating in the manufacture of MMHP turbines, five in the Kathmandu Valley and six in Butwal. A description of these firms is presented in Section 6.3. Attempts were made to contact all of the 11 identified companies, but only 10 companies have been included in the sample. Each firm was visited and interviewed for this study.

The reason for not being able to carry out the study using a universal sample was that one of the firms was impossible to contact for detailed interview and furthermore, it was learned that it had moved on to other business. However, data based on published information have been used to analyse the general status of the firm.

As the assessment of capabilities is qualitative in nature, every company analysed required several visits and extensive interviews. Despite constraints due to limited resources the survey has managed to cover almost all the firms operating in this sector. The interviews with personnel of the firms were directed at an assessment of their technology acquisition, assimilation, modification and innovation capabilities and their growth strategies.

The interviews were carried out in 1994 - 1995 in order to determine to what extent know-how capabilities have progressed into advanced innovative capabilities. A later visit in 1996-97 permitted the collection of further relevant information.

6.3 MMHP TURBINE MANUFACTURERS IN NEPAL

Table 6.1 presents a list of Nepalese MMHP turbine manufacturers and their locations. This section discusses some specific features of the sample firms.

Table 6. 1: Name and Location of Mini-Micro-Hydro Turbine Manufacturers

Name of Manufacturer	*Abbreviation of Firms*	*Location*	*Size*
Balaju Yantra Shala	BYS	Kathmandu	Small
Nepal Structural and Engineering Company	NSEC	Patan*	Small
Agricultural Engineering Works	AEW	Butwal	Small
Thapa Engineering Industry	TEI	Butwal	CI
Nepal Yantra Shala	NYS	Patan*	Small
Kathmandu Metal Works	KMI	Kathmandu	Small
Butwal Engineering Works	BEW	Butwal	Small
Inter-Tech Limited	ITL	Butwal	CI
Nepal Hydro and Electro Company	NHECO	Butwal	Small
Nepal Metal and Steel Structures	NMSS	Butwal	CI
Nepal Power Parts	NPP	Bhaktapur*	CI

Note: * Patan, Kathmandu and Bhaktapur are within the Kathmandu Valley, Butwal is 262 km. from Kathmandu

Source: Field Survey, 1995

Growth and Ownership

Table 6.2 sets out the ownership of the firms. It shows that the larger enterprises have been established through foreign collaboration, whereas the smaller ones were initiated by private entrepreneurs. The first hydro-equipment manufacturing firm, Balaju Yantra Shala (BYS), was established in 1961 as a joint venture between the Nepal Industrial Development Corporation (NIDC) and the Swiss Association for Technical Assistance (SATA). It was a public organisation, managed through a governmentappointed Board of Directors and Managing Director. However, in 1987 it was converted to a private company and shares were floated to the public. At present there are 17 shareholders. BYS started as a small mechanical workshop to undertake repair and maintenance jobs for the other firms developing around the capital and in the Balaju Industrial Estate within whose boundaries the firm still stands.

Three years after the establishment of BYS, the United Mission to Nepal (UMN), in co-operation with His Majesty's Government of Nepal (HMG/N) started a project for industrial development in Butwal. The initial objective of BTI was to train manpower for enterprises to be established within the Butwal Industrial Estate. Although BEW was involved in the design and manufacturing of hydro-power related equipment the need to develop local capability in the manufacturing of MMHP was strongly felt. Under this project the Butwal Technical Institute (BTI) for training of technical manpower was established. In 1977 BTI then divided into BTI, the 'Production-cum-Training' section and the Butwal Engineering Works (BEW) section which since then has developed into another leading mechanical engineering workshop in Nepal.

As an extension of BEW's involvement in designing and manufacturing of electrical and mechanical equipment for hydro-power projects, it was felt that Nepal must enhance its capability to design, manufacture, refurbish and repair equipment for the development of small and medium hydro-power resources in the country. In 1985, Nepal Hydro and Electro Company (NHECO) was established in collaboration with Kvaerner Energy (KEN) and ABB National Transformer AS (ABB), Norwegian partners. At present BEW and NHECO operate under the same management[1]. KEN provides technical support for the design, manufacture, refurbishment and repair of water turbines, governors, various types of gates and related equipment for hydropower projects. With support from ABB, NHECO has installed facilities to manufacture power-generation and transmission-control panels and for quality repair

1 Hence forth in this study BEW and NHECO is to be considered as the same firm and the term will be used interchangeably.

of distribution-transformers, it possesses a full-fledged workshop capable of handling multiple jobs required for hydro-power development support activities.

Over the years, with the exception of Kathmandu Metal Industry (KMI), headed by a traditional metal-work technician, other MMHP manufacturers have emanated from the two main establishments, i.e. BYS and BEW. The smaller firms fall into two groups: those established as private organisations with shareholders (NYS, AEW, NPP, NSEC and TEI) and one under sole proprietorship (ITL). KMI was initiated by a family of traditional metal-workers and NSEC established as a family business. ITL was established by a group of mechanical engineers. The remaining firms (NYS, TEI, NMSS and AEW) were established by technical personnel working for or trained at BYS or BEW who moved out to establish their own workshops and started manufacture as well as in the installation of MMHP plants.

Location

Except for KMI which is located in the heart of Kathmandu city, other firms in the Kathmandu area are located within industrial estates: BYS is situated within the Balaju Industrial Estate, NSEC and NYS are located within Patan Industrial Estates and NPP within Bhaktapur Industrial Estate (*See Table 6.1*). The distribution of these firms seems to be influenced foremost by the proximity of a larger industrial complex as well as access to necessary infrastructure. A similar trend is seen in the location of the firms in Butwal. While AEW and ITL are situated within the Butwal Industrial Area, TEI and NMSS are closer to the Butwal Technical Institute (BTI). BEW and NHECO are both located within the BTI complex. Of the total of 11 mini-micro-hydro turbine manufacturers nine are located in and around two of the most industrialised areas of the country, Kathmandu Valley and Butwal.

Size

For this study the firms are classified by size according to authorised investment in conformity with the method used by the Central Bureau of Statistics which carries out regular statistical studies of the manufacturing sector. This classification is also in accordance with that stipulated in *Industrial Policy 1992, Nepal*[2].

According to this classification the sector comprises of four small manufacturers and one medium sized firm *(See Table 6.2),* with the rest falling into Cottage and Village industries category. As can be seen from *Table 6.2.* ITL, NPP, NMSS and TEI are Cottage Industries; BYS, NSEC, AEW, NYS, KMI, BEW are small scale industries. NHECO is the only medium scale industry. As the turbine manufacturing sector is not separately classified it has been difficult to use the *Industrial Statistics* to get any helpful information.

Age Composition

Categorising the plants according to age presents us with four groups: less than 10 years, 10-20 years, 20-30 years and above 30. The two firms NPP and NMSS, both belonging to the cottage industry (CI) classification, fall into under 10 years group. Four plants, two in the CI category (ITL and KMI), one in the small (BEW) and one medium (NHECO), fall in the group aged between 10-20 years. Similarly four firms one in the CI (TEI) and three in the small scale category (NSEC, AEW and NYS), fall in the group of age between 20-30 years. BYS, a small scale firm, is the oldest and has been operating for 34 years.

Analysis by year of establishment indicates a change in the proportions, in terms of size of firms established: three firms in the CI category and one in the medium scale

2 According to the Industrial Policy (1992), the size of the industries is classified according to the fixed capital investment as follows:
Small Scale - not exceeding NRs. 10 million ; Medium scale - between NRs. 10 and NRs. 50 million; Large Scale - more than NRs. 50 million.

were set up after 1980, as compared to six small scale and one CI category firms established between 1970-1980. (*Refer to Table 6.2*)

Table 6. 2: Age, Size and Ownership of Mini And Micro Hydro Turbine Manufacturing Firms

Name of Manufacturer	*Established in*	*Authorised Capital ($NRs.10^6$)*	*Type*	*Foreign Counter-part*	*No. of Share-holders*
BYS	1960	7.00	Private	SATA (now private)	17
NSEC	1972	5.00	Private		5
AEW	1973	0.50	Private		3
TEI	1973	0.70	Private		3
NYS	1975	0.27	Private		2
KMI	1976	0.30	Private		3
BEW	1977	3.00	Private	UMN	3
ITL	1981	0.50	Private		2
NHECO	1985	25.00	Private	Norway	5
NMSS	1987	0.30	Private		
NPP	1988	0.40	Private		3

Source: Field Survey, 1995

Employment

According to information provided by the firms, the total employment within this sector amounts to 438 jobs (*See Table 6.3*).

Table 6. 3: Employment Provided in Various Firms

Size of Industry	*Number of Persons Employed*	*Unskilled (%)*	*Semi-skilled (%)*	*Skilled (%)*
Medium*	194	36	33	31
Small	206	24	49	27
Cottage and Village Industry	38	14	57	29
Total	438	25	46	29

* This includes the number of persons employed by NHECO as well

Source: Computed from Information Provided by Individual Industries

The skill composition indicates the employment of a large proportion of persons of low skill levels. This however, is not an indication of adoption of low-level technology alone, but rather a reflection of the nature of the labour-intensive technology due to the lower cost of labour. In case of firms categorised as small, except for BYS which employs 140 people, the others employ between 10 and 28 people. The firms registered in the Cottage and Village Industry category give employment to between 6 and 14 people. The lowest employment was found to be with NPP. The ratio of skilled labour to total labour in the firms of the Cottage and Village Industry category is about 29 percent. The corresponding figures for semi-skilled and unskilled labour are 57 percent and 25 percent respectively. The percent of skilled labour is highest, 31 percent, for medium scale firms. The semi-skilled and unskilled labour for this group is 33 percent and 36 percent respectively. In case of medium scale firms the ratio of skilled, semi-skilled and unskilled labours is 27 percent, 49 percent and 24 percent respectively.

Exports and Imports

Collecting information on the export and import propensities of the companies was hindered by the reluctance of the firms to provide sufficient information. However, even a qualitative scenario presents surprises on the export front. It is true that the mini-micro-hydro manufacturers have so far been catering largely to the local rural market. However, there have been occasional exports of the product to countries such as Malaysia, Papua New Guinea, India, Spain, Zimbabwe and Bhutan. The exporters have been mainly BYS, NYS and KMI with much support coming from ITDG. On comparing the cost of cross-flow turbines, the Nepalese turbines cost slightly more than those from Pakistan (*Junejo, 1994*). This cost difference is due to the larger safety factor incorporated by the Nepali manufacturers in designing the turbine. Another reason for the higher cost of the Nepalese product is that Nepal depends on imports for most of the raw materials used in production. A third reason for higher cost of the Nepalese turbines may be the nature of the package offered.

The raw materials for the manufacture of turbines (*See Table 6.4*) are mainly available in the local market as most of them are imported from India. These materials can be easily purchased with local currency and even the importer does not require any special import permit; for materials imported from any other than India a special import permit is required and an the importer has to make separate arrangements for payment in foreign currency. The high cost of materials is attributed mainly to the fact that the manufacturers depend totally upon imports. Some steel rods are produced in the country itself but steel pipes, flats and sheets are all imported, mostly from India; and in fact even when some products such as metal rods are manufactured in the country, the basic raw materials have to be imported. Bearings, bushes, sealing materials etc. come from third countries such as Japan, Bulgaria, Germany, United Kingdom, Singapore, Thailand etc. Polythene pipes and paints are all manufactured in Nepal from imported raw materials.

Table 6. 4: Raw Materials and Their Usage

Turbines *I*	*Machine equipment* *II*	*Penstock Pipes* *III*	*Paints* *IV*
Mild Steel Pipes	Bearings	Mild Steel Plates	Enamel
Mild Steel Plates	Bush	Mild Steel Sheets	Red Oxide
Mild Steel rods	Nuts and Bolts	Polythene Pipes HDP	
Mild Steel Flats	Rubber gaskets		
Mild Steel Channels			
Mild Steel Sheets			
Cold Rolled sheets			

Source: Adapted from Field Survey

As the production is 'demand specific'[3] and storage space is scarce, the manufacturers say it is fruitless to stock up large amounts of raw material. If larger stocks were carried, the cost of raw materials and of the final product itself would be to some extent reduced. In 1994 the price of steel materials were found to vary between NRs. 30 and NRs. 35/ kg. The availability of raw materials as such is not a problem; however, the availability of raw materials which conform to the required specifications is a problem; in consequence, the manufacturers are forced to resort

3 The turbine is produced only when it is ordered by the customer.

either to using material of higher specification, increasing not only wastage but also the cost of the final product, or to using lower specification material, at the cost of quality.

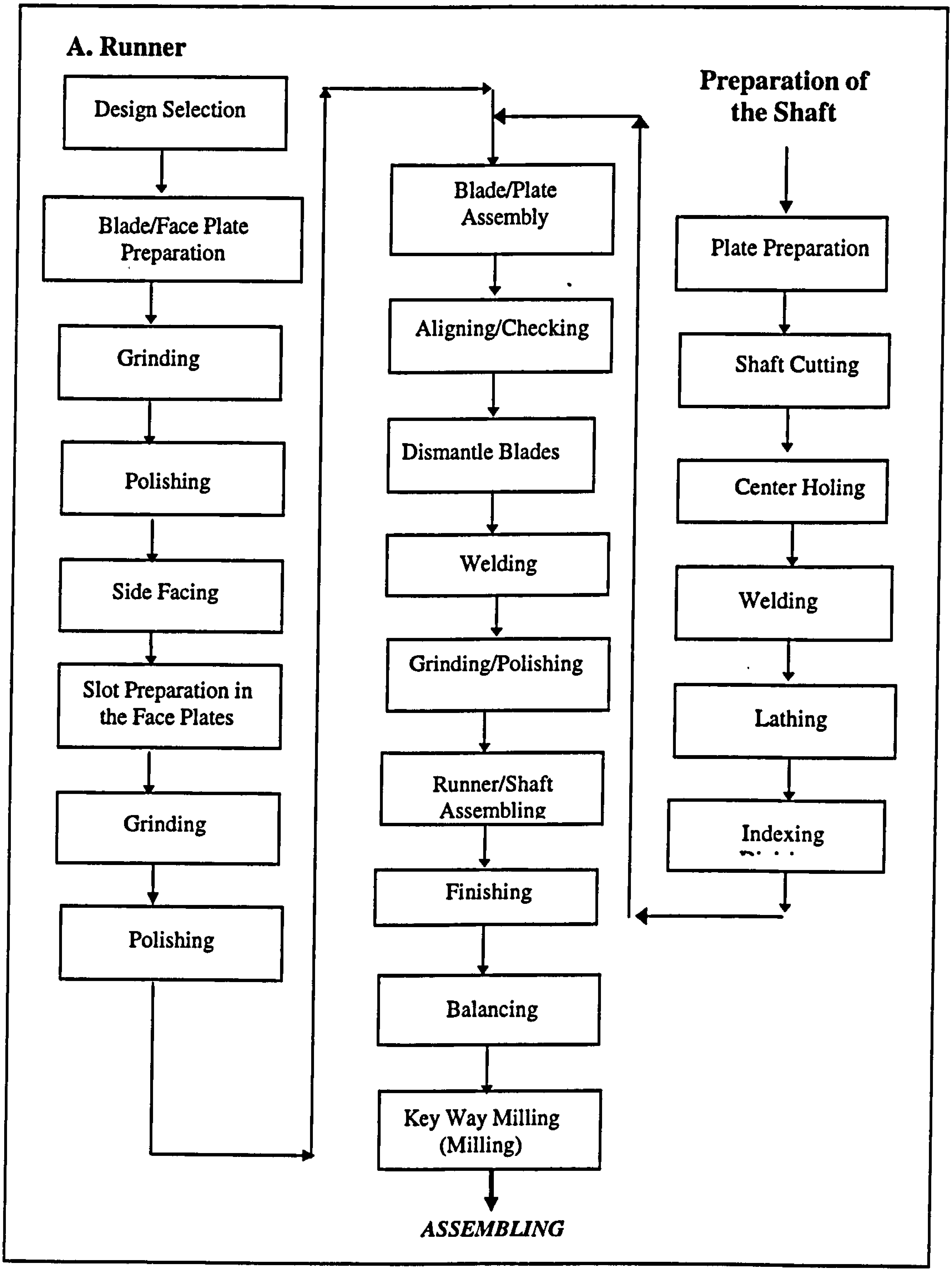
Just as in the case of raw materials for the turbines almost all the elements that go into the making of the ELC, mainly electronic components, have to be imported though they are mostly available in the local market. Such inputs are acquired mainly from the UK. Singapore and India, though items such as wire and switches are made in Nepal itself.

6.4 PRODUCTION PROCESS

In order to determine the technological capabilities of these machinery manufacturing firms it is important to identify the various steps involved in the production process. The general process commonly adopted has been described in Chapter 3. *Chart 6.1* shows the production process involved in the manufacture of various turbine parts. In general the process involves the machining of components and their assembly. Cutting, welding, forging, casting, rolling etc. are carried out as per the requirement of the product. Some of the machining operations involve the use of expensive specialised machine tools, but many of the assembly operations are labour intensive. Most firms depend upon general workshop machines and tools such as lathes, drilling, milling, rolling, sawing, and welding machines and equipment.

Particular processes may be carried out mechanically or manually. In Nepal the use of machines and men in the various production steps of turbine manufacture differs from firm to firm depending upon scale of operations; however, the degree of sophistication of the machines is low.

Chart 6. 1: Production Process of Turbine Runner



The designing of the rotor, and the finishing as well as the assembly of the individual components, are all undertaken by the manufacturers themselves. In view of the fact that the complete production (of the turbine sets) is carried out by individual manufacturers, it is not surprising that each of the firms possesses all the required equipment. However, the degree of sophistication of the equipment is found to vary from firm to firm, depending on the size of the firm.

In the production process, skill-based activities are encountered mostly in designing and machining the profiles of rotors and regulating valves, in achieving the proper alignment of the turbine runner to the shaft (for attaining dynamic balance of the system) and in the design of the governor (to help match the water-flow and demand of the system). Other operations requiring particular attention are related to the design of the casing etc. Assembly of the various components requires more skilled capabilities than do activities such as turning, milling, grinding, welding etc.

In interviews with the manufacturers it was indicated that experienced supervision is of the utmost importance for achieving proper dynamic balance during the process of manufacturing. This reflects the fact that these firms do not possess facilities for testing the dynamic balance. It is important to attain precision in manufacturing in order to prevent untimely wear and tear and reduction in efficiency and to maximise the operating life of the turbine.

From the discussion so far it is evident that the MMHP technology in Nepal is based on conventional mechanical workshop technology. The following section focuses on the technological capability of the MMHP manufacturers.

6.5 MMHP MANUFACTURING IN NEPAL

As noted above the first MMHP manufacturer was set up as a simple workshop in 1961 and the second enterprise was established three years later. As the initial phase in both these firms was dedicated to development of technical manpower it was only in the late 1960s that production in the true sense was initiated. The result of this conjunction of forces is that from the 80 mini-micro-hydro units in all of Nepal in 1981, an average of 76 per year was installed from 1981 to 1988, so that there were 615 in operation in 1988. This was the boom period. Although there has been a slowing down in the market, an average of 45 turbines per year were being installed in the country between 1988 and 1995.

The major force behind this impetus was the emergence of the Agricultural Development Bank (ADB), major supporter of mini-micro-hydro development, which viewed the technology as a potentially significant stimulant to rural development. The ADB was generous in its lending policies and created a technical and promotional service that actively pursued mini-micro-hydro investment opportunities in the rural areas of Nepal.

Local manufacturing capacity developed at several nodes with BYS, DCS and KMI all making their own versions of mill-turbines. Foreign collaboration stressing efficiency, and indigenous knowledge stressing lower cost led to a number of innovations including the low-cost MPPU introduced in 1981. The MPPU was the most common type of unit chosen during the surge of investment in the mid-eighties.

Table 6. 5: Production and Installation of Turbines by Purpose

Firm	*Electrical*	*Mechanical*	*Electrical and Mechanical*	*Total*
AEW	6	11		17
BYS	4	112	10	126
DCS	13	208	30	251
IT		6		6
KMI	10	49	9	68
NMSS		44	7	51
NPP	1	2	1	4
NSEC	1	164	35	200
NYS	1	72	7	80
TEI		81	19	100
Joint	3	3	9	15
Unidentified	10	2	3	15
Total	49	754	130	933

Source: WECS, Kathmandu, Nepal, 1994/95

ADB promotion of rural electrification led in 1984 and 1985 to two significant policy measures (details of these policies are discussed in Chapter 7). Concurrently manufacturers, especially DCS, BYS and KMI were developing add-on and stand-alone electrification units to be locally manufactured and of lower cost (*Jantzen and Koirala, 1989*). *Table 6.5* presents a scenario of the proportion of turbines installed by various manufacturers by type of end-use i.e. whether the turbines installed are used for agro-processing, add-one electricity generating or stand-alone electricity generating plants. The Table also indicates that most turbines, about 80 percent, are installed for use in agro-processing, 14 percent as add-on systems and only 6 percent have been installed as stand-alone systems.

Table 6.6, listing installations, includes mainly cross-flow, MPPU and few other different types of mini-micro-hydro turbines. In recent years the peltric turbine has gained popularity in rural electrification projects. In a span of four years more than 150 peltric turbines ranging from 0.4 to 5 kW have been installed in Nepal (*See Table 6.7*) providing a total capacity of 235 kW. Their rising popularity has encouraged the manufacturer, KMI, to venture into production of Peltric turbines of higher capacity.

A grand total of nearly 1100 turbines was installed in Nepal between the period 1962-1995 (*See Table 6.6*). Since 1992, 156 Peltric turbines have been installed, mainly for electrification. Principal turbine installers, by number of units set up are DCS (251) and NSEC (200). But the leading turbine installer with a total of 282 turbines (166 turbines for electricity only) is KMI.

Table 6. 6: Number of Turbines Installed by Various Manufacturers Over the Years

YEARS	*AEW*	*BYS*	*DCS*	*ITL*	*KMI*	*KG*	*NPP*	*NMSS*	*NSEC*	*NYS*	*TEI*	*JOINT*	*UNSPECIFIED*	*TOTAL*
1962		1												1
1963		1												1
1966		1												1
1970		1												1
1972		1												1
1975									1					1
1976									1	1				2
1977			3							1				4
1978		1	10							1		1		13
1979		5	10							1				16
1980		3	12						1			1		17
1981		2	18		2				7	5	1			35
1982	1	16	19		2				22	8				68
1983	4	9	20	4	4				33	5	4	3		86
1984	3	7	21		4				37	2	6			80
1985	3	15	23	2	7				23	8	17	1	3	102
1986	1	8	19		5				24	14	11	3	2	87
1987		8	18		10			1	17	14	15	4	4	91
1988		8	22		7			2	8	6	1		1	55
1989		6	18		8		1	4	5	2	1	1		46
1990		4	9		6		1	3	3	3	6		2	37
1991		9	8		2			10	5	3	11	1		49
1992		6	6		1			6	3	1	3		1	27
1993					3			9		1				13
1994		6	3		85			11		1				106
1995		2			25	46		5		3				81
UNSPECIFIED	4	6	21				2		10		24			68
TOTAL	16	126	260	6	62	46	4	51	200	80	100	15	15	1089

Source: WECS, 1995

Table 6. 7: Peltric Turbines Installed in Nepal for Rural Electrification

District	No. of Turbines	Total Capacity (kW)
Baglung	12	17
Bhojpur	1	1
Darchula	1	1.5
Dhading	1	1
Dhankuta	3	3
Dolakha	1	1.5
Gorkha	7	6.8
Illam	60	73.9
Jumla	2	4
Kaski	1	0.4
Kathmandu	1	0.6
Khotang	2	2
Lamjung	12	49.4
Manang	1	5
Mugu	1	1
Okhaldhunga	10	11.5
Panchthar	4	3.2
Rupandehi	1	3
Salyan	2	4
Sankhuwasabha	9	11.6
Solukhumbu	3	4.5
Surkhet	3	4
Taplejung	6	8.5
Tehrathum	2	2
Udayapur	5	6.1
Not Specified	5	8.6
TOTAL	156	235.1

Source: ICIMOD, 1995

6.6 ASSESSMENT OF TECHNOLOGICAL CAPABILITIES

6.6.1 Acquisition Capability

As stated in the introductory chapter, MMHP technology is not new to Nepal. Traditional forms of water-wheels have been in use in the country for many years. However, the modern turbine technology was introduced to Nepal with the establishment of BYS in Kathmandu in 1961. Equipment and expertise were supplied by SATA while space and manpower were provided by the Nepalese government. The technology transfer contracts covered all aspects of basic and detailed engineering know-how, technical assistance and administrative services. In general, the involvement of foreign capital seems to have precluded any choice of technology. Selection of the technology at this stage was not independent. The technology selection in case of BYS was constrained by factors other than technological ones.

The choice of foreign manufacturing technology in the cases of BYS and BEW reflected the fact that there was no local technology available at that time. There was confidence in technology from abroad. In view of the fact that the first firm was established with assistance from foreign countries (European), it is not surprising that most of the equipment initially used in this sector came from abroad (European countries). But since privatisation, about six years ago, BYS started purchasing replacement equipment from countries nearer home. This is also true of NHECO where most of the precision equipment originally came from European countries.

Other manufacturers employ very few people and work with the equipment typically found in a basic workshop[4]. These firms have shown a preference for either Indian or Chinese equipment. The use of Indian equipment is influenced not by price but by proximity, as well as the openness of the border, which makes Indian machines and spare parts easily available in the local market. The use of Chinese equipment on the other hand has been encouraged by the establishment of National Trading Limited which provides access to Chinese products. A picture of the types and sources of equipment used in various firms is presented in *Table 6.8.* A factor relating to the source of equipment is that neither foreign currency nor special import licenses are required for purchase from India.

4 Basic workshop facilities as documented by SKAT (Meier, 1985) includes such machinery as a turning lathe, a drilling machine and boring attachment, a milling machine or shaper, an acetylene cutting torch or plate shear, arc welding equipment, specific jigs and fixtures and general hand tools. Rolling and forging equipment are optional.

Table 6. 8: Source and Types of Common Machines Used in Selected Firms

Firm	*Lathe Machine*	*Milling*	*Drill*	*Grinder*	*Welding*	*Plate Rolling/ Cutting*
NHECO	Europe India	Europe India	Europe India	Europe India	Europe, India	Self-designed
NMSS	India	India		India	India, China	Self designed
KMI	India, China & Europe		Europe, India	India	China, India	India
BYS	Switzerland, Czechoslovakia	Switzerland	Germany Czechoslovakia	India	Switzerland Italy	Switzerland India

Source: Field Survey

A relatively large proportion of foreign machinery is seen to be in use with NHECO as well as with Balaju Yantra Shala. In these firms machinery is from Norway, Germany, Switzerland, Italy, Czechoslovakia, China and India. NHECO, like BYS, uses a few machines developed within their own workshops. The small firms characterised by smallness of investment, have ventured into making some equipment which is in frequent use. Firms like NMSS and TEI have made their own sheet-cutting as well as bending machines, using parts from scrap or outdated machines. NHECO too has constructed its own bending and cutting machines (*See Photo*). However, such machines are produced only for the particular firms' own use. It is observed here that familiarity with the production equipment has enabled these firms to choose the technology most suitable for the country. Due to the limited out-put market, equipment from abroad was often operated below capacity; highly expensive equipment was thus not justified by expected returns, so inducing a search for equipment of smaller capacity, lower cost and less precision.

The larger firms in the sample have access to a wider range of information sources, such as courses, conferences and training, both local and abroad. By the acquisition of books and technical journals mostly through acquaintance with their foreign counterparts, KMI and NPP have followed the same path. The remaining smaller firms rely on their parent[5] larger firms for technological information or even search the market themselves, given that the equipment they use is easily available either at home or across the border.

In the context of acquisition capability, the turbine manufacturing firms have, while displaying a certain ingenuity in devising appropriate tools for use in their own workshops, have shown generally, in respect of manufacturing technology, no great initiative in acquiring more advanced technology. In case of the large firms, their equipment was offered as a package with very little importance given to technology assessment. Although the firms did indicated their awareness regarding the availability of various alternative technologies and even the need for technology more sophisticated than presently being used, factors such as financial constraints as well as difficulties in getting proper manpower to operate such technology, were stated as major obstacles inhibiting its introduction.

6.6.2 Assimilative Capability

Criteria

The degree of technology assimilation achieved by the turbine manufacturers can be assessed through the use of proxy criteria such as:

capacity increases or overall productivity improvements;
degree of dependence on the original (supplying) technologist for jobs related to process operation;
the quality of product achieved;
the importance assigned to training of the workforce.

In this section an attempt is made to form an assessment of the assimilative capability

5 The word parent indicates the original firm at which the owner of the smaller firm was once employed

of the firms in question by examining their performance in terms of these criteria.

Productivity Improvement

As the manufacture of turbines is a made-to-order job it is difficult to assess the productivity increase here. However one can draw attention to maximum size of turbine manufactured by the firms as well as to the manufacture of products related to the installation of the mini-micro-hydro turbines. *Table 6.9* indicates the years in which various firms have managed to increase their capability to produce turbines of higher capacity as compared to the previous years. Presently the larger firms are able to manufacture turbines of larger scale i.e. 250 (as is the case with BYS and BEW) whereas the smaller ones produce turbines of up to 50 kW without any external support.

Table 6. 9: Growth in Turbine Size As Manufactured by Various Firms

Year of Establishment	*AEW*	*BYS*	*DCS*	*ITL*	*KMI*	*NMSS*	*NSEC*	*NYS*	*TEI*
1972		18							
1975								8	
1976								15	
1977			13						
1978			14						
1979		16							
1980			17						
1981							4	20	7
1982	4								
1983	9	30	15.5	10	4				9
1984	13	40					12		11
1985	50			45					20
1986		50			5				21
1987			25		10	13	16	25	
1988		100				15			
1989		200	36		15				
1990					50				
1991			50		70	20			
1992						45			
1993			50						

Source: ICIMOD, 1994, Field Survey

Skill Development

Most of the training needs of BYS and BEW/ NHECO are met through inputs from international experts (collaborating agents) who interact with these companies on a regular basis. Training imparted mostly concerns matters related to plant design including the layout, civil works, electric and mechanical equipment design, manufacturing methods, quality control, and installation procedures. A number of regional as well as national training programmes have been organised by international organisations such as the Intermediate Technology Development Group (ITDG) and the Swiss Centre for Development Co-operation in Technology and Management (SKAT). These have been relevant for the manufacturers and for other groups such as planners, designers, surveyors and managers. Similarly regular training programmes are organised by the Hangzou Regional Centre for Small Hydro Power (HRC-SHP) for participants from the whole Asia-Pacific Region. ITDG/N also organised a training programme on manufacture of Pelton turbines in Nepal in 1991 which was specially relevant for the manufacturers.

Locally too considerable measures have been taken to train and thereby upgrade the staff. With periodic training incorporated in the factory mandate, both BYS and BEW have managed to deliver the required knowledge. A further step taken by BEW in this respect is very commendable. This organisation has developed an understanding with the manufacturers in Butwal such that the workers are provided 'Theoretical Upgrading' every year while 'Practical Knowledge' is provided by the manufacturers on a periodic basis. However, most of the other smaller manufacturers, who happen to be handling the bulk of MMHP manufacture at present, are not sufficiently exposed. Attempts to upgrade the skill of their employees as well as that of the operators [6] are evident in the case of most manufacturers *(See Table 6.10)*.

6 Owners are usually the operators of the turbines

In case of small firms internal training involves on-the-job training for shop floor workers and vocational training for technicians. The training is mainly in the form of apprenticeship development. The knowledge imparted to the workers depends upon the skill level of the master and his willingness to share this knowledge. As the training, both local and international, was not on a regular basis it was difficult to obtain the cost allocated for it for any of the firms.

Table 6. 10: Details of Training Conducted by Various Mini and Micro Hydro Turbine Manufacturers

Manufacturers	*Numbers of People Trained till 1997*
BYS*	25
BEW	150
NPP	10
NSEC	100
NYS	180
TEI	120

* only technical training, while training provided by other industries also include the training of operators

Source: Field Survey

The sample firms have achieved competence in operating the technology. In case of the smaller firms all the jobs at the mini-micro-hydro scale are undertaken independently by themselves without any support from outside. In the case of the larger firms there is a certain degree of dependence on the foreign technology suppliers for certain aspects of technology input. This however, is associated more with risk aversion rather than failures in the assimilation of the technology. Overall it can thus be said that the firms have assimilated the foreign technology and achieved capabilities related to processes that require considerable engineering skills. This has been achieved mainly through effort-based learning-by-doing.

Product Quality

Quality control would be a method of reducing not only the cost of the product but also of making it competitive in the international market. However, only BYS and NHECO have reported availability of testing facilities for quality control and standardisation of the finished products. Their available facilities include:

Turbine performance testing plant
Pressure testing facility
Non-destructive testing
a) die penetrant testing
b) magnetic particle testing
c) ultra sonic testing
d) X-ray testing
e) balancing

In the absence of testing facilities for turbines and pen-stock pipes manufacturers adopt dimensional control. Special care is taken in welding turbines and penstock pipes. Experienced technical staff carefully supervise the manufacturing of products to maintain quality. Although it was apparent that the manufacturers were aware of the need for standardisation of the product (matching size and design with respect to range of head and flow of the available water resource) so far not much progress has been made in this respect.

Repair and Maintenance Capability

The ability to undertake repair and maintenance of the production machinery is limited in both large and small firms. Minor repairs are easily made by in-house staff, but major problems have to be left for either local or foreign experts depending upon the severity of the problem. The repair of precision and automated equipment, as used mostly by the larger firms, is carried out under the supervision of the local or foreign experts depending upon the extent of the problem. In case of smaller firms, due to the simpler nature of the equipment in use, the repair support is mostly sought from local experts.

6.6.3 Innovation and Modification Capability

Manufacturing Innovation

As discussed in Chapter 2, studies carried out in developing countries indicate very little innovation or modification being carried out on the original equipment. This holds true as well in the case of the MMH turbine manufacturing firms in Nepal. However, the development of supporting equipment by even the smaller firms does indicate their familiarity with the production process rather than the complete curve[7]. Given the financial constraints experienced by firms of this size, the ability to develop items of equipment for use in their own workshops for increasing productivity becomes a measure of capability measurement and an innovation in itself, though it is far from the scale of innovation observed in the developed countries.

Product Innovation

Product innovation and modification have been central to the development of this sector. The Nepalese manufacturers have constantly been involved in developing better hydro-equipment. Improvement of the traditional '*Pani-Ghatta*' led to the development of the MPPU which is not only easy for the rural people to understand but, compared with the '*Pani-Ghatta*', has better efficiency and multiple uses.

Experimental installation of the propeller turbine led to the selection of the cross-flow turbine as the most suitable technology for the country. Several installations provided the opportunity to develop upon the conventional turbine technology through various amendments. These amendments have resulted in the manufacture of cross-flow

7 For details on 'complete curve' terminology see Lall, 1997 p 33

turbines suitable to rural site in terms of ease of operation, ease of transportation to site as well as ease in repair and maintenance. This achievement has been widely acclaimed in the various publications of ITDG as well as by local users. Although not a major 'breakthrough or frontier innovation' this minor improvement of the existing technology has gone a long way to making the technology more acceptable particularly for the non-accessible terrain of Nepal.

The introduction of a safety device to prevent abrasion of the bearings was another step towards improvement of the product. In the last few years some firms have also started producing the Pelton turbine. These turbines are developed for lower ranges of power production at higher head and are more compact. Firms have acquired the ability to produce turbines of both cross-flow and Pelton types of various capacities. BYS is able to produce cross-flow turbines of up to 250 kW capacity; BEW produces Peltons of up to 200 kW while the smaller firms produce cross-flow as well as Pelton turbines of up to 50 kW.

Research and Development

Activity in research and development should enhance the innovation and modification capacities of the turbine manufacturing firms. It is however, difficult to estimate exactly what research and development work is being carried out, as most is done in an informal basis. It can however be stated that the R&D activities of the manufacturers are not confined to the improvement of turbine technology alone They also include the R&D of other components required for more efficient performance of the turbine. This is apparent from the priorities assigned to a variety of R&D activities for the future by various firms (*See Table 6.11*).

The research work is apparently guided by the aim, not only of improving the general efficiency of the plants, but also of developing equipment suitable for use in the hilly, rural areas of the country. Major objectives have been to achieve longevity, easy exchangeability of spare parts, increased efficiency and ease in assembly on site.

Table 6. 11: R&D Priorities of the Manufacturers

Name of Firm	*R&D Priority*
BYS	Quality control and standardisation low head turbines civil structures turbine testing facilities improvement in the present foundry services new materials
BEW	Quality control and standardisation Turgo and low head turbines civil structures turbine testing facilities improvement in the present foundry services
KMI	new materials such as Teflon, turbine development, Francis turbines, current limiting devices, low-cost mechanical/hydraulic flow control governors
NPP	low-head turbines, IGC, bursting plates for penstock, material technology, current limiting devices, civil works, automation
NHECO	Quality control and standardisation, development of high head turbines, switch-gears, control and protection devices
NMSS	mainly improvement in the design to improve operation and make repair and maintenance easier
NYS	turbine development: propeller, cross-flow and pelton, civil works.

Source: Field Survey

Growth Strategies

The output this sector can deliver depends upon the sets ordered and the length of runs - if orders are popularly used turbine sets, the manufacturers can produce more than if they make an assortment of other units. As the local rural areas constitute the major market for this product, and the market is very much constricted due to low buying capacity in these areas, the only source of survival of the manufacturers is to expand the range of production. It is, therefore, not surprising to note that all the manufacturers are involved in the production of turbine accessories as well as spare parts for other industries. Being basically mechanical-engineering workshops together with the fact that they are small, these enterprises have some flexibility in diversifying their production.

None of the turbine manufacturers depends entirely on turbine manufacturing. These firms also produce auxiliary items relating to the turbine installation such as penstock pipes as well as the transmission towers. They manufacture as well products such as steel trusses, suspension bridge components, sheet metal products and other items as per customer order. Some of these firms manufacture the agro-processing units for shelling, polishing, oil expelling, winnowing and grinding.

Most of the mini-micro-hydro schemes provide direct power for operations such as grain milling and rice hulling. In such case the speed of the turbine is not critical and manual control by varying the water flow is quite sufficient. The same does not hold good when a turbine is used for electricity generation: here greater control is generally required as the electrical equipment is designed to work within a specific voltage and frequency range. The electronic load control (ELC) technology, initially developed in UK by Gerry Pope, was introduced in Nepal by ITDG. The manufacturers involved in ITDG rural electrification projects were provided with an opportunity to see closely the technology in operation. Training courses were also conducted by ITDG/N in Nepal on theory, demonstration, operation, manufacture and installation of ELC[8]. However, at this early stage only part of the ELC was made in the country and the main board (the black-box) had to be imported from UK. Since 1994, NPP has been involved in making even the main board.

Involvement in the production of complementary equipment enables the turbine manufacturers to provide package services to the customer; 60 percent of manufacturers are capable of delivering a "package service" which comprises a feasibility study and supply and installation of the turbine. The smaller enterprises are found to produce fewer distinct products and those for which total demand is small. The main reason for these firms integrating the provision of services such as design and production of necessary components in-house are:

1. To maintain control of production, in terms of timing and quality supplies

8 ELC - Electronic Load Controller was jointly invented by Gerry Pope of Electronics and Rupert Evans of Evans Engineering in United Kingdom. It has also been awarded the International Inventor's Award. It is also known as the GP-ELC

2. To maintain secrecy about products and processes, particularly those not protected by patents[9] and commercial information such as the identity of customers
3. To acquire and retain experience and knowledge about products and production
4. To ensure that the firms get the benefits of cost reductions attributable to learning and economies for producing repeated batches of same components
5. To utilise the time and skills of proprietors and managers and/or to spread overheads

Besides production of the turbines the manufacturers have also gathered knowledge of their installation from the preliminary survey for suitable sites. This extended activity has provided the manufacturers with the opportunity of studying the turbines on site and thereby improving them where necessary. This feedback is the main source of information leading towards the improvement of the technology. Besides, this has also induced the manufacturers to diversify their range of product.

Table 6. 12: Production Range of Various Manufacturers

Name of Manufacturer	*Production*
AEW	Water Turbines, huskers, polishers, paddy drier
BY S	Water Turbines (cross-flow), pen-stock and sluice gates, agro-processing units,
BEW	Turbine (cross-flow, Pelton, Francis) and pen-stock pipes, electronic load controller
ITL	Suspension bridge, trolleys and tractors, truss, under ground petrol tanks
KMI	Turbines (cross-flow, Pelton), pen-stock pipes, electrical equipment, electronic load controllers, grinder for milling
NPP	Turbine (cross-flow, Pelton, MPPU), pen-stock pipes, electronic load controller, panel board, induction generator
NSEC	Water turbine, pen-stock pipes, MPPUs
NHECO	Turbine (cross-flow, Pelton, Francis) and pen-stock pipes, electronic load controller, hydraulic governors, radial gates, steel structures, tubular poles, transformer repair
NMSS	Turbines (cross-flow, Pelton), corn -sheller, vibrator, pen-stock, overhead tower, husker and polisher for paddy
NYS	Water turbines (cross-flow, Pelton, MPPU), electronic load controller,
TEI	Water turbines, pen-stock pipes, grinder for milling

Source: Field Survey

9 Implementation of protection through patent rights is still in its rudimentary stages in Nepal

The additional products are mainly related to the installation of turbines i.e. penstock pipes, gate valves as well as agro-processing units (*See Table 6.12).* The technology package - including survey, turbine supply, supervision, installation and after sales service - as offered by various firms is presented in *Table 6.13.* It is evident from this Table that AEW, NPP, NMSS, NYS and TEI can undertake turnkey projects upto 50 kW, ITL upto 100 kW, BYS upto 200 kW and BEW upto 250 kW.

Table 6. 13: Technology Package as Offered by Some of the Manufacturers

Name of Firm	*General Capability*	*Technology Package*
AEW	Surveys for below 100 kW turbine installation, manufacture of turbines below 100 kW turbines, Supervision, Installation	Potential for turnkey projects below 50kW
BYS	Surveys for below 200 kW turbine installation, Manufacture, supervision, and installation of turbines below 200 kW turbines	Potential for turnkey projects Up to 200 kW
BEW	Surveys for below 250 kW turbine installation, Manufacture, supervision, and installation of turbines below 250 kW turbines	Potential for turnkey projects Up to 250 kW
ITL	Surveys for below 100 kW turbine installation, manufacture of turbines below 100 kW turbines, Supervision, Installation	Potential for turnkey projects Upto 80 kW
KMI	Surveys for below 100 kW turbine installation, manufacture of turbines below 100 kW turbines, Supervision, Installation	Potential for turnkey projects Upto100 kW
NPP	Supply electronic components like ELC, IGC, AVR etc. Surveys for below 50 kW turbine installation, Manufacture, supervision, installation of turbines below 50 kW turbines, Supervision, Installation	Potential for turnkey projects below 50 kW
NMSS	Surveys for below 50 kW turbine installation, Manufacture, supervision, and installation of turbines below 50 kW turbines	Potential for turnkey projects below 50 kW
NYS	Surveys for below 100 kW turbine installation, Manufacture, supervision, and installation of turbines below 100 kW turbines	Potential for turnkey projects Upto 50 kW
TEI	Surveys for below 100 kW turbine installation, Manufacture, supervision, and installation of turbines below 100 kW turbines	Potential for turnkey projects below 50 kW

Source: Field Survey

The improvements and modifications made in the MMHP technology are seen to cover a range of turbine products extending from the improvement of the traditional water-wheel, *'Pani-Ghatta'*, indigenous development of multi-purpose-power-unit (MPPU), improvements to the cross-flow and propeller turbines and the development of another indigenous product, the peltric system. The various technological developments are indicative of the gradual learning that has taken place at the shop-floor.

6.6.4 Innovation and Modification: Two Leading Firms

In this section the activities of BYS and KMI are examined more closely in order to shed further light on the innovation and modification capabilities these firms have developed.

Balaju Yantra Shala

Different turbine models jointly developed by BYS and SATA were tried and BYS has achieved its present mastery of the technology after confronting several setbacks as well as making notable breakthroughs. These developments are indicated in *Chart 6.2.* The analysis has taken account of characteristics such as: plant reliability and operating life; production quality; standardisation; plant safety; range expansion/output; local skill level; technology dissemination and convenience. The details of these developments are tabulated below *(See Table 6.14).* The various drawbacks and the development of each of the turbine types are explained in *Annex-6.A.*

The improvements gained in the efficiency of various cross-flow turbines are shown in *Chart. 6.2.* The efficiency curve for T12 indicates that it can be used even in cases where the ratio of operating discharge and design discharge is as low as 10 percent to 80 percent. (*See Chart 6.3*).

For comparison of three cross-flow turbines with respect to design and application, the main specifications are tabulated in *Table 6.15.* It may be noted that the attempt at optimisation has resulted in a gain of 5 percent efficiency between T3 and T12; besides that, the speed range is more suitable for electricity generation[10]. The head range covered in both T3 and T12 is greater than in the case of T1. T12 is suited to a larger range of head difference thus making it useable even also for very low heads and for low-speed mechanical power transmission.

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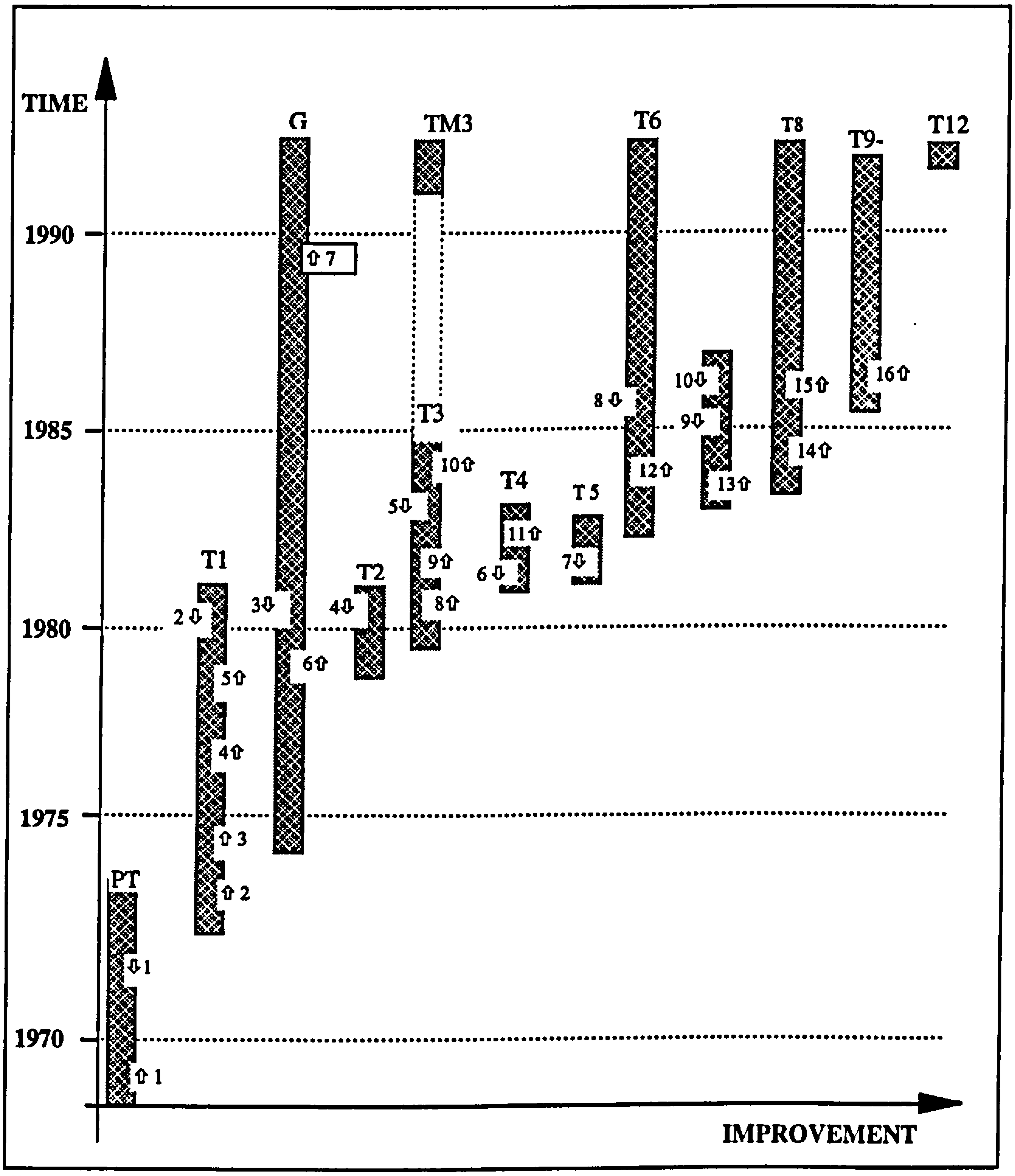
10 direct coupling to an alternator is possible without the need for step up transmission.

Table 6. 14: Historical Development of the SKAT and BYS Turbine

Legend	*Progress ⇧*	*Setbacks ⇩*
Propeller turbine	Driving rice huller/oil expellor with a propeller turbine	Ill-situated designed propeller turbine, difficult flow regulation
T1 Cross-flow turbine model T1	First cross flow turbine driven mill installation First "cross-flow mill" financed by Agriculture Development Bank Nepal (ADB/N), so far the Bank granted loans for diesel sets only First order for a village Testing to measure turbine and governor performance completed	Loosing complete station due to landslide
G Turbine governor	Governor prototype operating Fully automatic control	Control system damage due to governor failure
T2 Low-cost turbine		Low-cost turbine, no market acceptance
T3 Compact design cross-flow model T3 and successor TM3	Systematic model test for the optimisation of runner geometry for the more compact T3 design Standardisation of fabrication Installation with a head of 80 m. completed	Under designed bearing concept, short life span
T4 First cross-flow for governor operation	First village electrification project completed equipped with a T4 turbine including governor	Fatigue failure in equipment base frame
T5 Big size cross flow		Design office comes up with a machine size not manageable in the workshop
T6 High discharge cross flow model T6	Winning tender against international competition	Loosing contracts in inter-national competition due to image problem
T7 Circular wing cross flow model	Plant with two units running in parallel completed, synchronisation problem solved	Alternator damage due to improper lighting protection. Runner failure
T8 Standard design model T8	First standard design, range of application defined First unit with an output of more than 100 kW	
T9 High efficiency cross flow model T9	First machine with exchangeable spare parts	

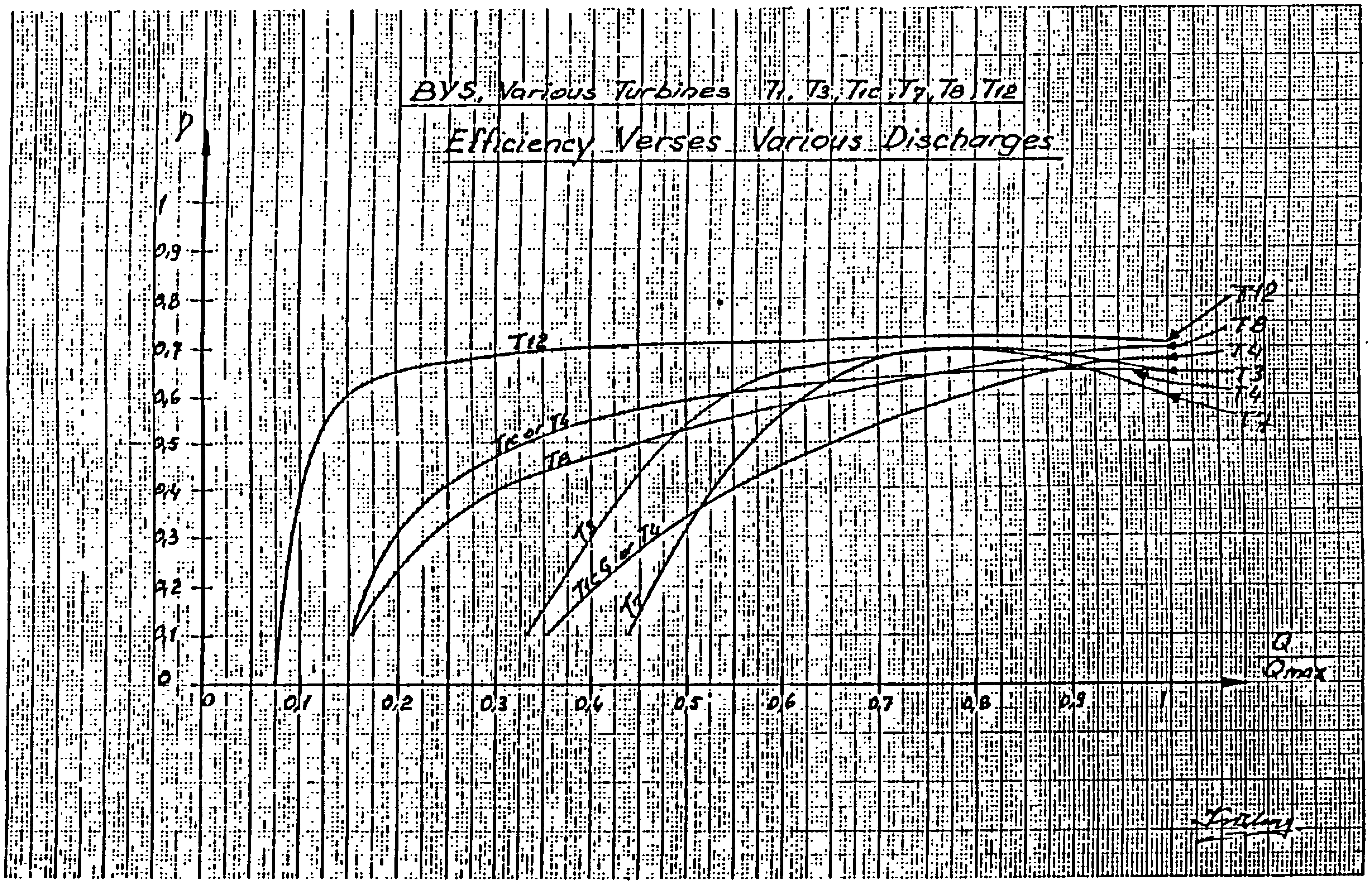
Source: Balaju Yantra Shala, 1997

Chart 6. 2: Historical Development of Various Turbines



Source: Balaju Yantra Shala, Field Survey

Chart. 6.3: Efficiency Curves of BYS Cross-Flow Turbines



Source: BYS, 1997

Table 6. 15: Technical Features of Cross-flow Turbines T1, T3 and T12

Turbine Type	*T1*	*T3*	*T12*
Rotor Ø D (mm)	400	200	300
Blades:			
Nos.	28	32	28
Thickness	5	2.5	5
Inside radius of curvature, r (mm)	65	31	48
Radial rim width rw (mm)	61	32	192
Inlet width (mm)	x=50 to 400	bo=50 to 920	bo= 6 to750
Speed: N (RPM) $= \frac{39.4}{D} * \sqrt{H}$	$N = 98.5 * \sqrt{H}$	$N = 197 * \sqrt{H}$	$N = 133 * \sqrt{H}$
Head Range: (m)	H = 2 to 19	H= 7 to 80	H = 4 to 100
Speed Range (RPM)	140 to 430	520 to 1750	200 to 1500
Specific Discharge Qs	0.35	0.15	0.8
Efficiency (maximum)	$\eta = 70\%$	$\eta = 75\%$	$\eta = 75\%$

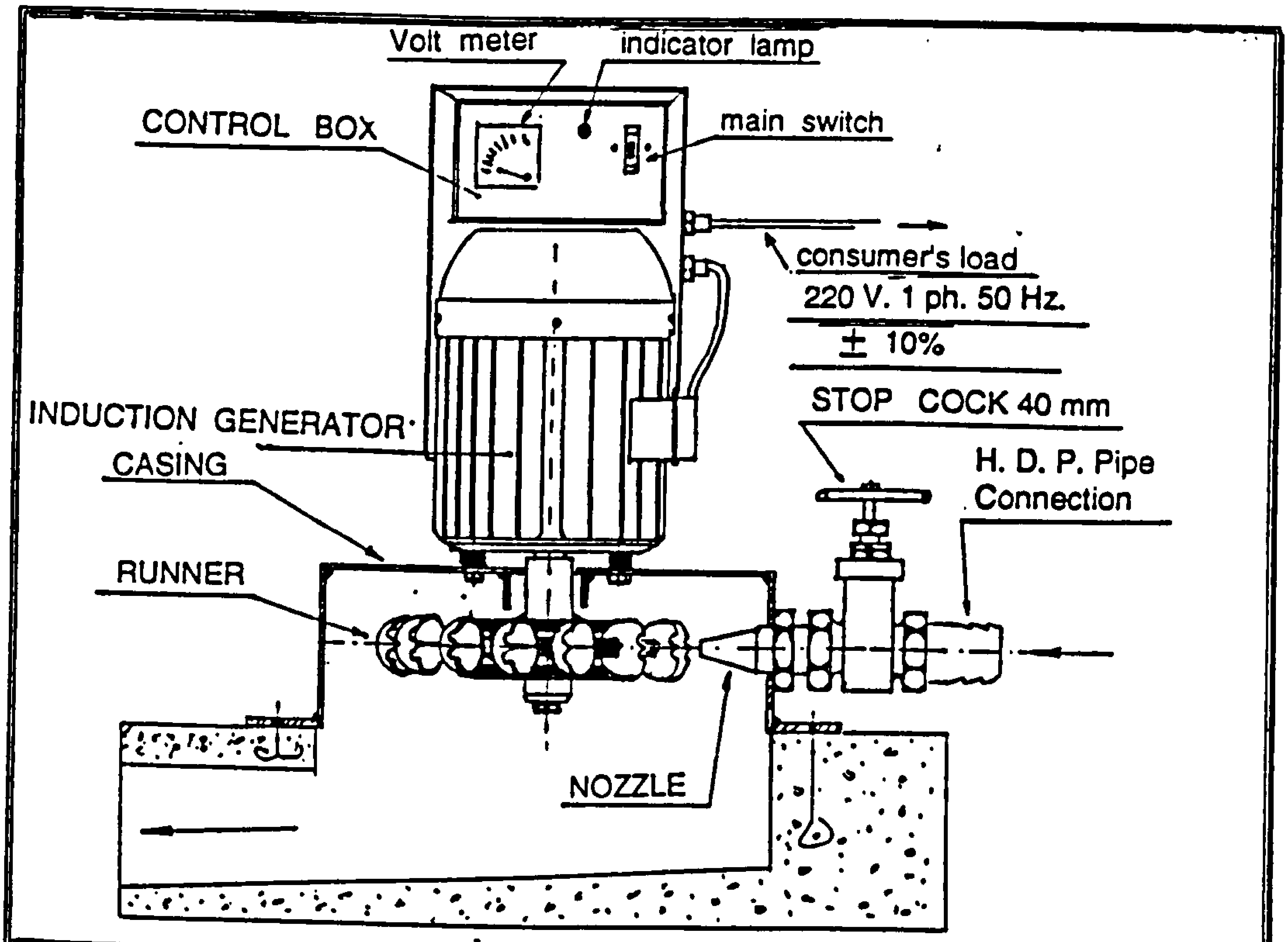
Source: Data provide by BYS

Kathmandu Metal Industries (KMI)

KMI is known for its innovative development of the Multi-Purpose-Power-Unit (MPPU) in 1981 and the Peltric turbine in 1990. The MPPU is a modular system which is a modern version of the traditional "*Pani-Ghatta*". Unlike the "*Pani-Ghatta*" it consists of a nozzle with regulating device and single-spoon metallic buckets as runners which are attached to the vertical shaft (*refer to Chapter 3 for details and also see Photo*).

The Peltric turbine is an indigenously developed turbine system with a Pelton-wheel coupled with an induction type electric generator (*see Fig. 6.1*). This system is most suited for electricity generation for lighting and for operating electronic appliances. The system is manufactured for capacity ranges 0.5 kW to 5 kW. The popularity of this system lies in the fact that it has been designed as a portable unit (*weighing about 40 kg),* very convenient in the hilly and inaccessible areas of Nepal. As per the manufacturer's specifications the system is most suitable for water discharge between 3 lps to 25 lps and head of 20 m to 50 m and has an efficiency of 65 percent. It is also easy to install the system using ordinary polythene pipes to feed water. This helps reduce the installation cost. An added advantage of the system is simplicity of

Fig. 6.1: Portable Peltric Set for Electricity Generation



PELTRIC SET:

Runner:	The Runner is made from Bronze Buckets Bolted on and securely locked by Dove tail groove, on Hob & Disc. Runner is Keyed directly on the generator shaft
Casing:	The Casing is fabricated from 6 mm thick M.S. plates to ensure long lasting against Rust.
Generator:	The generator is of Induction type Brush less, & self excited. It is durable, and vertually mentinance free except the Bearing to be changed every 10,000 Hours of Running
Control Box:	Control Box Contains all necessary excitation circuit, volt meter, Indicator Lamp, and Main Switch (M.C.B.). The miniature circuit Braker, lets no overloading on generator.
Inlet:	The Inlet Consists of Gun metal 40 mm Ø stop coke to On d Off the Peltric set. But it does not regular the flow.
Nozzle:	The Nozzle is fabricated prom M.S. and is of conical type.

Source: KMI Brochure on Peltric Set

installation thus making it possible even for an entrepreneur to install it himself. It is a unit that can be purchased as an off-the shelf product.

6.6.5 SUMMING -UP ON TECHNOLOGICAL CAPABILITIES

The general trend is indicative of the fact that the firms have learnt to draw upon the external sources of information, whether foreign or local. They have been able to incorporate this knowledge into the process of internal learning. The mini-micro-hydro firms in Nepal undertake significant in-house technological activity. They are however, not involved in systematic innovation activity. The sample firms have 'learnt to learn.' They know how to define their needs and they have formulated a system for themselves to access information. While the larger firms have been found to retain their reliance on foreign sources, the smaller firms work more independently. The reliance on the foreign sources is also due to aspects of risk aversion rather than seek help from local technical personnel.

The firms were found to have developed a capability to modify the imported technologies to adapt to local conditions via in-house design, research and minor innovations. The fact that the design of the turbine is dependent on the site conditions, and the fact that the product is made only on receiving an order, generally the performance of the turbine with respect to site, site accessibility, cost reduction were factors which determined the technical changes. Long-term technological changes did not feature prominently.

The R&D conducted tends to be focused on adaptation and improvement of the product; R&D is not considered as part of a major innovative process. Seeking major technological advance was beyond the manufacturers scope due to lack of adequate information and finance. The larger firms depended more on their foreign counterpart while the smaller firms relied more on the improvement of the technology already available to them.

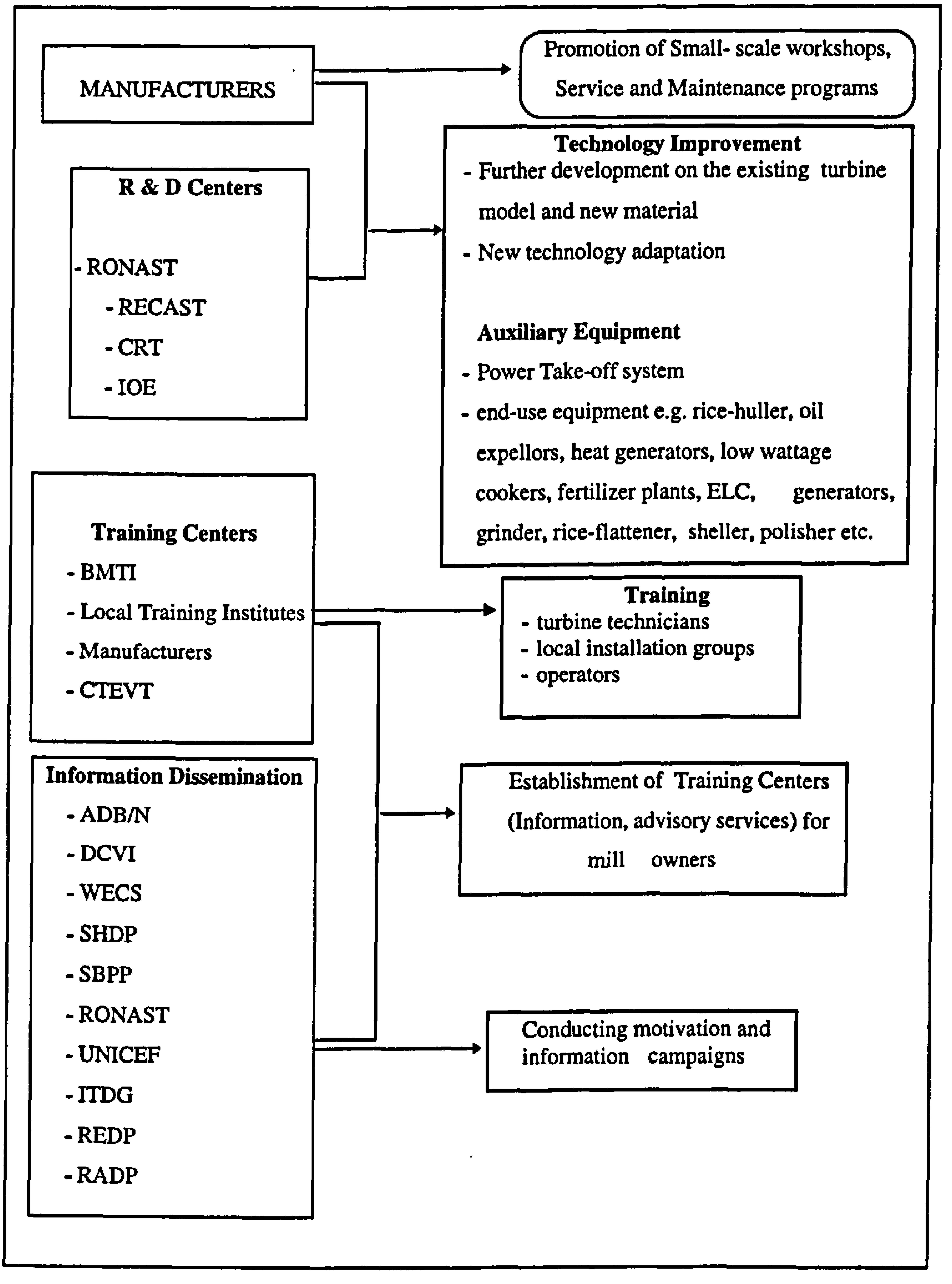
Only the larger firms in the sample were found to engage even graduate engineers at different levels including management positions. The firms did not possess any formalised R&D departments but rather engaged in continuous improvements upon the product. Although the firms were aware of the impact of MMHP technology they were not on the path towards developing independent technologies or to modify major jumps from the existing ones due to risk aversion factors, complacency and lack of incentives to become technological leaders.

6.7 LINKAGES

Chart 6.3 presents the existing linkages between various institutions that supported the technology development quest of this sector. However, these are not formal linkages. The organisations that have contributed to the development of this sector have given support through R&D, training and information dissemination.

Linkages with collaborating agencies such as SATA and ITDG/N have been the main source for technological information and advice. They have provided opportunities for upgrading of the technical staff. Working together with the foreign counterparts has helped firms gain experience in design, development of manuals, identification of appropriate technology as well as is product development as required for the home market. Continued relations with the foreign partners have also provided information on new developments in the area. The adoption of the ELC with help in information acquisition through ITDG is another example of this advantage. Support from ITDG has been realised in the acquisition of other information related to turbine technology, training of operators as well as training of manufacturers.

Chart 6. 4: Structural Linkage Between Manufacturers and Related Organisations



Local organisations like WECS and RONAST provide information on rural energy needs, rural energy technologies as well as technical information on their installations. The dissemination of the technology to the rural areas through ADB/N, UNICEF, Rural Energy Development Programme of United Nations in Nepal (REDP/UN), Governments Rural Area Development Programme (RADP) as well as RONAST has helped in extending the market. The Small Business Promotion Board of Department of Cottage and Village Industries through its entrepreneur development programmes, has helped likewise in dissemination of turbine technology at the rural level.

The staff employed in this sector are mostly without much education. They are the product of informal training or vocational training at the Mechanical Training Centre at Balaju or the Butwal Training Institute. Periodic upgrading of staff qualifications is also carried out in these training institutes. Linkages with other institutes affiliated to the Centre for Technical and Vocational Training and other local institutions involved in manpower-training are frail.

Linkages with R&D organisations are very weak but time and again the manufacturers have sought help on technology development aspects from the Royal Nepal Academy of Science and Technology (RONAST), the Research Centre for Technology and Applied Science (RECAST) and the Institute of Engineering. The lack of university-industry linkages has however, been a major obstacle to the development of this sector.

6.8 CONCLUSION

In this chapter the results of the survey made of the turbine manufacturing firms have been reported. In many respects these findings tell a story of success - a technology hitherto unknown in Nepal has been introduced and firmly established; the firms concerned have demonstrated (in terms of categories employed in this study) capabilities in investment and technology assimilated and, in some ceases have achieved notable results in innovation and product modification. An outstanding breakthrough came with modification of the design of the cross-flow turbine making it more readily portable and suitable for the inaccessible areas of the country; the Multi-Purpose Power-Unit is another example of appropriate and successful product innovation.

While the survey reveals clear evidence of very positive achievements by the turbine manufacturing firms, it does at the same time indicate the existence of certain cloud on the industry's horizon. The fact is that the turbine firms have not shown any urge to improve their production technology, apparently being content to continue with the same production methods they used when they began operations. Indeed, when they have subsequently invested in new equipment, instead of going for more sophisticated times for use in the production process, that is to say for machines such as might be obtained from European suppliers, they have displayed a preference for acquiring, from Sub-Continental manufacturers, cheaper equipment of relatively simple types. Even if the turbine manufacturers are expanding their capacity through such investment, they are not enhancing the technological capabilities, not achieving the ability to produce to higher standards and to manufacture more complex and sophisticated items of hydropower equipment.

There are, however, a number of reasons why it is not essential that the turbine manufacturing firms should seek to raise their technological capabilities by developing mastery of more advanced methods of production. It is vital both for the firms themselves, and for the prospect of economic progress in Nepal, that they do not allow themselves to stagnate, but move forward to higher levels of technological competence in hydro-turbine manufacturing.

The following three considerations point very clearly to the need for technological upgrading by the turbine firms of their manufacturing processes:

I. The requirements of the domestic market are becoming more demanding - installations will have to be made in more difficult sites. To meet this challenge, the manufacturers will have to 'raise their game' - go beyond their present capacities. If they can do that, there is a large - far from exhausted - market out there for them.

2. If the turbine manufacturers want to build on their success so far in the domestic market and enter into export markets, enhanced technological competence will be required - they need to compete with higher product standards, different types of turbines; again technological upgrading - improved process technology is implied

3. The role of the turbine manufacturing sector with respect to economic development in Nepal is, as a nucleus of modern engineering technology, to bring - within the MMHP sector itself, and through spill-over effects to other sectors of the economy - new technological capabilities to the country. The turbine manufacturers, if they are to play this key role effectively, must not now rest on their laurels, but should involve themselves in continued and continuing upgrading of their technological capabilities.

The manufacturers involve themselves in R&D activities in only a limited way and even then it interferes with the scope of expansion of production facilities. BEW and KMI along with NPP have distinguished themselves by their innovative and development activities on different aspects of mini-micro-hydro technology and its ancillary equipment. The contribution of formal research institutions have been negligible. R&D institutions have to be encouraged to do relevant research. Simultaneously there has to be an arrangement for smooth transfer of information from these institutes to the manufactures.

On one hand is the concerns regarding the nature of new entrants into the turbine manufacturing sector are more of entrepreneurs with small investments and with less educational qualifications. While on the other is the selection of lower technology-content products the firms choose to deliver within their diversification programme. Although one may question as to whether the sector is falling back instead of climbing up the technology content, in defence of the turbine manufacturing firms, the point should be made that the context in which they are at present operating is certainly not as conducive as it might be to their adoption of a strategy of progressive technological advance. To encourage and support the turbine manufacturers in that desirable strategy, a more positive contribution form the government and from other relevant institution. The role of the government and other institutions is considered in the following chapters.

CHAPTER - 7

ROLE OF GOVERNMENT AND INSTITUTIONS: PROMOTION OF MINI-MICRO-HYDRO[1]

7.1 INTRODUCTION

The objective of this chapter is to review the role of government and institutions in the promotion of mini-micro-hydro turbines in Nepal. The analysis is presented in the following subsections. The government policies affecting the ownership and size of the enterprises as well as financial support for this sector is reviewed in section 7.2. Although the MMHP turbine production has been approached as a manufacturing sector, as it is closely linked with energy sector, the impact of policies formulated for the water and electricity sectors cannot be ignored. Therefore, the impact of these policies is reviewed in this section. The existing institutional structure for fostering the development of mini-micro-hydro systems is assessed in section 7.3. A comparison of the institutional status for MMHP development in Nepal with that in selected developing countries is presented in section 7.4. Section 7.5 provides the conclusion of the review on the role of government and related institutions in the promotion of MMHP in Nepal.

1 Also see Shakya, I., (1997): "State Role in Capability Building: Case Study of Mini and Micro Hydro Turbine Manufacturers in Nepal" and Shakya, I., (1994): "Role of Linkages Between Research Institutes and Industries for the Development of Science and Technology in Nepal" for industrialisation in Nepal

7.2 GOVERNMENT POLICES AND THE MMHP SECTOR

7.2.1 Development Objectives in Nepal

It was only in the 1950s that Nepal assumed many of the forms of the modern state. Even today the country is very much dependent upon foreign technology for its industrial development. The strategy of Nepal, as expressed in all the country's development plans, has focused on achieving socio-economic growth with basic needs fulfilment, emphasising rural development, equity in distribution, people's participation and employment generation (*See Table 7.1*).

The earlier development efforts concentrated particularly on building up the infrastructure, with the main emphasis being on road concentration. Efforts have been made to provide education and health-care facilities. In regard to industrialisation, subsequent Five Year Plans have continued the drive of the Sixth Plan for modernisation and foreign investment. Priority has been accorded to the development of small-scale and import-substitution industries.

Table 7. 1: The Objectives of the Various Plans

Plan	*Objective 1*	*Objective 2*	*Objective 3*	*Objective 4*
I	Production	Employment	Standard of Living	General Well-being
II	Standard of living	Employment	Social Service	Distributive Justice
III	National income	Per capita income	Food grain production	Basic Infrastructure
IV	Maximising Output	Physical Infrastructure	Expansion Diversification of International Trade	Economic Stability
V	Maximising Output	People oriented production	Maximum utilisation of manpower	Regional Development
VI	Increase in Productivity	Productive Employment Opportunity	Basic minimum needs	
VII	Increase in Productivity	Productive Employment Opportunity	Basic minimum needs	
VIII	Sustainable Economic Growth	Alleviation of poverty	Reduction of Regional* Imbalance	

* Development Regions of the Country

Source: Series of Five -Year Plan Publications, Kathmandu, Nepal

The objectives of sectoral production activities in relation to economic growth are summarised in *Table 7.2*. The national plans and programmes are directed towards three major goals: sustainable economic growth, alleviation of poverty and reduction of regional imbalance.

Table 7. 2: Derivatives of Production Sector Objectives from Eighth Plan Objectives

Production Sector	*Sustainable Economic Growth*	*Alleviation of poverty*	*Reduction of Regional Imbalance*
Agriculture: Crops, Fisheries, Livestock, Forestry	Reduce imports, Increase exports, Increase Agriculture, Productivity	Increase production	to generate off-farm income
Communication: Post, Telegrams, Telephones and TV	Increase efficiency, Increase production	Improve access	Lower cast of usage, improve relay of services
Education: Primary, Secondary, Vocational, Tertiary Training	Develop human resources	Provide education	eliminate illiteracy
Energy: Renewable Sources, Non-Renewable Sources	Improve distribution, Improve efficiency	Increase production, reduce loss	Lower cost of usage, Improve reliability of supply, minimise environmental degradation
Housing & Construction: Various types of Buildings, Irrigation, Bridges, Towers	Encourage low cost construction, Facilitate utilisation of local material, develop local capability	Provide shelter	ensure sound construction, provide pleasant environment

Source: NPC, 1991/92

7.2.2 The Industrialisation Programs and Energy Policy

In contrast to the organised manufacturing industries, the cottage industries of unorganised category are large in number and scattered throughout the country. These industrial activities, carried out on a small scale and mainly tied to the local market or farm, are based on indigenous resources - the skills and experiences of local craftsmen and artisans. In all of Nepal's national programmes special facilities have been accorded to encourage small-scale industries (*See Table 7.3*).

Table 7. 3: Details of Tax Exemption under the Industrial Acts (*1981 and 1992*)

	1974		*1981*		*1992*
Type of Industry[2]	**Exemption**	**Remarks**	**Exemption**	**Remarks**	**Exemption**
Cottage Industry	5 years		6 years		full
All Sizes, using local labour and raw materials	tax holidays		5 - 10 years	depending upon the value added	
Priority industries					additional 2 years
Industries producing essential goods	15 years	investment >50 million	Additional 2 years		
Energy and mining industries	15-20 years	mineral based with investment >250 million	6 - 12 years	depending upon the value added	5 years
Tourism industry	tax holidays		5 -7 years	depending on the location	5 years
Service industries			3 years		
Agro-based special industries			10 years		5 additional years
Industries located in backward regions	preferential facilities		3 additional years		5 years
Export based	tax holidays		none on profit from export		

Source: HMG, Ministry of Industries

Reviews of Nepalese Industrial Policy (*Regmi, 1994, Maxell, 1992*), conclude that the government has in fact, on account of inadequate incentives and lack of suitable manpower, had little success in stimulating private investment in large scale operations; with the exceptions of BYS and BEW, both of which were set up with foreign support, the firms that have been established have been of the small cottage scale.

The Fifth Plan (1970/76 - 1979/80) for the first time considered the role of small hydro plants, including plants in the micro-hydro range, in rural electrification. The

2 Industries classified according to investment by various Industrial Polices

	1974	1981	1991
Cottage	up to 0.2M	up to 0.5M	< 10M and based upon specific skill, use of local raw material, labour intensive, related with national tradition, art and culture
Small	0.2-1M	0.5 - 2M	upto 10M
Medium	1-5M	2-10M	10-50M
	Large	above 5M	above 10M above 50M

objectives of rural electrification as per the plan were to promote expansion of agriculture, commerce and small-scale industries. The plan further recognised the role of small hydropower plants in maintaining regional balance in generation and distribution of electricity. Under the guidance of the plan the Small Hydropower Development Board was established in 1975; this Board has played a crucial role in electrification of rural hill areas.

The Sixth Plan (1980/81-1984/85) subsequently specified the following goals for rural electrification:

a) promotion of tourism;

b) conservation of fuel-wood and fossil fuels by substituting them with electricity;

c) promotion of social services in rural areas by setting up social amenities such as hospital x-ray facilities and surgical operation theatres, night schools for adults, libraries and reading rooms etc.

The Rural Electrification Project was instituted in 1981 to promote rural electrification through the installation of micro-hydro plants. The Agricultural Development Bank of Nepal (ADB/N) provided technical as well as financial assistance for mini-micro-hydro (MMHP) promotion. HMG of Nepal, with a view to encourage private participation in rural electrification, initiated the de-licensing of MMHP installations. This initiative was further extended to provision of subsidies in 1985. Under this provision 75% of the cost of electric components of MMHP was subsidised for remote districts and 50% for the remaining districts. Since then the government has been actively pursuing rural electrification[3] .

The Seventh Five Year Plan (1985/86-1990/91) identified quantitative targets for rural energy development. Targets as specified in the plan are shown in *Table 7.4.* Priority was accorded in the Plan to research and development of less-expensive,

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3 Subsidy allowed for electrical equipment includes generator, control/instrument panel, ELC, transmission lines, etc.

simple and easy-to-operate water-mills and other water-based equipment. A total of NRs. 3.2 million was ear-marked for this research programme.

The Eighth Five Year Plan (1991/92 - 1995/96) which constituted a turning point for Nepal in that it embraced a market-oriented liberal economic policy for national development, set as a target of installation 5 MW capacity MHP through private initiative. The plan also recognised the need to simplify administrative procedures, speed up the decision-making process and liberalise government policies in order to encourage the effective participation of the private sector.

Table 7. 4: Targets for Alternative Energy Development in the Seven and the Eighth Plan Periods

Area	*Seventh Plan*		*Eighth Plan*	
	Programme Target	*Budget Outlay (Million NRs.)*	*Programme Target*	*Budget Outlay (Million NRs.)*
Alternative Energy Development:		50.00		1650
Bio-gas Plants (No.)	4000	20.00	30,000	1050
Improved cooking stoves (No.)	160,000	17.50	2950,000	70
Multipurpose (MPPUs) Water-mills	640			
(No.)	320	4.80	5000	300
Cross-flow turbines (No.)		2.50		230
Solar and Wind Energy Development				
Research and Development		3.20		
Training Programme		2.00		
Rural Electrification				1800

Source: The Seventh Plan, 1985-1990, HMG/N, National Planning Commission, Singha Durbar, 1985

The main thrust of energy policy is to reduce dependence on traditional fuel sources and on imported oil through development of water resources and non-traditional energy sources such as bio-gas and solar and wind power. Investment in small hydro-power plants in the private sector through a participatory approach and the mobilisation of local resources is a principal feature of energy development in Nepal. The Hydro-power Development Policy (*1992*) emphasise the need to cater for remote and inaccessible mountain regions where extension of the national electricity grid is not possible. The policy therefore makes the implementation of small-hydro-power projects in rural and remote area a matter of priority.

7.2.3 The Hydropower Development Policy (*1992*)

The Hydropower Development Policy (*1992*), emphasises the need for installation of MMHP/SHP plants to meet the demand of remote and inaccessible mountain regions, where the extension of national-grid for provision of electricity is not possible. The policy accords priority to the extension of transmission of electricity to the rural areas, especially through hydropower development. In order to achieve this, the participation of the private sector, including foreign entrepreneurs, has been actively solicited through provision of permission to transfer profits and tax holidays. The policy also places special emphasis on local manufacture, as far as possible, and allows a number of concessions in this regard. It allows the investors to generate electricity and distribute it, fix tariffs, and collects revenues from the consumers. No license or any kind of approval is required for installations up to 100 kW. In case of the MMHP in the range 101 to 1000 kW a notice is to be given to the concerned government agency. The highlights of Hydropower Development Policy (*1992*) and Electricity Act (*1992*) are presented in *Table 7.5:*

Table 7. 5: Highlights of Hydropower Development Policy (*1992*) and Electricity Act (*1992*)

a)	No license shall be required to be obtained by national or corporate body for the generation, transmission or distribution of hydro-electricity upto 1000 kW.
b)	No income tax shall be levied on the person or corporate body who is generating, transmitting or distributing hydro -electricity up to 1000 kW
c)	No Royalty shall be imposed on the electric power generated through hydro-electricity plants having the capacity up to 1000 kW.
d)	Only one percent of customs duty shall be levied on the import of construction equipment, machinery tools and their spare parts if they are not produced in Nepal. Import license fee, sales tax etc. shall not be levied thereto: and
e)	Financial institutions shall make available concessional loans if the private sector desires to generate and distribute electricity up to 1000 kW in any rural area.

Source: Hydropower Development Policy 1992 and Electricity Act 1992

7.2.4 The Electricity Act (*1992*)

Likewise the Electricity Act (*1992*) provides facilities such as: relaxation of income tax to a person or a corporate body who is generating, transmitting and distributing hydro-electricity up to 1000 kW. It encourages licensees if they reinvest in hydroelectricity project in order to diversify the project or to expand their installed capacity by 25 percent or more or to modernise the technology or to develop the subsidiary industry. Such investors may deduct an amount of 50% of the new additional fixed asset from the taxable income of such hydro-electric projects. Such deductions may be made at a time or from to time within three years. The facility is extended by levying customs duties and sales tax as per the prevailing schedule for import of construction equipment, machinery, tools and spare parts required for operation and maintenance if they are produced and sold by local industries. Only 1 percent customs duty shall be levied on the import of materials which are not produced in Nepal.

7.2.5 Water Resources Policy (*1992*)

Water policy is also relevant to MMHP matters. The principal element of the Water Resources Act (*1992*) which relates to MMHP developments is its ranking of various water uses in terms of priority,. Utilisation of water for generation of electricity has been listed after drinking/domestic use, irrigation and other agriculture - related uses. However, despite this ranking of priorities, no legal or other safeguards have been included in the Act against problems being encountered by MMHP operators - problems which might arise, for example, on account of the diversion of water for irrigation purposes. (In fact there have been cases of closure of micro-hydro projects due to diversion of water for irrigation - e.g., installations in Dhading district (*ICOMOD, 1995*). In these circumstances entrepreneurs may perceive hydropower investments as high-risk, and be hesitant about committing resources to MMHP projects.

7.2.6 Budgetary Support for MMHP Development

Government financial support for mini-micro-hydro programmes was first given in 1985/86. Examining the budget allocations for alternative energy sources (*Table 7.6 and 7.7*), we observe that micro-hydro was allotted a minimal share as compared with bio-gas and solar programmes. The budget allocation of the Eighth Plan (*Table 7.7)* implies that a higher volume of MMHP investment is being financed by the private sector than by the government.

Table 7. 6: Budget Layout for Alternate Energy Development in the Eighth Plan(1990-95)

DEVELOPMENT Programmes	PROGRAMME TARGET	*INVESTMENT IN '00, 000* Government	Private	Total
Micro-hydro Electricity	5000 kW	500	2,500	3,000
Bio-gas Plant installation	30,000 nos.	2,500	8,000	10,500
Solar Energy		100	1,900	2,000
Solar Water Heater	5,000 nos.			
Solar Cooker	5,000 nos.			
Solar Dryer	2,500 nos.			
Wind Energy	Preliminary Studies and Master Plan	50	250	300
Bio-mass Energy	Improved Cook-stoves Distribution	200	500	700
Total		3,350	13,150	165,50 0

Source: Eighth Plan,1990, Kathmandu Nepal

Table 7.8 presents the national and international contributions to R&D expenditures in Nepal. It is evident that over 67 percent is contributed by the foreign sector, and that total R&D outlays amount to only 0.33% of GDP. The R&D budget is allocated to different activities which include applied research, technology development, studies and trials, analyses, surveys and quality control. They also include funding for extension and services, policy studies and infrastructure. An analysis of sector-wise financing shows that classical low technology users, notably in agriculture, mining, transport sectors have been the largest recipients of expenditures from the R&D budget. Essentially, there is no R&D activity being conducted in basic sciences.

Fig 7.1 gives a breakdown of the R&D expenditures in various sectors over the years. The largest beneficiary is in the agricultural sector followed by industry. Most of the R&D budget allocated to the industrial sector, more than 80%, is consumed in mining. It is difficult to specify the actual amount that really goes to manufacturing-oriented R&D, and even more difficult to identify the recipient sectors. However, from the survey of the MMHP firms, and also according to experts working in this sector, it is evident that none of the R&D funds are allocated to the MMHP turbine manufacturing sector.

Table 7. 7: Percentage of Budget Allocation by Government in Various Power Sector for the Period 1982/83 - 1993/94

Fiscal Year	*Micro Hydro*	*Small Hydro*	*Bio-gas*	*Solar Power*	*Wind Power*	*Alternate Energy*
1982/83		5.46				0.11
1983/84		7.93				1.11
1984/85		7.62				0.18
1985/86	0.15	8.76				0.50
1986/87	0.14	5.07		1.75	0.12	
1987/88	0.15	7.00		0.94	0.11	
1988/89	0.22	6.69		0.65	0.01	
1989/90	0.15	3.85		1.60	0.01	
1990/91	0.15	3.02			0.09	
1991/92	0.42	2.83				
1992/93	0.37	3.72	1.33			
1993/94	0.48	0.41	1.94			

Source: WECS, 1995

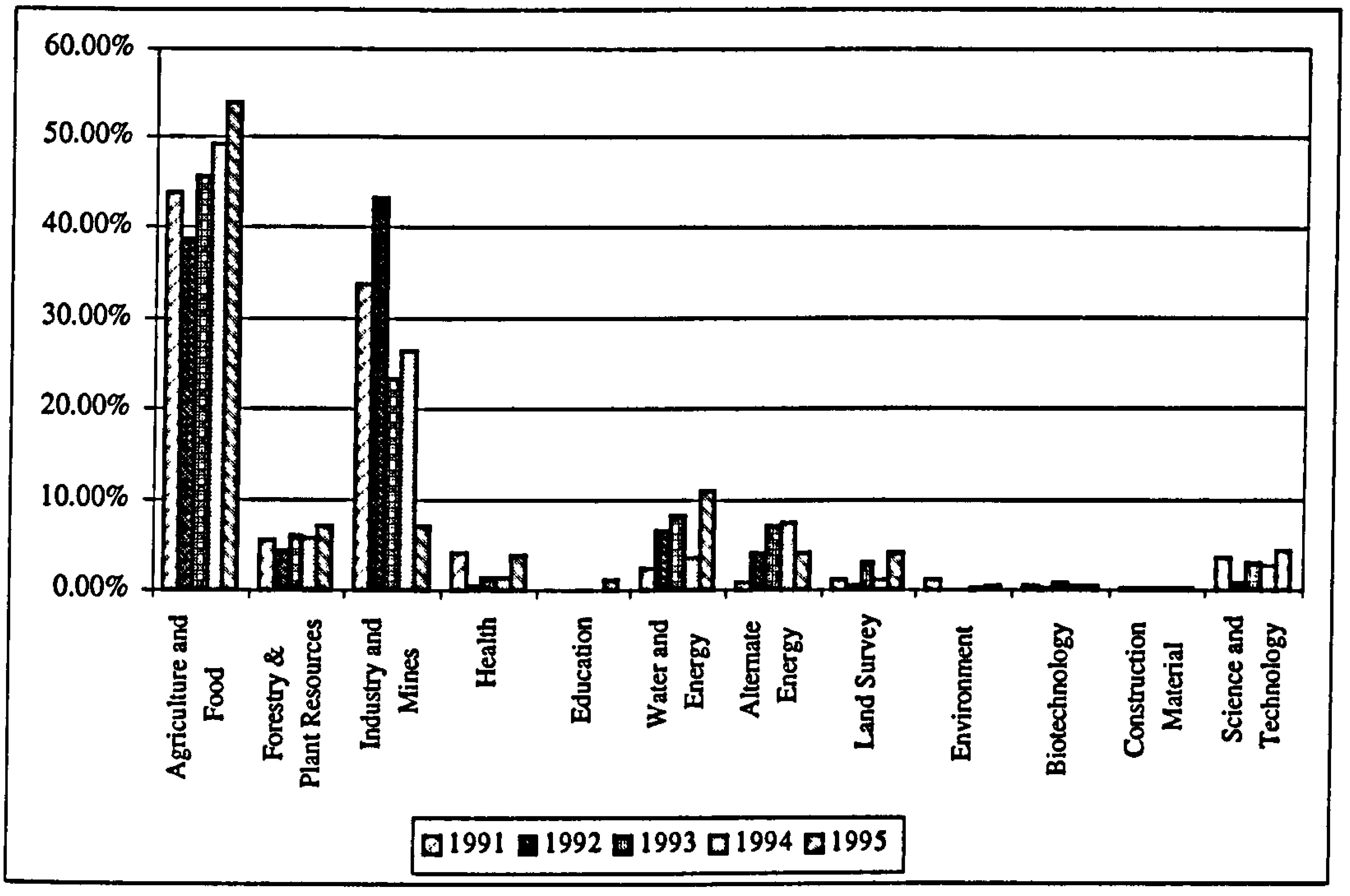
Table 7. 8: Details of R&D[4] Budget ***(in NRs. Million)***

Detail	*1991/92*	*1992/93*	*1993/94*	*1994/95*	*1995/96*
GNP at current price	152200	174617	203079	224399	254349
Total budget allocation for R&D	559	834	823	742	686
National Allocation	181	192	455	376	309
Foreign Contribution	378	642	368	366	378
Total Budget Allocated for Education	3151	4298	4522	5118	5416
Total R&D Budget as % of GNP	0.37%	0.48%	0.41%	0.33%	0.27%
National Allocation as % of GNP	0.12%	0.11%	0.22%	0.17%	0.12%
Foreign Contributions % of GNP	0.25%	0.37%	0.18%	0.16%	0.15%
Foreign Contribution as % of Total R&D Budget	67.59%	76.99%	44.73%	49.32%	55.10%
R&D Budget as % of Education Budget	17.75%	19.41%	18.20%	14.50%	12.67%

Source: Economic Survey, FY 1992/93 - 1995/96 HMG, MOF, Kathmandu

4 As to the data itself, some comments are at hand. The data related to R&D activities are hard to get. Generally one can get data on budgetary allocations in some sectors e.g. agriculture, mining, transport etc., data on actual expenditures were not given. Presumably, even with a loose definition, various components like salary etc. were difficult to separate from R&D expenditures. Eighty percent of the budget probably goes to pay-checks and non-essential services any way. Evidently, the trend has to be amended. A second comment on the data relates to a functional definition of R&D activities. Unless these are defined rigorously, it would be impossible to separate essential ones. This is specially important since almost all foreign funded projects have R&D component built into them. In the absence of a rigorous definition, this component may be used for purposes other than R&D. It should also be noted that R&D activities are not inherent in our developmental activities, while experience of other countries shows that it should be made as a matter of professional and managerial culture.

Fig. 7. 1: Research and Development (R&D) Budget Allocation by Sector and Type of Activity (1991/92) in NRs. '000



Source: A Study on R&D Investment in Nepal, (Draft), NCST, 1996

7.2.7 Trade Policy

The general objectives of trade policy in Nepal have been export promotion, import regulation and trade diversification.

Existing customs regulations, unfortunately for the manufacturers of MMHP equipment, favour traders rather than producers. For instance, raw materials required in turbine manufacture (steel plates, angles, etc.) are charged a customs duty of 20% whereas the duty on a turbine itself is only 5 percent. This anomaly evidently encourages the import of turbines rather than their domestic manufacture.

Again, although conditions for waiving of quantitative restrictions and licensing requirements for access to foreign exchange do exist, no specific facilities for energy-related industries have been provided. A summary of the implications of current trade policies for energy-related industries is given in *Table 7.9.*

Table 7. 9: Implications of Trade Policy

Trade Policy	*Implication*
Waiving of the quantitative restriction and licensing system and provision of foreign exchange facilities-Convertibility of Nepalese currency for current accounts	While no specific facilities for energy-related industries have been made, such industries are likely to gain from these policies. However, there have been some problems in implementation of the policies. For instance industries exporting for third countries in convertible currency find no problem in exporting whereas export to India is constraints regarding the local component contents
Nepalese raw material and labour content requirement for export to India	Recent trade agreement with India has done away with this condition and may resolve this problem

Source: Trade Policy: Nepal, 1992

7.2.8 Credit Policy

An aim of the Eighth Plan was to increase priority sector financing by commercial banks to 15 percent of their total loan amounts. However, an anomaly observed in this regard is the preference of the banks to be penalised rather than mobilise their resources for lending in the priority sector.

Although policies regarding priority lending and concessional interest rates have been formulated there appears a gap between the formulation and the actual implementation of the policies. Commercial banks are found reluctant to invest in priority sector lending on account of lack of expertise and high costs. Nepal Bank Limited and Rastriaya Bank have been financing alternative energy programmes mainly related with bio-gas since 1995/96, although a concessional loan facility does not seem to have been provided for rural and alternative energy projects. Sources of other credit-financing for this sector are also limited. Furthermore, delays in the sanctioning of loans, mainly due to the non-cooperative attitude of the bank staff stands out as a major hurdle. *Table 7.10*, summarises certain features and deficiencies of the credit situation.

Table 7. 10: Credit Policy Statement and Its Implications

Credit Policy	*Implication*
Committing 15% of total loan portfolio to priority sector lending	Commercial banks are reluctant to invest in priority sector lending due to lack of expertise and high operation costs. Nepal Bank Limited and Rastriya Banijya Bank have been financing alternative energy programmes mainly related with bio-gas since 1995/96. Other joint venture banks do not fulfil the requirement
Freedom to fix rates of interest on credit	A concessional loan facility does not seem to have been provided for rural and alternative energy projects. Borrowers prefer timely availability of credit to interest subsidy
Credit will be extended to the private sector on a priority basis	The budget allocation to rural and alternative energy financing by major financial institutes is limited
Simplify and upgrade the quality of loan procedures	Delays in sanctioning of loans are mainly due to the non-co-operative attitude of bank staff and policy
Lowering of statuary liquidity ratio	No implication since commercial banks' lending activities in the rural energy sector is nominal

Source: ICIMOD, 1997

7.2.9 Deficiencies and Inconsistencies of Government Policy

The Water Resources Act (*1992*) statement indicates that no license is required for running water-mills or water-mill grinders; however, under the Industrial Policy (*1992*) unless the plants are registered no fiscal or other facilities can be made available to them. As under this Act Government can acquire and develop water resources for the purpose of extensive public use and hand them over to a users' association, thus the entrepreneurs are hesitant to invest in and install micro-hydro units. Under this statement mini-micro-hydro is considered a high risk investment by entrepreneurs. There have been cases of closure of micro-hydro projects due to diversion of water resources for irrigation purposes, e.g. micro-hydro projects in Dhading district (*ICIMOD, 1995*).

Similar implications are evident in the Hydropower Development Policy. The statement provides concessional loans to generate and distribute electricity at an interest rate of 16% plus one percent service charge and a loan period of 5-7 years. According to the plant owners, the acquisition of the loan is not easy and is time consuming. The timely availability of loans is preferable to the entrepreneurs. The waiving of the license requirement for surveys, generation, transmission and distribution, by Hydropower Development Policy does not entitle the firms which are classified under the cottage scale industries to fiscal or other facilities as they are without registration as an Industrial Policy. Customs duty facility is levied on alternators imported for micro-hydro generators, whereas no customs duty is levied on alternators for diesel/petrol generators. Since the cost of diesel engines is lower than that of micro-hydro projects, diesel engines are competing with micro-hydro.

Micro-hydro plants may be replaced by small hydropower plants or the central grid. In such case Nepal Electricity Authority (NEA) is supposed to provide compensation if it extends its grid to existing private power in the form of micro-hydro etc. However, lack of clarity over payment of compensation has created a dispute between NEA and the micro-hydro plant owners as experienced in Tamghas (*WECS, 1994*).

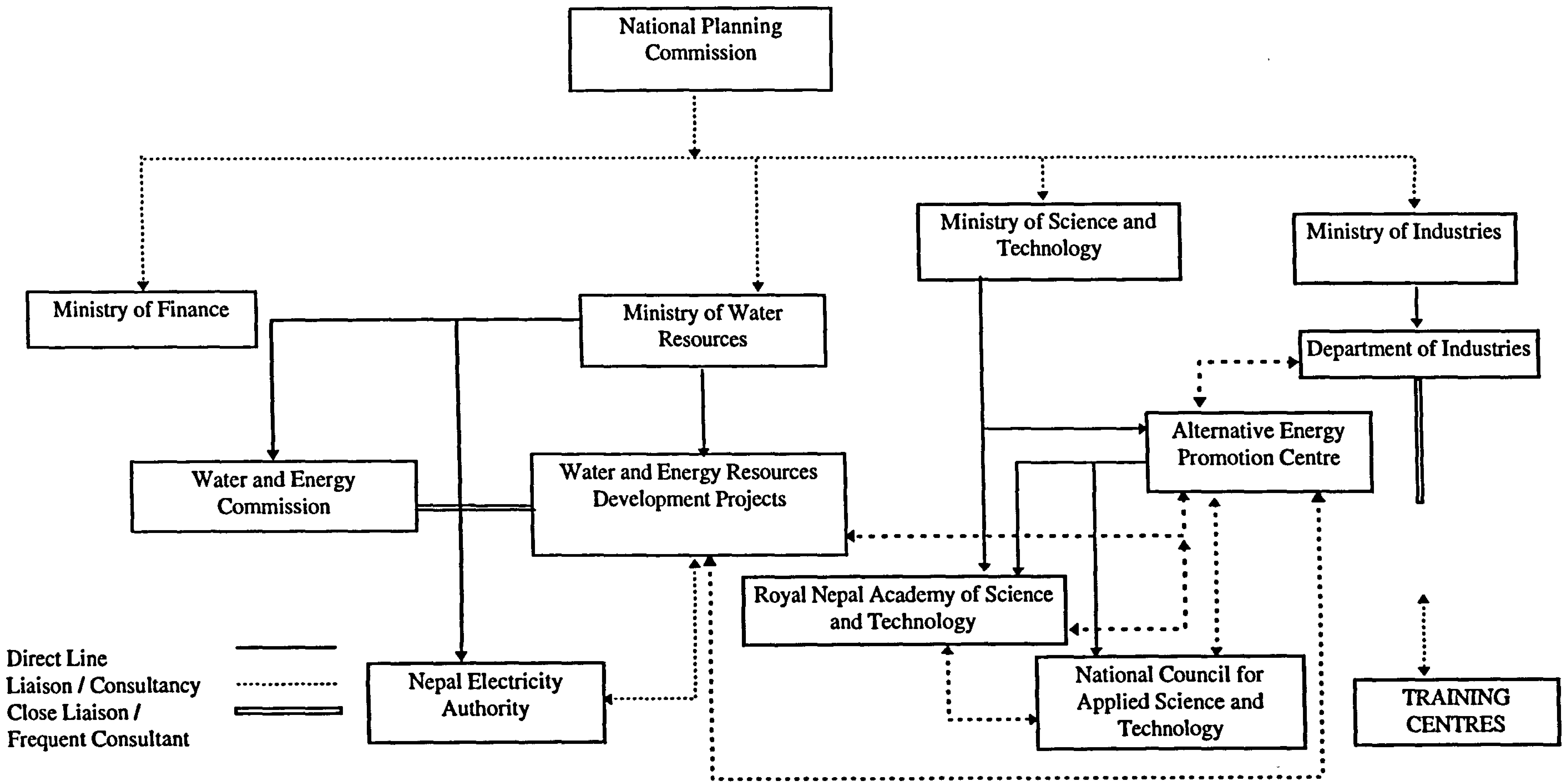
According to the Industrial Policy (*1992*), removal of licensing and registration for industries does not entitle the firms classified as cottage scale industries to any form of fiscal or other facilities as these cannot be made available without registration as an industry. As industries manufacturing fuel-saving devices and hydro-power generation and distribution fall under national priority industries, industrialists/entrepreneurs are attracted to investing in such industries due to the increased facilities rather than in the manufacture of turbines. Rebate on duties and no levy of double sales tax does not benefit the local manufacturers who do not import bulk quantities of raw material but depend on local supplies. The availability of supplies is of greater importance for firms than rebates. The firms are required to pay duties on supplies due to vagueness of classification in the tariff structure which states that no double sales tax will be levied on the raw materials and products of any industry. Furthermore, industries have to pay 15% sales tax on purchases from local manufacturers or the local market whereas they pay only nominal duties in the import of finished goods.

Inconsistencies also exist between the facilities accorded by Electricity Act (*1992*) and by the Industrial Policy. The Electricity Act (*1992*) exempts the income tax on private sector projects generating, transmitting and distributing hydroelectricity up to 1000 kW, while the Industrial Policy exempts income tax only for a period of seven years in case of hydro power generation and distribution which is categorised under industries of national priority. License for generation, transmission and distribution of hydro electricity is lowered by 10 percent (*Electricity Act, 1992*) below the prevailing rate while according to Industrial Policy such enterprises are entitled to reduction in tax rate by 5% (*Industrial Policy, 1992*) . License for hydroelectricity generation, transmission and distribution exempted from income tax for 15 years from date of generation, transmission and distribution (*Industrial Policy, 1992*). Energy-based industries are exempted from income tax for five years from the date of commercial production. Under EA license for hydroelectricity transmission and distribution is exempted from income tax for 10 years whereas under Industrial Policy the national priority industries (hydro power generation and distribution) are entitled to an additional two years of exemption. Licensed operators and managers or purchase of hydroelectricity generation plants owned by HMG/N are exempted from income tax for 5 years. On one hand Industrial Act (*1992*), states that cottage and small-scale firms are reserved for Nepalese citizens only while foreign investment of upto 100 per cent is allowed in medium and large scale firms. On the other hand the Electricity Act (*1992*) permits 100 percent investment by one or more foreign investors for power projects, including generation, transmission and distribution, irrespective of the size of the project.

7.3 INSTITUTIONAL FRAMEWORK

Rural energy overlaps with energy planning and development as well as with rural development. Activity under both of the areas involves a large number of players that fall into a wide range of categories: government line agencies, ministries and other entities, development assistance programs, local and international NGOs (*See Chart 7.1 for existing linkages between various organisations responsible for national energy development*). The rural development efforts, which constitute the major portion of the development effort in Nepal, are distributed over many line agencies. The major ministries involved are Agriculture, Industry, Local Development, Water Resources, Forests and other social sector line ministries.

Chart 7. 1: Institutional Structure Linking Various Organisations Related to the Mini-Micro-Hydro Sector



7.3.1 Central Government

The Ministry of Local Development has responsibility for rural development in general, but does not specifically cover assessment of the energy needs and identification of possible sources for meeting such needs at the village level. The Water and Energy Commission Secretariat (WECS) conducts studies on these aspects for policy recommendation to HMG/N. WECS, based upon its studies, assesses the energy consumption by rural population disaggregated, if possible by fuel type and end-use and forecasts the demand. Local development offices at the district level, the forestry department and NEA branches formulate individual programs for implementation and submit them to their respective central offices. Separately, based upon its analysis, WECS recommends various policy options related to rural energy supplies and demands to National Planning Commission (NPC) and other appropriate forums (e.g., Ministry of Finance). A development program is then formulated by NPC. After budgetary approval from the Ministry of Finance, financial allocation is made at the central offices. Once funds are allocated and approved, they are managed by individual sub-sectors. At the same time, private entrepreneurs can participate in rural energy development with financial assistance in the form of grant subsidies on capital and interest through ADB/N.

The National Planning Commission (NPC) is responsible for the integration of the rural energy development programs with comprehensive national energy planning. WECS assists NPC in performing this function. However, other major institutions play a significant role in annual planning and implementation in rural energy; these institutions[5] and their functions are:

Agricultural Development Bank - financing small scale energy projects such as mini-micro-hydro, bio-gas, solar photovoltaic with HMG/N subsidy on implementation

5 Here we consider only those institutions related with mini-micro-hydro development programs

Ministry of Water Resources - looks after rural electrification through NEA. HMG also influences development through various types of grants and matching funds which are implemented via the Ministry of Local Development (MLD) which plays a major role and helps the Village Development Committees (VDCs) in the following:

a) At the central level, the MLD monitors the Village Development and Self Reliance Program (VDSP) program through a separate unit within the ministry.
b) MLD is involved in institutional strengthening (capacity building) of the Village Development Committees (VDCs) and District Development Committees (DDCs) to meet the skilled human resources needs and to supply technical support
c) MLD also provides manuals and training programs to VDC administration on the collection and use of revenue and on human resource development as assistance in the implementation of various programs
d) MLD has a fund with initial capital of NRs. 10 million to support inter-village programs
e) MLD can exercise some control over the VDC and DDC under 2048 Act (1991/92) which allows it to dissolve these local governments

At the central government level, there is also the new entity being set up to co-ordinate and undertake a comprehensive set of functions related to alternative energy which largely overlaps with rural energy issues. This new entity, AEPC, is established under the Ministry of Science and Technology .

7.3.2 Alternate Energy Promotion Centre (AEPC)

Under the Ministry of Science and Technology, the HMG/N has created the Alternative Energy Promotion Centre (AEPC). This unit is just beginning to be staffed and organised. It has been assigned the following functions:

a) to develop alternate energy technology by formulating appropriate policy and programs for its development and expansion
b) to monitor and evaluate alternate energy programmes.
c) to set up standards for alternate energy technologies
d) to co-ordinate the implementation of alternate energy development programs to be prepared with resources from HMG, foreign and national organisations involving local agencies
e) develop networking for acquisition of information for development of alternate energy technologies
f) to formulate and implement model projects relating to alternate energy

7.3.3 Agents in the National Energy Planning Process

There is no Ministry or Department of Energy in Nepal. The Water and Energy Commission (WEC), created by a decision of HMG in 1976 is responsible for energy policy formulation, analysis and planning and recommending short and long term development strategies to HMG for the energy sector. The WEC functions as an Inter-ministerial body and operates under the Ministry of Water Resources, which provides a link to the Cabinet regarding the activities, proceedings and recommendations of the Commission. The policy recommendations are accomplished through surveys, investigations and studies. Responsibility for the energy sector is spread over many other entities such as line ministries and sectoral entities, along with increasing participation of the private sector. The Ministry of Finance is responsible for co-ordinating and securing external sources of finance for development assistance for the energy as well as other sectors. It also has an interest in the financial implications of energy investments and financial operations of energy agencies. The National Planning Commission (NPC), which is responsible for national economic planning, reviews the energy sector programs and projects, particularly in connection with the preparation of the national five-year development plans and annual budgets. The NPC presently makes energy sub-sectoral allocations at the macro-level. As the energy sub-sectors are presently under various line ministries, the allocations within energy sub-sectors are taken care of by the NPC. The program and project level allocations are made at the line agency level. Finance arrangements for large projects alone are considered at the finance ministry level; otherwise, the financing mechanisms and arrangements are considered as the responsibility of the line ministries and agencies. The operation and maintenance of energy projects are financed through the projects themselves.

7.3.4 Funding Agents

7.3.4.1 Nepal Industrial Development Corporation (NIDC)

For the provision of financial and technical assistance the Industrial Development Centre was established in 1957 and later renamed as the Nepal Industrial Development Corporation in 1959. Its main function is to provide medium and long term loans to industrial ventures which are technically sound and economically feasible. Besides dealing with shares, stock, bonds and debentures, it is also engaged in industrial consultation, feasibility studies, training, compilation and dissemination of industrial and commercial information relating to investment. It has played an active role in the establishment of Balaju Yantra Shala. However, not much of the same active role has been realised since then in the mini-micro-hydro sector.

7.3.4.2 Agricultural Development Bank

Historically the Agricultural Development Bank of Nepal (ADB/N) has been active in rural energy planning and implementation. For a number of years, the ADB/N (via appropriate technology units) was the only rural energy development financing institution with a vision of its role not limited to project appraisal and financing. The ADB/N has taken the role of a technology extension agency working at the forefront of rural development, combining credit operations with support services which include:

- field-testing, demonstration and dissemination of technologies most notably in micro-hydro and bio-gas
- promotion of technology
- development of marketing channels by acting as liaison between technology users and manufacturers
- promotion of local entrepreneurial skills
- provision of local entrepreneurial skills
- provision of training and credit to rural entrepreneurs and farmers
- monitoring and evaluation of impacts
- some devolution of responsibilities to branch offices
- attempts at a decentralised strategy

However, ADB/N has not been able to generate a consistent and long term commitment either from HMG or form agencies. ADB/N is now moving towards a solely credit-provision role Also based on loan recovery information there appears to be inadequacies both in creditor assessment and capacity to move aggressively on delinquencies due to limited technical assistance.

Table 7.11 presents the planning and implementation strategies of the bank. It shows participatory strategy in the planning and implementation of mini-micro-hydro systems. It indicates closely co-ordinated work between the various parties involved in this sector, manufacturers, financiers and entrepreneurs as well as the local community development workers . The bank is involved right from the feasibility study and provides security to the entrepreneurs through issuing a mandatory letter of acceptance on its behalf before final payment is made. The bank is also involved in the follow-up study regarding the performance of the turbine during the guarantee period offered by the manufacturers for the system.

Table 7. 11: Planning and Implementation of the Mini-Micro-Hydro System

Procedural	*Activities*	*Involved Parties*
Site Survey and Project Identification	* Resource Assessment - water volume, speed, effective head; terrain condition; - assessment of customers /services(milling, electricity) * Discussion on Water Rights * Feasibility /interest ascertained	* Local Entrepreneurs * Community * Technician/Manufacturer * ADB/N Staff
Quotation sent to Owner	* Owners specific preferences recommended # Manufacturer specifies available equipment	* Local Entrepreneurs * Community # Technician/Manufacturer
Loan Request and Assessment	* Owner provides collateral security # AB/N staff checks financial and technical viability	* Local Entrepreneurs * Community # ADB/N Staff
Loan Approval	* ADB/N issues approval notice to owner * ADB/N issues "coupon" for equipment order and provides 50% cash advance to manufacturer on behalf of the owner	* Local Entrepreneurs * Community * Technician/Manufacturer * ADB/N Staff
Preliminary Activities at the Site	* Construction of intake and canal * Preparation of turbine site; Collection of construction material; * Transportation of equipment to site	* Local Entrepreneurs * Community
Installation of Equipment	* Supervision of Civil works and equipment installation # Civil works	* Technician/Manufacturer # Local Entrepreneurs # Community
Testing of Equipment	* Issuing of document of acceptance by owner upon satisfactory operation # Training of owner/operators on operational procedures & regular maintenance	* Local Entrepreneurs * Community * ADB/N Staff # Technician/Manufacturer
Final Payment	* Final Payment to manufacturer on behalf of the owner	* Technician/Manufacturer * ADB/N Staff
Follow-up and Supervision	* Periodic follow-up, supervision and suggestion for appropriate measures to be taken if required	* Local Entrepreneurs * Community * Technician/Manufacturer * ADB/N Staff
Operation and Maintenance	* Routine operation and maintenance	* Local Entrepreneurs * Community * Technician/Manufacturer

Source: Prepared by Author on the Basis of discussions with staff from ADB/N

The Agricultural Development Bank started providing loans for agro-processing in order to promote the production of agricultural products. Initially in this process diesel mills were financed. In the hilly areas, due to difficulties in the transportation of diesel, investment into agro-processing remained limited. But when a suitable hydro technology became available, ADB/N could expand its financing in this sector for the hilly areas (*Singh K, M, 1989*). The bank has already invested about 100 million NRs. for the implementation of MMHP agro-processing projects in Nepal since it started financing for water-turbine projects in 1970s. As for the electrification projects which include stand-alone, add-on and Peltric systems the bank has invested more than 43 million NRs. for about 500 MMHPs since 1981 (*Adhikari, 1998*). ADB/N acts not only as a financing house but also carries out surveys, feasibility studies, technical assistance, training of manufacturers and owners and promotion of local manufacturers. With the initiation of the rural electrification programme in 1981, the bank started providing financial and technical assistance to local manufacturing companies to produce and install micro-hydro equipment (*Adhikari D. 1993*).

In 1981, ADB/N signed a contract with ITDG to promote technology and to provide technical assistance to MMHP programs in Nepal. It was a three year agreement. Now the management of ADB/N is concentrating more on the financial aspect rather than on the technological part. The ADB/N promotes MMHP programme through its 238 field offices, 395 Small Farmers Development Programmes, 2 Appropriate Technology Units and 4 Training Centres spread across the country (*Adhikari D. 1993*). Normally the entrepreneurs contact the ADB/N field offices for MHP site identification. The ADB/N normally forward such requests to the manufacturers. Sometimes the entrepreneurs make direct contact with the manufacturers. The manufacturers, after preliminary assessment of the site selected by the entrepreneur, conduct site survey. They prepare preliminary design and cost estimates based on this survey, which is forwarded to ADB/N in a prescribed format.

The ADB/N, after receiving a loan request from an entrepreneur conducts financial appraisal of the proposed project and at the same time assesses the manufacturer's proposal. Once the technical and financial viability of the proposed MMHP is established the ADB/N approves the loan request. Loans upto Rs. 900, 000 are approved by the regional field offices, whereas loans over that amount are the responsibility of the ADB/N Central Office. On approval of the loan the bank issues the order to the manufacturer along with an advance payment equal to 50 percent of the estimated cost. At the same time the borrower receives a loan for canal construction and mill establishment. With few exceptions most part of the civil works are managed by the borrower. Apart from that he arranges transportation of the equipment to the site. The manufacturer receives the balance payment after he has successfully commissioned the plant. However, the borrower is legible for loan only after fulfilling certain conditions such as:

a) contributing 15 percent of the total project cost in form of labour and local construction material
b) owning land at the project site
c) pledging enough assets as collateral; 20 to 30 percent of the plant value is accepted as collateral

(*Adhikari, D. 1993 and Singh, K. M. 1989*)

Chart 7.2 presents the flow of subsidies in the mini-micro-hydro projects. The subsidies provided by the government are often supplemented by the donor agents through the Agricultural Development Bank. In a few MMHP projects the subsidies have been provided by the donor agents directly to the entrepreneurs as well as the manufacturers. Direct subsidy from donor agents to the entrepreneurs are mainly limited to community owned plants. The ADB/N has been the only agency which through its loan and subsidy programme has taken a direct interest in the implementation of MMHP projects. The ADB/N efforts were facilitated by two important policy decisions concerning rural electrification by the Government:

a) delicensing of all electricity installations below 100 kW initiated in 1984
b) 50 percent subsidy (75 percent in case of remote areas) on electro-mechanical[6] costs, including generators, initiated in 1985

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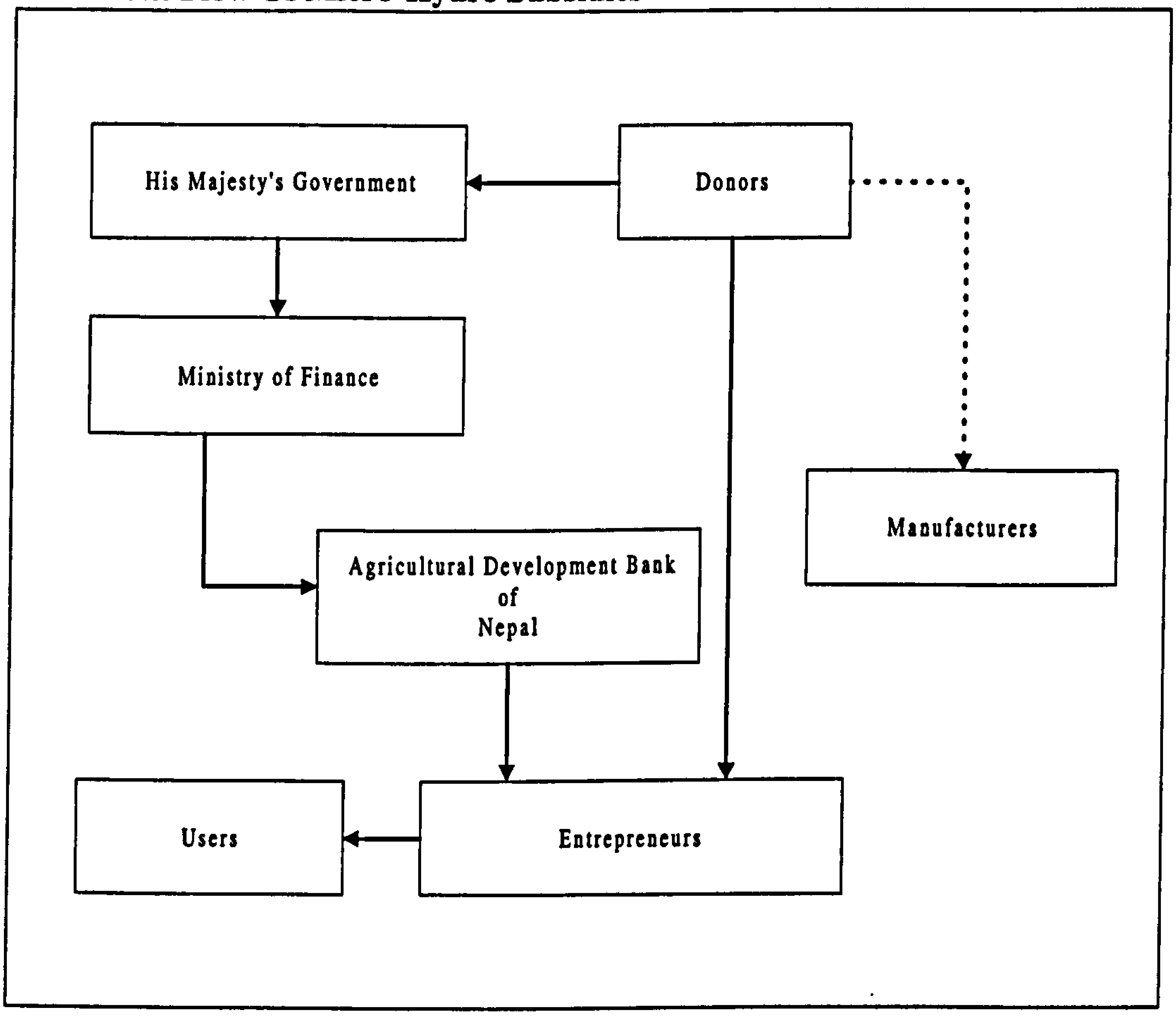
6 Subsidy is not provided for the turbine, intake system etc.

Chart 7. 2: Flow Of Micro-Hydro Subsidies

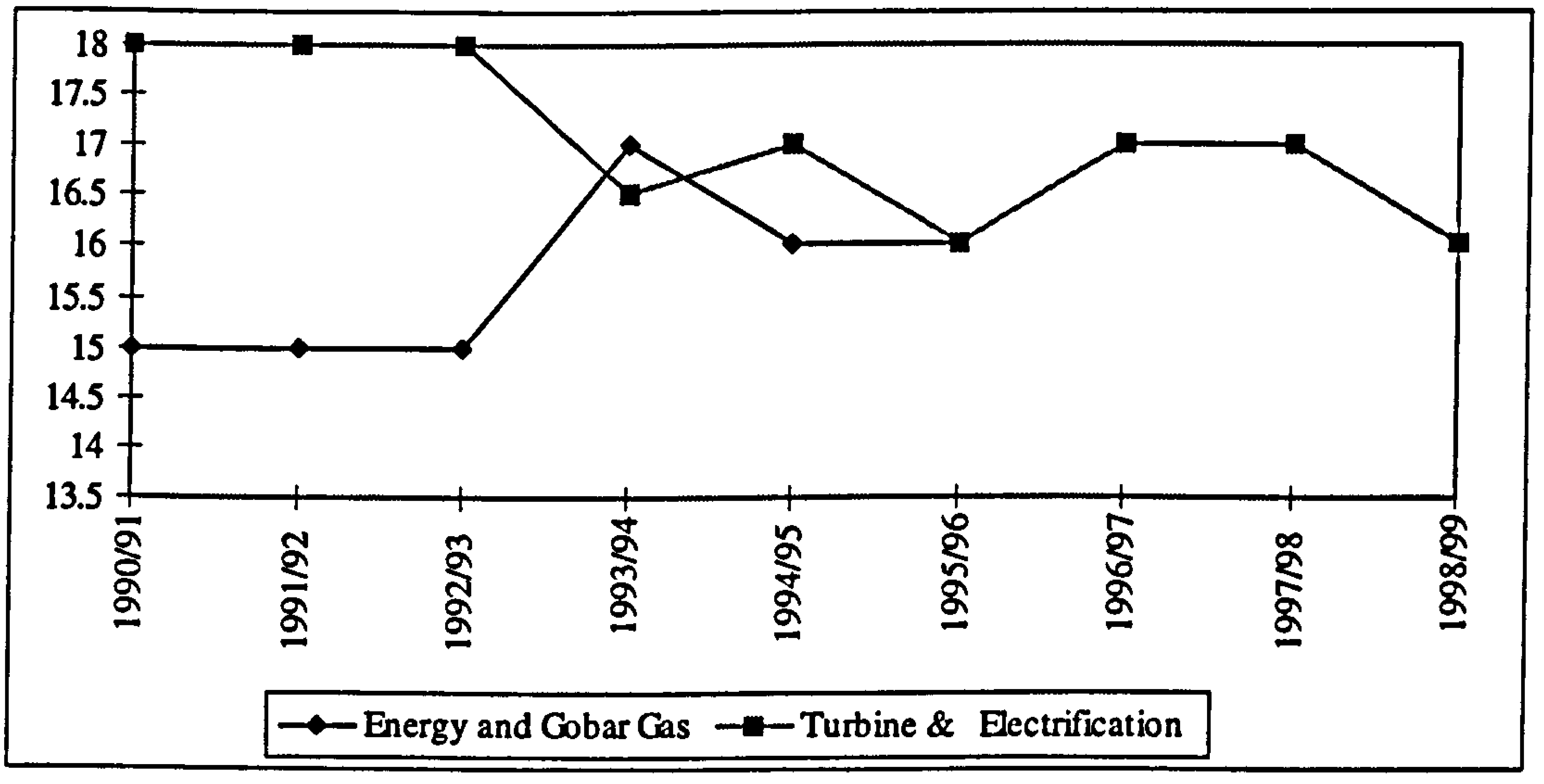


However, the availability of the funds for this programme has not been consistent. Funds were available for some years; while they were almost non-existent for others. The interest rates have varied from 15 percent to 19 percent but have recently been reduced to 17.5 percent[7]. Most of the time the interest rate on loans for mini-micro-hydro has remained higher than that for bio-gas programmes. It is only in recent years that the interest rate for both these technologies has been the same *(See Fig.7.2)*. Similarly, the subsidy policy and its inconsistency is a cause of major grievance on the part of the mini-micro-hydro sector in Nepal. The subsidy was initiated in 1985, discontinued in 1986, reinstated in 1988 and after being stable for a year, was once

7 Contacts with manufacturers as well as entrepreneurs

again discontinued only to be reinstated in 1993. These inconsistencies inevitably affected the confidence of the recipients and also caused large variation in the volume of business for the manufacturers, as well as forcing them to switch over to do other alternatives. Although not on a regular basis, the Agricultural Development Bank has been known to provide necessary credit assistance to the manufacturers and entrepreneurs for technological innovations (*Adhikari, D. 1993 and Singh, K. M. 1989*).

Fig. 7. 2: Variation in the Interest Rate on the Loan Sanctioned by ADB/N Over the Years



Source: ADB/N, 1998

A scenario of the influence of the ADB/N subsidy on the growth of micro-hydro systems is apparent from *Table 7.12*. The number of plants installed between the years 1981/ 82 to 1986/87 was above 60, with the largest, 102 plants installed in 1984/85 the period with subsidy programme. This was followed by 90 plants in 1985/86. But the number of plants being installed since have fluctuated but have remained below 55.

Table 7. 12: ADB/N Loans and Subsidies for Rural Electrification (Value in NRs. Current Prices)

	Total No. of Units Installed	*No. of Units Receiving Loans/Subsidy*	*Total Capacity kW*	*Total Cost (NRs. '000)*	*Cost per kW (NRs. '000)*	*Total Loan (NRs. '000)*	*Loan as % of Cost*	*Total Subsidy (NRs. '000)*	*Subsidy as % of Cost*
1981/82	68	1	3	18000	6000	18000	100	0	0
1982/83	84	2	13	847000	65154	624000	74	0	0
1983/84	80	3	14	111000	7929	88000	79	23000	21
1984/85	102	4	21	319000	15190	172000	54	88000	28
1985/86	88	11	72	781000	10847	400000	51	351000	45
1986/87	90	18	171	2155000	12602	1142000	53	832000	39
1987/88	55	11	99	1511000	15263	800000	53	659000	44
1988/89	46	9	79	2744000	34734	1652000	60	865000	32
1989/90	37	11	149	4039000	27107	973000	24	1355000	34
1990/91	50	4	105	1958795	18655	8039000	41	954965	49
1991/92	27	3	47	2431160	51727	986570	41	846969	35
1992/93	13	12	129	5975388	46321	917001	15	2820429	47
1993/94	22	80	364	23675101	65041	2726287	12	9098585	38
1994/95	10	71	172	11156023	64861	8691089	78	4637980	42
1995/96		140	286			16558029		7630785	

Source: ADB/N Records

7.3.5 Research and Development Organisations

Nepal has been giving due attention to building up scientific and technological capabilities as well as their application for a rapid economic development of the country. Steps towards the integration of R&D with the basic objectives of economic development have taken since 1976 through the establishment of the National Council for Science and Technology during the Fifth Plan for the formulation of science and technology policy (*APCTT, 1986*). The Sixth Plan (*1980-85*) contained an explicit science and technology policy statement. The Seventh Plan (*1985-90*) followed the same line, stressing the need to further the scientific and technological capabilities by improving upon and increasing the structural facilities, developing and disseminating required technologies, mobilising international co-operation and collaboration.

Despite these steps Nepal has to rely entirely upon imported technology for almost all the major programs in various economic sectors. There is no concrete program for technological self-reliance or for balancing the import and export of technology for long-term sustainable development. The emphasis on S&T education and necessity or R&D for the development of local capability can be seen in the recognition of the government Five - Year Plans right from the Sixth Plan (*See Annex*). However, not much has been achieved in this sector as is revealed by the figures of S&T personnel and R&D expenditures.

Research organisations such as the Royal Nepal Academy of Science and Technology (RONAST) and the Research Centre for Applied Science and Technology (RECAST), have been working on various alternate energy technologies. RONAST is involved in other hydro-based energy technologies other than mini-micro-hydro turbines. RECAST was involved in the investigation of traditional water-wheels, prototype construction of improved water-mills and site-testing for mini-micro-hydro development. RECAST has also been involved in the replacement of metal cross-flow turbine blades with high density polythene (HDP) material to lower the cost of the turbine. However, co-ordinated efforts between research organisations, manufacturers and users are not apparent.

7.3.6 Manpower Training

Training needs are multifaceted in the field of alternate energy technologies which includes MMHP. Various studies and reports have indicated that there is an urgent need to produce a cadre of lower, middle and higher level technicians engaged in promotion, technical services, and research and development in the field of alternate energy technologies in Nepal.

ADB/N was involved in the organisation of regular training for micro-hydro operators, technicians and persons involved in financial and management activities, but at present it attaches little importance to this area. Regarding micro-hydro, the manufacturers themselves train operators during installation of the plants. In addition, national institutions (WECS, NEA) as well as international ones (ITDG, ICIMOD, UNDP, etc.) are currently engaged in preparing training materials. Institutions under the Council for Technical Education and Vocational Training (CTEVT) and the Institute of Engineering (IOE) are involved in producing middle and higher level technicians. Gaps still remain at lower and middle levels of technical human resources. These existing training centres could play a more effective role by reorienting their curricula and courses to produce a cadre of skilled technicians of different categories.

The Council for Technical Education and Vocational Training is the policy formulation and co-ordinating body for technical and vocational training programs in Nepal. It was initially formed under the Technical Education and Vocational Training Act (1988) and was amended under the Technical Education and Vocational Training Council Act (*1992*). The council is an autonomous body [8] having executive powers. The primary purpose of the Council is to facilitate the growth and development the of the human resources of the nation. Its main objectives are:

8 The council; has 24 members and a governing board of seven members. The assembly and the council are chaired by Honourable Minister of education. It also has a full time Vice Chairman and a member secretary.

a) to provide necessary support and services to both its own institutions and to private institutions so that training is need-based, effective and as efficient as possible

b) to ensure quality of middle and basic level technical education and vocational training so that it results in improvement of quality of life or facilitates income generation through self-employment or wage-earning.

The Council currently operates with ten technical schools. It carries out man-power needs assessment as well as grant recognition and accreditation to other level technical education and vocational training programs and institutions. CTEVT has about 860 professional and supportive personnel. The CTEVT runs nine technical schools and trains about 1200 trainees per year. Besides these long courses about 6000 trainees obtain short courses in diversified trades each year.

Table 7. 13: Technical Schools Currently Operating Under CTEVT and CTEVT Affiliated Institutes

Name of Institute	*Trade Areas*	*Level of Certificate*	*Remark*
Butwal Technical Institute	Mechanical Electrical Welding, Automobile	Technician	Affiliated to CTEVT
Sanothimi Technical School	Mechanical Welding, Printing	Technician	Affiliated to CTEVT
Balaju Technical Training Centre	Electrical, Mechanical, Sanitation	Senior Technician, Junior Technician	Operates Under CTEVT
Lahan Technical School	Construction, Agriculture	Technician (SLC)	Operates Under CTEVT
Jiri technical School	Construction, Agriculture	Technician (SLC)	Operates Under CTEVT
Karnali Technical School	Construction, Agriculture	Technician (SLC)	Operates Under CTEVT
Seti Technical School	Construction, Agriculture, Health	Technician (SLC)	Operates Under CTEVT
Bheri Technical School	Mechanics, Welding, Electricity, Electronics, General	Technician (SLC) and Training	Operates Under CTEVT
Rapti Technical School	Mechanics, Construction, Agriculture, Health	Technician (SLC) and Training	Operates Under CTEVT

Source: CTEVT, 1996

Similarly, CTEVT-affiliated training institutions provide training in different trade areas. Of the several schools operating under CTEVT the schools which provide skills for the mini-micro-hydro sector are only three in number. These are concerned with electrical and mechanical trades. The training given is to senior and junior technician levels. Besides CTEVT is also affiliated to other mechanical training institutes like the Butwal Technical Institute and the Sanothimi Technical School. *Table 7.13* presents the list of technical institutes operating under CTEVT and affiliated institutes providing skills appropriate for the MMHP programs.

7.3.7 Other Non-Government Organisations

Over and above governmental and semi-governmental institutions like MOWR, WECS, NEA, ADB/N, RONAST and RECAST, there are other agencies, including private companies, which are playing key roles in the development of hydropower in Nepal. These are briefly described below:

Association of Mini-Micro-Hydro Manufacturers (AMHM): The AMHM association was set up during 1991 to share experiences and information amongst the manufacturing companies. All the turbine manufacturing companies of Nepal are associated with this organisation. The association has set up common standards for the industry, in agreeing to follow the mechanical and electrical guidelines developed jointly by ADB/N and ITDG.

United Mission to Nepal (UMN): The UMN has been actively involved in Nepal since March 1954. It has established a number of projects to support and implement the mini-micro-hydro program in Nepal. It has actively supported the program through the establishment of the Butwal Technical Institute (BTI) in 1963, Development and Consulting Services in 1972, Butwal Engineering Works in 1977 and Nepal Hydro Electric Company (NHE) in 1986.

Swiss Federal Institute of Technology (SKAT): The SKAT is jointly owned by the Swiss government and Helvetas. It is an agency for the promotion of appropriate technology. It has provided technical and financial assistance to different institutions working in the field of MMHP.

Swiss Association for Technical Assistance (SATA): Since 1960, SATA (presently known as Swiss Development Co-operation) has supported the micro-hydro program in collaboration with Balaju Yantra Shala (BYS) in Nepal. It has provided technical expertise to improve the different models of cross-flow turbines in Nepal. It had also given support in the field of small hydro power development through technical and financial assistance programs.

German Technical Co-operation Agency (GTZ): The GTZ has collaborated with different Nepalese agencies on improved *ghatta* projects. Presently it is also involved in a joint program with NEA on a Small Hydro Master Plan Project.

Association for Appropriate Technology (FAKT): The FAKT is a German church-based consulting company concentrating on appropriate technology. It has supported through UMN the development of micro-hydro end-use technology in Nepal.

Japan International Co-operation Agency (JICA): It is a Japanese government agency for development co-operation in Nepal. This agency has worked closely with the Royal Nepal Academy of Science and Technology (RONAST) to conduct a joint research project on alternate energy technologies. The project concerned research & development and experimentation/implementation of river current powered technologies like boat, generator and pump besides activities on solar and bio-mass sources of energy. The study has provided an opportunity to analyse the energy needs of some of the rural areas of Nepal as well as to assess the appropriateness of the technologies.

Association for Technical Co-operation in Himalayan Region (ATCHA): This Japanese association initiated field experimentation and demonstration of the technologies powered by river current and hydraulic ram in rural areas of Nepal.

United States Agency for International Development (USAID): The USAID signed an agreement with the ADB/N in 1990 to support Private Rural Electrification. It is a pilot project to develop different modalities of mini-micro-hydro. Through this project, it provides grant and training support in the field of mini-micro-hydro installations.

Intermediate Technology Development Group (ITDG): The ITDG has been working to strengthen the mini-micro-hydro sector in Nepal. It was established in 1960 in Britain. It has financially and technically supported the Development Consulting Services (DCS) rural electrification project since its inception in 1979. ITDG has worked closely with ADB/N on a three year plan of co-operation within the field of mini-micro-hydro power and appropriate technology. It is also actively involved in the field of research and development of mini-micro-hydro equipment, technology and end-use equipment.

Centre for Rural Technology (CRT): CRT was established in 1989 for the promotion and dissemination of rural technologies. It is, presently working in two districts to popularise improved *ghatta* technology with assistance provided by GTZ.

United Nations Development Program (UNDP): UNDP, has funded WECS to carry out studies on mini-micro-hydro aiming at compilation of an inventory of the prospective MMHP sites and scheme preparation works of most attractive sites in six districts and training program for prospective MMHP entrepreneurs. This study also addresses issues of the improvement of the economic viability of mini-micro-hydro plants. This study formed the basis for formulation of a project document for securing funding for mini-micro-hydro development under the Global Environment Fund (GEF).

International Centre for Integrated Mountain Development (ICIMOD): ICIMOD, inaugurated in 1983 was the first International Centre working on integrated mountain development activities to be established in Nepal. It links eight countries of the Hindukush-Himalayan region. It has recently years carried out several studies on various aspects of MMHP. Its recent activity focuses on the preparation of manuals on MMHP technology as well as its operation. Regular International/National seminars on this topic have made it possible to gain access to information related to MMHP issues in member countries and provided an opportunity to learn from their experiences.

7.4 GOVERNMENT INCENTIVES AND POLICIES FOR MMHP DEVELOPMENT IN SELECTED COUNTRIES

The Governments of China and India have accorded special recognition in their planning and policy documents to the MMHP/SHP for meeting the energy needs of some areas. Government of India, through its erstwhile Department of Non-conventional Energy Sources formed in 1982, later in 1992 converted to a full fledged Ministry of Non-conventional Energy Sources (MNES), has extended multi-dimensional support *(See Table 3.14)* in the form of subsidy, loans and tax-breaks for the development of mini-micro-hydro (upto 3 MW) as one of the benign renewable energy technologies, keeping in tune with the Government's overall policy on liberalisation of economy and private sector participation in power development. This sector was also declared as the thrust area in the Eighth Plan. Besides these Central Government measures the different states have provided separate incentives in accordance with the guidelines of the MNES. The incentives are in the form of capital subsidy, electricity duty exemption for 5 years, sales tax exemption , demand charge exemption.

Table 7. 14: Fiscal Incentives Offered by the Indian Government

Schemes involving capital upto 1000 Million need no prior clearance from central Electricity Authority, even if they are single source
Income Tax holiday for power @ 16% upto 75% of the project cost
Short term loans through IREDA for schemes upto 25 MW
Confessional custom duty @ 20% to 10% for non-captive use
Incentives for detailed project survey and investigation, 100% Grant - in - Aid subject to certain ceiling depending upon the type of schemes
Incentives for preparation of detailed Project Report, 50% Grant - in - Aid subject to certain ceiling depending upon the type of schemes
For schemes upto 100 kW in hills for societies, NGOs, state agencies -capital subsidy of Rs. 15,000/kW
For schemes in North East Region - Capital subsidy upto 50% of project cost limited Rs. 30,000/- per kW
For projects below 3 MW, an interest subsidy of 5%, capitalised at the rate of Rs. 1.18 crores /MW for project in hills.

Source: MNES, 1996, India

In China the Government is following the "three-self policies, namely, self-construction, self management and self consumption" [9] (*HRC-SHP, 1993*). The Governments (Central, Provincial, Prefecture and County) provide considerable funds as grants to the sub-districts and villages for installation of MMHP/SHP plants.

In case of Pakistan also many announcements have been made to support rural electrification and promote renewable energy including small hydro-power. However, no policy of tangible incentives for private MMHP installations has been announced (*Junejo 1994*). The Appropriate Technology Development Organisation provided all the required incentives free of cost in its initial phase for motivating the use of this technology. However, in recent years the subsidy has been phased out and is confined to 50 percent of the cost of generator, which is only about 20 percent of the overall cost (p.c. *ATDO, 1997*).

The purpose here is to assess the institutional structure present in Nepal for fostering the development of micro-hydro systems in the country. *Table 7.15* below, presents the necessary institutional activities required and the presence or lack of such

9 This means people who invested and constructed MMHP stations have the right to manage the plant, to use the output and get benefits from the station.

institutions in the country. The scenario is then compared with that of Pakistan and India.

All three countries have a government organisation dealing with policy and legislation formulation besides planning, fund procurement from donors and fund allocation. However, unlike India, Nepal and Pakistan lack Central Specialist Agency to undertake activities related to MMHP technology promotion, preparation of implementation methodology, determination of subsidy levels, interest rates, advisory service to government, master plans, technical standards /guidelines, to overseeing overall implementation, co-ordinating, sponsoring relevant studies, for initiating and arranging R&D, including end uses and appliances, training programs and materials, development of field repair facilities, The existing Rural Electrification Support Units for site identification, assistance in planning, installation and commissioning, promotion, monitoring and backstopping, advice and assistance in repairs need more strengthening in case of Nepal and Pakistan. Furthermore, Fund disbursement Agencies like Banks, Finance Co-operations, NGOs undertaking appraisal and approval of subsidy/loan applications, disbursement of funds, monitoring, loan recovery, completion certificates, are limited in number and exist only in a few areas in the case of Nepal as well as Pakistan.

Although all three countries do have turbine manufacturers, Nepal and India have a more organised sector than Pakistan where the work is undertaken by local metal craftsmen under the supervision of their client, PACT and AKRSP. India has a manufacturing sector which has the capability to produce turbines in the larger-size range. Manufacturers in Nepal, on the other hand, have the capability to undertake the total project on a turnkey basis i.e. site investigation, installation of plants as well as their manufacture.

Table 7. 15: Status of Institutional Set - Up in Nepal

Name and Function	*Status in Nepal*	*Status in Pakistan*	*Status in India*
Government Federal/Central (Ministry, division/Deptt./Directorate) ⇒ policy and legislation formulation ⇒ planning ⇒ fund procurement from donors ⇒ fund allocation	exists	exists	exists
Provisional /State Govt. ⇒ policy formulation ⇒ policy implementation ⇒ program implementation	not applicable	not applicable	Exists. In India hydro power is a state- government subject
Central Specialist Agency ⇒ mobilisations of fund ⇒ promotion ⇒ preparation of implementation methodology ⇒ fixation of subsidy levels, interest rates ⇒ advisory service o government ⇒ master plans ⇒ technical standards /guidelines ⇒ oversee overall implementation ⇒ co-ordination ⇒ initiating/sponsoring relevant studies ⇒ initiating and arranging R&D, including end uses and appliances ⇒ training programs and materials ⇒ development of field repair facilities	does not exists	does not exists	Exists. Cover some of the aspects only. SHP programme is being dealt in different tones
Rural Electrification Support Units ⇒ site identification ⇒ assistance in planning, installation and commissioning ⇒ promotion ⇒ monitoring and backstopping ⇒ advice and assistance in repairs	does not exists [2]	does not exists [2]	Exists but mainly in Government sector, in centralised manner. It only provides fund for electrification
Fund disbursement Agencies (Banks, Finance Co-operations, NGOs) ⇒ appraisal and approval of subsidy/loan applications ⇒ disbursement of funds ⇒ monitoring ⇒ loan recovery ⇒ completion certificates	exists [1]	exists [1]	Exits, MNES, IREDA, REC, NABARD, SIBDI etc. provide funds

Table 7. 15: Status of Institutional Set-Up in Nepal *(continued ......)*

Name and Function	*Nepal*	*Pakistan*	*India*
Implementation Agencies (INGOs/NGOs, Manufacturers, Consultants) ⇒ site survey/assessment ⇒ plant and layout design ⇒ planning for installation ⇒ mobilisations of community participation ⇒ installation, commissioning and testing ⇒ equipment transportation ⇒ initial information package, including operating manual ⇒ training ⇒ participation in monitoring and backstopping	exists[1]	exists[1]	Exists. It is done by consultants, in-house engineers, NGOs and manufacturers covering different portions
Manufacturers ⇒ design of components and machinery ⇒ manufacturer ⇒ procurement of other parts/systems ⇒ quality control and testing	exists [2]	exists [2]	Exists (there are over 10 of them)
R&D Organisation ⇒ improvement of quality performance and reliability ⇒ cost reduction ⇒ improvement of assembly/disassembly and installation	exists [3]	exists [3]	Exists. AHEC is one of them
Local Repair Facilities ⇒ undertake repairs	does not exists[2]	does not exists[2]	does not exist in organised manner
Monitoring and Evaluation (Consultants, Technical Agencies, Experts) ⇒ undertake monitoring & evaluation	exists [3]	exists [3]	Exits. Not undertaken in an organised manner
Training Organisations (Manufacturers, Educational Institutions, Specialists Agencies, Promoting Agencies) ⇒ Organise and conduct various raining program ⇒ prepare training materials ⇒ evaluate and improve training programs	partly exists [4]	partly exists [4]	Exists.

Although appropriate organisations do exist, besides the manufacturers, these are not currently engaged in any R&D activities related to MHHP to any significant extent[10]. Thus, their capabilities have to be improved considerably to enable them to undertake worthwhile R&D work. In Nepal especially the manufacturers are making a

10 Also see Shakya, I., (1994a): "Role of Industrialisation in the Economic Development of Nepal" and Shakya, I., (1994b): "Role of Linkages Between Research Institutes and Industries for the Development of Science and Technology in Nepal".

considerable effort, usually with sizeable assistance from expatriate expert agencies, Still it would be helpful if some R&D agencies were also involved in this field. In the case of India a single body - Alternate Hydro-Energy Centre, is one such organisation that is involved in this activity. Local repair facilities as well as monitoring and evaluation agencies, exist in an organised manner India, but is not so in the cases of Nepal and Pakistan.

Some regular training programs for operators and managers are being organised in Nepal; however, they are not meeting the needs. Preparation of special manuals requires to be undertaken by the central specialist agency. At the same time, some other agencies, such as technical education institutes in appropriate locations, should be involved in organising training programs. The situation in Pakistan is similar; however, India has a better organised system for such training.

7.5 CONCLUSION

So far the government of Nepal has taken a positive attitude towards hydro-power development but the emphasis has been more on the users needs rather than the manufacturers. This is clear from the lack of policies related directly with the development of this sector. The government policy of subsidy to electrification schemes, combined with the loans from ADB/N, has encouraged the proliferation of several micro-hydro units in the country and created a market for the manufacturers which is a source of incentive for them.

Inconsistencies/contradictions in the various sectoral policies concerning the facilities and priorities granted to the energy based industries have caused confusion amongst entrepreneurs contemplating entry into this sector. A similar inhibition is created by lack of consistency in the subsidy policy as well by the variability of the interest rate on loans sanctioned for MMHP. The facilities granted under the priority industries schemes are not applicable to the MMHP turbine manufacturers as most are registered as cottage and small scale firms.

There is lack of any budget for R&D activities in the industrial sector as a whole and even less is available in the MMHP sector. Most R&D activities are carried out by the manufacturers themselves with support from non-government organisations working in this area. The establishment of the AEPC is indicative of the rise in this sector in recent years. But it is too early to comment at this stage on the impact of this new government organisation.

Private sector involvement in the installation of power plants of this mini-micro scale is favoured in some countries while in others like Pakistan the emphasis is on public sector alone. But the same does not apply in the case of manufacturers of the equipment. Any incentive for the manufacturers comes only indirectly - as a side-effect of the government policy for meeting rural energy needs through electrification programmes.

CHAPTER 8

SUMMARY AND POLICY IMPLICATIONS

8.1 INTRODUCTION

The study has been conducted with two principal objectives in view. The first was to assess the potential of mini-micro-hydro to supply a solution to the rural energy problem, and the second was to determine whether the manufacture of MMHP equipment could form a vehicle for the transmission of technical expertise to Nepal. A third objective was to appraise the contribution of the government and other institutions to promoting MMHP installation and fostering the development of an MMHP equipment manufacturing capability. To forward these objectives the study has analysed the following issues:

a) conditions of MMHP operation from the users' perspectives;
b) the financial and economic viability of the MMHP plants;
c) the technological capability of the MMHP manufacturing firms;
d) the role of government and other institutions in the development of this sector.

Information on plant operating conditions and the findings of the financial and economical feasibility analysis, derived from the field survey conducted of 90 plants in various regions of the country, are summarised in section 8.2. This is followed, in section 8.3, by the results of the technological capability assessment made of the MMHP turbine manufacturing firms. The roles of government, financial institutes and research institutes are reviewed in section 8.4; lessons drawn with respect to MMHP development policies are reported in section 8.5. Finally, some suggestions for further research are put forward in section 8.6.

8.2 MINI AND MICRO HYDRO PLANTS IN NEPAL: A SURVEY

Features of the Sample Plants and their Operation

The sample studied consists of 90 plants from 17 districts of the country. Investment in MMHP projects is heavily dependent on loans which cover more than 70 percent of total installation costs. The preparatory feasibility study for most of the plants was carried out by ADB/N, while the actual installation was done by the turbine manufacturer. The cost of installation has in fact increased over time - per kW of turbine capacity rising by 182 percent between 1977 and 1995. The sample plants were mostly installed during the period 1981-1991; the establishment of 14 new plants in 1987 represents the maximum annual rate of plant installation. Most plants are located in the Central and the Western hills and typically, plants are situated within 30 km of a main road. The capacity range of the installed plants is from 1-50 kW; of the total sample, 20 percent fall within the 1-5 kW, 40 percent within 5-10 kW range and the remaining 40 percent exceed 10 kW capacity. The annual operating cost of a plant varies between NRs 8, 000 and NRs. 36000, depending on the number of operators engaged and their mode of payment. Operators' salaries were lower for plants which provided board and lodging for the operators.

The plants are mainly operated by staff with little technical background and no more than minimal education; the literacy level is low with only 56 percent of the operators being literate, and only 8 percent of the operators having passed the SLC level. 64 percent of the operators have received some training in running the plants, albeit limited to the training given at the time of plant installation; their knowledge is enhanced only through experience in working with the plants. The 36 percent of operators who are untrained have gathered their know-how of plant operation from previous operators.

More than 50 percent of owners in all the regions reckon the training of plant-operators to be inadequate; satisfaction with operation was however, expressed in instances where operation was by the owners themselves with the assistance of family members. The poor state of the machinery in some plants revealed mis-handling by operators. Frequent wearing out of the key-way shafts and of the pulleys of the oil-expellor and other agro-equipment could be attributed to mis-alignment and loose fitting on occasion of maintenance or repair. This implies limited knowledge of proper operational or maintenance procedures on the part of owners and operators and poor 'technical back-stopping'. Major problems associated with the turbines had to be referred to the manufacturers, although other repairs were taken care of by the operators or owners, either by themselves or with the help of a local workshop.

The picture of plant management is a mixed one: 35 percent of plants are managed by the owner, 9 percent by his son and 6 percent by some relation, a member of his family and the remaining 40 percent are managed by a hired hand. As with the operators, so also is the case with the managers that they have little or no training, though most of them emphasise the need for training. Symptoms of management deficiencies were observed: only 15 percent of 40 plants maintained a log-book of the stock of spare- parts, and only 28 percent kept some sort of account book. No more than 25 percent of plants had access to an operating manual, though at half of the plants it was thought important to have one. Regular maintenance was not much emphasised: attention was given mostly when machines ceased to function properly.

The major problems associated with operation of the turbines were the wear and tear of bearings, worms and gaskets; 83 percent have listed these as major sources of trouble. 10 percent experienced breakdown of the turbine itself. Much time is lost when repairs are required, mainly due to the fact that the spare-parts needed are not locally available, implying a requirement to travel to the nearest town to purchase them.

In terms of end-use applications of the turbines, the preference is apparently for the combined operation of grinding, rice-hulling and oil-expelling services. Stand-alone systems for electrification are not as popular as add-on systems - i.e. systems combining electricity generation with the operation of agro-processing units. The plant factor (of 33 plants) indicates that operation below capacity is common: 46 percent of the plants were operating at 30-40 percent plant factor (PF) and only 10 percent operating at as much as 50 percent PF. The remaining 44 percent were operating below 30 percent plant factor.

The nearby existence of competing plants is observed to affect plant business, the impact of competitors being experienced in loss of customers. Although the ADB/N has tried to prevent the setting-up of plants within ≈ 6 km of each other, this rule has not been adhered to.

The study suggests that there are six types of problems which need to be taken care for a more sustainable development of the mini-micro-hydro plants :

1. management of the plants which affect the quality and reliability of service rendered by the plant
3. technical difficulties arising from lack of locally available spare-parts and competent staff to handle repair and maintenance
4. low level of demand in case of electrification plants
5. high cost of installation
6. financing of the projects

Financial Returns

With respect to financial performance, the regional location of the plants is significant. The plants in the Eastern Hills were found to show the best results, with an average FIRR of 14.21 percent; next were those in the Central Hills with 13.53 percent, and third came those operating in the Western Hills with an average FIRR of 12.08 percent. Not unexpectedly, the plants located in the more remote mountain areas yielded lower returns. In fact of plants in the mountain areas, only those in the Central Mountains showed an acceptable rate of return (average FIRR of 10.95

percent); returns from plants in Western Mountains (6.8 percent) an in the Eastern Mountains (minus 3.34 percent) failed to reach the critical rate of 10 percent. Using the benefit-cost ratio criterion, plants in the Eastern Mountains were again identified as the least profitable; all regions except the Eastern Mountains showed benefit -cost ratios in excess of unity.

Analysis of the commercial profitability with respect to end-use indicates that plants used for grinding and rice hulling (average FIRR of 23.09 percent) yielded the highest returns. The combination of electricity generation with oil-expelling, grinding and rice-hulling also performed well (average FIRR 11.93 percent). The same can be said on the whole of add-on systems combining electricity generation with agro-processing services. On the other hand the plants providing additional end-uses in the form of battery charging, saw-mill operation and paper-making were not found to perform as well as had been expected. An important finding of the study is that stand-alone electricity generating installations were not profitable; they had an average FIRR of no better than 4.41 percent. The negative finding of the field survey of MMHP plants as to the profitability of single function electricity generating plants is supported by analysis of WEC data which show that, in the case of the WEC sample of stand-alone plants, profitability could be achieved only through operation at much higher values of plant factor than are in fact typical of micro-hydro operations.

Plant profitability is affected adversely as the number of competing plants in the vicinity increases. Plants in the Central and Western Hills are able to withstand up to eight competitors, those in the Eastern Hills not so many. Plants installed in the mountain regions are more sensitive to competitions: not so many. The plants in the Central Mountains can compete with only as many as 4 rival plants, with the ability to compete decreasing as the competition increases from 4-8 to greater than 8 plants. Installations in the Eastern and Western Mountains cannot really cope with any competition from nearby plants.

The rate of utilisation of capacity is an important influence on plant profitability. The stand-alone electricity generating plants which, as reported above show poor returns, operate with low system load factors. The reason that the potential of these plants to supply electricity is so little exploited is that the predominant use of electricity in the rural and the remote areas (90 percent of usage) is merely for domestic and commercial lighting; there is little or no energy use in productive activities - in either the industrial or commercial sectors - such as would make much greater demand of the generating units. Analysis of the plants generating electricity alone indicates that best results were to be achieved at PF higher than 60 percent. Under these conditions, considering 60 percent PF as the practical optimum, the computed cost per kW lies in a range from NRs. 1.5 to NRs. 4.5.

Economic Returns

Economic, as distinct from financial or commercial returns, were estimated by adjusting the investment and operating costs of MMHP installations. To take into account of differences between market prices and the true social costs of imported materials and labour employed in setting up and operating the plants. Using shadow prices for these inputs economic costs of investment were computed and related to returns to arrive at economic rates of return for the plants.

Plants in all regions - hills and mountains - have higher returns in economic than financial terms, the difference in cost of installation of the plants ranging from 20 to 40 percent. Similarly the difference between financial and economic costs of generating energy ranges from 30 to 60 percent.

Plants in the Eastern and Western Mountains remain below the acceptable average EIRR as well as failing to meet the EB/C criterion under all conditions of competition. In case of plants in the Central Mountains, those with less than eight competitors are economically viable, though those with more than that number of rivals in the vicinity cannot (in terms of economic return) cope with the competition, showing average EIRR of under 10 percent and EC/B ratio of less than unity.

Results of the economic analysis with respect to end-usage still fail to justify stand-alone generating systems. Even when employed in combination with grinder, or grinder plus oil-expellor or grinder plus rice-huller, electricity generating plants do not meet the criteria with respect to EIRR or EB/C ratio.

In addition to the direct benefits to the users of services, provision of which has been made possible by the installations of mini-micro-hydro plants in the rural areas (value of the benefits being expressed in the charges paid for use of electricity and agro-processing services), further 'external' or 'spill-over' effects from the introduction of these energy-generating plants are evident. Most obviously, the demand for these rural energy-generating facilities has induced the development of a supporting manufacturing industry, supplying the equipment required for mini-micro-hydro installations. This may be regarded as one of the key external benefits of a programme of MMHP installations in the country-side: new sources of employment are thus generated, and an opportunity created of building up technical expertise - technological capabilities - of which Nepal has much need if economic progress is to be achieved. Enhanced technological capabilities - if such are in fact achieved - and strengthened development potential may be reckoned as 'intangible' benefits indirectly flowing from MMHP installations.

Likewise application of the MMHP plants to a variety of agriculture-related purpose has also created a market for end-use equipment, encouraging the turbine manufacturers to extend their operations to the production of that equipment and at the same time providing openings for the establishment of new firms specialising in these products. Firms working in engineering, in the manufacture of agro-processing equipment such as rice-hullers, shellers, grinders, traditional rice-flake (chiura) - pounders and ice-plants have benefited from the wide dissemination of the micro-hydro turbines. The same can be said as regards the production of low-wattage cookers and ballast (heat storage used mainly for heating water in the tourist lodges) which have been promoted so as to reduce the use of fuel-wood in the rural areas. (That environmental benefit may be categorised as one of the 'intangible' - and important - returns from mini-micro-hydro installation.) The introduction of electricity in the rural areas has also promoted the use of electronic load controllers (ELC) as the most appropriate means of load-control; the manufacture of these controllers has consequently been developed in Nepal - implying the realisation of 'tangible' benefits in the form of the expertise gained in electric engineering, an activity new to the country. A further consequence of MMHP plant installation in rural areas is that, for the first time in these areas, a demand has emerged for the services and training of, technical people as required for the construction and the operation, maintenance and repair of the mini-micro-hydro and their associated equipment. This need is being met through the setting up, by Development Consulting Services, of local repair shops which employ local people. In this way, some familiarity with modern technology and elements of technical expertise are brought to the rural areas - knowledge which may be of value not only in the servicing of the generating installations, but also in making it more possible for local people to appreciate, and act on, the possibilities of applying modern technology in the rural context. (Again this could be reckoned as an 'intangible' benefit.)

In arriving at a verdict on the worthwhileness of mini-micro-hydro installation in the rural areas account should also be taken of the contribution these plants make in terms of 'external' and 'intangible' benefits. The values of such benefits were not comprehended in the calculation of 'economic' returns and the fact that, even in the cases of the least profitable installations, the returns, reckoned in economic terms, were not all that far below the critical value should be borne in mind. If a relatively small improvement in returns is all that is required to bring such plants up to an acceptable rate of economic return, it may be judged that the 'external' and 'intangible' benefits associated with the plants at least correspond to this necessary margin of improvement. Conclusion regarding case for promoting the installation of these plants in the remote mountain areas, must be derived from a reckoning not simply of financial returns, not even of economic returns (calculated - as in this study - in terms of readily quantifiable elements), but from a comprehensive assessment which takes into account the contribution of the plants in generating less readily quantifiable 'external' and 'intangible' benefits.

Mini-Micro-Hydro vis-a vis Other Alternative Energy Sources

The mini-micro-hydro plants offer better financial and economic returns than solar photovoltaic systems and diesel-powered plants. Although the solar photovoltaic (SPV) system has a longer life span and lower repair maintenance cost, its high initial investment cost puts that system at a disadvantage. On the other hand, the higher operating and maintenance costs of the diesel plants more than offset their relatively low installation cost thus reducing their rate of return below that of mini-micro-hydro installations.

8.3 TECHNOLOGICAL CAPABILITY OF THE TURBINE MANUFACTURING FIRMS

Technology Sources and Labour Training

The technology of conventional MMHP turbine manufacture was introduced to Nepal when Balaju Yantra Shala (BYS) was set up in a joint operation by the Nepal Industrial Development Corporation and the Swiss Association for Technical Assistance (SATA). A similar understanding with the United Mission to Nepal led to the establishment of Butwal Engineering Works (BEW). These two joint ventures are classified as small scale firms. Of the eight other firms, which with BYS and BEW comprise the turbine manufacturing sector, one is a medium scale firm, four are small and the remaining four are registered as Cottage and Village industries. The paths these firms have followed in capability building differ according to their size category.

The capability building of the two main firms, BYS and BEW, has taken place through the participation with their foreign counterparts in setting up, the operations, and subsequently in developing their production capabilities. Skill development and technology upgrading, to keep up with trends in product development and to meet the difficult requirements of local demand as well as competition from the rivals, has been undertaken by these manufacturers through training of technicians which has mostly taken place in the work-place. They have been able to formalise technology know-how into transferable knowledge and have sponsored vocational training and technical education in foreign as well as local institutions. This strategy has produced good quality trained personnel possessing varied technical skills which match the specific requirements of the firms.

Most of the technicians employed in the larger firms have, at least a minimum, a secondary school qualification and have received training at one of the vocational training centres, Balaju Mechanical Training Institute (BMTI) and Butwal Training Institute (BTI). The transfer of technology, in the case of the larger firms, comes via the hardware installed, the formal transmission of technical know-how, and the development of human resources through both formal and informal manpower training. Except for KMI, most of these small firms have been established by people who initially worked at either BYS or BEW. The skill level of the employees differ markedly according to the nature of the firms: the larger firms employ persons with specific skills in different engineering disciplines; the smaller firms prefer to recruit less qualified people and train them for specific jobs.

In case of the smaller firms, technical learning is restricted to informal learning system on the shop-floor. Here the picture is one of on apprenticeship system; the knowledge gained is dependent upon the skills of the master and his readiness to impart these skills. The willingness of the owners to do so is affected by their fear of the frequently occurring movement of trained labour, to other employers or to set up competing enterprises. The sort of training given in the small firms enables the workers to be good at what they know but leave them poor at adapting to new situations; the production is of improvisers rather than workers with sufficient knowledge to become innovators. It is not surprising, therefore, that amongst the smaller firms product duplication is typical without much product upgrading.

In case of Kathmandu Metal Industries (KMI), a traditional metal-worker, product development has been chiefly due to innovative activities of the present owner. Skill development in this firm has been restricted to family members; the same fears of trained workers migrating to other firms or setting up competing operations have led this employer to limit the transfer of skill to the workers.

Regular training programmes are organised by the Micro-Hydro Development Association together with the Intermediate Technology Development Group in Nepal (ITDG/N) and the Balaju and Butwal training centres. These training programmes are however, limited to basic workshop activities and turbine installation rather than providing training in the fabrication of the turbines.

Product Innovation: Research And Development

In BYS, BEW and KMI much effort has been put into upgrading the turbine technology. Major improvements to the cross-flow turbine have been achieved by BYS with the help of SKAT. BYS has, over the years, been involved in modification of the turbine technology to suit the country. The modifications made in the cross-flow turbine to attain the present 75-80 percent efficiency is one such example; another is modification of the casing to make the unit more portable and to facilitate maintenance and repair. BEW is involved in the improvement of turbine technology as well as of end-use equipment. KMI is engaged in similar activities.. Some of the most notable developments in mini-micro-hydro technology have been made by this firm; The owner has in fact been acclaimed as a pioneer of these technologies. The Multi-Purpose-Power-Unit (MPPU), as well as the indigenous peltric turbine which is a single unit, a combination of pelton turbine and a generator, have been in production since 1970s and 1993 respectively. This indigenous product, which is used for electricity generation, has a maximum capacity of 5kW. At present KMI is also involved in improvising the Francis turbine to suit the local conditions and in exploring the use of new materials like plastic for the turbine runner.

The extent of research and development activity varies from firm to firm. The product modifications undertaken by some of the firms indicate that, without perhaps being fully aware of what they are doing, these firms are undertaking a considerable amount of expenditure on research and development. This expenditure approximates to up to

20 percent of the firm's miscellaneous expenditure. This however also suggests that R&D expenditure is not being undertaken in a planned systematic way; such outlays depend on the interest of the executive and are not planned on a long-term basis. Other R&D spending is mainly related to minor improvements. Matters of quality control and standardisation do not always seem to be given appropriate priority.

Strategies For Growth

Common strategies followed by most of these turbine manufacturing firms were to diversify into the manufacture of allied products and to take on all the functions of the plant installation - site feasibility studies as well as the actual setting up of the plant.

The larger firms extended their production to related items of equipment - pen-stock pipes, transmission towers and end-use equipment such as expellors, rice-hullers and grinders. Of such auxiliary items, the smaller plants manufacture mainly penstock pipes. KMI on the other hand has ventured into the production of a new turbine product - peltric turbines - and manufacture of the electronic load controller. KMI also manufacturers penstock pipes, rice-hullers and grinders. National Power Products (NPP) at present concentrates mainly on electronic load controllers and induction generators.

All of these firms conduct site-feasibility studies in addition to carrying out the installation of the MMHP units; they are thus in a position to offer package programmes to customers. The after-sales servicing of the turbine plants is undertaken solely by the respective manufacturers. The availability of suitable workshop equipment has also led the firms into the manufacture of construction components for suspension bridges and buildings (trusses) and various types of sheet metal working.

Process Technology: Lack of Innovation

While firms have been active in improving and diversifying their products, they are typically less active in developing and upgrading their production processes. Most firms have made, since their establishment, some investments in production equipment, but these have generally involved either the purchase of additional or replacement machines for carrying on existing production procedures rather than investment in new process technology. It appears that the active upgrading of their production technology is not an important part of the development strategy of the turbine manufacturing firms.

All the firms - both the larger and the smaller ones - when investing in new equipment evidently prefer to acquire, instead of equipment imported from Europe, machines manufactured nearer home, that is., in China or India. Reasons cited for this preference were that such equipment were cheaper to buy, was available more quickly and was easier to maintain and repair; such sourcing was also viewed as giving the advantage of easier access to spare parts. Above all, not requiring the use of foreign currency which requires special procedures. The larger firms explained that the simpler technologies available from these sources not only reduced purchase cost but also reduced the need to employ highly specialised and scarce manpower, and as well, avoided the involvement of foreign experts in maintenance and repair. They argued too that the use of less complicated equipment reduced down-time, meaning better capacity utilisation.

In so far as the turbine manufacturing firms are catering for the local market, the combined circumstances of a small market and distance costs offer some protection against more productive foreign rivals. But at the same time, it can be argued that productivity improvement is a potential source of competitive advantage against other domestic manufacturers. While the importance of productivity improvement for competitiveness will vary according to the characteristics of a firm's product market, very few manufacturing firms can afford, as turbine manufacturers appear to be doing, to ignore it. Firms such as BYS, KMI and Nepal Yantra Shala (NYS) have ventured into external markets but are reported to have refused offers to engage in technology transfer to neighbouring countries; that refusal stems from the firms' perception of a lack of protection of intellectual property rights and patent rights.

8.4 GOVERNMENT POLICIES AND OTHER INSTITUTIONAL INPUTS

Contribution of the Government

In many respects Nepal is ahead of Bhutan and Pakistan in instituting government policies which give assistance to the renewable energy sector in general and the MMHP sector in particular. Important supporting initiatives in Nepal take the forms of:

1. the provision of loans on special terms;
2. the offer of subsidies against the cost of electrical component;
3. and the de-licensing of plants of up to 1000 kW capacity.

Loans and subsidies presently on offer in Nepal to the MMHP sector are as follows. (The availability of funds for loans and subsidies has however, varied considerably in recent years, as has the rate of interest on the loans).

1. The turbine machinery, civil works and agro-processing units qualify for loans that are lightly cheaper than commercial loans, but more expensive than loans available to small scale firm; loans may be provided to cover up to 80 percent of the total cost.
2. Subsidy is provided only for the electrical components of the mini-micro-hydro plants; this subsidy comes at alternative rate depending on plant location; 75 percent of costs is awarded in remote areas and 50 percent in the rural areas.

Nevertheless, despite the existence of these supportive measures, there appears to be scope for action to be taken by the government to give better backing to the MMHP sector. A number of factors - wholly or partly under the control of the government - which are tending to inhibit the growth of the sector are listed below:

I. **Policy Bias.** While government does intervene to promote MMHP development, it provides assistance only to the installers of the MMHP units, with subsidies available to installers only of electricity generating plants. There are two elements of bias here:

(i) the subsidy offered for installation of electricity generating units is denied to entrepreneurs setting up agro-processing units, yet agro-processing facilities are not only in themselves worthwhile investments but investments which can increase the notably low profitability of stand-alone electricity generating plants;

(ii) although the assistance given directly to entrepreneurs setting up MMHP plants should indirectly benefit the plant manufacturers also via positive effects on the demand for their product, no specific measures of assistance are targeted at the machinery manufacturers. The argument is developed below that the manufacturers' potential contribution, in pioneering the introduction of advanced technologies to Nepal, is of sufficient importance to the country to deserve direct government support.

2. **Tariff Anomalies.** The machinery building firms are penalised by negative protection: low import duty is imposed on the product they manufacture, while at the same time, high duties are levied on materials which have to be imported by the manufacturers.

3. **Procurement Bias.** Government procurement of equipment is biased towards overseas sources on account of aid being tied.

4. **Policy Contradictions.** The several policies under the Electricity Act, the Water Act and Industrial Policy contain contradictory term; the effect is to add the uncertainty and apprehension of entrepreneurs contemplating ventures involving new technology.

5. **Lack of Infrastructure.** The lack of roads in many parts of the country adds to the difficulties and costs of plant installation, and hampers the procurement of parts with adverse effects on capacity utilisation.

6. **Lack of Industrial Skills.** Education and training facilities are not adequate.

7. **Lack of an Information Network.** This is a serious handy-cap to the entrepreneurs in identifying and selecting suitable.

Financial Institutions

The ADB/N has been the single financial institution which has provided major funding for the implementation of mini-micro-hydro project in Nepal. The Bank enlists the turbine manufacturers for surveying potential sites, manufacturing the equipment and for installation of the units. The prospective owner selects one of the manufacturers to examine the site and to carry out the feasibility survey; depending on the report. a loan may be granted by the Bank. Eventually the Bank, on behalf of the owner, makes the final payment to the manufacturer after receiving the recommendation letter from the owner.

As regards other financing bodies, the commercial banks have shown reluctance to provide loans to the MMHP sector, either to the turbine manufacturers or to entrepreneurs contemplating MMHP installations. The consequent situation is that the funds allocated by the government for the subsidy of rural electrification have not been fully used up; in fact ADB/N has been able to spend only 50 percent of the subsidy which has been available in each of the annual budgets since 1993.

Academic and Research Institutions

At present linkages with the Academic institutions like Tribhuvan University and the Institute of Engineering, as well as research organisations, are negligible. The support for research and development activities which could have come from these quarters is non-existent. Instead, whatever research and development work has been carried out has evolved either from collaboration with foreign partners, as in the case of BYS, or personnel interest of the proprietor, as in the case of KMI.

The Need for Greater Technological Dynamism: Policy Implications

We return in this section to the matter of the technological competence of the turbine manufacturing firms and the question of whether the government could play a more direct part in supporting their continuing progress to higher technological capability.

The turbine manufacturers in Nepal have displayed commendable levels of in-house technical activity in assimilating the imported technology, making adaptations to suit domestic conditions and, in particular, in developing the product in ways appropriate to the requirements of the local market in the hills and mountains of Nepal. As has been described, innovative new generating units have been successfully introduced. However, autonomous development of the technology of production has been absent, limiting the firms' innovative potential. It appears that experience in using imported technology does not, of itself, automatically lead to the acquisition of higher forms of technological capability.

Given the evident need, as explained in Chapter 6, for the turbine manufacturing firms to move on to a path of continuous upgrading of their process technology, the question may be asked - how best can they be stimulated and encouraged to move forward in that way? Is it enough to rely on market forces and the profit incentive to guide the turbine manufacturers in that direction, or might some more positive action be required? Might it in fact be necessary for the government to intervene with a new strategy - new policies designed to push technological advance in the engineering sector? The current rather lackadaisical attitude of the turbine manufactures does not bode well for a strategy of simply relying on the market; furthermore, the turbine manufacturers are relatively small firms, and as such as may be expected to experience difficulties in achieving expansion and upgrading of their manufacturing capacities:

they may have problems in financing the necessary investment and indeed in finding out about the technical possibilities that exists.

The answer appears to be the government should make a more positive contribution to technology advancement. Perhaps relevant lessons can be learned from the sort of strategies which have been employed by the East Asian NICs. While it might well be that the kind industrial targeting and close supervision of industry that the industrial ministries of these countries have been able to carry out is beyond the present competence of the Nepali authorities, some supportive intervention - investment incentives directly to the manufacturers, training support and assistance with information might be feasible.

8.5 POLICY RECOMMENDATIONS

It is evident from the present study that promotion of the mini-micro-hydro sector offers a prospect of valuable benefits to Nepal, both in terms of extending the provision of socially valuable services - electricity generation, agro-processing - to the remote and rural areas, and in terms of the further development of a manufacturing sector which, through its successful achievement of technological capability in a line of engineering activity relatively new to Nepal, has demonstrated as potential for enhancing the development prospects of the country. To build on the foundations already established certain policies and institutional arrangements may be appropriate. Until now measures for developing this for developing sector have been undertaken somewhat in a piece-meal fashion, with a strong bias towards the users. From a perspective of the present study which yields a comparative overview of the sector as a whole, certain practical recommendations which relate to both wings of the sector may be put forward. Policy recommendations may be classified under three headings:

1. Actions to promote the installation of MMHP units in the remote and rural areas, and to ensure the better use of the plants that are installed;

2. Policies to encourage and support the turbine manufacturing sector, specially in upgrading process technology and enhancing productivity;
3. Policies supporting development of the sector as a whole .

These are discussed below in turns.

Recommendation (A) :

(1) Consideration should be given to revision of the current policy on grant subsidies

i. That the present system of providing subsidy only against the cost of electrical equipment used in electricity generation and not for the purchase of agro-processing equipment (nor for the turbines themselves) is optimal maybe doubted. This bias in favour of stand-alone electricity plants may have the unfortunate effect of encouraging entrepreneurs to go for a single function installation in preference to investing in multi-purpose plants. But the latter are the more desirable installations. Stand-alone plants are least profitable MMHP installations, offering relatively poor returns, while multipurpose plants supplying agro-processing services typically yield much better returns to their owners, as well as at the same time providing the local community with a wider range of valuable services. Nothing is gained by promoting electricity generation alone rather than as part of a package of mini-micro-hydro services.

ii. On the subject of subsidies it is significant to note that, across the board, the economic returns on MMHP installations exceeded the financial returns - even without account being taken of external and intangible benefits. In other words the social profitability of such installations is greater - by an amount perhaps substantially exceeding the difference revealed by comparing the financial and economic returns (as calculated in this study) - than the private profitability to the entrepreneurs. This suggests that there exits a *prima facie* case for the introduction of a general subsidy on mini-micro-hydro turbine installation which would bring private inducement and social return into closer alignment.

(2) The study reveals that the electricity generating capacity of MMHP plants is typically much under utilised. This state of affairs suggests that if fuller advantage is to be taken of these installed facilities encouragement should be given to using electricity, not merely for lighting purposes, but (as similar circumstances in other countries) in further applications such as cooking and commercial (income-generating) purposes. If better use is made of the available generating capacity, not only are further services being enjoyed by rural communities, but the generating plants are able to operate at higher plant factors, implying lower unit costs of electricity.

(3) An observed problem of MMHP operations is that plants are frequently run in an inefficient manner, with poor operating practices leading to breakdowns and unreliable services (experience which tends to give the technology - unjustifiably - a bad name). This calls attention to the need to provide better training to mangers and operators, who are likely to be rural people without much education or understanding of the technologies involved. Some steps have been taken to establish rural centres for the purpose of imparting training. This is a development which should be encouraged.

(4) Greater efficiency of MMHP installations could be achieved on this basis of better knowledge of the conditions under which they are required to operate. Plants have incurred problems of lack of water and of damaged civil-engineering works; the availability of more reliable data on the volumes of water flow could permit more appropriate design of plant and civil works and less interrupted operations. It is therefore suggested that assessment should be made, on a district basis of the geographical conditions and of potential for mini-micro-hydro development, and systematic plans formulated to develop appropriate schemes through location specific feasibility studies.

(5) Finally under this heading of proposals to promote the installation and efficient use of MMHP plants, the confusion and inconsistencies of existing legislation - inconsistencies for instance between the Water Resources legislation and the

terms of Electricity Act - should be eliminated. The present unsatisfactory state of affairs serves only to complicate the situation and add to the uncertainties facing the potential entrepreneur considering investment in mini-micro-hydro.

Recommendation (B) :

Policies to Support and Encourage the turbine manufacturing Sector

(1) **The provision of financial assistance for investment in appropriate production upgrading.** The provision of financial assistance for investment in appropriate production upgrading. An important policy concern stems from the fact that the turbine manufacturing firms are evidently disinclined to undertake investment in improved production equipment. Their failure to upgrade their process technology in order to raise product quality and increase competitiveness is a matter of much concern. Provided that it is part of a wider package of targeted support that would enable production upgrading to be linked to active market development, there is a case for offering financial assistance to firms willing to invest some of their own resources in order to upgrade their technology base.

(2) **The provision of improved training facilities.** Although some firms are making use of 'off-the-job' training provision, the principal strategy of the managers has been to recruit unskilled staff and then train them 'on-the-job'. If there is to be an upgrading of the technological base of the turbine manufacturing firms, there will need to be a greater input of external training by specialists institutions. The successful implementation of this strategy will require not only the provision of appropriate training courses, as well , a change in attitude on the part of the firms.

(3) **The provision of training facilities should be complemented by a systematic government policy of support of research and development' support which is negligible at present.** Research and development institutes should be encouraged to investigate new technologies and explore more effective ways of implementing technological training. Fostering strong linkages

between R&D institutions and the manufacturing firms will go a long way towards meeting the industry's difficulties in achieving technological upgrading and moving into the production of different types of turbine.

(4) It could be of considerable value to the turbine manufacturing industry if institutional arrangement could be established for the process of giving advice and assistance to the firms in the management of their production process. Guidance on matters such as establishing systems of quality control and performance testing of turbines and generators, and in moving towards greater standardisation of product design and in developing modular/standard mini-micro-hydro packages suitable for a range of water flow and head conditions could help the manufacturers to achieve higher standards of efficiency in production and quality of output.

(5) The impediment to the progress of the turbine manufacturing sector which currently exists in the form of the anomalous tariff structure that tends to handicap in the market the products of domestic manufacturers relative to imported equipment should be removed.

Recommendation (C) :

Policies supporting development of the sector as a whole .

This relates to government action which could be to the benefit of both parties - investors in MMHP facilities and turbine manufacturers. There is a perception that - for investors and for manufacturers - bank credit is difficult to come by. If, therefore, on account of reluctance of the commercial banks to lend to the MMHP sector, entrepreneurs seeking to set up hydro-installations, or manufacturers requiring credit find it a problem to raise the funds they need, the authorities might be well- advised to consider strengthening the measures already in place to encourage the banks to lend to the MMHP sector.

8.6 ISSUES FOR FURTHER RESEARCH

This study of the mini-micro-hydro turbine manufacturing is the first such study of this sector and also the first study of technological capability building in Nepal. This being an initial investigation, it is to be expected that information remains to be sought in several areas. The present discussion is now concluded by drawing attention to three possible topics of further research - issues the fuller understanding of which would be relevant to the broad objective of developing the MMHP sector to the general benefit of Nepal.

(1) There is some evidence to the effect that mini-micro-hydro turbines are being produced at less costs in other countries than in Nepal. It would be worthwhile carrying out a comparative analysis of the characteristics and the cost of production of MMHP turbines manufactured in Nepal and in other countries, in order to identify the relative capabilities of the different countries in the manufacture of such turbines and assess the prospects of the Nepali industry being able to compete in export markets.

(2) The recommendations been made above that consideration be given to changing the terms of the present policy in Nepal of awarding grant subsidies to the MMHP sector. It would therefore be useful to conduct both a close investigation of the possible consequences of eliminating the bias of the present policy against agro-processing installations and also of the level of subsidy which would be consistent with the theoretically an ideal situation of (at last approximate) corresponding between the private returns on investment in MMHP installations, as perceived by the entrepreneurs, and the greater social returns to the community as a whole of such investments.

(3) With regard to promoting greater efficiency in the manufacture of MMHP turbine, through making possible longer production runs and the employment of consequent economies of scale, it would be advantageous to investigate, with respect to market conditions, the possibility of developing modular series of various turbines suited to particular range of water-flow, water head and generating capacity.

Annex-3A: Questionnaire Form Field Survey of MMHP Plants

A. LOCATION & OWNERSHIP

1. Name /Identity of MHP — 2.Name of Owner
3. Village — Ward — VDC — District
4. Travel Route
   - Road Name — Point of Disembarkation
   - Distance from roadhead

B. INSTALLATION DETAILS

1. Year of Installation
2. Gross Head (m) — Design Flow (l/s)
3. Turbine Type: — Capacity: — Manufacturer:

C. INITIATION & INSTALLATION

1. Name of Initiator — 2. Name of Surveyor
3. Name of Manufacturer — 4. Role of ADB/N

D. LEVEL OF COMPETITION

1. No. of Plants in the Vicinity — 2. Distance between the Plants
3. Type of Competing Plant — 4. Distance from Grid -electricity (km.)
5. Degree of Affect

E. PLANT UTILISATION

1. End Uses
   - Electricity Generation — Grinder
   - Rice -Huller — Oil-Expellor
   - Others

2. Tariff
   - Electricity — Grinder — Rice -Huller
   - Oil-Expellor — Others

F. OVERALL CONDITION OF THE PLANT

1. Civil Works — 2. Penstock — 3. Generator
4. End-use Equipment — 5. Coupling/Drives — 6. Power-house
7. Turbine — 8. Overall Status

G. PLANT MANAGEMNT AND OPEARATION

1. Name of Manager — Relation with Owner
2. Salary/month
   - Training Details — Was it Adequate

3. Name of Operator
   - Educational Qualification — Salary/month
   - Working Hours/day — Training Received

4. Operation Timings
Electricity
Others
Agro-processing

H. HISTORY OF MAJOR BREAKDOWNS

Type of Breakdown
Cost of Repair
Period of closure
Repairer

I. COST AND FUNDING

1. Plant Costs:
   Total Cost
   Power House
   Cost of Penstock
   Transportation
   Civil Works
   Electro/Mechanical Equipment
   End-use Equipment
   Labour

2. Funding Sources
   Loan:
   Land (Cost)
   Subsidy
   Contribution in Kind:
   Own Funds (Cash)

J. REVENUE AND EXPENSE

1. Revenue
   Electricity
   Other Services
   Agro-processing
   Total Income

2. Expenses
   Current Salary
   Spares Purchased
   Total Expenses
   Maintenance
   Other Expenses

3. Changes In Revenue From Previous Years
   Electricity
   Other Services
   Agro-processing
   Reasons

K. DEBIT SERVICING

Owner Investment
Starting Year for Payment
Total Investment
Loan Amount
Payment Period
Interest Rate
Instalment

L. RECORD KEEPING AND MAINTENENCE

1. Log Book Practices
2. Account Book Practices
3. Is Operation and Maintenance Manual Available and Used?
4. Which Spare Parts are Kept?
5.Which Components are Inspected/cleaned/Painted/Repaired by the Operators/Managers

M. Comments of the Owner/Operator

N. Comments/Obseravtions of the Interviewer

Annex 3B List of Plants Using Cross-flow Turbines

S. No.	*District*	*Capacity (kW)*	*Type of Turbine*	*End Use*	*Installation Date*	*Manufacturer*
1	Accham	12	CF	M	1994	NMSS
2	Accham	18.5	CF	M		TEI
3	Accham	10	CF	M	1984	DCS
4	Accham	8	CF	M		DCS
5	Accham	8	CF	M	1988	DCS
6	Accham	9	CF	M	1985	TEI
7	Accham	7.3	CF	M	1989	DCS
8	Accham	5.8	CF	M	1983	DCS
9	Arghakhanchi	7.5	CF	M+E	1978	DCS + TEI
10	Arghakhanchi	5.6	CF	M	1991	DCS
11	Arghakhanchi	12.5	CF	M	1991	NMSS
12	Arghakhanchi	14	CF	M	1981	DCS
13	Arghakhanchi	15	CF	M	1991	NMSS
14	Arghakhanchi	4.5	CF	M+E		TEI
15	Arghakhanchi	3	CF	M	1985	TEI
16	Arghakhanchi	7	CF	M	1988	TEI
17	Arghakhanchi	11.7	CF	M+E	1990	DCS
18	Arghakhanchi	17.5	CF	M	1979	DCS
19	Arghakhanchi	5	CF	M	1985	TEI
20	Arghakhanchi	4.5	CF	M	1986	TEI
21	Arghakhanchi	6.3	CF	M	1977	DCS
22	Arghakhanchi	5	CF	M		DCS
23	Arghakhanchi	8.9	CF	M	1988	DCS
24	Arghakhanchi	14	CF	M	1981	DCS
25	Arghakhanchi	6	CF	M	1978	DCS
26	Arghakhanchi	9.5	CF	M	1982	DCS
27	Arghakhanchi	9.3	CF	M	1980	DCS
28	Arghakhanchi	7	CF	M+E		TEI
29	Arghakhanchi	7.5	CF	M	1986	TEI
30	Arghakhanchi	11	CF	M	1982	DCS
31	Arghakhanchi	1	CF	M	1978	DCS
32	Arghakhanchi	4.9	CF	M	1986	DCS
33	Arghakhanchi	7.5	CF	M	1979	DCS
34	Arghakhanchi	4	CF	M+E	1995	NMSS
35	Arghakhanchi	13	CF	M	1987	DCS
36	Arghakhanchi	13.5	CF	M	1987	DCS
37	Arghakhanchi	12	CF	M	1990	NMSS
38	Arghakhanchi	5.5	CF	M	1981	DCS
39	Arghakhanchi	7	CF	M	1987	TEI
40	Arghakhanchi	5.6	CF	M	1984	TEI
41	Arghakhanchi	3.5	CF	M	1981	DCS
42	Arghakhanchi	3.4	CF	M	1980	DCS
43	Arghakhanchi	7.2	CF	M	1985	DCS
44	Arghakhanchi	17	CF	M+E	1985	DCS
45	Arghakhanchi	7	CF	M	1990	NMSS
46	Arghakhanchi	13	CF	M	1987	NMSS
47	Arghakhanchi	14	CF	M	1980	DCS
48	Arghakhanchi	9	CF	M	1983	Agro

List of Plants Using Cross-flow Turbines *(continued)*

S. No.	*District*	*Capacity (kW)*	*Type of Turbine*	*End Use*	*Installation Date*	*Manufacturer*
49	Arghakhanchi	9.7	CF	M	1982	DCS
50	Arghakhanchi	7.5	CF	M	1981	DCS
51	Arghakhanchi	5	CF	M	1986	TEI
52	Arghakhanchi	9.3	CF	M	1983	DCS
53	Arghakhanchi	3.5	CF	M		TEI
54	Arghakhanchi	9	CF	M	1978	DCS
55	Arghakhanchi	6.8	CF	M	1992	TEI
56	Arghakhanchi	12.9	CF	M	1988	DCS
57	Arghakhanchi	13	CF	M	1993	NMSS
58	Baglung	7.3	CF	M	1985	DCS
59	Baglung	14	CF	M	1988	NMSS
60	Baglung	6.3	CF	M	1985	DCS
61	Baglung	6	CF	M	1992	NMSS
62	Baglung	14.5	CF	M+E	1984	DCS
63	Baglung	13	CF	M+E	1977	DCS
64	Baglung	12	CF	M	1991	NMSS
65	Baglung	15	CF	M	1976	NYS
66	Baglung	7.5	CF	M+E	1980	DCS
67	Baglung	3	CF	M	1987	DCS
68	Baglung	7	CF	M+E	1984	DCS
69	Baglung	10	CF	M	1980	DCS
70	Baglung	15	CF	M+E	1988	DCS
71	Baglung	8	CF	M	1975	NYS
72	Baglung	3.5	CF	M	1988	DCS
73	Baglung	14	CF	M+E	1981	DCS
74	Baglung	15.4	CF	M	1987	DCS
75	Baglung	12	CF	M	1994	NMSS
76	Baglung	12.3	CF	M	1986	DCS
77	Baglung	13	CF	M+E	1987	DCS
78	Baglung	6	CF	M	1988	DCS
79	Baglung	14	CF	M+E	1981	DCS
80	Baglung	10	CF	M	1990	NMSS
81	Baglung	12	CF	M	1994	NMSS
82	Baglung	10	CF	M	1983	IT
83	Baglung	25	CF	M	1987	NYS
84	Baglung	12	CF	M	1993	NMSS
85	Baglung	5	CF	M	1985	DCS
86	Baglung	18	CF	M+E	1972	BYS
87	Baglung	5.3	CF	M	1989	DCS
88	Baglung	3.1	CF	M+E	1989	DCS
89	Baglung	15	CF	M+E		TEI
90	Baglung	9.1	CF	M+E	1991	DCS
91	Baglung	6	CF	M	1992	NMSS
92	Baglung	25	CF	M+E		TEI
93	Baglung	13.5	CF	M	1987	DCS
94	Baglung	8.4	CF	M	1987	DCS
95	Baglung	10	CF	M	1987	DCS
96	Baglung	8	CF	M	1985	DCS
97	Baglung	12	CF	M	1992	NMSS

List of Plants Using Cross-flow Turbines *(continued)*

S. No.	*District*	*Capacity (kW)*	*Type of Turbine*	*End Use*	*Installation Date*	*Manufacturer*
98	Baglung	12.5	CF	M	1984	DCS
99	Baglung	9	CF	M	1989	NMSS
100	Baglung	8.6	CF	M	1980	DCS
101	Baglung	4.5	CF	M	1982	DCS
102	Baglung	10	CF	M	1983	IT
103	Baglung	4.8	CF	M	1987	DCS
104	Baglung	12	CF	M+E		TEI
105	Baglung	10	CF	M	1978	DCS
106	Baitadi	9.1	CF	M+E	1988	DCS
107	Baitadi	5	CF	M	1991	TEI
108	Baitadi	14.3	CF	M+E	1986	DCS
109	Baitadi	8.8	CF	M	1985	DCS
110	Baitadi	5	CF	M	1985	DCS
111	Baitadi	5	CF	M	1986	TEI
112	Baitadi	16	CF	M+E	1992	DCS
113	Baitadi	6.6	CF	M	1987	TEI
114	Bajhang	8	CF	M	1988	NS
115	Bajhang	20	CF	M+E	1986	TEI
116	Bajhang	21	CF	M	1986	TEI
117	Bajhang	7.5	CF	M+E	1986	NS
118	Bajhang	8	CF	M+E	1986	NS
119	Bajhang	5.6	CF	M+E	1985	TEI
120	Bajhang	12	CF	M+E	1987	TEI
121	Bajhang	15	CF	M+E	1987	TEI
122	Bajhang	18	CF	M+E	1987	TEI
123	Bajura	18	CF	M	1987	TEI
124	Bajura	14	CF	M+E		TEI
125	Bhojpur	14	CF	M	1985	BYS
126	Bhojpur	17	CF	M	1987	BYS
127	Bhojpur	10	CF	M	1989	BYS
128	Bhojpur	11	CF	M	1984	BYS
129	Bhojpur	18	CF	M	1986	BYS
130	Bhojpur	10	CF	M	1989	BYS
131	Bhojpur	17	CF	M	1991	BYS
132	Bhojpur	10	CF	M	1994	BYS
133	Bhojpur	9	CF	M	1983	BYS
134	Bhojpur	22	CF	M	1985	BYS
135	Bhojpur	18	CF	M	1986	BYS
136	Bhojpur	0	CF	M		BYS
137	Bhojpur	15	CF	M+E	1985	BYS
138	Chitawan	5	CF	M	1988	NS
139	Chitawan	4	CF	M	1980	BYS
140	Chitawan	11	CF	M+ED	1986	NS
141	Chitawan	14	CF	M	1987	BYS
142	Chitawan	10	CF	M	1988	BYS
143	Chitawan	11	CF	M+E	1982	BYS
144	Chitawan	14	CF	M	1982	BYS
145	Chitawan	10	CF	M	1986	DCS + NS
146	Dadeldhura	8	CF	M+E	1985	DCS

S. No.	*District*	*Capacity (kW)*	*Type of Turbine*	*End Use*	*Installation Date*	*Manufacturer*
147	Dadeldhura	8.4	CF	M	1986	DCS
148	Dadeldhura	18.4	CF	M	1988	DCS
149	Dadeldhura	4.5	CF	M	1986	DCS
150	Dadeldhura	5	CF	M	1992	DCS
151	Dadeldhura	5	CF	M	1986	TEI
152	Dadeldhura	3.2	CF	M	1990	DCS
153	Dailekh	2.5	CF	M	1984	DCS
154	Dailekh	8.5	CF	M	1982	DCS
155	Dailekh	11	CF	M	1984	DCS
156	Dailekh	7	CF	M	1989	KMI
157	Dailekh	7	CF	M	1991	TEI
158	Dailekh	10	CF	M	1987	TEI
159	Dailekh	7	CF	M	1988	KMI
160	Dailekh	8	CF	M	1990	TEI
161	Dailekh	6	CF	M	1983	DCS
162	Dailekh	4	CF	M	1989	DCS
163	Dang	10	CF	M	1983	DCS
164	Dang	3	CF	M	1988	NS
165	Dang	10	CF	M	1985	DCS
166	Dang	3	CF	M	1982	DCS
167	Dang	10	CF	M	1986	TEI
168	Dang	7.3	CF	M	1983	DCS
169	Dang	8.4	CF	M	1985	DCS
170	Dang	4.4	CF	M	1984	DCS
171	Darchula	3.4	CF	M	1989	DCS
172	Darchula	12	CF	M	1989	DCS
173	Darchula	10.5	CF	M	1987	TEI
174	Darchula	13	CF	M+E	1986	DCS
175	Darchula	7.6	CF	M+E	1986	DCS
176	Dhading	6	CF	M	1987	KMI
177	Dhading	12	CF	M	1982	BYS
178	Dhading	5	CF	M	1988	KMI
179	Dhading	8	CF	M	1989	BYS
180	Dhading	1	CF	E	1988	DCS
181	Dhading	11	CF	M	1982	BYS
182	Dhading	6	CF	M	1989	KMI
183	Dhading	8	CF	M	1981	NYS
184	Dhading	15	CF	M+E	1985	BYS
185	Dhading	11	CF	M+E	1986	BYS
186	Dhading	10	CF	M	1990	KMI
187	Dhading	4.5	CF	M	1985	TEI
188	Dhading	17	CF	M	1985	TEI
189	Dhading	6	CF	M	1988	KMI
190	Dhading	10	CF	M	1987	BYS
191	Dhading	16	CF	M	1985	BYS
192	Dhading	12	CF	M	1994	BYS
193	Dhading	13.4	CF	M	1992	BYS
194	Dhading	4	CF	M+E	1989	KMI

List of Plants Using Cross-flow Turbines *(continued)*

S. No.	*District*	*Capacity (kW)*	*Type of Turbine*	*End Use*	*Installation Date*	*Manufacture*
195	Dhading	16	CF	M	1982	BYS
196	Dhading	13	CF	M	1985	BYS
197	Dhading	28	CF	M	1984	BYS
198	Dhading	9	CF	M	1990	KMI
199	Dhading	13	CF	M	1985	BYS
200	Dhading	8	CF	M	1985	NYS
201	Dhading	20	CF	M+E	1985	TEI
202	Dhading	12	CF	M+E	1990	BYS
203	Dhading	14	CF	M	1980	BYS
204	Dhading	10	CF	M+E	1985	
205	Dhading	8.4	CF	M	1991	BYS
206	Dhading	9	CF	M+E	1982	BYS
207	Dhading	11	CF	M	1982	BYS
208	Dhading	7.5	CF	M	1985	TEI
209	Dhading	42	CF	M	1985	BYS
210	Dhading	4	CF	M	1986	NYS
211	Dhading	10	CF	M	1983	NYS
212	Dhankuta	15	CF	M	1983	BYS
213	Dhankuta	7.6	CF	M	1984	DCS
214	Dhankuta	5	CF	M	1990	NS
215	Dhankuta	10.5	CF	M	1985	DCS
216	Dhankuta	3.5	CF	M	1989	DCS
217	Dhankuta	12	CF	M	1991	NMSS
218	Dhankuta	5	CF	M+ED	1983	Agro
219	Dolakha	8.5	CF	M	1989	NS
220	Dolakha	7	CF	M	1991	NS
221	Dolakha	15	CF	M	1994	BYS
222	Dolakha	16	CF	M	1987	NS
223	Dolakha	11.4	CF	M	1992	BYS
224	Dolakha	6	CF	M	1986	NS
225	Dolakha	6	CF	M	1989	KMI
226	Dolakha	10	CF	M	1991	KMI
227	Dolakha	12	CF	M	1992	NS
228	Dolakha	7	CF	E	1989	KMI
229	Dolakha	7	CF	M+E	1988	NS
230	Dolakha	9	CF	M	1985	NYS
231	Dolakha	6	CF	M	1989	NS
232	Dolakha	5	CF	M	1991	NYS
233	Dolpa	20	CF	M+E	1991	DCS
234	Doti	5.5	CF	M	1987	DCS
235	Doti	7	CF	M	1992	TEI
236	Doti	9	CF	M	1989	TEI
237	Doti	10.5	CF	M	1990	TEI
238	Doti	12	CF	M	1992	NMSS
239	Doti	10.5	CF	M	1991	TEI
240	Doti	6.7	CF	M	1987	TEI
241	Gorkha	15	CF	M	1979	NYS

S. No.	*District*	*Capacity (kW)*	*Type of Turbine*	*End Use*	*Installation Date*	*Manufacturer*
242	Gorkha	9	CF	M	1983	TEI
243	Gorkha	3	CF	M	1987	NYS
244	Gorkha	10	CF	M	1989	BYS
245	Gorkha	11.6	CF	M	1991	BYS
246	Gorkha	11.6	CF	M	1991	BYS
247	Gorkha	10	CF	M+E	1982	NYS
248	Gorkha	5	CF	M	1987	NYS
249	Gorkha	12	CF	M	1979	BYS
250	Gorkha	16	CF	M	1979	BYS
251	Gorkha	7	CF	M	1982	NYS
252	Gorkha	10	CF	M	1981	NYS
253	Gorkha	4	CF	M	1982	BYS
254	Gorkha	12	CF	M	1991	BYS
255	Gorkha	6	CF	M	1985	NYS
256	Gorkha	14	CF	M	1982	NYS
257	Gorkha	10	CF	M	1982	NYS
258	Gorkha	12	CF	M	1981	BYS
259	Gorkha	9	CF	M	1979	BYS
260	Gorkha	8	CF	M	1982	NYS
261	Gorkha	10	CF	M		DCS
262	Gulmi	1	CF	M		TEI
263	Gulmi	4	CF	M+E	1989	NMSS
264	Gulmi	12	CF	M	1994	NMSS
265	Gulmi	6.6	CF	M	1978	DCS
266	Gulmi	14.7	CF	M	1988	DCS
267	Gulmi	14	CF	M	1979	DCS
268	Gulmi	11.5	CF	M	1993	NMSS
269	Gulmi	6	CF	M+E	1987	TEI
270	Gulmi	40	CF	M		Agro
271	Gulmi	12	CF	M+E	1989	DCS
272	Gulmi	8.3	CF	M	1991	DCS
273	Gulmi	10	CF	M		DCS
274	Gulmi	7.5	CF	M	1979	DCS
275	Gulmi	14	CF	M	1991	NMSS
276	Gulmi	14.5	CF	M	1988	DCS
277	Gulmi	17	CF	M+E	1980	DCS
278	Gulmi	4	CF	M		DCS
279	Gulmi	3.75	CF	M	1987	TEI
280	Gulmi	2.9	CF	M+E	1989	DCS
281	Gulmi	11	CF		1987	DCS
282	Gulmi	3	CF	M	1980	DCS
283	Gulmi	5	CF	M	1987	TEI
284	Gulmi	2.2	CF	M	1989	DCS
285	Gulmi	9	CF	M	1985	Agro
286	Gulmi	9	CF	M	1982	DCS
287	Gulmi	11	CF	M	1980	DCS

List of Plants Using Cross-flow Turbines *(continued)*

S. No.	*District*	*Capacity (kW)*	*Type of Turbine*	*End Use*	*Installation Date*	*Manufacturer*
288	Gulmi	4.5	CF	M	1987	TEI
289	Gulmi	8	CF	M	1991	TEI
290	Gulmi	7.5	CF	M	1979	DCS
291	Gulmi	9	CF	M	1982	DCS
292	Gulmi	8	CF	M+E	1989	NMSS
293	Gulmi	5	CF	M	1984	TEI
294	Gulmi	2.5	CF	M+E	1992	DCS
295	Gulmi	3.5	CF	M+E	1981	DCS
296	Gulmi	4.5	CF	M+E	1983	DCS
297	Gulmi	12	CF	M	1985	TEI
298	Gulmi	7.5	CF	M	1981	DCS
299	Gulmi	2.4	CF	M	1988	DCS
300	Gulmi	6	CF	M	1991	TEI
301	Gulmi	4.9	CF	M	1980	DCS
302	Gulmi	10.4	CF	M	1985	DCS
303	Gulmi	3.8	CF	M	1983	TEI
304	Gulmi	12.5	CF	M+E	1985	DCS
305	Gulmi	8	CF	M		DCS
306	Gulmi	7	CF	M	1990	TEI
307	Gulmi	11.5	CF	M	1989	NMSS
308	Gulmi	9	CF	M		DCS
309	Gulmi	14	CF	M	1978	DCS
310	Humla	24	CF	M+E	1992	DCS
311	Humla	25	CF	M		DCS
312	Humla	6.5	CF	M+E	1994	NMSS
313	Ilam	17	CF	M	1986	BYS
314	Ilam	13	CF	M	1987	BYS
315	Ilam	5.5	CF	M	1990	DCS
316	Ilam	4.3	CF	M	1991	DCS
317	Ilam	5.5	CF	M+E	1984	DCS
318	Ilam	24.5	CF	M	1987	DCS
319	Ilam	10.9	CF	M	1987	DCS
320	Ilam	16	CF	M+E	1988	DCS
321	Ilam	10	CF	M	1986	DCS
322	Ilam	10	CF	M		DCS
323	Jajarkot	12	CF	M	1994	NMSS
324	Jajarkot	11.2	CF	M	1987	DCS
325	Jajarkot	11	CF	M	1989	DCS
326	Jajarkot	6	CF	M	1987	DCS
327	Jajarkot	10	CF	M	1985	IT
328	Jajarkot	11.1	CF	M	1991	DCS
329	Jajarkot	12	CF	M	1994	NMSS
330	Jajarkot	10	CF	M	1985	IT
331	Jajarkot	8.4	CF	M	1988	DCS
332	Jajarkot	4.3	CF	M	1984	DCS
333	Jhapa	10	CF	M	1987	KMI
334	Jumla	7.7	CF	M+E	1988	DCS
335	Jumla	20	CF	M+E		DCS

List of Plants Using Cross-flow Turbines *(continued)*

S. No.	*District*	*Capacity (kW)*	*Type of Turbine*	*End Use*	*Installation Date*	*Manufacturer*
336	Jumla	7	CF	M		DCS
337	Jumla	25	CF	M		DCS
338	Jumla	19	CF	M+E	1988	DCS
339	Kailali	6.8	CF	M	1986	DCS
340	Kalikot	9.6	CF	M	1986	DCS
341	Kalikot	11	CF	M+E	1990	DCS
342	Kaski	11	CF	M+E	1987	TEI
343	Kaski	12	CF	M	1984	BYS
344	Kaski	9	CF	M	1992	DCS
345	Kaski	6	CF	E	1988	DCS
346	Kaski	50	CF	E		DCS
347	Kaski	7	CF	M	1989	NS
348	Kaski	5	CF	M	1987	NS
349	Kathmandu	7	CF	M	1982	NYS
350	Kathmandu	5	CF	M	1983	NYS
351	Kavre	7	CF	M	1982	BYS
352	Kavre	8	CF	M	1982	BYS
353	Kavre	14	CF	M	1984	NYS
354	Kavre	4	CF	M	1986	NYS
355	Khotang	8	CF	M	1988	NYS
356	Khotang	15	CF	M	1985	BYS
357	Khotang	12	CF	M	1990	BYS
358	Khotang	12	CF	M	1988	BYS
359	Khotang	17	CF	M	1991	BYS
360	Khotang	21	CF	M	1987	BYS
361	Lalitpur	6.2	CF	M	1989	DCS
362	Lalitpur	4	CF	M	1987	NS
363	Lalitpur	4	CF	M	1988	KMI
364	Lalitpur	12	CF	M	1986	NS
365	Lalitpur	4	CF	M	1990	KMI
366	Lamjung	13	CF	M	1982	BYS
367	Lamjung	4	CF	M	1984	KMI
368	Lamjung	9	CF	M	1982	BYS
369	Lamjung	5	CF	M+ED	1984	Agro
370	Lamjung	10	CF	M	1986	BYS
371	Lamjung	40	CF	M+E	1986	DCS/BYS
372	Lamjung	12	CF	M	1978	BYS
373	Lamjung	6.6	CF	M	1986	DCS
374	Lamjung	11.3	CF	M	1986	DCS
375	Lamjung	14	CF	M	1985	Agro
376	Lamjung	8	CF	M	1979	BYS
377	Lamjung	12	CF	M	1989	BYS
378	Lamjung	12	CF	M+E	1988	BYS
379	Makwanpur	11.5	CF	M	1992	BYS
380	Makwanpur	7	CF	M	1988	BYS
381	Makwanpur	9.5	CF	M	1991	BYS
382	Makwanpur	4	CF	M	1983	KMI
383	Makwanpur	9	CF	M	1995	NYS

List of Plants Using Cross-flow Turbines *(continued)*

S. No.	*District*	*Capacity (kW)*	*Type of Turbine*	*End Use*	*Installation Date*	*Manufacturer*
384	Makwanpur	7	CF	M	1983	NYS
385	Mustang	12.6	CF	E	1989	DCS
386	Mustang	10	CF	E	1986	DCS
387	Mustang	15	CF	E	1989	DCS
388	Mustang	15	CF, P	E	1989	DCS+KMI
389	Mustang	5	CF	E	1983	DCS
390	Mustang	5	CF	E	1990	DCS
391	Mustang	10	CF	M	1979	DCS
392	Mustang	10	CF	E	1989	DCS
393	Mustang	10	CF	M	1988	DCS
394	Myagdi	4	CF	M	1986	NYS
395	Myagdi	9	CF	M	1979	DCS
396	Myagdi	5	CF	M	1988	NYS
397	Myagdi	11	CF	M	1986	NS
398	Myagdi	5	CF	M	1992	TEI
399	Myagdi	10	CF	M		DCS
400	Myagdi	13	CF	M	1983	DCS
401	Myagdi	15	CF	M		DCS
402	Myagdi	14	CF	M	1984	NYS
403	Myagdi	20	CF	M	1991	NMSS
404	Myagdi	10.4	CF	M	1983	DCS
405	Nawalparasi	7	CF	M	1981	DCS
406	Nawalparasi	8.1	CF	M	1984	DCS
407	Nawalparasi	10.5	CF	M	1984	TEI
408	Nawalparasi	10	CF	M	1986	TEI
409	Nawalparasi	8.7	CF	M	1990	DCS
410	Nawalparasi	5	CF	M		DCS
411	Nawalparasi	5	CF	M	1985	TEI
412	Nawalparasi	5	CF	M	1985	TEI
413	Nawalparasi	14.5	CF	M	1982	DCS
414	Nuwakot	6	CF	M	1986	NYS
415	Nuwakot	13	CF	M	1983	BYS
416	Nuwakot	5	CF	M	1986	NYS
417	Nuwakot	12	CF	M	1990	BYS
418	Nuwakot	9	CF	M	1983	BYS
419	Nuwakot	25	CF	M+E	1987	NYS
420	Nuwakot	8	CF	M	1987	KMI
421	Nuwakot	12	CF	M	1985	BYS
422	Nuwakot	8	CF	M	1987	KMI
423	Nuwakot	22	CF	M	1984	BYS
424	Nuwakot	22	CF	M	1984	BYS
425	Nuwakot	7	CF	M	1989	BYS
426	Nuwakot	6	CF	M	1979	BYS
427	Nuwakot	8.4	CF	M	1991	BYS
428	Nuwakot	6	CF	M	1986	NYS
429	Nuwakot	10	CF	M	1983	BYS
430	Nuwakot	6	CF	M	1988	NYS
431	Nuwakot	8	CF	M	1988	NYS

List of Plants Using Cross-flow Turbines *(continued)*

S. No.	*District*	*Capacity (kW)*	*Type of Turbine*	*End Use*	*Installation Date*	*Manufacturer*
432	Nuwakot	6	CF	M	1987	NYS
433	Nuwakot	10	CF	M	1986	NYS
434	Nuwakot	8	CF	M	1985	BYS
435	Nuwakot	10	CF	M	1988	KMI
436	Okhaldhunga	20	CF	M	1994	BYS
437	Okhaldhunga	12	CF	M	1990	NS
438	Okhaldhunga	4	CF	M	1986	NYS
439	Okhaldhunga	10	CF	M	1986	NYS
440	Okhaldhunga	12	CF	M	1988	NS
441	Okhaldhunga	5	CF	M	1986	NYS
442	Okhaldhunga	13.4	CF	M	1992	BYS
443	Okhaldhunga	12	CF	M	1988	BYS
444	Palpa	10	CF	M	1983	IT
445	Palpa	3	CF	M	1989	DCS
446	Palpa	15.5	CF	M	1983	DCS
447	Palpa	6	CF	M	1984	DCS
448	Palpa	12	CF	M	1994	NMSS
449	Palpa	7.6	CF	M	1984	DCS
450	Palpa	16	CF	M	1985	TEI
451	Palpa	5	CF	E	1986	KMI
452	Palpa	10	CF	M	1988	DCS
453	Palpa	10	CF	M		Agro
454	Palpa	4	CF	M+ED	1982	Agro
455	Palpa	10	CF	M	1977	DCS
456	Palpa	15	CF	M	1988	NMSS
457	Palpa	12	CF	M		Agro
458	Palpa	6.3	CF	M	1978	DCS
459	Palpa	18	CF	M	1991	NMSS
460	Palpa	6.6	CF	M	1981	DCS
461	Palpa	10	CF	M	1986	DCS
462	Palpa	5.8	CF	M	1984	TEI
463	Palpa	7	CF	M+E	1995	NMSS
464	Palpa	6.8	CF	M	1981	TEI
465	Palpa	6.1	CF	M	1988	DCS
466	Palpa	11	CF	M	1982	BYS
467	Palpa	8.5	CF	M	1980	DCS
468	Palpa	9.7	CF	M	1982	DCS
469	Palpa	8	CF	M		DCS
470	Palpa	4.4	CF	M	1983	TEI
471	Palpa	8.5	CF	M	1984	DCS
472	Palpa	5.4	CF	M	1986	DCS
473	Palpa	12	CF	M	1993	NMSS
474	Palpa	13	CF	M+E	1985	DCS
475	Palpa	3	CF	M	1983	DCS
476	Palpa	8.5	CF	M	1984	DCS
477	Panchthar	14	CF	M	1987	BYS
478	Panchthar	5	CF	M	1987	NS
479	Panchthar	12	CF	M	1985	BYS

S. No.	District	Capacity (kW)	Type of Turbine	End Use	Installation Date	Manufacturer
480	Panchthar	9	CF	M	1988	BYS
481	Parbat	10	CF	M	1987	DCS
482	Parbat	9.5	CF	M	1978	DCS
483	Parbat	2.5	CF	M	1994	DCS
484	Parbat	4.7	CF	M	1984	DCS
485	Parbat	5	CF	M	1991	NS
486	Parbat	3.7	CF	M	1985	DCS
487	Parbat	12	CF	M	1994	NMSS
488	Parbat	9	CF	M	1987	DCS
489	Parbat	9	CF	M	1982	DCS
490	Parbat	7	CF	M	1979	DCS
491	Parsa	10	CF	E	1990	NS
492	Pyuthan	8	CF	M	1982	DCS
493	Pyuthan	11.6	CF	M	1978	DCS
494	Pyuthan	12	CF	M		TEI
495	Pyuthan	4	CF	M		TEI
496	Pyuthan	12	CF	M	1993	NMSS
497	Pyuthan	6.4	CF	M	1992	DCS
498	Pyuthan	7.5	CF	M		DCS
499	Pyuthan	4	CF	M+E	1995	NMSS
500	Pyuthan	6	CF	M	1987	DCS
501	Pyuthan	7	CF	M		TEI
502	Pyuthan	13.5	CF	M	1982	DCS
503	Pyuthan	9	CF	M	1985	Agro
504	Pyuthan	11.5	CF	M	1982	DCS
505	Pyuthan	6	CF	M+E	1981	DCS
506	Pyuthan	8.2	CF	M	1986	TEI+NS
507	Pyuthan	5	CF	M	1985	TEI
508	Pyuthan	15	CF	M	1993	NMSS
509	Pyuthan	6.9	CF	M	1991	DCS
510	Pyuthan	10	CF	M	1981	DCS
511	Pyuthan	7.5	CF	M	1982	DCS
512	Pyuthan	4.3	CF	M	1983	DCS
513	Pyuthan	5	CF	M	1988	DCS
514	Pyuthan	8	CF	M+E	1987	DCS+TEI
515	Pyuthan	9	CF	M	1984	TEI
516	Pyuthan	5.8	CF	M	1983	DCS
517	Pyuthan	5	CF	M+E	1986	DCS+NS
518	Pyuthan	4.5	CF	M	1985	TEI
519	Pyuthan	12	CF	M	1991	NMSS
520	Pyuthan	4.7	CF	M	1981	DCS
521	Pyuthan	0.5	CF	M+E	1994	NMSS
522	Pyuthan	6.6	CF	M	1985	TEI
523	Pyuthan	10	CF	M	1981	DCS
524	Pyuthan	45	CF	M	1983	IT
525	Pyuthan	6	CF	M	1981	DCS
526	Pyuthan	11	CF	M	1987	NS
527	Pyuthan	4.6	CF	M	1986	TEI

List of Plants Using Cross-flow Turbines *(continued)*

S. No.	*District*	*Capacity (kW)*	*Type of Turbine*	*End Use*	*Installation Date*	*Manufacturer*
528	Pyuthan	9.5	CF	M	1983	DCS
529	Pyuthan	5.3	CF	M	1985	DCS
530	Pyuthan	9	CF	M	1995	NMSS
531	Pyuthan	3.4	CF	M	1989	DCS
532	Pyuthan	10.4	CF	M	1986	DCS
533	Ramechap	20	CF	M+E	1982	NYS
534	Ramechap	6	CF	M	1988	NYS
535	Ramechap	10	CF	M	1987	NS
536	Ramechap	7	CF	M+E	1987	NS+NPP
537	Ramechap	5	CF	M	1987	KMI
538	Ramechap	10	CF	M	1989	NS
539	Ramechap	5	CF	M	1986	NYS
540	Ramechap	14	CF	M	1987	NYS
541	Ramechap	11	CF	M+E	1987	NYS
542	Ramechap	10	CF	M	1987	NS
543	Ramechap	11	CF	M	1987	NYS
544	Ramechap	12	CF	M		NS
545	Ramechap	6	CF	M	1987	NYS
546	Rasuwa	20	CF	E	1995	BYS
547	Rolpa	6.3	CF	M		TEI
548	Rolpa	7.5	CF	M	1985	TEI
549	Rolpa	8	CF	M		TEI
550	Rolpa	8.6	CF	M	1984	DCS
551	Rolpa	13	CF	M	1993	NMSS
552	Rolpa	8	CF	M	1985	DCS
553	Rolpa	3.6	CF	M	1985	DCS
554	Rolpa	10	CF	M	1995	NMSS
555	Rolpa	12	CF	M	1993	NMSS
556	Rolpa	4.5	CF	M	1991	TEI
557	Rolpa	6.7	CF	M		TEI
558	Rolpa	3.7	CF	M		TEI
559	Rolpa	8	CF	M+E		TEI
560	Rolpa	12	CF	M	1993	NMSS
561	Rolpa	6	CF	M+E	1985	DCS+TEI
562	Rolpa	6	CF	M	1991	TEI
563	Rolpa	4	CF	M	1986	TEI
564	Rolpa	5.6	CF	M	1984	DCS
565	Rolpa	12	CF	M	1994	NMSS
566	Rukum	4.9	CF	M	1988	DCS
567	Rukum	9	CF	M+ED	1986	NS
568	Rukum	5	CF	M		DCS
569	Rukum	3.2	CF	M	1990	DCS
570	Rukum	8	CF	M		Agro
571	Rukum	12	CF	M	1991	NMSS
572	Rukum	8	CF	M	1987	NS
573	Rukum	10	CF	M	1986	NS
574	Rukum	13	CF	M	1991	TEI

List of Plants Using Cross-flow Turbines *(continued)*

S. No.	*District*	*Capacity (kW)*	*Type of Turbine*	*End Use*	*Installation Date*	*Manufacturer*
575	Rukum	16	CF	M+E	1994	DCS
576	Rukum	15	CF	M		DCS
577	Rukum	20	CF	M	1983	BYS
578	Salyan	4.5	CF	M	1990	TEI
579	Salyan	9	CF	M	1984	Agro
580	Salyan	6.5	CF	M	1983	TEI
581	Salyan	6.4	CF	M	1983	DCS
582	Salyan	9	CF	M	1983	DCS
583	Salyan	6	CF	M	1987	TEI
584	Salyan	3.9	CF	M	1981	NS
585	Salyan	9	CF	M	1985	BYS
586	Salyan	6.5	CF	M	1986	DCS
587	Salyan	6.6	CF	M	1984	TEI
588	Salyan	5.5	CF	M	1984	DCS
589	Salyan	5	CF	M	1984	DCS
590	Salyan	5	CF	M	1991	TEI
591	Sankhuwasabha	10	CF	M	1986	BYS
592	Sankhuwasabha	45	CF	M	1992	NMSS
593	Sankhuwasabha	18	CF	M	1987	BYS
594	Sankhuwasabha	15	CF	M	1984	BYS
595	Sankhuwasabha	11	CF	M	1992	NMSS
596	Syangja	10	CF	M	1983	BYS
597	Syangja	10	CF	M	1985	BYS
598	Sindhuli	10	CF	M	1983	NYS
599	Sindhuli	12.4	CF	M	1992	BYS
600	Sindhuli	12	CF	M	1994	BYS
601	Sindhuli	10	CF	M		NS
602	Sindhuli	6	CF	M	1985	NYS
603	Sindhuli	6	CF	M	1985	NS
604	Sindhuli	12	CF	M		NS
605	Sindhupalchok	7	CF	M	1981	BYS
606	Sindhupalchok	9	CF	M	1987	NYS
607	Sindhupalchok	4	CF	M	1986	NYS
608	Sindhupalchok	15	CF	M	1988	BYS
609	Sindhupalchok	6	CF	M	1985	NYS
610	Sindhupalchok	15	CF	M	1988	BYS
611	Sindhupalchok	7	CF	M	1989	NYS
612	Sindhupalchok	8	CF	E	1991	BYS
613	Sindhupalchok	14	CF	M	1990	BYS
614	Sindhupalchok	8	CF	M+E	1987	NPP+KMI
615	Sindhupalchok	5	CF	M	1985	NYS
616	Sindhupalchok	7	CF	M+E	1982	BYS
617	Sindhupalchok	12	CF	M	1994	BYS
618	Sindhupalchok	20	CF	M+E	1987	NYS
619	Sindhupalchok	12	CF	M	1982	NYS
620	Sindhupalchok	12	CF	M	1992	NS
621	Sindhupalchok	9	CF	M	1984	BYS
622	Sindhupalchok	12	CF	M		BYS

List of Plants Using Cross-flow Turbines *(continued)*

S. No.	*District*	*Capacity (kW)*	*Type of Turbine*	*End Use*	*Installation Date*	*Manufacturer*
623	Sindhupalchok	7.5	CF	M	1984	NS
624	Sindhupalchok	13	CF	M	1992	BYS
625	Solukhumbhu	24	CF	M	1995	NYS
626	Solukhumbhu	12	CF	M	1984	NS
627	Solukhumbhu	5	CF	M+E	1985	NYS
628	Solukhumbhu	15	CF	M+E	1990	KMI
629	Surkhet	4	CF	M	1983	DCS
630	Surkhet	7.5	CF	M		TEI
631	Surkhet	12	CF	M	1987	NS
632	Surkhet	4	CF	M		TEI
633	Surkhet	3.5	CF	M	1986	DCS
634	Surkhet	12.7	CF	M	1982	DCS
635	Surkhet	7	CF	M	1991	TEI
636	Surkhet	13.5	CF	M	1991	NMSS
637	Surkhet	4.3	CF	M	1985	DCS
638	Surkhet	5	CF	M	1990	TEI
639	Surkhet	9	CF	M		TEI
640	Surkhet	3	CF	M	1983	DCS
641	Surkhet	10	CF	M		NS
642	Surkhet	5	CF	M	1985	DCS
643	Surkhet	7	CF	M+E		TEI
644	Surkhet	9.8	CF	M	1986	DCS
645	Surkhet	3.5	CF	M	1985	DCS
646	Surkhet	4.8	CF	M	1985	DCS
647	Surkhet	8.5	CF	M	1980	DCS
648	Surkhet	9	CF	M	1982	DCS
649	Syangja	7	CF	M	1982	DCS
650	Syangja	12	CF	M	1983	DCS
651	Syangja	8	CF	M	1978	DCS
652	Syangja	12	CF	M	1983	BYS
653	Syangja	7	CF	M	1986	NS
654	Syangja	6	CF	M	1979	DCS
655	Syangja	3	CF	M	1985	TEI
656	Syangja	3.2	CF	M	1981	DCS
657	Syangja	11	CF	M+E	1979	DCS
658	Syangja	5	CF	M	1982	DCS
659	Syangja	4	CF	M	1991	TEI
660	Syangja	6	CF	M	1978	NYS
661	Syangja	5	CF	M	1985	NYS
662	Syangja	7.5	CF	M	1983	Agro
663	Syangja	12	CF	M	1982	BYS
664	Syangja	10	CF	M		DCS
665	Syangja	4.5	CF	M		TEI
666	Syangja	15	CF	M+E		TEI
667	Tanahu	9	CF	M	1983	BYS
668	Tanahu	13.5	CF	M	1984	DCS
669	Tanahu	2.6	CF	M+E	1990	DCS
670	Tanahu	9	CF	M+ED	1984	Agro

S. No.	District	Capacity (kW)	Type of Turbine	End Use	Installation Date	Manufacturer
671	Tanahu	7.5	CF	M	1986	Agro
672	Tanahu	4	CF	M+E	1981	DCS
673	Tanahu	7	CF	M	1981	NYS
674	Tanahu	20	CF	M	1981	NYS
675	Tanahu	7	CF	M+E	1990	TEI
676	Tanahu	9	CF	M+ED	1983	Agro
677	Tanahu	5	CF	M	1980	BYS
678	Tanahu	2.8	CF	M	1990	DCS
679	Tanahu	7	CF	M	1983	DCS
680	Tanahu	9	CF	M	1985	BYS
681	Tehrathum	10	CF	M	1987	NS
682	Tehrathum	7.5	CF	M	1988	NS
683	Udayapur	7.5	CF	M+E	1986	BYS
684	Udayapur	7.5	CF	M	1986	BYS
685	Udayapur	14	CF	M	1987	BYS
686		10	CF	M	1990	KMI
		6604.85				

Annex 3.C: Classification of Districts according to Regions as Used in this Study

Central Hill	Central Mountain	Eastern Hill	Eastern Mountain	Western Hill	Western Mountain
Arghakhanch i	Dhading	Bhojpur	Dolakha	Accham	Darchula
Baglung	Gorkha	Dhankuta	Okhaldhunga	Baitadi	Dolpa
Chitawan	Kaski	Ilam	Ramechap	Bajhang	Humla
Gulmi	Kathmandu	Jhapa	Sankhuwasabha	Bajura	Jajarkot
Makwanpur	Kavre	Khotang	Taplejung	Dadeldhura	Jumla
Nawalparasi	Lalitpur	Panchthar	Tehrathum	Dailekh	Rukum
Palpa	Lamjung	Sindhupalchok	Solukhumbhu	Dang	
Parbat	Mustang	Surkhet		Doti	
Parsa	Myagdi	Udayapur		Kailali	
Pyuthan	Nuwakot			Kalikot	
Syangja	Rasuwa			Rolpa	
Tanahu	Sindhuli			Salyan	

Annex- 4A: Data of Sample Plants (All costs in NRs.)

S. No.	Owner	Location	Year of Installation	Capacity kW	Supplied /Installed	Annual Cost	Benefit	R&M	End Use	Deflator (1990=100)	Region	Competing Plants
1	Angaha	Palpa	1992	3.2	DCS	20000	26890	8000	E	130	CH	4-8
2	P. B. Karki	Pyuthan	1987	4.5	KMI	10000	48734	10000	G R	73	CH	4-8
3	I. Sunwar	Pyuthan	1986	8	NYS	26000	63937	2000	G R	65	CH	4-8
4	M Gurung	Parbat	1991	5	NSE	9690	63638	9690	G R	109	CH	>8
5	B. R. Paudel	Chitawan	1988	2	NSE	27000	58641	12000	G R	82	CH	4-8
6	K N Paudel	Syangja	1991	4	TEI	32376	55888	10860	G R	109	CH	none
7	N. R. Khannal	Arghakhanchi	1988	7	TEI	27000	67595	9000	G R O	82	CH	4-8
8	K. Bhattarai	Palpa	1977	11	DCS	29660	140663	10000	G R O	28	CH	>8
9	J. B. lama	Makawanpur	1989	7.5	NSE	40250	61343	13240	G R O	91	CH	<4
10	K.B. Sunwar	Pyuthan	1987	14	NYS	52000	101909	20000	G R O	73	CH	4-8
11	K. B. Parsai	Palpa	1984	7.5	TEI	30180	93797	15000	G R O	51	CH	>8
12	I Rijal	Gulmi	1988	2.4	DCS	24617	78092	13080	G R O	82	CH	<4
13	A Aryal	Gulmi	1982	9	DCS	49799	183428	19780	G R O	43	CH	none
14	H P Paudel	Tanahu	1981	18.5	NYS	30237	135251	10080	G R O	39	CH	4-8
15	I Rijal	Gulmi	1989	11.5	DCS	38660	76732	9000	G R O	91	CH	>8
16	D B Bista	Parbat	1986	6.6	TEI	27696	69107	8340	G R O	65	CH	>8
17	O Sainju	Syangja	1985	13	BYS	30974	77840	9900	G R O	57	CH	>8
18	B. B. KC	Baglung	1984	7	BEW	32252	158437	11460	G R O	51	CH	>8
19	P. B. Shahi	Palpa	1990	9	TEI	52487	123388	25320	G R O	100	CH	none
20	N. Gautam	Arghakhanchi	1986	4.9	DCS	39990	147946	19500	G R O	65	CH	4-8
21	N. Gautam	Arghakhanchi	1987	13	NMS	41800	67763	18000	G R O	73	CH	none
22	S. R. Ghimere	Arghakhanchi	1978	9	DCS	44266	140223	12840	G R O	31	CH	none
23	Yagya Mill	Gulmi	1980	10	DCS	12500	88320	3500	G R O E	36	CH	4-8
24	K.B. Khadka	Pyuthan	1985	30	KMI	68000	123219	10000	G R O E	57	CH	4-8
25	C. S. Bhandari	Baglung	1987	12	DCS	35230	80295	13500	G R O E	73	CH	none
26	K. Ghimere	Baglung	1986	12	BEW	51800	139515	18000	G R O E	65	CH	none
27	C. S. Bhandari	Baglung	1991	9	DCS	32397	92630	12107	G R O E	109	CH	<4

Data of Sample Plants (*continued*)

S. No.	Owner	Location	Year of Installation	Capacity	Supplied /Installed	Annual Cost	Benefit	R&M	End Use	Deflator (1990=100)	Region	Competing Plants
28	D. B. Budathoki	Gulmi	1987	4.5	TEI	37180	129161	12000	G R O E	73	CH	<4
29	J. B. Shrees	Gulmi	1989	14	DCS	54940	189491	27000	G R O E	91	CH	4-8
30	D Lama	Pyuthan	1991	10	NSE	49840	195139	25000	G R O E	109	CH	4-8
31	B. B. KC	Baglung	1984	14.5	DCS	80856	173160	51600	G R O E	51	CH	4-8
32	K.B.Thapa	Baglung	1987	6	DCS	10000	43800	10000	R O	73	CH	4-8
33	T. N. Kandel	Baglung	1987	5	DCS	10000	38400	10000	R O	73	CH	4-8
34	SFDP	Baglung	1989	10.8	DCS	30000	72800	10000	R O	91	CH	none
35	K.B.Bhandari	Baglung	1984	5	DCS	33600	103550	10000	R O E	51	CH	>8
36	R. C. Sapkota	Baglung	1986	10	DCS	35560	61900	11560	R O E	65	CH	<4
												none
1	Bhadaure	Kaski	1992	1	KMI	30000	32200	12000	E	130	CM	4-8
2	S. K. Adhikari	Dhading	1985	10	BYS	37600	45247	13600	G R	57	CM	4-8
3	G. R. Sapkota	Gorkha	1987	3	NSE	26900	46823	10000	G R	73	CM	none
4	G B Gurung	Lamjung	1985	6	NYS	6900	58771	6900	G R	57	CM	none
5	P B Lama	Lamjung	1985	5	NYS	8100	54595	8100	G R O	57	CM	<4
6	P. Awasthi	Dhading	1986	10	BEW	21926	62671	12500	G R O	65	CM	none
7	N. B. Adhikari	Dhading	1989	7	KMI	22800	52230	10800	G R O	91	CM	<4
8	B. D. Thapa	Gorkha	1983	10.5	TEI	12600	65764	3000	G R O	46	CM	none
9	D. P. Dhittal	Gorkha	1979	13.5	BYS	22500	67332	4500	G R O	34	CM	none
10	P B Dhakal	Nuwakot	1983	10	BYS	6000	78602	6000	G R O	46	CM	none
11	Ghandruk	Kaski	1990	50	DCS	46000	99200	10000	G R O E	100	CM	none
12	H. B. Karki	Dhading	1985	16	BYS	57204	281484	35400	G R O E	57	CM	none
13	N. Koirala	Dhading	1985	20	TEI	30000	88240	8000	G R O E	57	CM	>8
14	H. B. Gurung	Gorkha	1980	4.6	KMI & BYS	9000	64400	9000	G R O E	36	CM	none

Data of Sample Plants (*continued*)

S. No.	Owner	Location	Year of Installation	Capacity	Supplied /Installed	Annual Cost	Benefit	R&M	End Use	Deflator (1990=100)	Region	Competing Plants
15	Barpak	Gorkha	1989	50	KMI	48200	256890	12000	G R O E	91	CM	none
16	D. B. Thapa	Kaski	1982	10	BYS	41800	151833	18000	G R O E	43	CM	none
17	D. P. Ghale	Gorkha	1982	9.8	NYS	18000	69943	6000	G R O E +	43	CM	>8
18	M. K. Shrestha	Gorkha	1980	10	NYS	9000	72557	9000	G R O E +	36	CM	none
1	S.S.Rai	Bhojpur	1990	19	BYS	37200	76120	10000	G R O	100	EH	none
2	R. Karki	Bhojpur	1985	22	BYS	28000	75753	10000	G R O	57	EH	4-8
2	D. D. Rai	Dhankuta	1990	5	NSE	39434	69584	20160	G R O	100	EH	<4
4	R. P. Shrestha	Ilam	1987	10.9	DCS	23400	54082	5400	G R O	73	EH	none
5	F. N. Dhakal	Ilam	1990	21	DCS	30000	87000	12000	G R O	100	EH	none
6	K. K. Subedi	Ilam	1985	13	DCS	43500	237250	7500	G R O E	57	EH	4-8
7	D.B Bohora	Ilam	1987	11.5	BYS	36700	129272	10700	G R O E +	73	EH	4-8
8	S. Thakuri	Ilam	1988	16	DCS	27000	82324	15000	G R O E +	82	EH	none
9	L. P. Khatiwada	Ilam	1988	20	DCS	47000	62923	23000	R O	82	EH	4-8
1	P G Sherpa	Solukhumbu	1990	9	NYS	26000	57408	8000	G O	100	EM	none
2	K. G. Sherpa	Solukhumbu	1993	16	KMI	74450	109840	26450	G R O E +	144	EM	<4
1	B. Rawal	Achham	1995	5.9	BEW	10250	32332	10250	G O	166	WH	<4
2	M. B. Thapa	Daheldhura	1987	7.5	DCS	12000	56224	12000	G O E	73	WH	>8
3	T R Paudel	Salyan	1980	8	DCS	5400	46464	5400	G R	36	WH	>8
4	P. Chand	Baitadi	1987	6.6	TEI	8811	50958	8811	G R O	73	WH	>8
5	Y. B. Shahi	Dailekh	1990	5.8	BEW	11264	60186	11264	G R O	100	WH	<4
5	D. R. Regmi	Dailekh	1982	8.5	DCS	8000	65525	8000	G R O	43	WH	4-8
7	N D Shahi	Dailekh	1991	7.2	TEI	13290	55208	13290	G R O	109	WH	>8
8	P. B. Shahi	Dailekh	1988	8	TEI	12450	69520	12450	G R O	82	WH	>8

Data of Sample Plants (*continued*)

S. No.	*Owner*	*Location*	*Year of Installation*	*Capacity*	*Supplied /Installed*	*Annual Cost*	*Benefit*	*R&M*	*End Use*	*Deflator (1990=100)*	*Region*	*Competing Plants*
9	B B Singh	Ramechap	1988	12	TEI	27420	75211	15000	G R O	82	WH	none
10	G B Shahi	Ramechap	1982	13.5	DCS	18485	83511	8880	G R O	43	WH	>8
11	K K Shrestha	Ramechap	1981	10	DCS	14806	50925	6360	G R O	39	WH	>8
12	N B Khadka	Ramechap	1985	4.5	TEI	26106	78592	14100	G R O	57	WH	4-8
13	R B Thapa	Ramechap	1987	11	NSE	19500	98462	19500	G R O	73	WH	4-8
14	B. P. Sharma	Dailekh	1989	8	KMI	20420	58756	12020	G R O E	91	WH	4-8
15	P. R. Josh	Doti	1992	12	NMSS	21000	55804	12000	R O	130	WH	none
16	U. R Bhatta	Salyan	1984	6	BEW	16558	77950	7560	R O	51	WH	4-8
17	D B Gharti	Salyan	1995	6.5	TEI	30311	54139	16980	R O	166	WH	>8
18	K B Gharti	Salyan	1983	7.5	BEW	34061	71714	15850	R O	46	WH	4-8
19	J. S. Rokaya	Salyan	1990	5	TEI	10000	34500	10000	R O	100	WH	4-8
1	K. Institute	Jumla	1990	16	KMI	179940	340980	127500	G E	100	WM	none
2	K. B. Chetri	Jajarkot	1984	4.3	BEW	9590	33655	2000	G R	51	WM	4-8
3	N. B. Oli	Darchula	1989	10	NSE	30000	79745	30000	G R E	91	WM	none
4	S. M. Shrestha	Rukum	1979	15	BYS	35200	79694	17200	G R O	34	WM	<4
5	K P Dhakal	Jajarkot	1984	22	BYS	55843	81270	13920	R O	51	WM	none
6	B. M. Bhabuk	Rukum	1987	5.2	BEW	10695	59021	10695	R O	73	WM	<4

NOTE: Within 2 hrs. Walking Distance

Annex-4B: FINANCIAL DETAILS OF SAMPLE PLANTS (All Costs are in NRs.)

S. No.	Owner	Total Installation Cost	Loan	Repayment Period	Cost of Electrical Components	Subsidy Rate	Subsidy	Cost of Other Equipment	Civil	Mechanical Cost	Transport Cost	Labour Cost	O&M Cost
1	Angaha	119860	65000	7	36539	0.50	18269	0	15908	25364	13861	8189	12000
2	P. B. Karki	73371	55000	8				17609	11739	30816	7337	5870	0
3	I. Sunwar	84605	65000	7				20305	13537	35534	8461	6768	24000
4	M Gurung	161500	110000	8				38760	25840	67830	16150	12920	0
5	B. R. Paudel	115000	51750	10				27600	18400	48300	11500	9200	15000
6	K N Paudel	181000	135750	8				43440	28960	76020	18100	14480	21516
7	N. R. Khannal	255000	153000	7				61200	40800	107100	25500	20400	18000
8	K. Bhattarai	150000	112500	8				36000	24000	63000	15000	12000	19660
9	J. B. lama	54000	43200	7				12960	8640	22680	5400	4320	27010
10	K.B. Sunwar	239963	210000	8				57591	38394	100784	23996	19197	32000
11	K. B. Parsai	350000	227500	8				84000	56000	147000	35000	28000	15180
12	I Rijal	218000	142500	7				52320	34880	91560	21800	17440	11537
13	A Aryal	163000	89000	8				39120	26080	68460	16300	13040	30019
14	H P Paudel	168000	125000	10				40320	26880	70560	16800	13440	20157
15	I Rijal	150000	100000	10				36000	24000	63000	15000	12000	29660
16	D B Bista	139000	90000	8				33360	22240	58380	13900	11120	19356
17	O Sainju	165000	120000	8				39600	26400	69300	16500	13200	21074
18	B. B. KC	191000	95000	8				45840	30560	80220	19100	15280	20792
19	P. B. Shahi	422000	220000	8				101280	67520	177240	42200	33760	27167
20	N. Gautam	325000	175000	7				78000	52000	136500	32500	26000	20490
21	N. Gautam	300000	195000	7				72000	48000	126000	30000	24000	23800
22	S. R. Ghimere	214000	149800	7				51360	34240	89880	21400	17120	31426
23	Yagya Mill	254527	165000	8	93131	0.75	69849	37415	28532	55996	25453	15272	9000
24	K.B. Khadka	157584	110000	10	57660	0.75	43245	23165	17665	34669	15758	9455	58000

FINANCIAL DETAILS OF SAMPLE PLANTS *(continued)*

S. No.	Owner	Total Installation Cost	Loan	Repayment Period	Cost of Electrical Components	Subsidy Rate	Subsidy	Cost of Other Equipment	Civil	Mechanical Cost	Transport Cost	Labour Cost	O&M Cost
25	C. S. Bhandari	266164	180000	8	97389	0.75	73042	39126	29837	58556	26616	15970	21730
26	K. Ghimere	354885	225000	8	129852	0.75	97389	52168	39783	78075	35489	21293	33800
27	C. S. Bhandari	633020	345000	8	231622	0.75	173717	93054	70962	139264	63302	37981	20289
28	D. B. Budathoki	446049	192500	8	163209	0.75	122407	65569	50002	98131	44605	26763	25180
29	J. B. Shrees	473491	360000	8	173250	0.75	129938	69603	53078	104168	47349	28409	27940
30	D Lama	328065	300000	8	120039	0.75	90029	48226	36776	72174	32807	19684	24840
31	B. B. KC	517337	350000	7	189294	0.75	141970	76049	57993	113814	51734	31040	29256
32	K.B.Thapa	179085	95000	7				42980	28654	75216	17909	14327	0
33	T. N. Kandel	131092	85000	7				31462	20975	55059	13109	10487	0
34	SFDP	172448	110000	7				41388	27592	72428	17245	13796	20000
35	K.B.Bhandari	178459	120000	7	65298	0.75	48974	26233	20005	39261	17846	10708	23600
36	R. C. Sapkota	171978	110000	10	62927	0.75	47195	25281	19279	37835	17198	10319	24000
1	Bhadaure	189944	0	0	45593	0.50	22796		11142	17766	9708	5735	18000
2	S. K. Adhikari	60000	48000	8				14400	9600	25200	6000	4800	24000
3	G. R. Sapkota	50000	27500	8				12000	8000	21000	5000	4000	16900
4	G B Gurung	115000	80000	8				27600	18400	48300	11500	9200	0
5	P B Lama	135000	100000	8				32400	21600	56700	13500	10800	0
6	P. Awasthi	141510	91000	8				33962	22642	59434	14151	11321	9426
7	N. B. Adhikari	118000	75000	8				28320	18880	49560	11800	9440	12000
8	B. D. Thapa	125000	100000	9				30000	20000	52500	12500	10000	9600
9	D. P. Dhittal	75000	45000	7				18000	12000	31500	7500	6000	18000
10	P B Dhakal	148800	110000	7				38192	22128	54336	18080	16064	0
11	Ghandruk	425862	162000	8	155823	0.50	77911	62602	47739	93690	55362	12776	36000

FINANCIAL DETAILS OF SAMPLE PLANTS *(continued)*

S. No.	Owner	Total Installation Cost	Loan	Repayment Period	Cost of Electrical Components	Subsidy Rate	Subsidy	Cost of Other Equipment	Civil	Mechanical Cost	Transport Cost	Labour Cost	O&M Cost
12	H. B. Karki	697941	383500	8	255376	0.50	127688	102597	78239	153547	69794	41876	21804
13	N. Koirala	441092	300000	10	146273	0.50	73137	59115	56087	198199	34636	36782	22000
14	H. B. Gurung	156521	85000	8	57271	0.50	28635	23009	17546	34435	15652	9391	0
15	Barpak	1256991	650000	7	980585	0.50	490293	43124	31057	59710	95323	47194	36200
16	D. B. Thapa	354885	135000	10	129852	0.50	64926	52168	39783	78075	35489	21293	23800
17	D. P. Ghale	219535	65000	8	80328	0.50	40164	32272	24610	48298	21954	13172	12000
18	M. K. Shrestha	197382	140000	8	72222	0.50	36111	29015	22127	43424	19738	11843	0
1	S.S.Rai	211702	150000	8				50808	33872	88915	21170	16936	27200
2	R. Karki	126822	80000	8				30437	20292	53265	12682	10146	18000
3	D. D. Rai	136000	74800	8				32640	21760	57120	13600	10880	19274
4	R. P. Shrestha	90000	65000	8				21600	14400	37800	9000	7200	18000
5	F. N. Dhakal	313220	150000	8				75173	50115	131552	31322	25058	18000
6	K. K. Subedi	490613	228105	7	179515	0.50	89758	72120	54998	107935	49061	29437	36000
7	D.B Bohora	254444	175000	7	93101	0.50	46551	37403	28523	55978	25444	15267	26000
8	S. Thakuri	630813	350000	10	319594	0.50	159797	58396	27913	152158	20345	52407	12000
9	L. P. Khatiwada	167105	95000	10				30079	20053	70184	16711	13368	24000
1	P G Sherpa	440000	330000	8				105600	70400	184800	44000	35200	18000
2	K. G. Sherpa	1527164	750000	8	558789	0.75	419092	224493	171195	335976	152716	91630	48000
1	B. Rawal	98800	65000	8				23712	15808	41496	9880	7904	0
2	M. B. Thapa	200000	160000	8	73180	0.50	36590	29400	22420	44000	20000	12000	0

FINANCIAL DETAILS OF SAMPLE PLANTS *(continued)*

S. No.	*Owner*	*Total Installation Cost*	*Loan*	*Repayment Period*	*Cost of Electrical Components*	*Subsidy Rate*	*Subsidy*	*Other Equipment*	*Civil*	*Mechanical*	*Transport*	*Labour*	*O&M*
3	T R Paudel	90000	58500	8				21600	14400	37800	9000	7200	0
4	P. Chand	146848	95450	8				35244	23496	61676	14685	11748	0
5	Y. B. Shahi	187725	130000	8				45054	30036	78845	18773	15018	0
6	D. R. Regmi	122265	90001	10				29344	19562	51351	12227	9781	0
7	N D Shahi	242459	150000	8				58190	38793	101833	24246	19397	0
8	P. B. Shahi	169499	152500	7				40680	27120	71190	16950	13560	0
9	B B Singh	250000	187500	8				60000	40000	105000	25000	20000	12420
10	G B Shahi	148000	96000	8				35520	23680	62160	14800	11840	9605
11	K K Shrestha	106000	69000	8				25440	16960	44520	10600	8480	8446
12	N B Khadka	235000	129250	8				56400	37600	98700	23500	18800	12006
13	R B Thapa	325000	217500	7				78000	52000	136500	32500	26000	0
14	B. P. Sharma	344665	203953	10	126113	0.75	94585	50666	38637	75826	34467	20680	8400
15	P. R. Josh	218000	110000	8				52320	34880	91560	21800	17440	9000
16	U. R Bhatta	126005	80000	8				30241	20161	52922	12601	10080	8998
17	D B Gharti	283000	99000	8				67920	45280	118860	28300	22640	13331
18	K B Gharti	97500	45000	8				23400	15600	40950	9750	7800	18211
19	J. S. Rokaya	114839	75000	8				27561	18374	48232	11484	9187	0
1	K. Institute	2166523	1275000	8	792731	0.75	594548	318479	242867	476635	216652	129991	52440
2	K. B. Chetri	74984	55000	8				17996	11997	31493	7498	5999	7590
3	N. B. Oli	201102	93500	8	73583	0.50	36792	29562	22543	44242	20110	12066	0
4	S. M. Shrestha	120000	66000	7				28800	19200	50400	12000	9600	18000
5	K P Dhakal	232000	150000	8				55680	37120	97440	23200	18560	41923
6	B. M. Bhabuk	178250	120000	10				42780	28520	74865	17825	14260	0

Annex 4C: Result Of Financial And Economic Analysis

Plant Details					Financial			Economic		
S. No.	Owner	Region	Capacity kW	End Use	FNPV NRs.	FIRR %	FB/C	ENPV NRs.	EIRR %	EB/C
1	Angaha	CH	3.2	E	-41831	1.24%	1	7135	11.67%	1.03
2	P. B. Karki	CH	4.5	G R	147438	28.56%	2	85456	23.27%	1.52
3	I. Sunwar	CH	8	G R	97241	19.16%	1	154888	24.46%	1.40
4	M Gurung	CH	5	G R	205839	27.86%	2	134795	24.13%	1.64
5	B. R. Paudel	CH	2	G R	84189	18.75%	1	114946	23.74%	1.37
6	K N Paudel	CH	4	G R	-64402	4.76%	1	62330	17.24%	1.19
7	N. R. Khannal	CH	7	G R O	-85212	6.24%	1	36704	12.02%	1.07
8	K. Bhattarai	CH	11	G R O	59578	11.45%	1	61684	12.77%	1.09
9	J. B. lama	CH	7.5	G R O	70945	24.46%	1	442431	26.10%	1.57
10	K.B. Sunwar	CH	14	G R O	-152414	3.99%	1	50013	12.08%	1.07
11	K. B. Parsai	CH	7.5	G R O	-437094	0.76%	1	478856	20.99%	1.48
12	I Rijal	CH	2.4	G R O	52719	12.57%	1	40802	20.90%	1.12
13	A Aryal	CH	9	G R O	556105	29.42%	2	339143	29.28%	1.79
14	H P Paudel	CH	18.5	G R O	157091	15.07%	1	-92304	6.86%	0.87
15	I Rijal	CH	11.5	G R O	60263	15.16%	1	-64924	8.31%	0.93
16	D B Bista	CH	6.6	G R O	28653	11.81%	1	185462	23.52%	1.46
17	O Sainju	CH	13	G R O	-59479	7.24%	1	118070	21.32%	1.27
18	B. B. KC	CH	7	G R O	527393	28.86%	2	24116	11.44%	1.05
19	P. B. Shahi	CH	9	G R O	39653	11.33%	1	55790	12.54%	1.09
20	N. Gautam	CH	4.9	G R O	224749	16.00%	1	-105788	3.88%	0.84
21	N. Gautam	CH	13	G R O	-347947	-2.31%	1	93790	13.67%	1.15
22	S. R. Ghimere	CH	9	G R O	-227949	5.63%	1	688296	30.68%	1.90
23	Yagya Rice Mill	CH	10	G R O E	-183532	5.45%	1	3038	10.08%	1.00
24	K.B. Khadka	CH	30	G R O E	97511	16.39%	1	231015	20.10%	1.38

Result Of Financial And Economic Analysis *(continued)*

Plant Details					*Financial*			*Economic*		
S. No.	Owner	Region	Capacity kW	End Use	FNPV NRs.	FIRR (%)	FB/C	ENPV NRs.	EIRR %	EB/C
25	C. S. Bhandari	CH	12	G R O E	-61825	7.09%	1	514245	24.59%	1.57
26	K. Ghimere	CH	12	G R O E	89661	12.82%	1	230658	16.51%	1.29
27	C. S. Bhandari	CH	9	G R O E	-92664	7.09%	1	66299	11.86%	1.08
28	D. B. Budathoki	CH	4.5	G R O E	205234	16.20%	1	-75687	4.87%	0.90
29	J. B. Shrees	CH	14	G R O E	392322	22.23%	1	-79690	7.22%	0.91
30	D Lama	CH	10	G R O E	683126	46.50%	2	-40996	7.54%	0.94
31	B. B. KC	CH	14.5	G R O E	-408275	3.23%	1	-360025	3.17%	0.69
32	K.B.Thapa	CH	6	R O	-33158	8.11%	1	154044	22.73%	1.42
33	T. N. Kandel	CH	5	R O	-21977	8.37%	1	161823	20.49%	1.52
34	SFDP	CH	10.8	R O	76802	15.24%	1	70213	16.42%	1.29
35	K.B.Bhandari	CH	5	R O E	150761	16.93%	1	45197	12.90%	1.09
36	R. C. Sapkota	CH	10	R O E	-88631	3.49%	1	23224	11.15%	1.04
				0						
1	Bhadaure	CM	1	E	-6946	7.57%	1	-7574	8.04%	0.97
2	S. K. Adhikari	CM	10	G R	-102494	-3.86%	1	65555	19.94%	1.18
3	G. R. Sapkota	CM	3	G R	68028	23.28%	1	88601	29.53%	1.35
4	G B Gurung	CM	6	G R	112475	17.27%	1	333718	34.48%	2.35
5	P B Lama	CM	5	G R O	9414	10.52%	1	185777	22.32%	1.64
6	P. Awasthi	CM	10	G R O	19610	11.22%	1	86666	16.53%	1.24
7	N. B. Adhikari	CM	7	G R O	52127	15.36%	1	225844	22.99%	1.63
8	B. D. Thapa	CM	10.5	G R O	-15136	9.25%	1	116379	18.51%	1.31
9	D. P. Dhittal	CM	13.5	G R O	61527	13.68%	1	258878	22.55%	1.71
10	P B Dhakal	CM	10	G R O	81808	13.18%	1	43019	15.49%	1.15
11	Ghandruk	CM	50	G R O E	47882	11.96%	1	-58776	7.51%	0.92

Result Of Financial And Economic Analysis *(continued)*

S. No.	Owner	Region	Capacity kW	End Use	*Financial* FNPV NRs.	FIRR %	FB/C	*Economic* ENPV NRs.	EIRR %	EB/C
12	H. B. Karki	CM	16	G R O E	425850	15.59%	1	1296078	26.24%	1.81
16	N. Koirala	CM	20	G R O E	-606820	-2.08%	1	237039	18.78%	1.48
14	H. B. Gurung	CM	4.6	G R O E	-29714	8.87%	1	-440654	3.93%	0.74
15	Barpak	CM	50	G R O E	512426	17.30%	1	528190	20.20%	1.48
16	D. B. Thapa	CM	10	G R O E	131994	12.92%	1	-204686	5.05%	0.79
17	D. P. Ghale	CM	9.8	G R O E +	20258	10.72%	1	241040	17.17%	1.40
18	M. K. Shrestha	CM	10	G R O E + 0	-197370	4.31%	1	7564	10.26%	1.01
1	S.S.Rai	EH	19	G R O	-3294	9.79%	1	96179	17.40%	1.21
2	R. Karki	EH	22	G R O	69874	14.21%	1	224395	36.74%	1.79
3	D. D. Rai	EH	5	G R O	63520	16.37%	1	179827	19.21%	1.35
4	R. P. Shrestha	EH	10.9	G R O	56986	16.00%	1	74700	18.84%	1.19
5	F. N. Dhakal	EH	21	G R O	95145	14.23%	1	66376	14.96%	1.16
6	K. K. Subedi	EH	13	G R O E	672347	22.33%	1	-476470	-1.55%	0.59
7	D.B Bohora	EH	11.5	G R O E +	210229	19.57%	1	-78498	8.17%	0.92
8	S. Thakuri	EH	16	G R O E +	-337413	1.16%	1	51086	12.50%	1.09
9	L. P. Khatiwada	EH	20	R O 0	-109575	1.04%	1	1701	10.15%	1.00
1	P G Sherpa	EM	9	G O	-405623	-3.34%	1	50639	11.97%	1.08
2	Khakpa Ginje Sherpa	EM	16	G R O E + 0	-666454	-2.81%	1	-183830	6.84%	0.88
1	B. Rawal	WH	5.9	G O	87510	28.99%	1	85615	31.53%	1.41
2	M. B. Thapa	WH	7.5	G O E	-34341	8.12%	1	-12761	9.18%	0.96
3	T R Paudel	WH	8	G R	-23163	8.73%	1	76234	15.07%	1.27

Result Of Financial And Economic Analysis *(continued)*

S. No.	Owner	Region	Capacity kW	End Use	*Financial* FNPV NRs.	FIRR %	FB/C	*Economic* ENPV NRs.	EIRR %	EB/C
4	P. Chand	WH	6.6	G R O	50623	13.37%	1	20180	11.14%	1.04
5	Y. B. Shahi	WH	5.8	G R O	86154	16.31%	1	114579	19.75%	1.44
6	D. R. Regmi	WH	8.5	G R O	51934	12.44%	1	86891	17.05%	1.34
7	N D Shahi	WH	7.2	G R O	43663	12.62%	1	-3047	9.76%	0.99
8	P. B. Shahi	WH	8	G R O	76033	14.46%	1	47981	13.90%	1.17
9	B B Singh	WH	12	G R O	-83085	6.35%	1	-126831	2.88%	0.73
10	G B Shahi	WH	13.5	G R O	33275	11.31%	1	2417	10.16%	1.01
11	K K Shrestha	WH	10	G R O	-90329	5.36%	1	166525	19.39%	1.50
12	N B Khadka	WH	4.5	G R O	-79067	7.29%	1	79111	13.24%	1.13
13	R B Thapa	WH	11	G R O	-94752	6.98%	1	22993	10.90%	1.04
14	B. P. Sharma	WH	8	G R O E	-61489	7.01%	1	-25431	8.81%	0.95
15	P. R. Josh	WH	12	R O	69633	15.76%	1	64102	16.28%	1.21
16	U. R Bhatta	WH	6	R O	139975	17.51%	1	-13925	8.54%	0.96
17	D B Gharti	WH	6.5	R O	15308	11.35%	1	148995	19.65%	1.42
18	K B Gharti	WH	7.5	R O	51012	13.43%	1	-85285	2.13%	0.81
19	J. S. Rokaya	WH	5	R O	31801	13.70%	1	159534	30.86%	1.89
1	K. Institute	WM	16	G E	-945656	1.94%	1	-986476	0.91%	0.61
2	N. B. Oli	WM	4.3	G R	-29343	7.33%	1	28460	12.90%	1.12
3	K. B. Chetri	WM	10	G R E	181325	23.09%	1	-25698	7.91%	0.94
4	S. M. Shrestha	WM	15	G R O	-109872	5.56%	1	-107532	4.23%	0.82
5	K P Dhakal	WM	22	R O	-415146	-3.93%	1	-174347	2.55%	0.76
6	B. M. Bhabuk	WM	5.2	R O	25843	11.52%	1	182109	37.97%	2.11
					72352	12.89%	1	246754	20.44%	1.43

Annex 4.D: Financial Analysis of Plants Providing Different Services with Respect to Location

	E	GE	GOE	GR	GROE	GROE+	ROE	GO	GRE	GRO	RO
Central Hills											
FNPV in NRs.	-41830.89				80173.28		31065.01		94061.08	29190.82	7222.42
FIRR in %	1.24%				15.22%		10.21%		19.82%	12.35%	10.58%
FB/C	0.85				1.10		1.03		1.29	1.06	1.00
Central Mountains											
FNPV in NRs.	-6945.98				80269.58	-88556.10			26002.82	9516.24	
FIRR in %	7.57%				10.52%	7.52%			12.23%	12.44%	
FB/C	0.98				1.03	0.91			1.09	0.58	
Eastern Hills											
FNPV in NRs.					672346.89	-63592.13				56446.24	-109574.94
FIRR in %					22.33%	10.37%				14.12%	1.04%
FB/C					1.44	0.99				1.10	0.84
Easter Mountains											
FNPV in NRs.						-666454.19		-405623.47			
FIRR in %						-2.81%		-3.34%			
FB/C						0.66		0.61			
Western Hills											
FNPV in NRs.			-34340.70		-61489.04			87510.09	-34340.70	-555.18	61545.99
FIRR in %			8.12%		7.01%			28.99%	8.12%	10.65%	13.01%
FB/C			0.94		0.91			1.47	0.94	1.02	1.09
Western Mountains											
FNPV in NRs.		-945656.12		181325.0 8					-29343.25	-109871.82	-194651.79
FIRR in %		1.94%		23.09%					1.94%	5.56%	3.79%
FB/C		0.79		1.35					0.79	0.87	0.86

NOTE: G - Grinder; R - Rice-Huller; O - Oil Expeller; E - Electricity; + - additional services

Source: Computed from Field Survey

Annex-4E: Comparative Results of Financial and Economic Cost of Installation and Energy Generation (in NRs.)

			Financial Values			Economic Values		
S. No.	*Owner*	*Location*	*Annuity Cost of Installation*	*Cost per Energy Generated*	*Cost per Capacity Installed*	*Annuity Cost of Installation*	*Cost per Energy Generated*	*Cost per Capacity Installed*
1	Angaha	Palpa	20756	4.44	24005	13122	2.81	31206
2	P. B. Karki	Pyuthan	23258	2.36	22335	9641	0.98	16305
3	I. Sunwar	Pyuthan	38425	4.39	41514	23783	2.72	45250
4	M Gurung	Parbat	34285	3.13	29633	21221	1.94	32300
5	B. R. Paudel	Chitawan	30119	1.72	16270	11117	0.63	10576
6	K N Paudel	Syangja	32452	7.41	70122	15111	3.45	57500
7	N. R. Khannal	Arghakhanchi	71960	4.69	44425	33507	2.19	36429
8	K. Bhattarai	Palpa	87717	4.45	42119	21418	1.09	18111
9	J. B. lama	Makawanpur	97651	4.95	46889	55451	2.81	46889
10	K.B. Sunwar	Pyuthan	95096	3.34	31612	39420	1.38	23077
11	K. B. Parsai	Palpa	159741	8.10	76703	28120	1.43	23778
12	I Rijal	Gulmi	13731	0.84	7912	7096	0.43	7200
13	A Aryal	Gulmi	61519	11.70	110772	28645	5.45	90833
14	H P Paudel	Tanahu	123964	5.15	48701	19710	0.82	13636
15	I Rijal	Gulmi	158804	9.67	91503	45990	2.80	46667
16	D B Bista	Parbat	49484	3.42	32401	18265	1.26	21061
17	O Sainju	Syangja	38143	1.51	14333	19710	0.78	13043
18	B. B. KC	Baglung	66984	2.35	22267	21681	0.76	12692
19	P. B. Shahi	Palpa	86662	5.65	53501	25097	1.64	27286
20	N. Gautam	Arghakhanchi	76065	2.48	23480	31531	1.03	17140
21	N. Gautam	Arghakhanchi	99680	2.46	23285	22075	0.54	9081
22	S. R. Ghimere	Arghakhanchi	115700	10.78	102041	42705	3.98	66327
23	Yagya Rice Mill	Gulmi	163604	5.60	70702	33445	1.15	25453

Comparative Results of Financial and Economic Cost of Installation and Energy Generation (in NRs.)*(continued)*

			Financial Values			Economic Values		
S. No.	*Owner*	*Location*	*Annuity Cost of Installation*	*Cost per Energy Generated*	*Cost per Capacity Installed*	*Annuity Cost of Installation*	*Cost per Energy Generated*	*Cost per Capacity Installed*
24	K.B. Khadka	Pyuthan	84370	2.41	30384	34974	1.00	22180
25	C. S. Bhandari	Baglung	126339	3.61	45498	46632	1.33	29574
26	K. Ghimere	Baglung	134386	5.11	64528	83179	3.17	70336
27	C. S. Bhandari	Baglung	141391	10.76	135783	58611	4.46	99122
28	D. B. Budathoki	Gulmi	63974	0.73	9215	20707	0.24	5253
29	J. B. Shrees	Gulmi	120402	2.95	37166	62217	1.52	33821
30	D Lama	Pyuthan	69646	2.39	30098	43108	1.48	32807
31	B. B. KC	Baglung	234729	5.54	69958	67978	1.61	35678
32	K.B.Thapa	Baglung	43851	1.85	17547	22660	0.96	15967
33	T. N. Kandel	Baglung	56767	4.32	40887	23532	1.79	29848
34	SFDP	Baglung	41554	3.79	35916	17225	1.57	26218
35	K.B.Bhandari	Baglung	61224	2.10	26458	22598	0.77	17198
36	R. C. Sapkota	Baglung	80971	5.55	69984	23450	1.61	35692
1	Bhadaure	Kaski	16559	11.34	69188	11819	8.09	89944
2	S. K. Adhikari	Dhading	24358	1.11	10526	7884	0.36	6000
3	G. R. Sapkota	Gorkha	15849	2.41	22831	6570	1.00	16667
4	G B Gurung	Lamjung	46686	3.55	33626	15111	1.15	19167
5	P B Lama	Lamjung	54805	5.01	47368	17739	1.62	27000
6	P. Awasthi	Dhading	50378	2.30	21771	18594	0.85	14151
7	N. B. Adhikari	Dhading	62880	2.73	25880	16425	0.71	11905
8	B. D. Thapa	Gorkha	51044	1.73	16340	9855	0.33	5556
9	D. P. Dhittal	Gorkha	81809	3.74	32348	19552	0.89	14880

Comparative Results of Financial and Economic Cost of Installation and Energy Generation *(continued)*

			Financial Values			Economic Values		
S. No.	*Owner*	*Location*	*Annuity Cost of Installation*	*Cost per Energy Generated*	*Cost per Capacity Installed*	*Annuity Cost of Installation*	*Cost per Energy Generated*	*Cost per Capacity Installed*
10	P B Dhakal	Nuwakot	30006	1.96	18524	15505	1.01	16857
11	Ghandruk	Kaski	111320	0.76	8517	55958	0.38	8517
12	H. B. Karki	Dhading	283339	6.06	76529	91709	1.96	43621
13	N. Koirala	Dhading	100608	7.49	94517	20567	1.53	34026
14	H. B. Gurung	Gorkha	286254	1.96	27626	165169	1.13	25140
15	Barpak	Gorkha	190978	6.54	82531	46632	1.60	35489
16	D. B. Thapa	Kaski	162448	2.78	38692	57959	0.99	22055
17	D. P. Ghale	Gorkha	126873	4.34	54828	25936	0.89	19738
18	M. K. Shrestha	Gorkha	118141	4.13	52097	28847	1.01	22402
1	S.S.Rai	Bhojpur	48988	1.18	11142	27818	0.67	11142
2	R. Karki	Bhojpur	28529	1.20	11311	11826	0.50	8257
3	D. D. Rai	Dhankuta	72479	1.58	14915	41157	0.89	14915
4	R. P. Shrestha	Ilam	31470	2.87	27200	17870	1.63	27200
5	F. N. Dhakal	Ilam	51485	1.07	10113	16664	0.35	5765
6	K. K. Subedi	Ilam	199172	5.25	66210	64467	1.70	37739
7	D.B Bohora	Ilam	125894	2.69	48080	82889	1.77	39426
8	S. Thakuri	Ilam	80655	2.40	30309	33434	1.00	22126
9	L. P. Khatiwada	Ilam	47156	1.08	10189	21958	0.50	8355
1	P G Sherpa	Solukhumbu	101816	5.17	48889	57816	2.93	48889
2	Khakpa Ginje Sherpa	Solukhumbu	245407	5.25	66283	200669	4.30	95448
1	B. Rawal	Achham	13772	1.07	10088	12982	1.00	16746
2	M. B. Thapa	Daheldhura	63397	2.89	36530	26280	1.20	26667

Comparative Results of Financial and Economic Cost of Installation and Energy Generation *(continued)*

			Financial Values			Economic Values		
S. No.	*Owner*	*Location*	*Annuity Cost of Installation*	*Cost per Energy Generated*	*Cost per Capacity Installed*	*Annuity Cost of Installation*	*Cost per Energy Generated*	*Cost per Capacity Installed*
3	T R Paudel	Salyan	57850	3.30	31250	11826	0.68	11250
4	P. Chand	Baitadi	70549	2.68	25407	32850	1.25	20833
5	Y. B. Shahi	Dailekh	43440	3.42	32366	24667	1.94	32366
6	D. R. Regmi	Dailekh	46549	3.22	30479	19296	1.33	22250
7	N D Shahi	Dailekh	51472	3.26	30894	31859	2.02	33675
8	P. B. Shahi	Dailekh	47832	2.73	25838	22272	1.27	21187
9	B B Singh	Ramechap	79645	2.69	25495	19447	0.66	10963
10	G B Shahi	Ramechap	62893	2.87	27179	13928	0.64	10600
11	K K Shrestha	Ramechap	65796	3.53	33451	16066	0.86	14384
12	N B Khadka	Ramechap	95402	9.68	91618	30879	3.13	52222
13	R B Thapa	Ramechap	103021	4.28	40473	42705	1.77	29545
14	B. P. Sharma	Dailekh	87644	3.75	47344	45289	1.94	43083
15	P. R. Josh	Doti	38804	1.48	13974	28645	1.09	18167
16	U. R Bhatta	Salyan	39450	2.77	26228	37186	2.61	43538
17	D B Gharti	Salyan	57172	4.35	41178	16557	1.26	21001
18	K B Gharti	Salyan	49047	2.99	28261	12812	0.78	13000
19	J. S. Rokaya	Salyan	26574	2.43	22968	15090	1.38	22968
1	K. Institute	Jumla	501333	10.73	135408	284681	6.09	135408
2	N. B. Oli	Darchula	36599	3.89	38752	11167	1.19	19764
3	K. B. Chetri	Jajarkot	51137	2.34	22099	26425	1.21	20110
4	S. M. Shrestha	Rukum	81671	1.86	23529	15768	0.36	8000
5	K P Dhakal	Jajarkot	105264	2.18	20677	30485	0.63	10545
6	B. M. Bhabuk	Rukum	36939	3.24	18325	9141	0.80	13377
	Total		86289	3.88	31123	35127	1.58	22124

Annex - 4E: Analysis with Respect to Operation Practices

		Size (kW)	Services Rendered	Operating Practice
1	R. Karki	22	O, H, G	Multiple Load
2	D. R. Regmi	8.5	O, H, G	Multiple Load
3	K.B. Khadka	30	O, H, G, E	Multiple Load
4	R. C. Sapkota	10	O, H, E	Multiple Load
5	T. N. Kandel	5	O, H	Multiple Load
6	S.S.Rai	19	O, H, G	Multiple Load
7	K.B.Bhandari	5	O, H, E	Multiple Load
8	N D Shahi	7.2	O, H, G	Single Load
9	L Sunwar	8	H, G	single
10	SFDP	10.8	O, H	Multiple Load
11	K.B.Thapa	6	O, H	Single Load
12	J. S. Rokaya	5	O, H	2 at a time
13	Bhadaure	1	E	Single Load
14	Angaha	13	O, H, G, E, *	Multiple Load
15	Yagya Rice Mill	10	O, H, G, E	Multiple Load
16	Ghandruk	50	O, H, G, E, **	Multiple Load
17	Khakpa Ginje Sherpa	16	H, G, E, **	Multiple Load
18	K.B. Sunwar	14	O, H, E	Multiple Load
19	K. K. Subedi	13	O, H, G, E	Multiple Load
20	D. P. Ghale	9.8	O, H, G, E, *	Multiple Load
21	Barpak	50	O, H, G, E, **	Multiple Load
22	L. P. Khatiwada	20	H, G	Multiple Load
23	H. B. Gurung	4.6	O, H, G, E	Single Load
24	M. K. Shrestha	10	O, H, G, **	Single Load
25	F. N. Dhakal	21	O, H, G	Multiple Load
26	S. Thakuri	16	O, H, G, E, *	Multiple Load
27	P. B. Shahi	8	O, H, G	Multiple Load
28	B. P. Sharma	8	O, H, G, E	Single Load
29	D.B Bohora	11.5	O, H, G, E, *	2 at a time
30	P. B. Karki	4.5	H, G	Multiple Load

Source: Field Survey

Annex - 6A: Brief Description of Cross-flow Turbine models T1 - T12

Model Name	*Description/Improvement*
T 1	Hand regulated, drive flat belt transmission to operate agro-processing machinery such as flour mills, rice huskers and oil expellers.
T 2	Low cost design. The expensive housing was omitted to an extent to cut cost. This resulted in having water splashing all around the equipment, increasing the humidity in the mill house and spoiling the flour. This design is obsolete
T 3	A compact design and the first machine with a butterfly valve to regulate flow. The bearing concept is under-designed and not suitable for outputs higher than 20 kW
T 3 M	A redesigned version of T3 overcoming the flaws of its predecessor
T 4	Has circular ring for flow regulation. It was the first turbine with automatic governor control and used in village electrification project.
T 5	It is basically an enlarged T 3 model. However, the machine size was not adequate for the production facilities available in Nepal. The design was obsolete.
T 6	Suitable for governor control, having a butterfly valve as flow regulating device. The machine is much stiffer than previous designs, therefore, it has lower vibration and noise level during operation. It has a good design for high specific discharge
T 7	It is the first model with fully machined turbine blades in order to increase the efficiency. But this advanced technology led to runner failure due to fatigue stress problems. By now this design is also obsolete.
T 8	Replaced the T7 design. It is a fully tested machine with known characteristics. This allowed to define the application range and to standardise the design.
T 9-11	These are test models for the following T12, with all performance tests executed at the University of Hong Kong, The design adheres to the concept of the T8 series with a modified hydraulic profile and secured quality control to guarantee the exchangeability of spare parts
T 12	Emphasises longevity, rugged design, utilises new concept to ventilate the jet (free jet approach and is specially suited for flow control

Annex - 6B: Chronology of Technology Development of Mini-Micro-Hydropower in Nepal

Year	*Events*
by 1960	1. Different overshot and undershot water wheel construction, with horizontal axis, made of wood and later metal by KMI
	2. Improved grinding devices by KMI
1962/64	Fabrication and installation of first propeller turbine, horizontal axis, made by BYS
1973	Development and installation of first cross-flow turbine by BYS
1974	Development of a cross-flow turbine by BTI
1975	1. Initiated work on hydraulic governor by BYS
	2. Development of pelton turbine by BTI
1976	1. Installation of first cross-flow turbine by BTI/BEW
	2. Development of cross-flow turbine by NYS
1978	1. Cross-flow turbine installed for rural electrification by BYS
	2. Development of Mini-Pelton turbine by KMI
	3. Trials with a power take-off from a traditional water mill by KMI

Chronology of Technology Development of Mini-Micro-Hydropower in Nepal

(Continued)

Year	Events
1980	1. Metal construction of Multi-Purpose Power Unit-(MPPU) by KMI
	2. Development of open cross-flow turbine by KMI, NYS, NSECO
1981	1. Design and Installation of Cross-flow turbine T-3 model by BYS
	2. First Cross-flow turbine by TEW
	3. First MPPU installed by NSECO
	4. Construction of a vertical axis propeller turbine by NYS
	5. Construction of Petrol-drum propeller turbine by KMI
1982	1. Construction of a wooden cross-flow turbine by KMI
	2. Development and construction of a Turgo Impulse water turbine by KMI, NSECO
	3. Development and construction of a wooden water mill curved blades (wooden pelton)
	4. Construction of Segner's wheel by BYS
	5. First electrification by NYS
	6. First electrification from MPPU by KMI
1983	1. Development and installation of first split-flow turbine by BYS
	2. First cross-flow turbine installed by KMI
	3. First stand alone electrification unit produced by BEW
	4. First add-on generator installed by DCS
	5. Development and construction of a propeller turbine in a scroll case by KMI
	6. Development and construction of a mini poncelet water wheel by AEW
1984	First installation of T-7 cross-flow turbine by BYS
1985	Electric motor converted to induction generator by KMI
1986	1. Redesign of MPPU by NSECO
	2. Cross-flow turbine with double inlet-valves produced by TEW
1987	Production of cross-flow turbine by NMSS
1988	Pelton wheel on a 1 kW induction generator tested by DCS
1989	1. 50 kW stand -lone electrification plant installed by DCS
	2. Training Course held in Nepal to explain and demonstrate theory, operation, construction and manufacturing of ELC, Engineer Ben Van Wijhe acted as resource person (ELC Jointly invented by Gerry Pope of GP Electronics and Rupert Evans of Evans Engineering in UK. Awarded International Inventor's Award in 1986), the training was conducted by ITDG
1990	1. Peltic set developed by KMI
	2. 50 kW electrification with Pelton wheel installed by KMI/NPP
	3. Developed T-12 cross-flow turbine by BYS
	4. ITDG Nepal started making available Mark GP ELC to Nepali manufacturers
1992	1. 100 kW stand-alone rural electrification project initiated by DCS
	2. Design, manufacture and commissioning of 250 kW Francis turbine by NHECO
	3. High tension lattice transmission line towers tested and developed by NHECO
1994	1. Agreement between ITDG Nepal and Gerry Pope to transfer the technology to Nepali manufacturer. Training on ELC technology transfer held in co-operation with DCS in October. Three Nepali manufacturer were entitled to manufacture

Source: Field Survey

ANNEX - 7A: SCALE DIVISION OF INDUSTRIES

(as per Clause 4.3 Industrial Policy 1992)

1.Traditional Cottage industries:
Labour Intensive , Traditional Industries based on Art and Culture and special skill, utilising local raw materials or resources as specified below

2.Small Scale Industries:
Industries Other than Traditional Cottage Industries with Fixed Capital investment not exceeding NRs. 10 million.

3. Medium Scale Industries:
Industries with fixed capital investment of more than NRs. 10 million and less than NRs. 50 million.

4.Large Industries:
Industries with fixed capital investment of more than NRs. 50 million.

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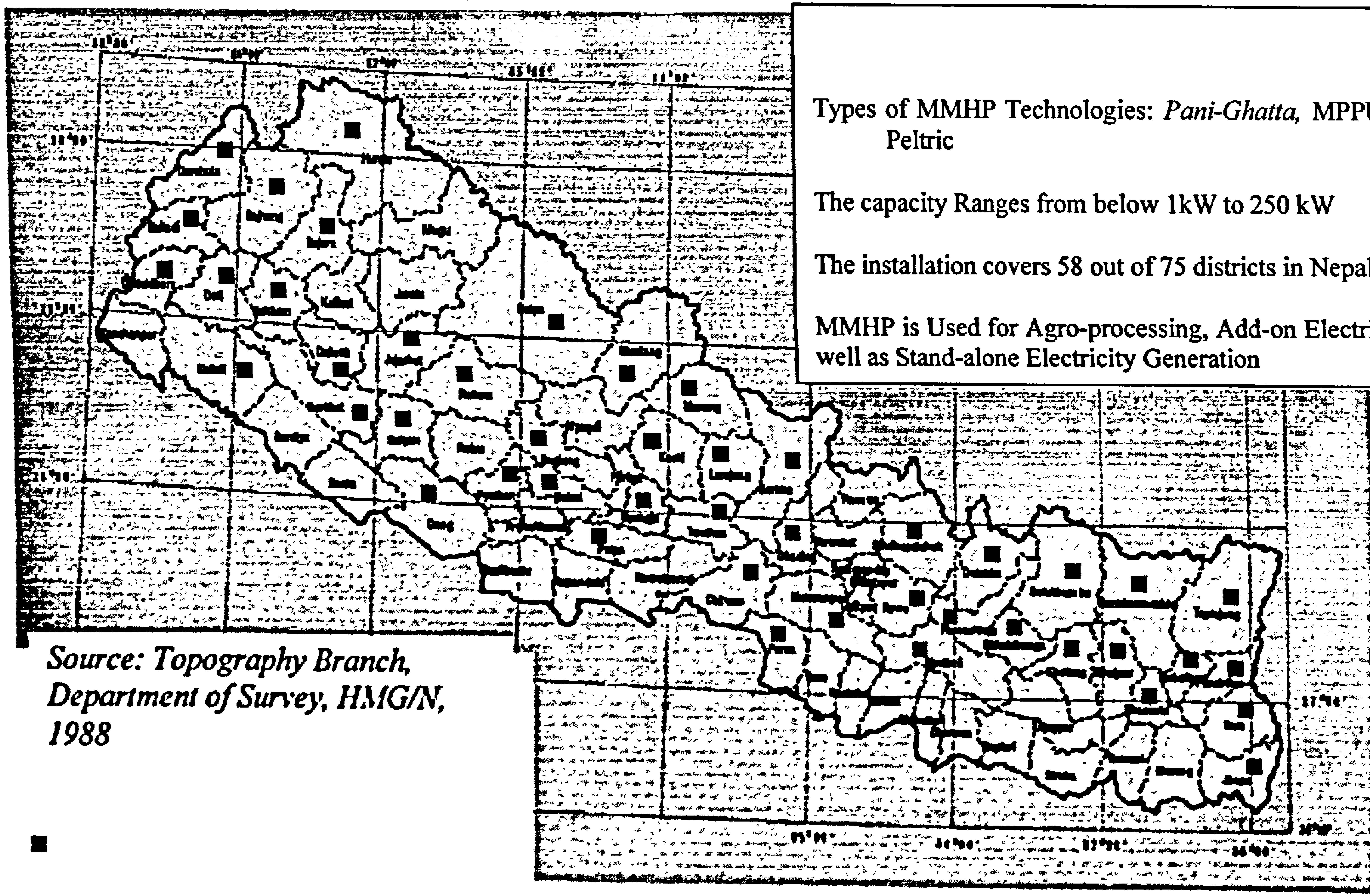
MAP 1.1: Mini-Micro-Hydro Plant Installations



Types of MMHP Technologies: *Pani-Ghatta,* MPPU, Cross-flow and Peltric

The capacity Ranges from below 1kW to 250 kW

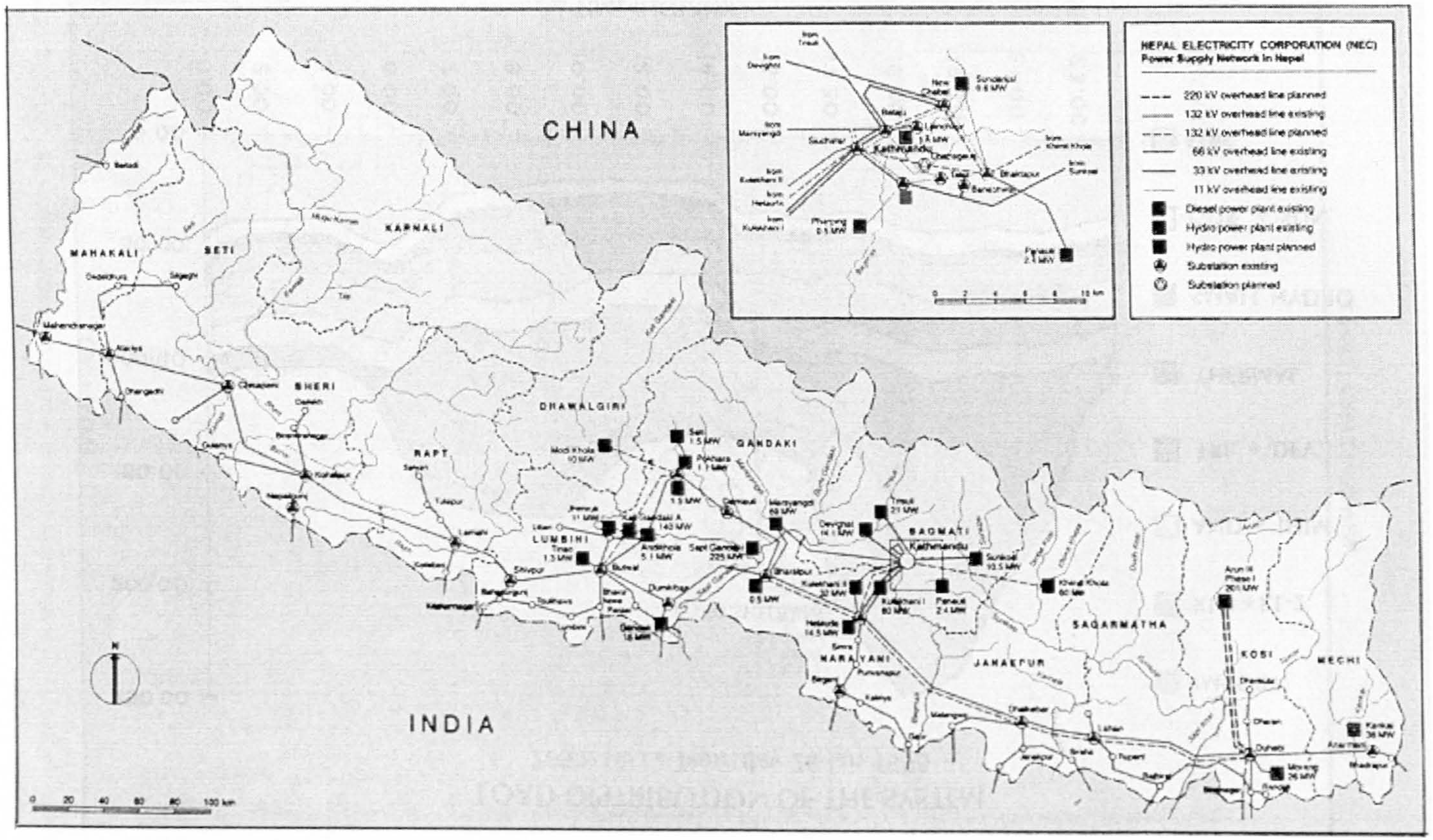
The installation covers 58 out of 75 districts in Nepal

MMHP is Used for Agro-processing, Add-on Electricity Generation as well as Stand-alone Electricity Generation

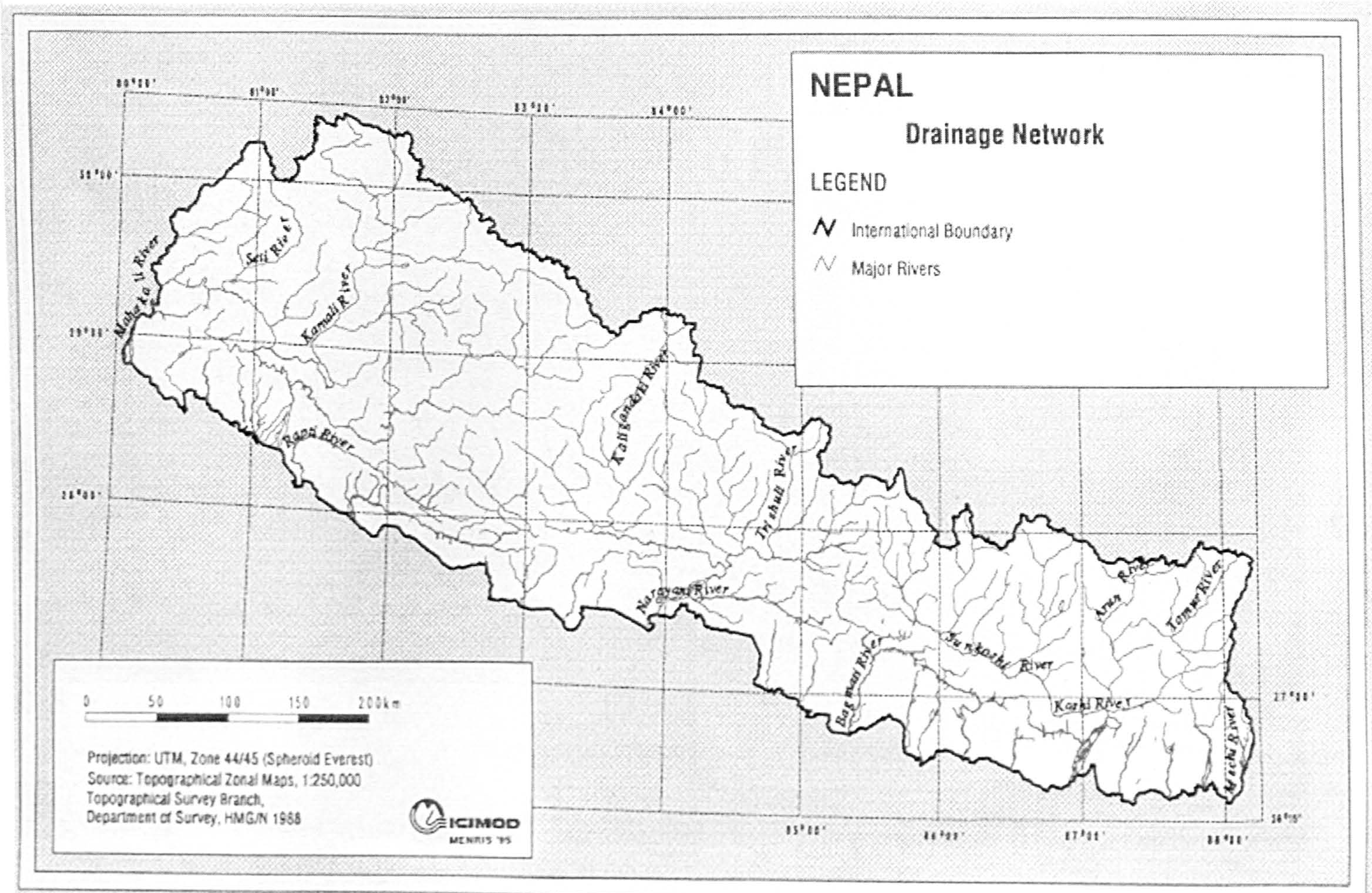
Source: Topography Branch, Department of Survey, HMG/N, 1988

■

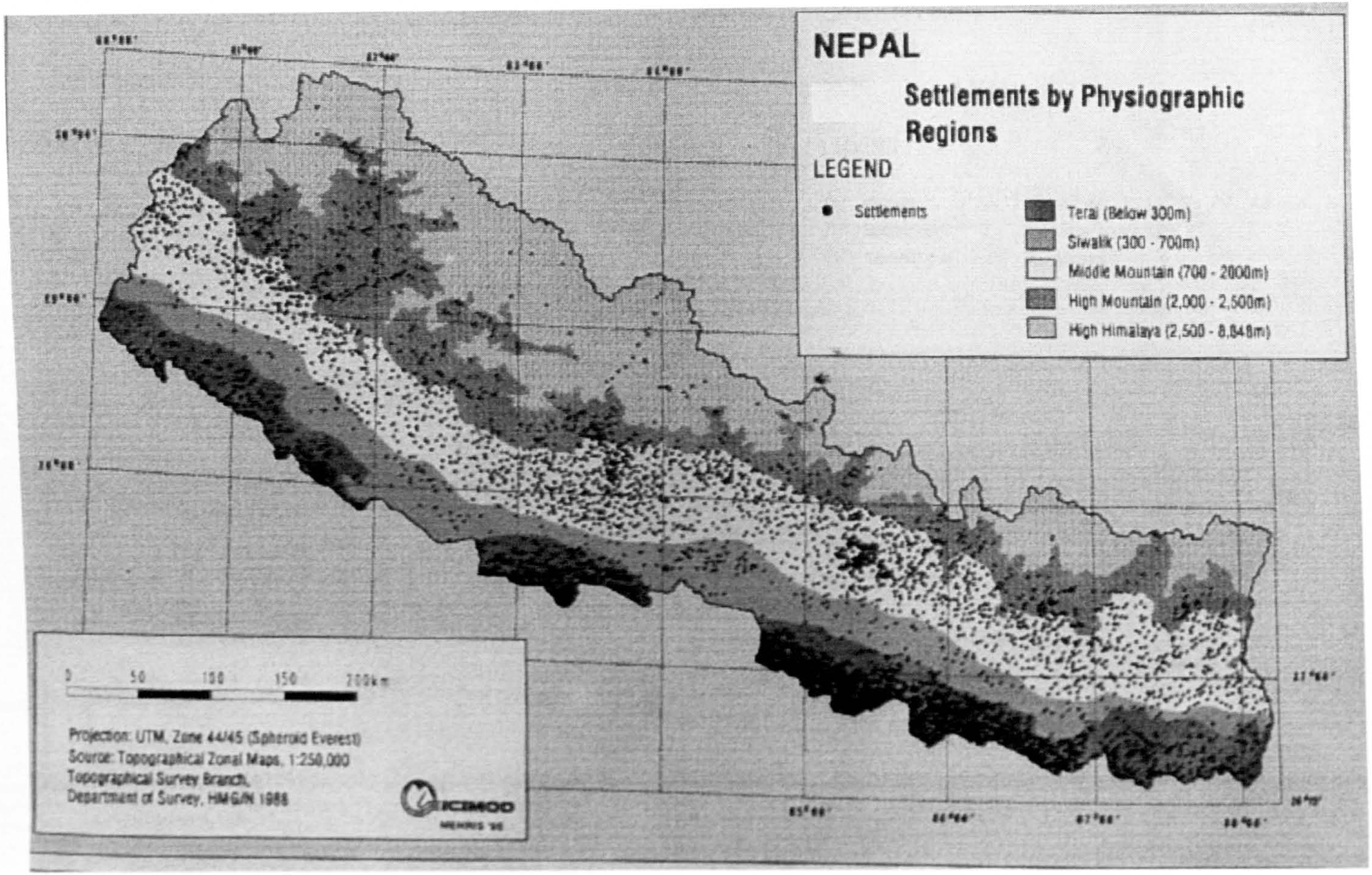
MAP 1.2: The Existing National Grid Electricity System in Nepal



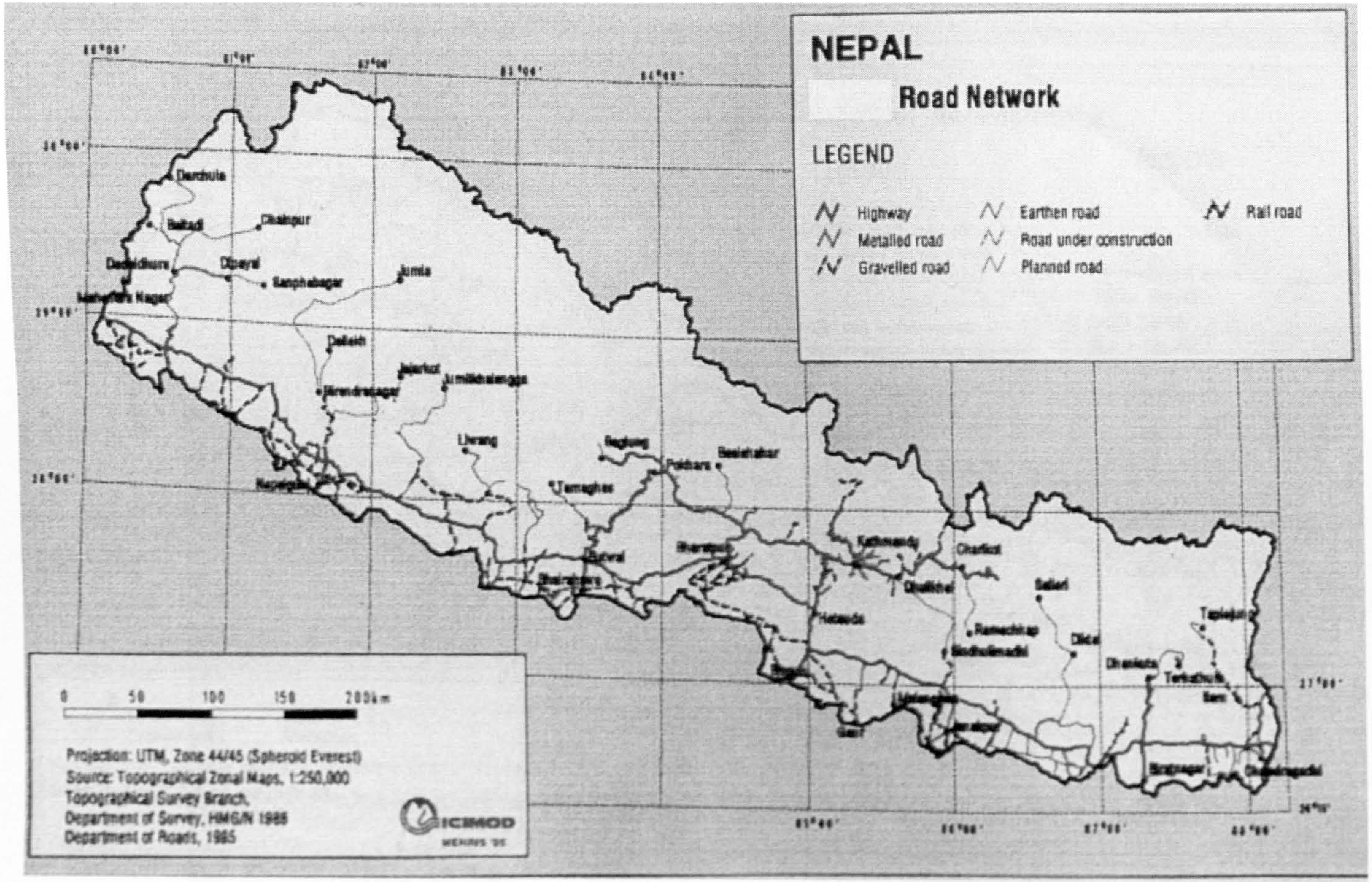
MAP 1.3: The Distribution of Water Resources in Nepal



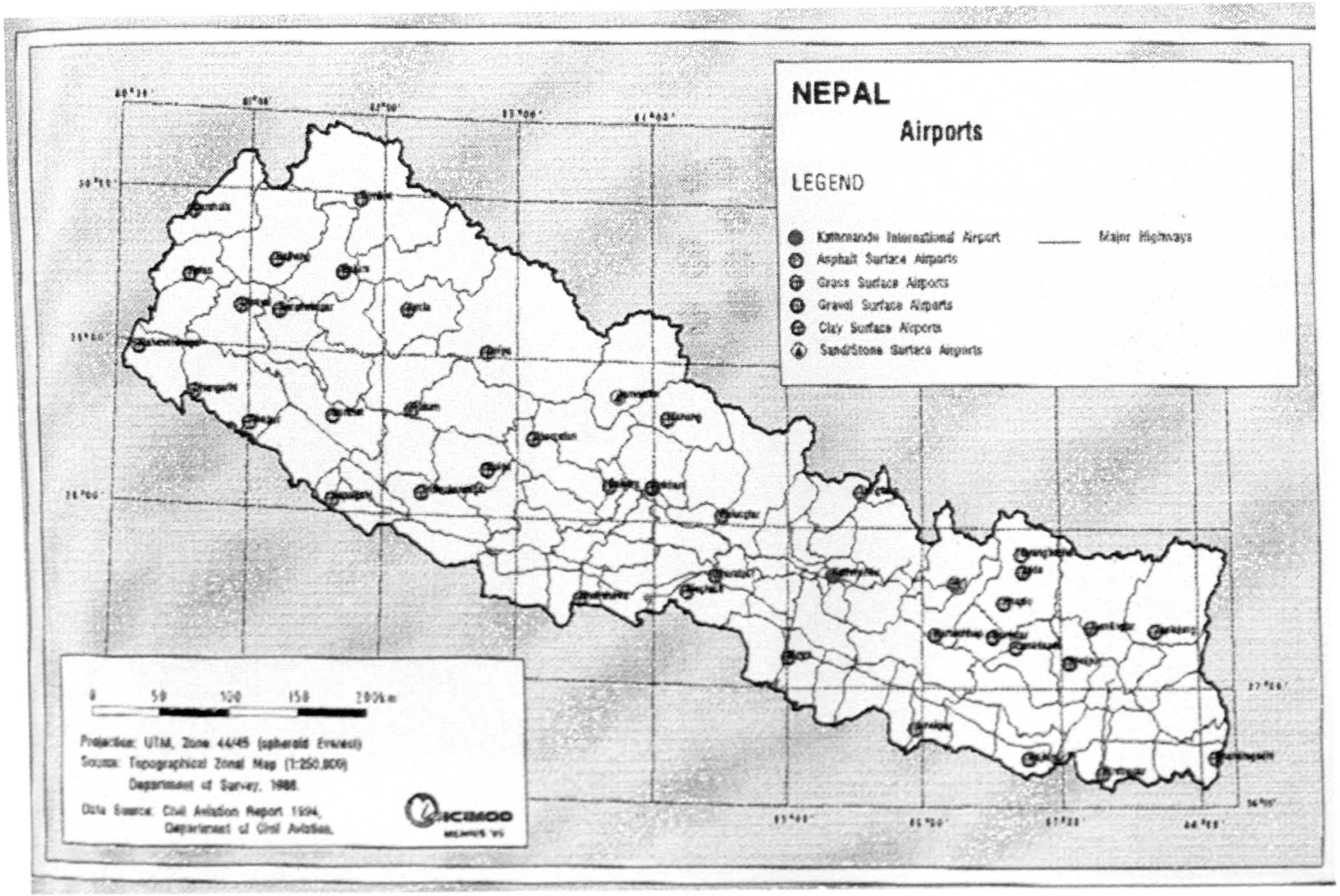
MAP 2.1: Settlement By Physiographic Regions



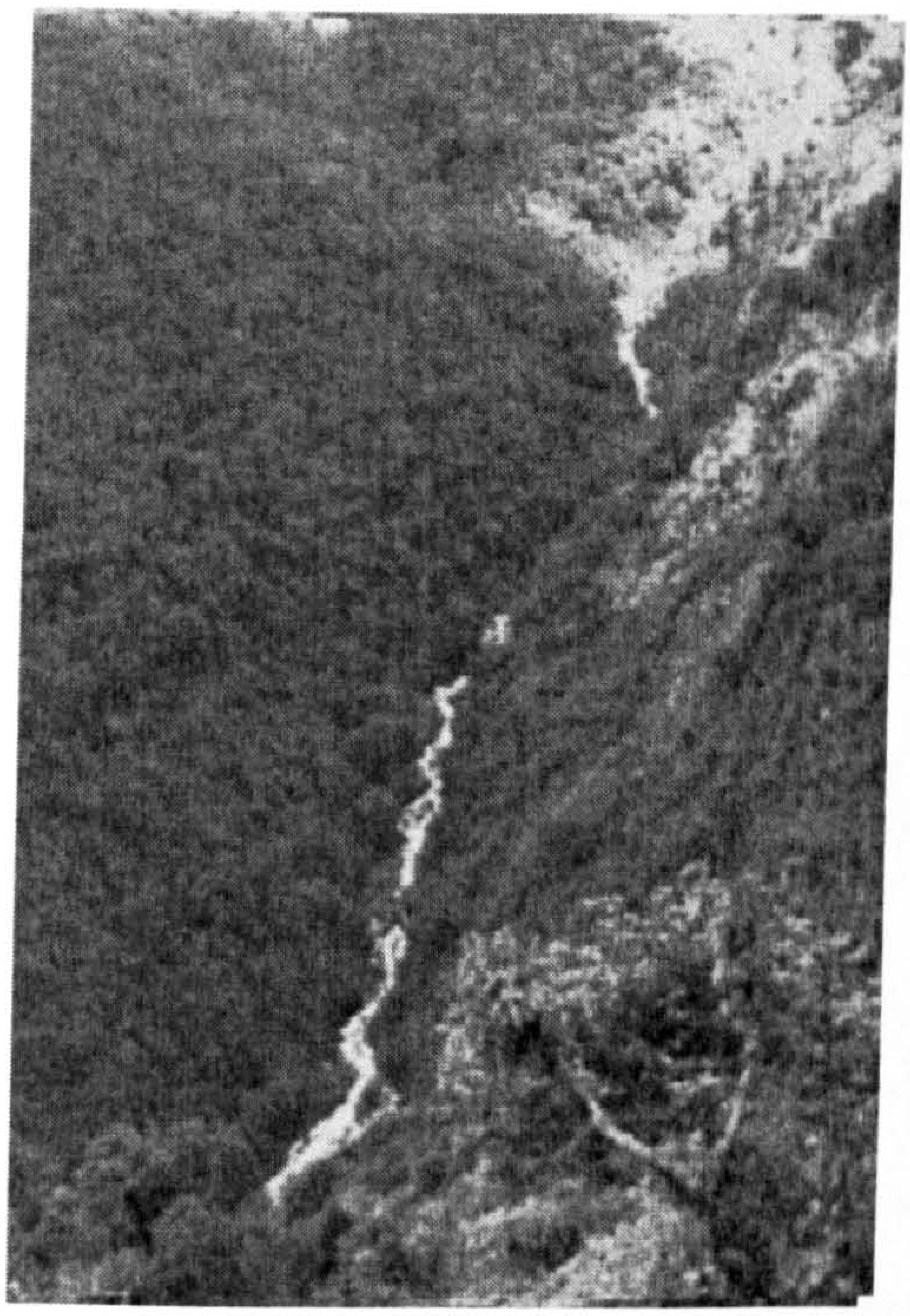
MAP 3.1: The Roads Network Distribution in Nepal



MAP 4.2: The Distribution of Airports in Nepal



Available Water Resources and Typical Mini-Micro Hydro Sites



One of the Widely Available Streams

Stream Diverted for Intake

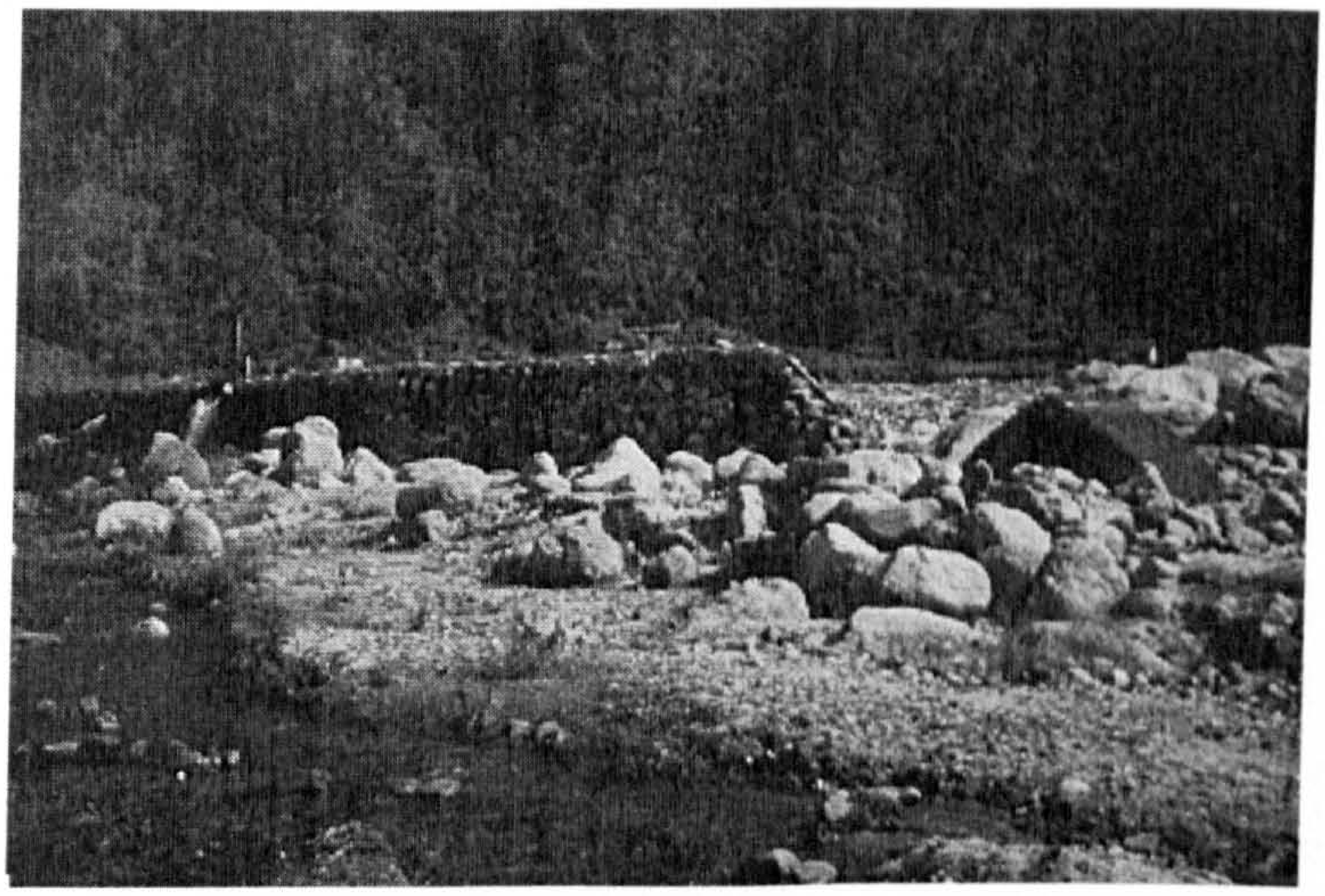
Intake System

Local Participation at Construction Phase

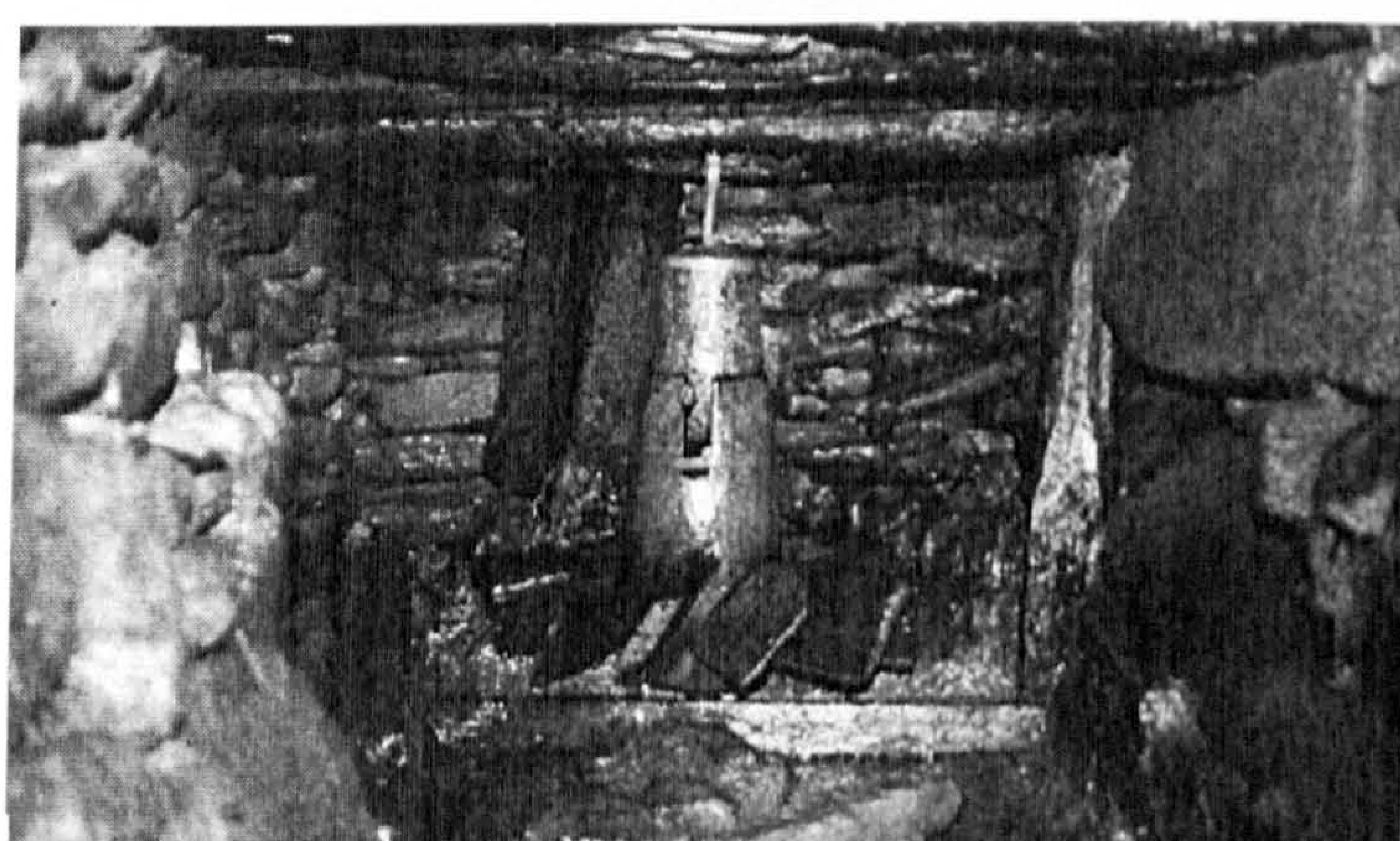
MMHP Installation

Traditional *Ghatta* Being Replaced by MMHP

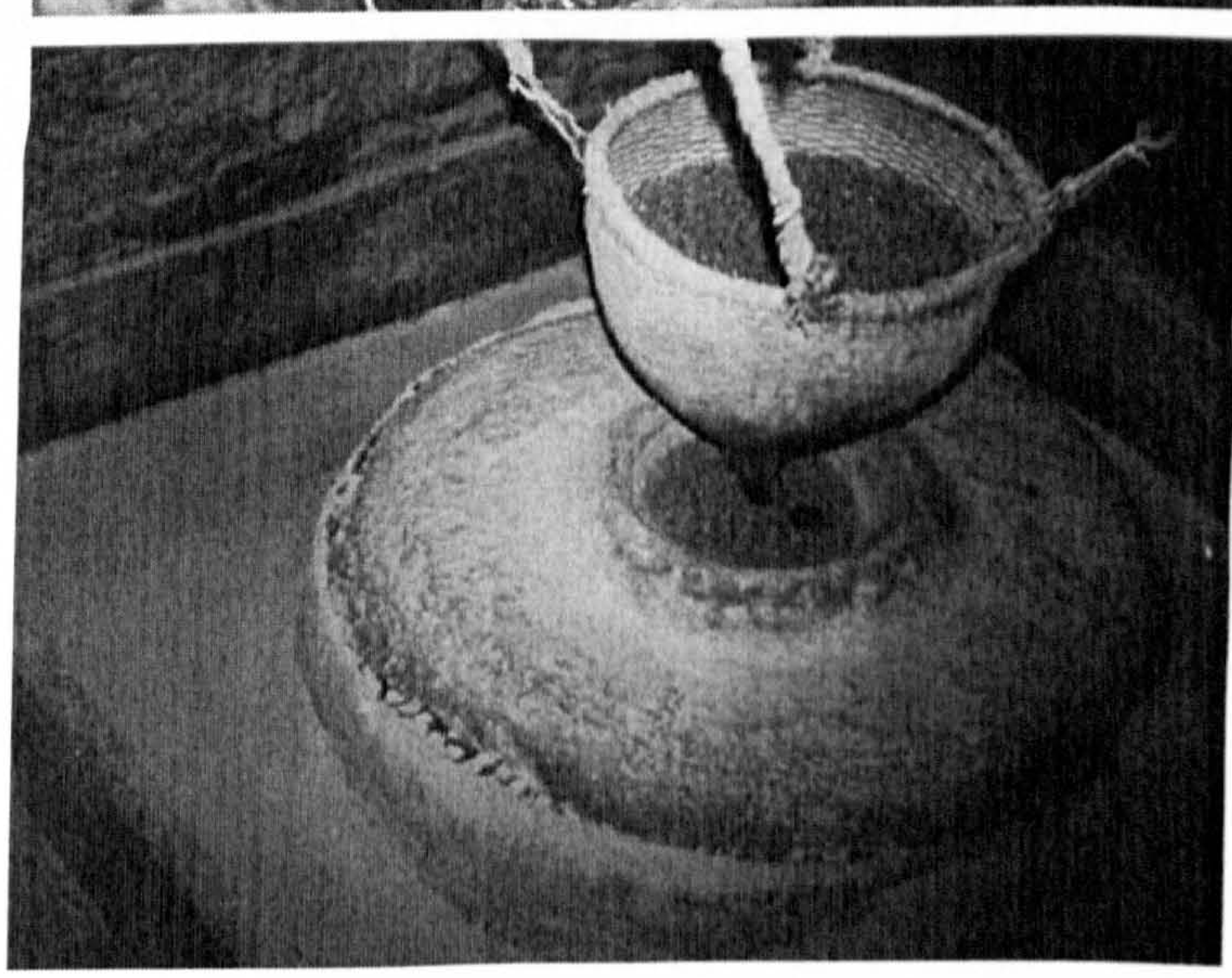
TRADITIONAL *PANI - GHATTA*



Typical Site for Traditional *Pani-Ghatta*



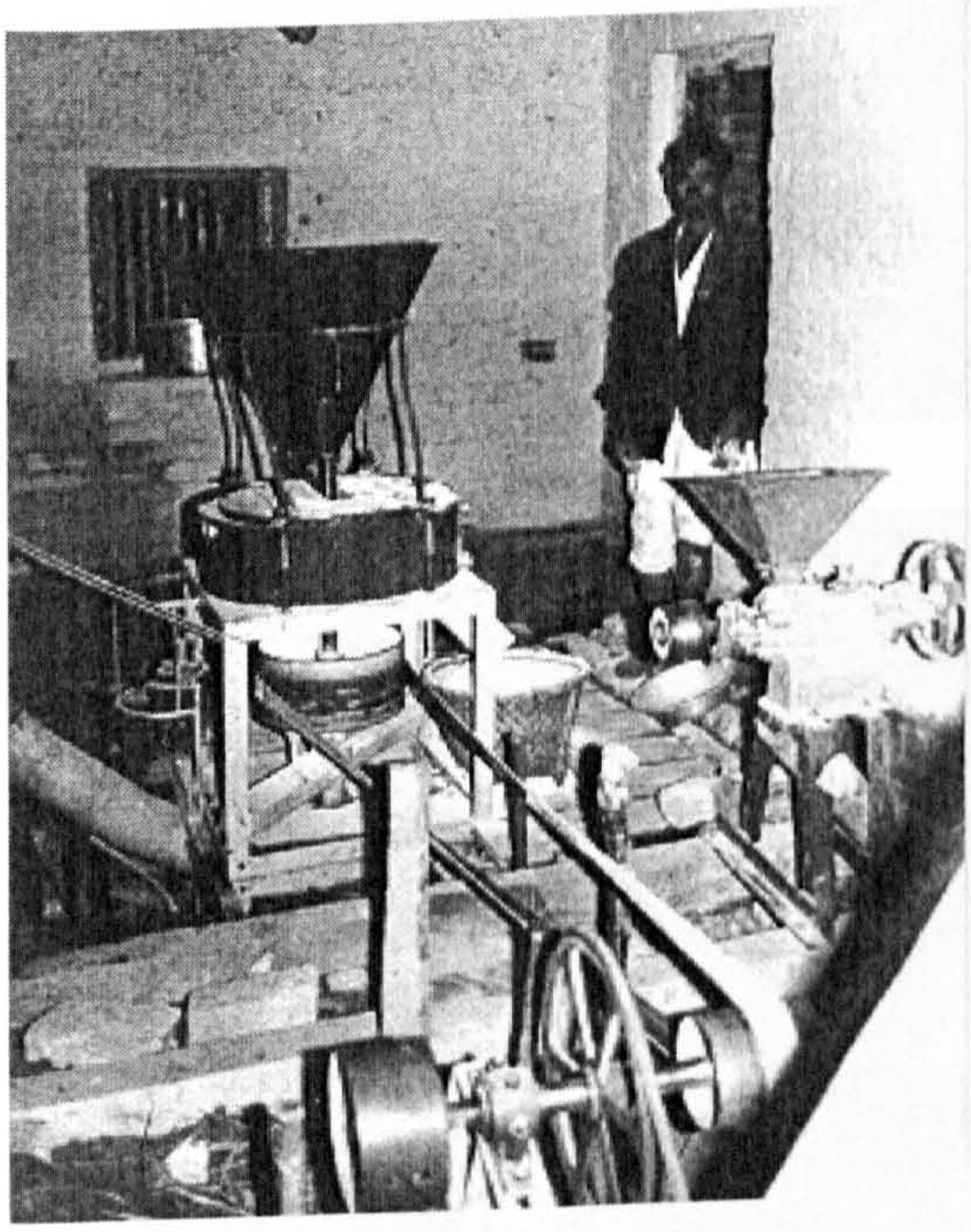
Pani-Ghatta Runner



Traditional Grinder Powered by *Pani Ghatta*

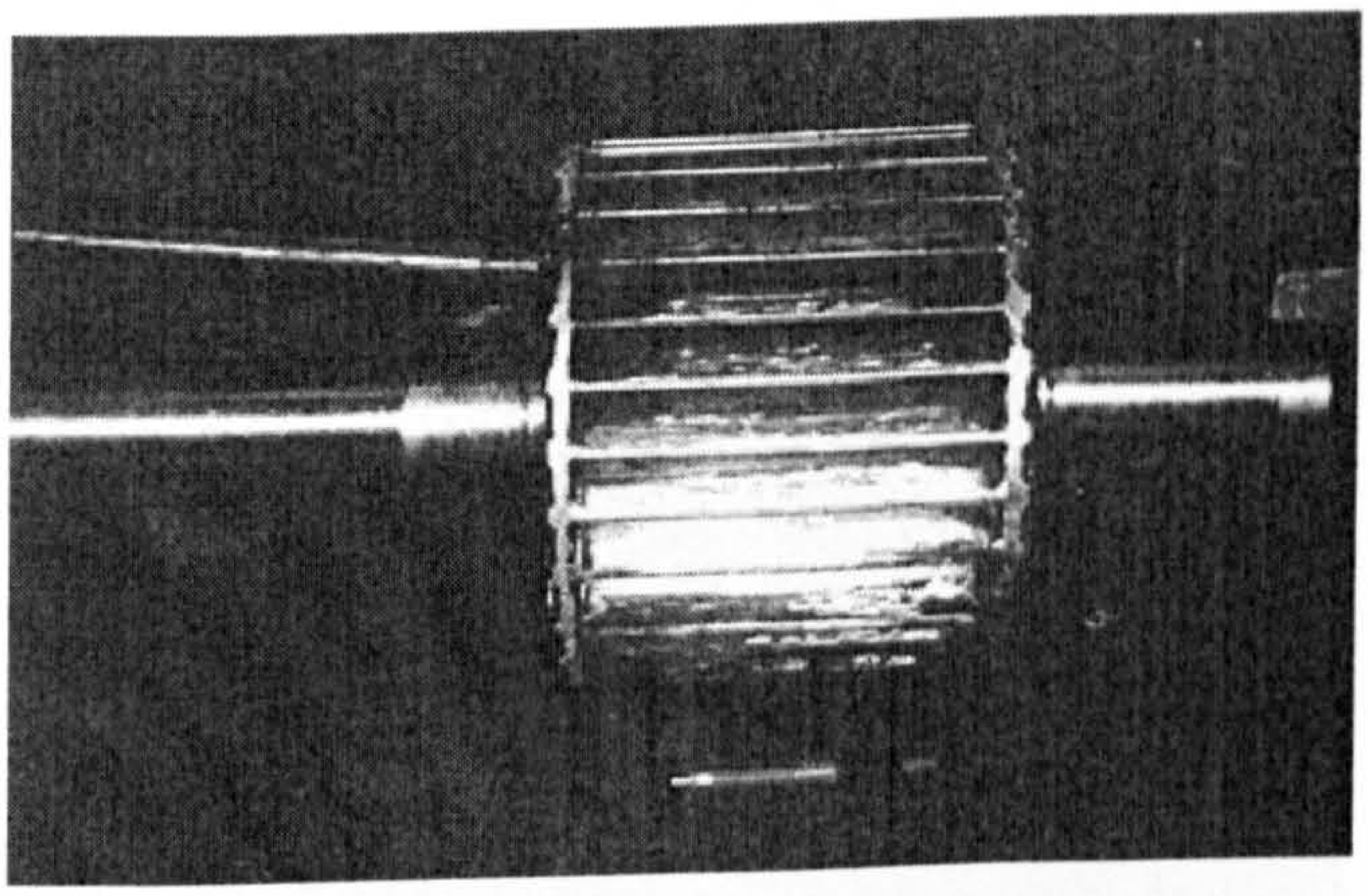
MULTI-PURPOSE POWER UNIT (MPPU) System

MPPU with Penstock Pipe

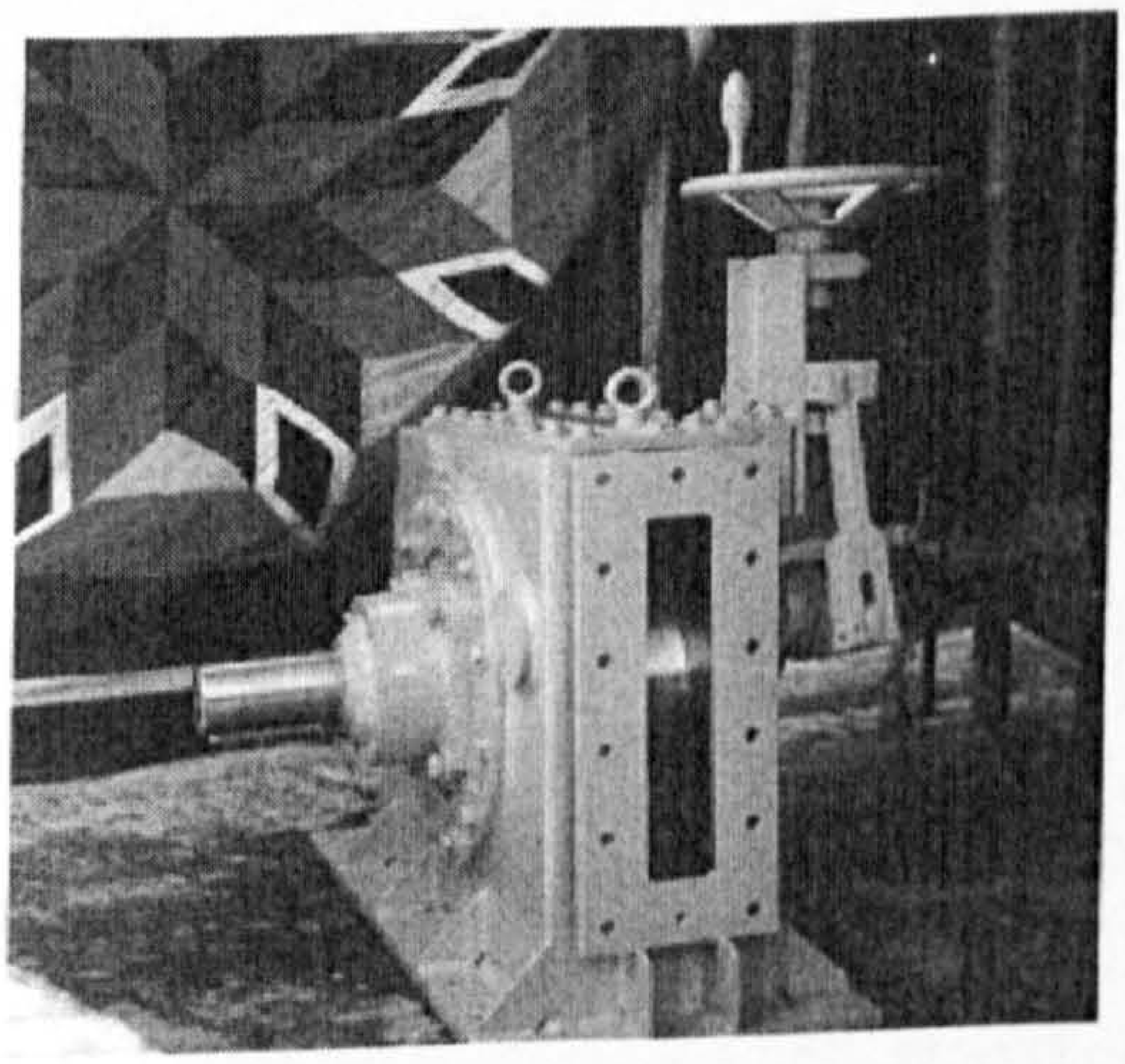


MPPU with Grinder and
Power-Take-off System

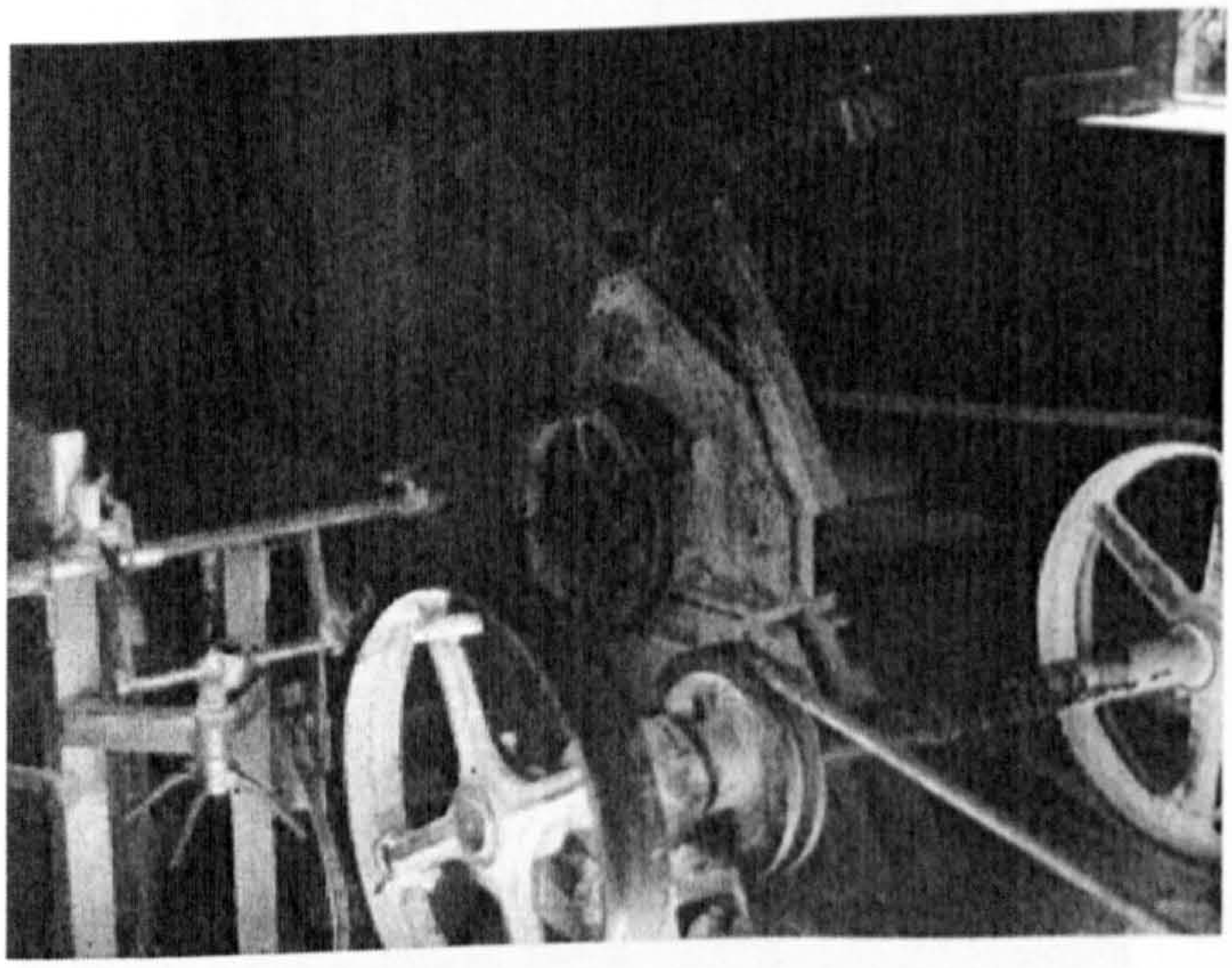
CROSS-FLOW TURBINE SYSTEM



Cross-Flow

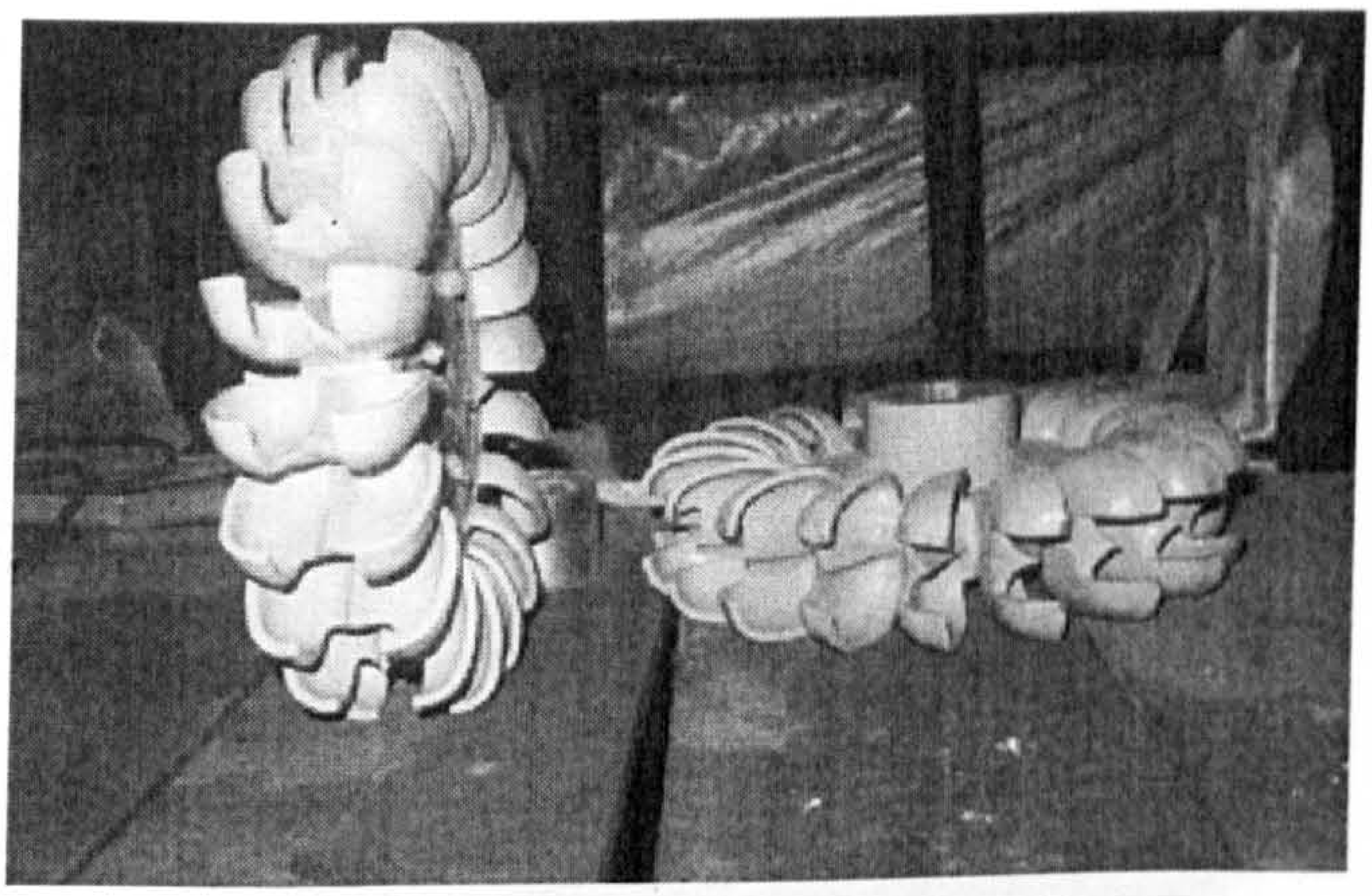


Cross-Flow Turbine Set



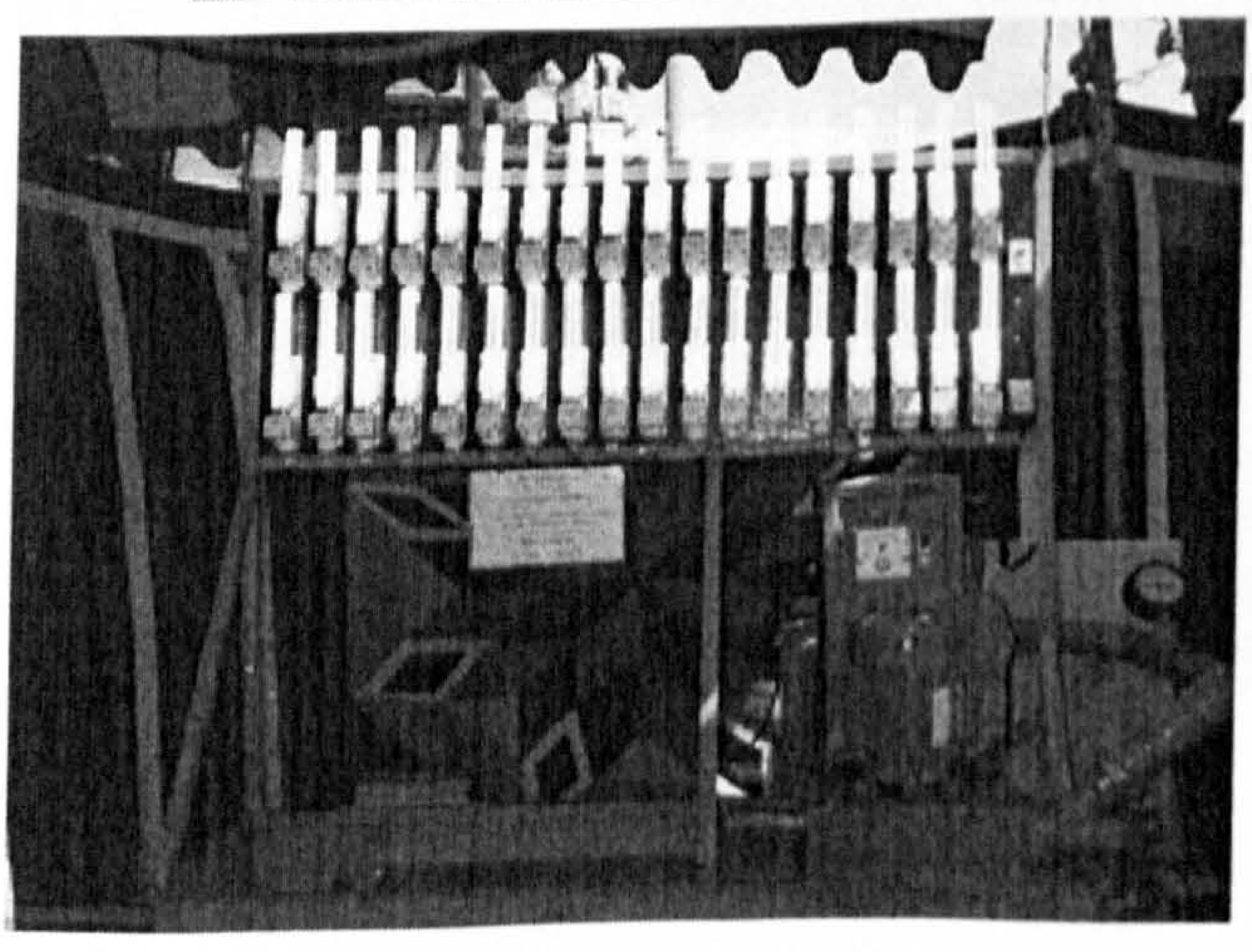
Cross-Flow System with Multiple Power Take-off System

PELTON RUNNER AND PELTRIC SET



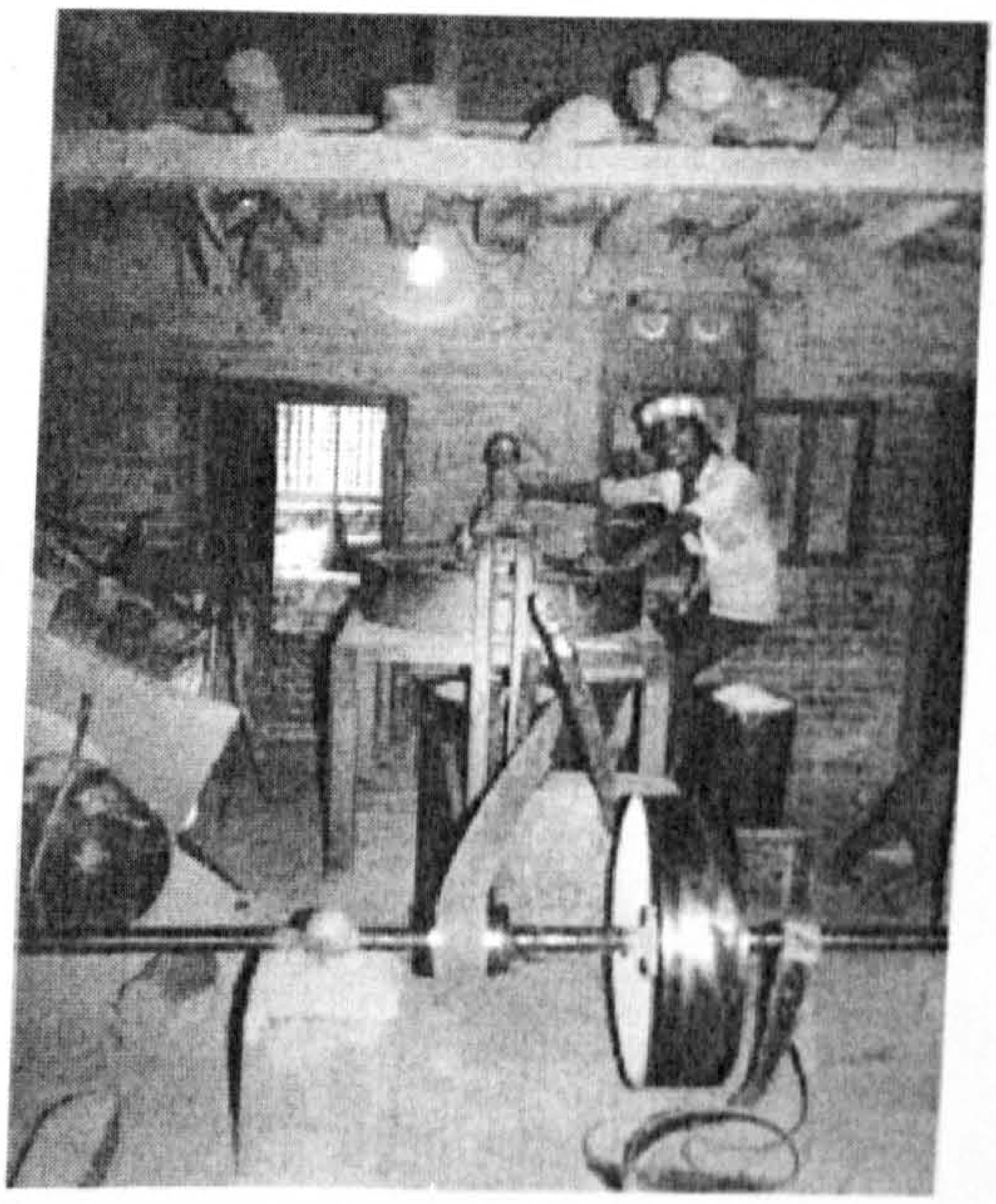
Peltric Runner

Pelton Wheel with Double Inlet-Nozzles



Peltric Set with 36 PL Lamps

VARIOUS END-USES OPERATED ON MMHP



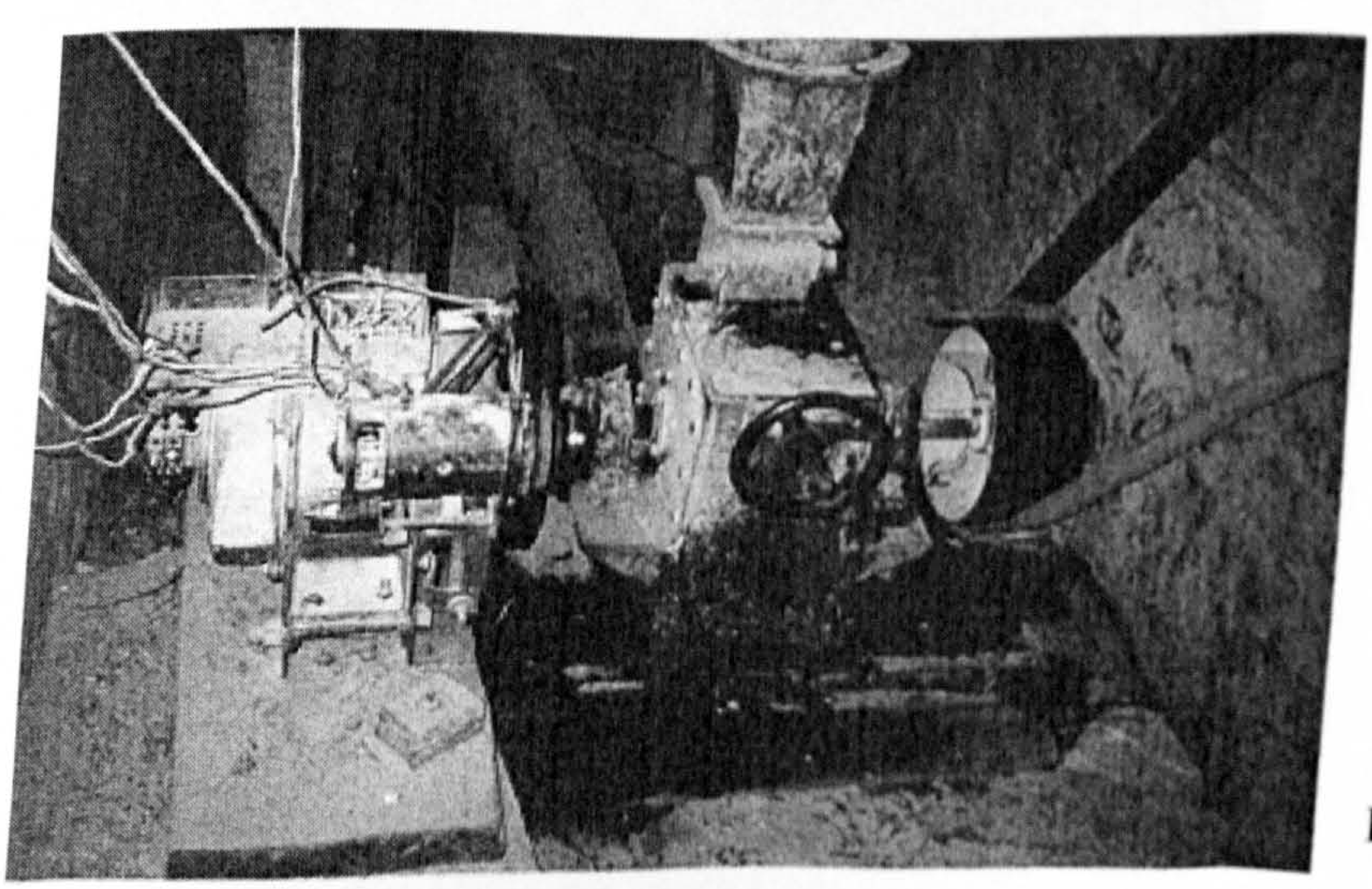
Grinder and Electricity

Rice-Huller

VARIOUS ENDUSE EQUIPEMENT OPERATING ON MMHP

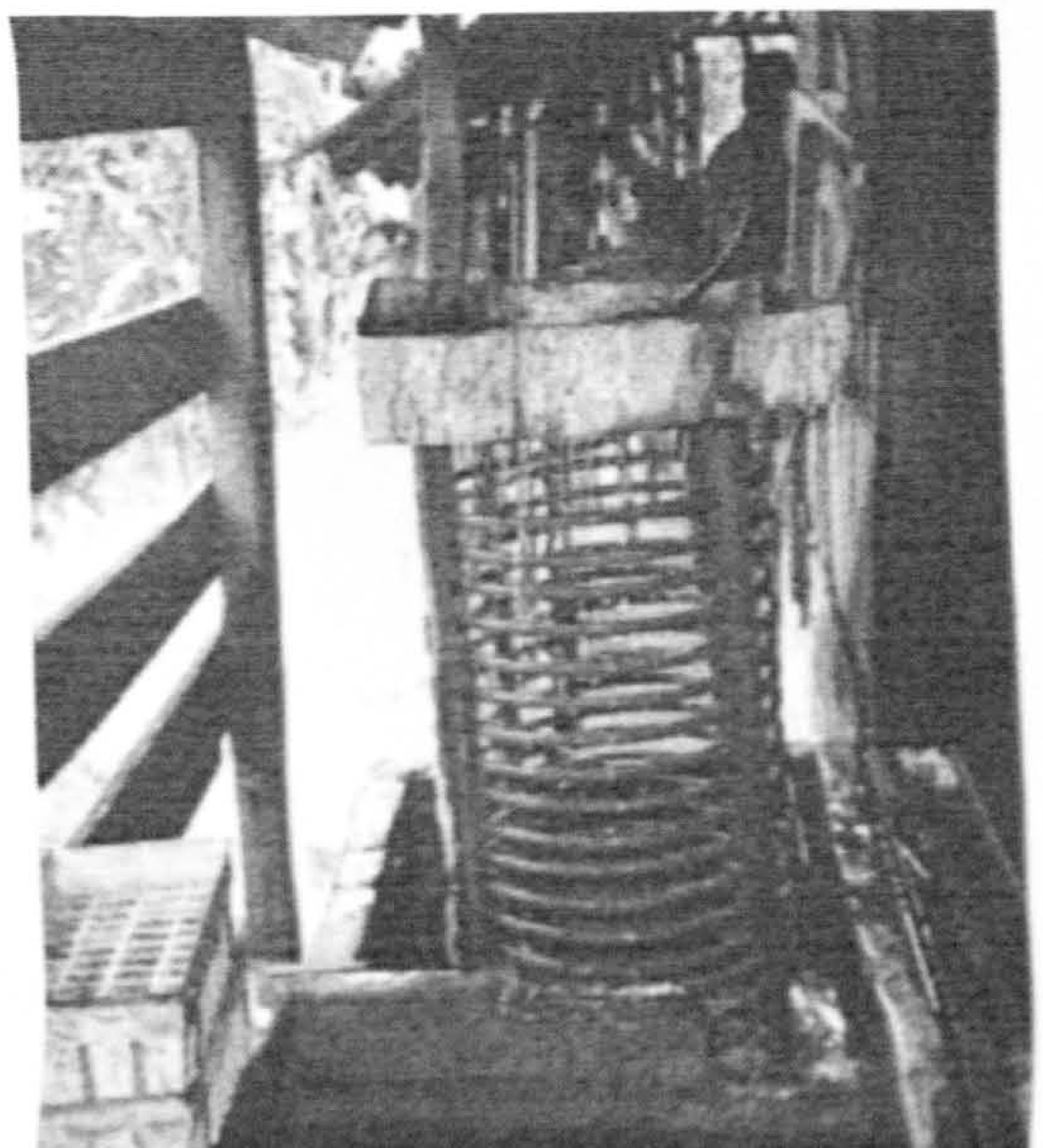
Oil Expeller

Sheller and Polisher

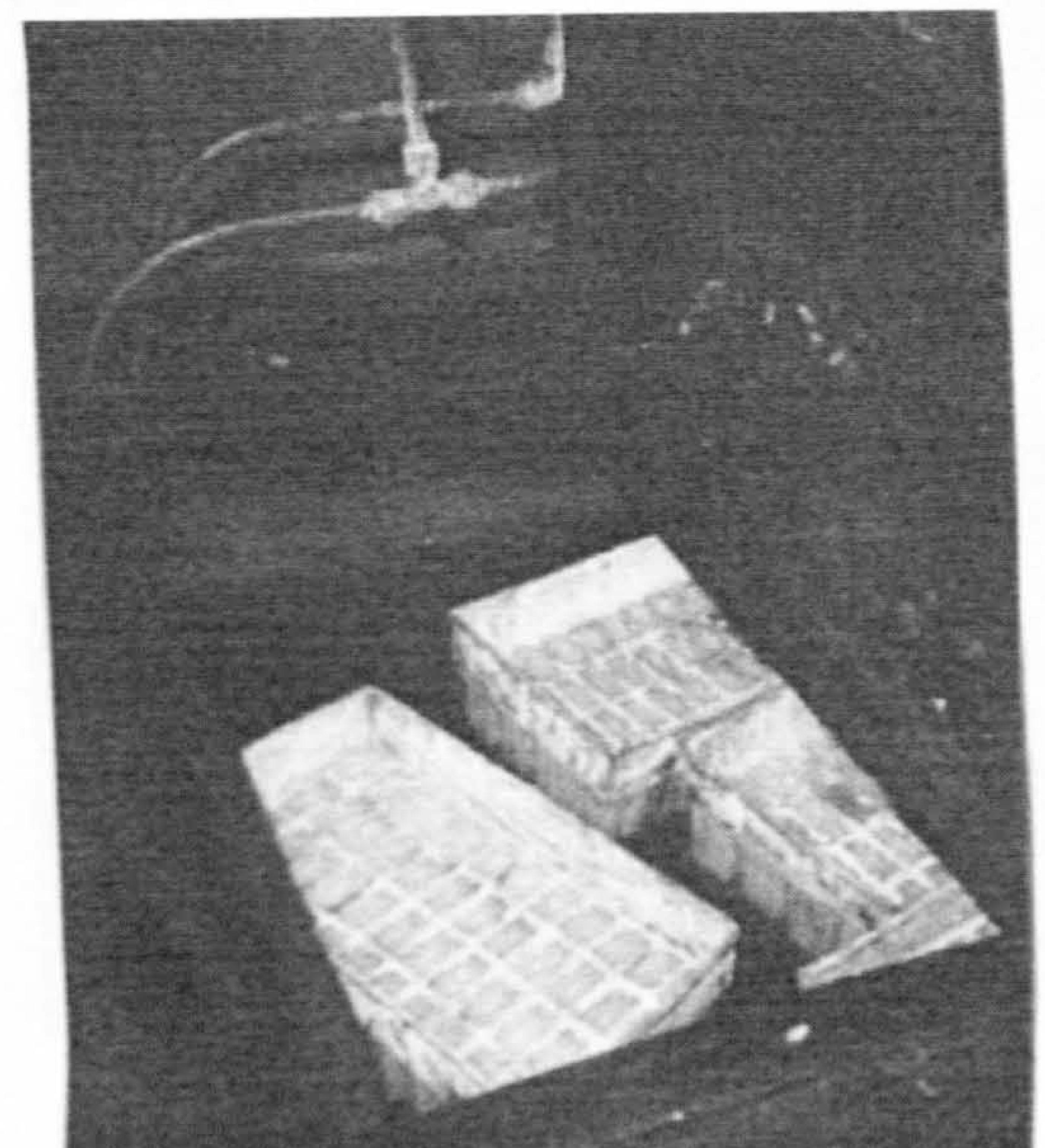


Electric Generator

VARIOUS END - USES OPERATED ON MMHP

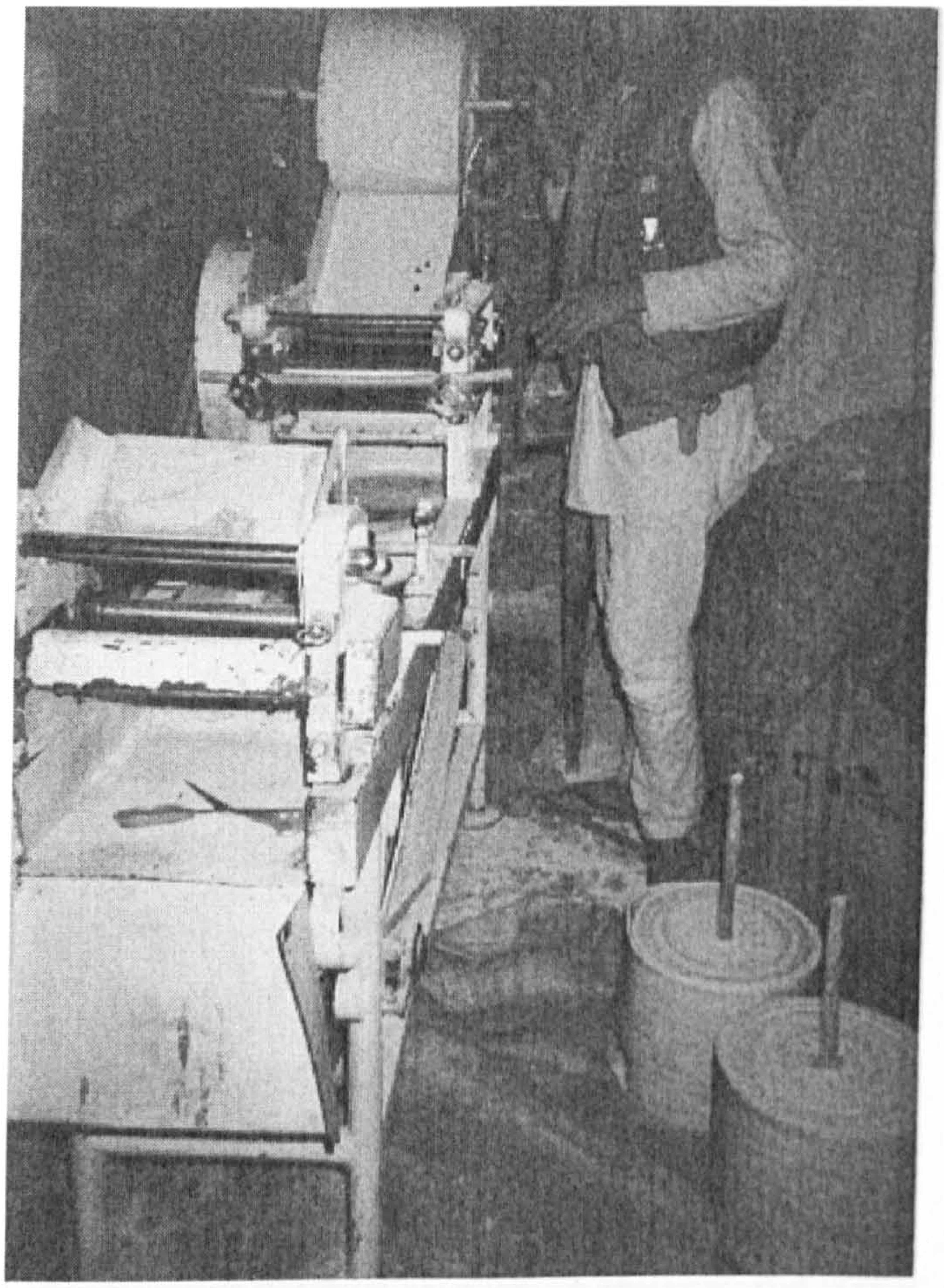


Ice-Making



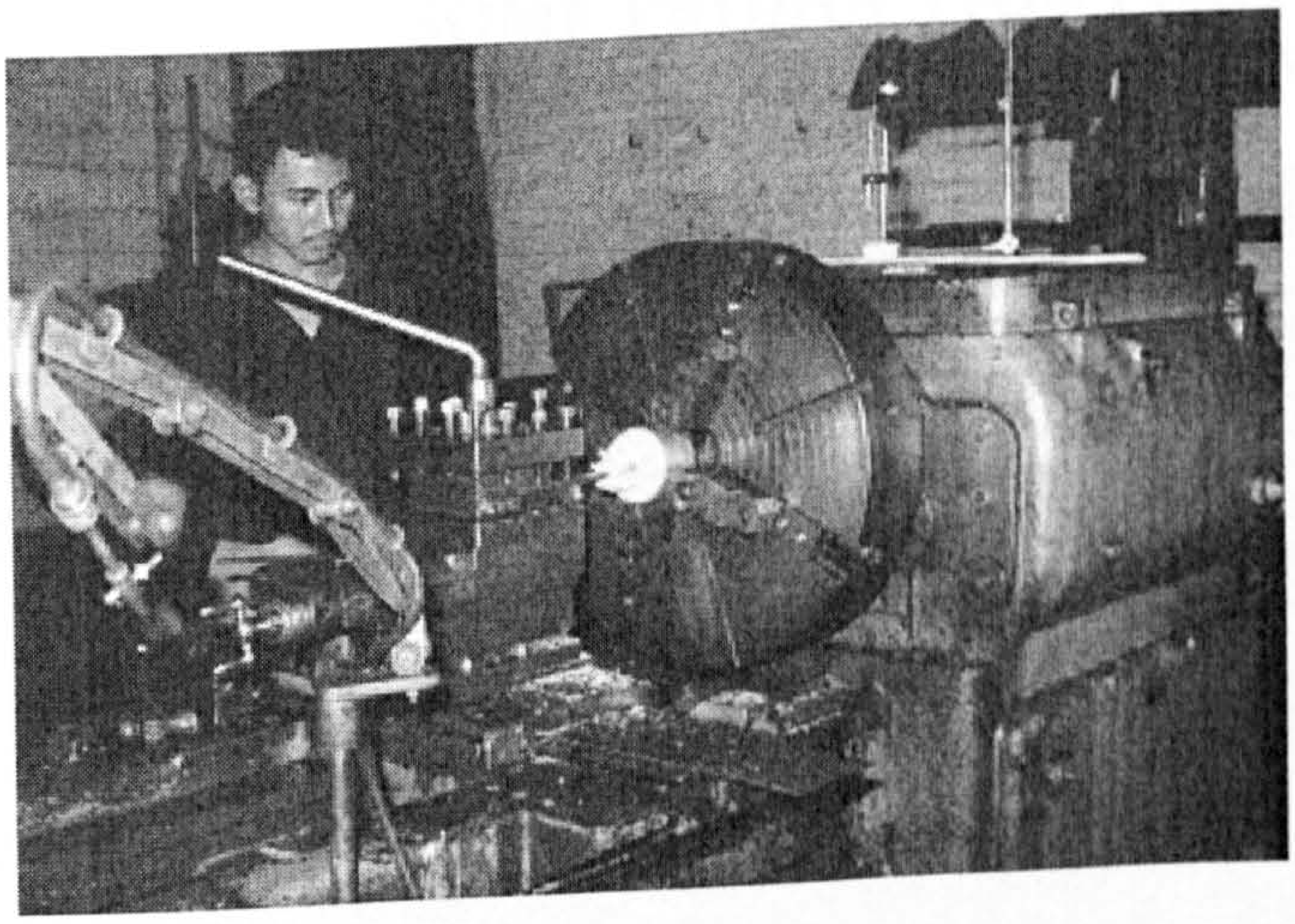
Ice-Cubes/Ice Cream

Turbine-Pump for Irrigation

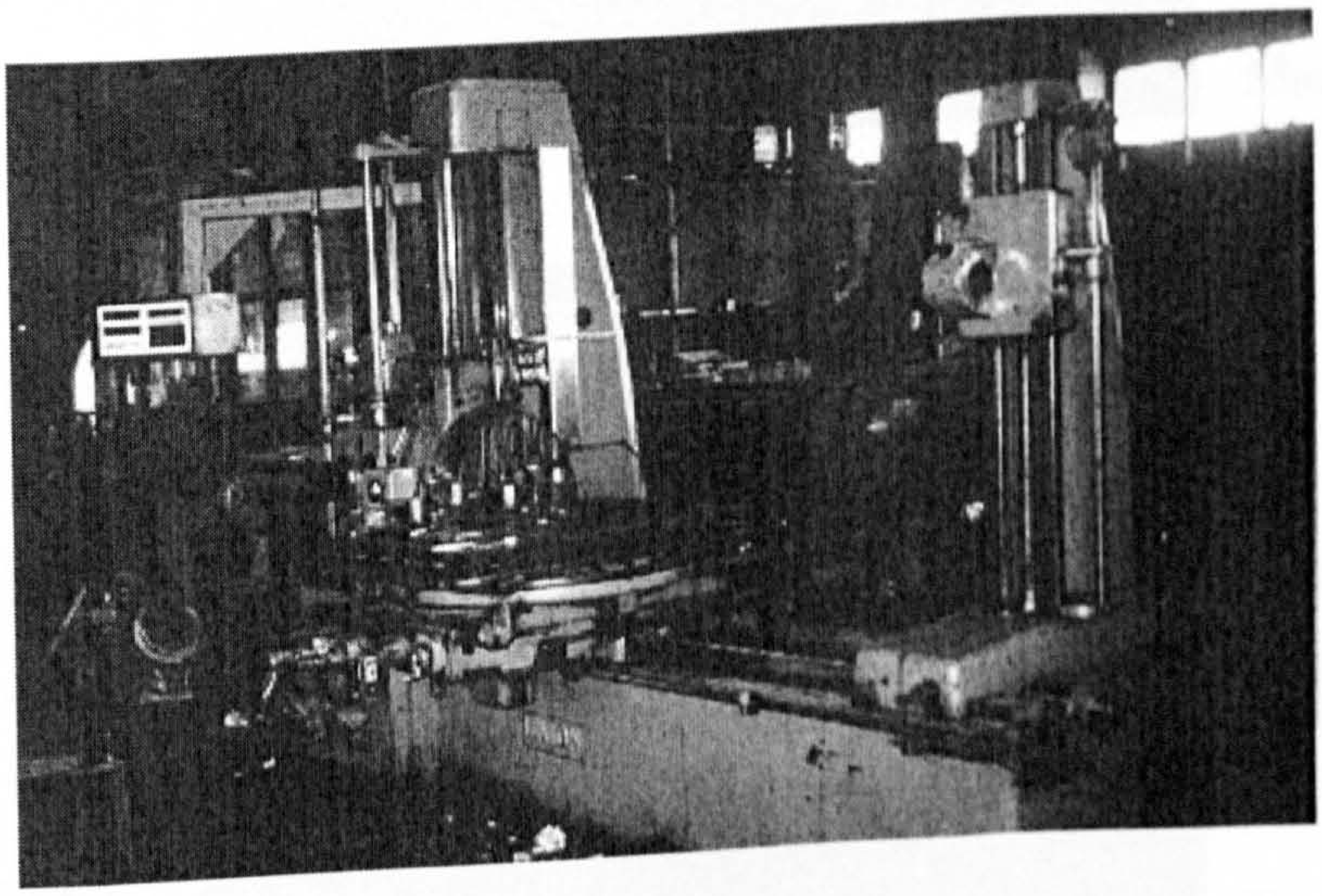


Noodle Machine

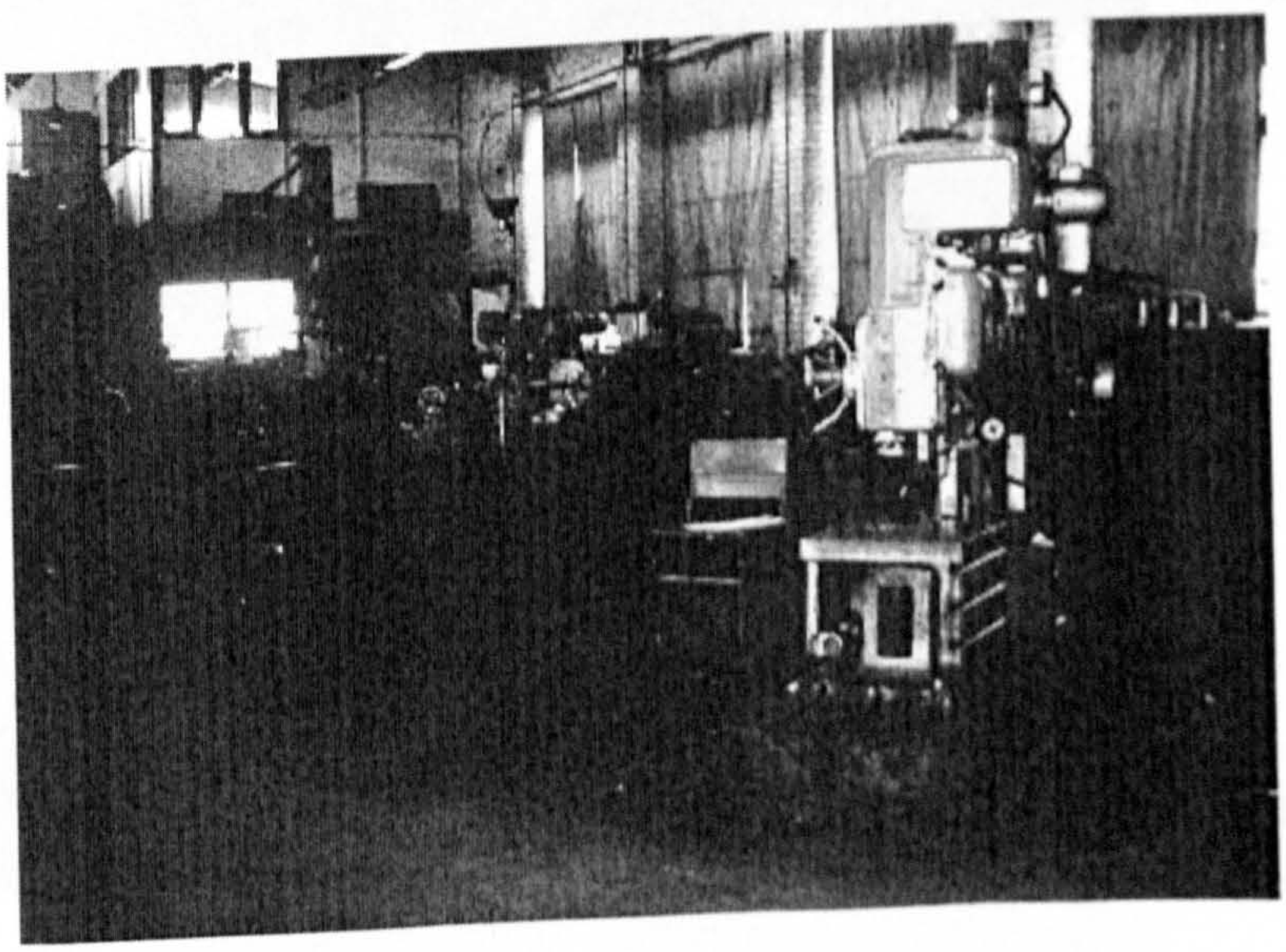
WORKSHOP EQUIPMENT FOR MANUFACTURING MMHP



Lathe Machine



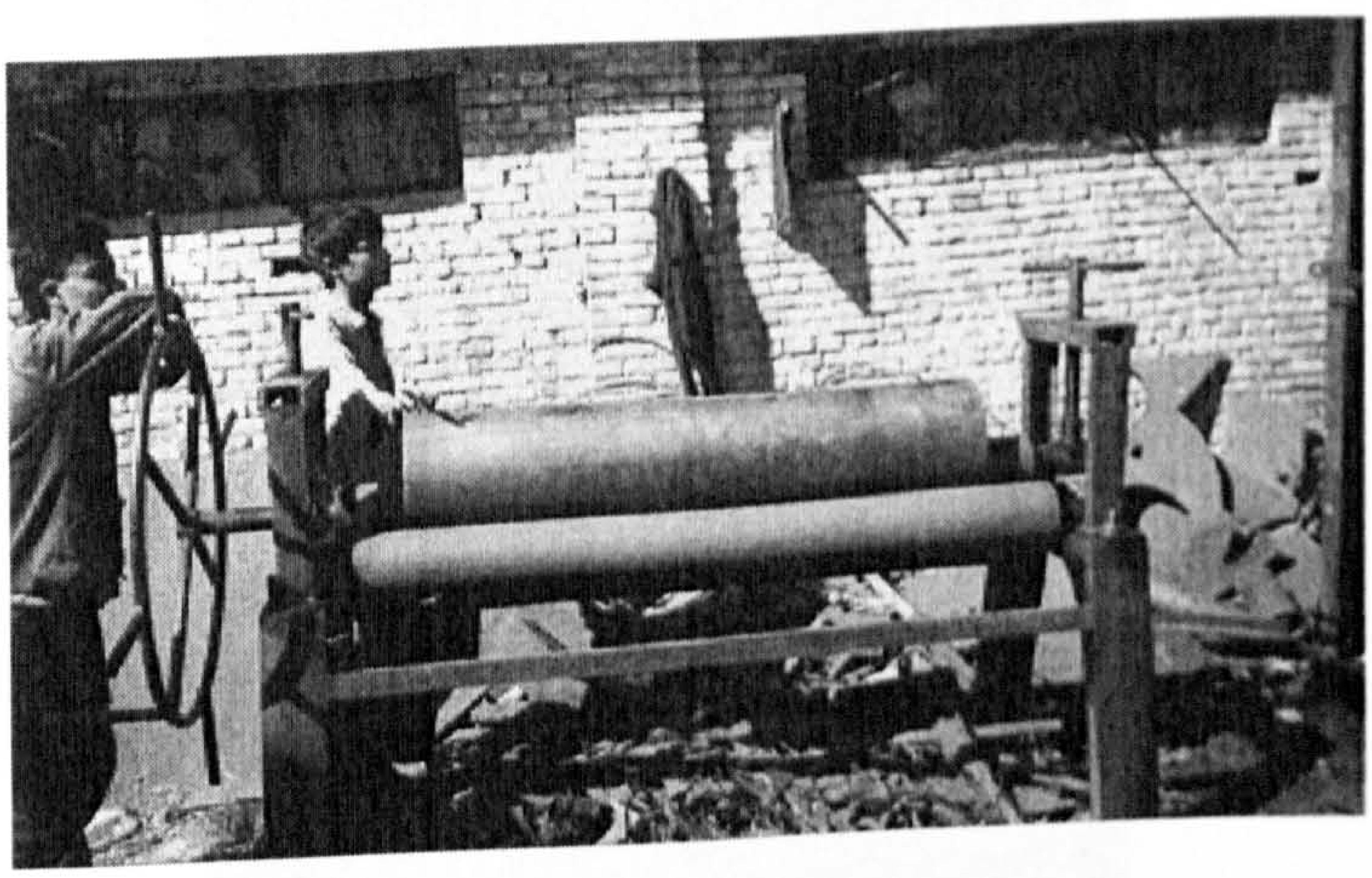
Milling Machine



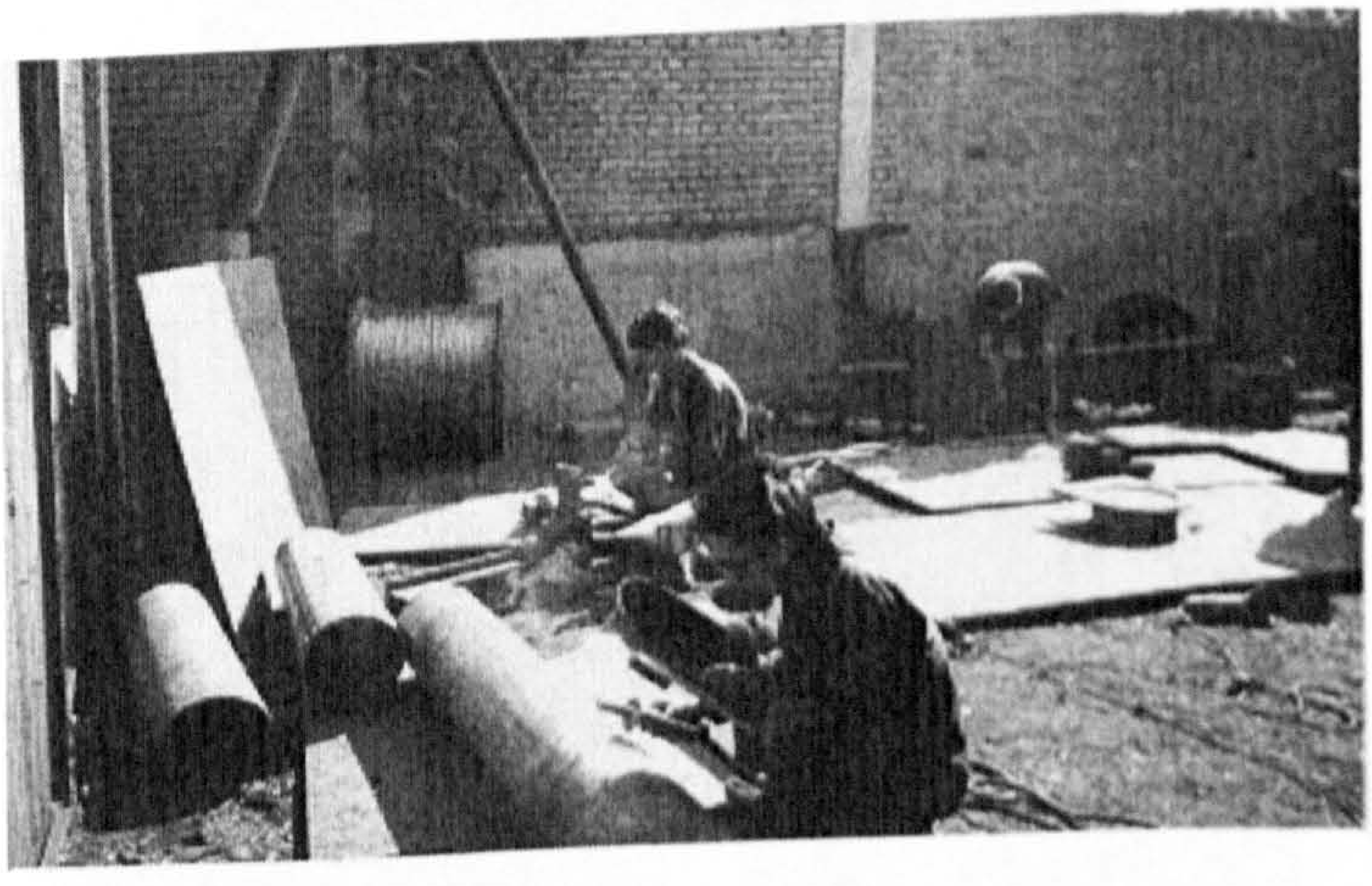
Drilling Machine

SOME PRODUCTION PROCESSES ADOPTED IN THE FIRMS

Manual Metal Cutting



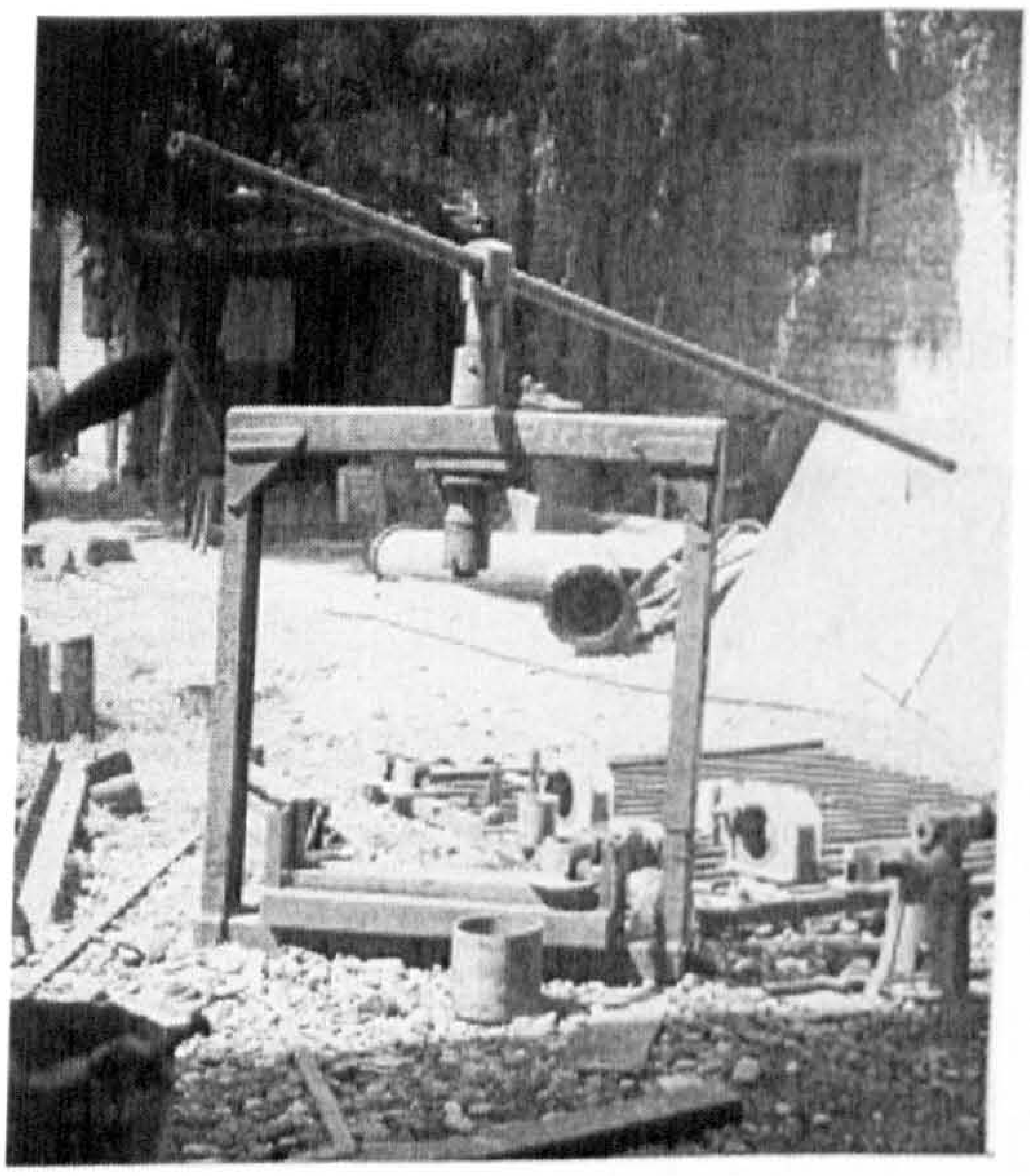
Sheet Metal Cutting



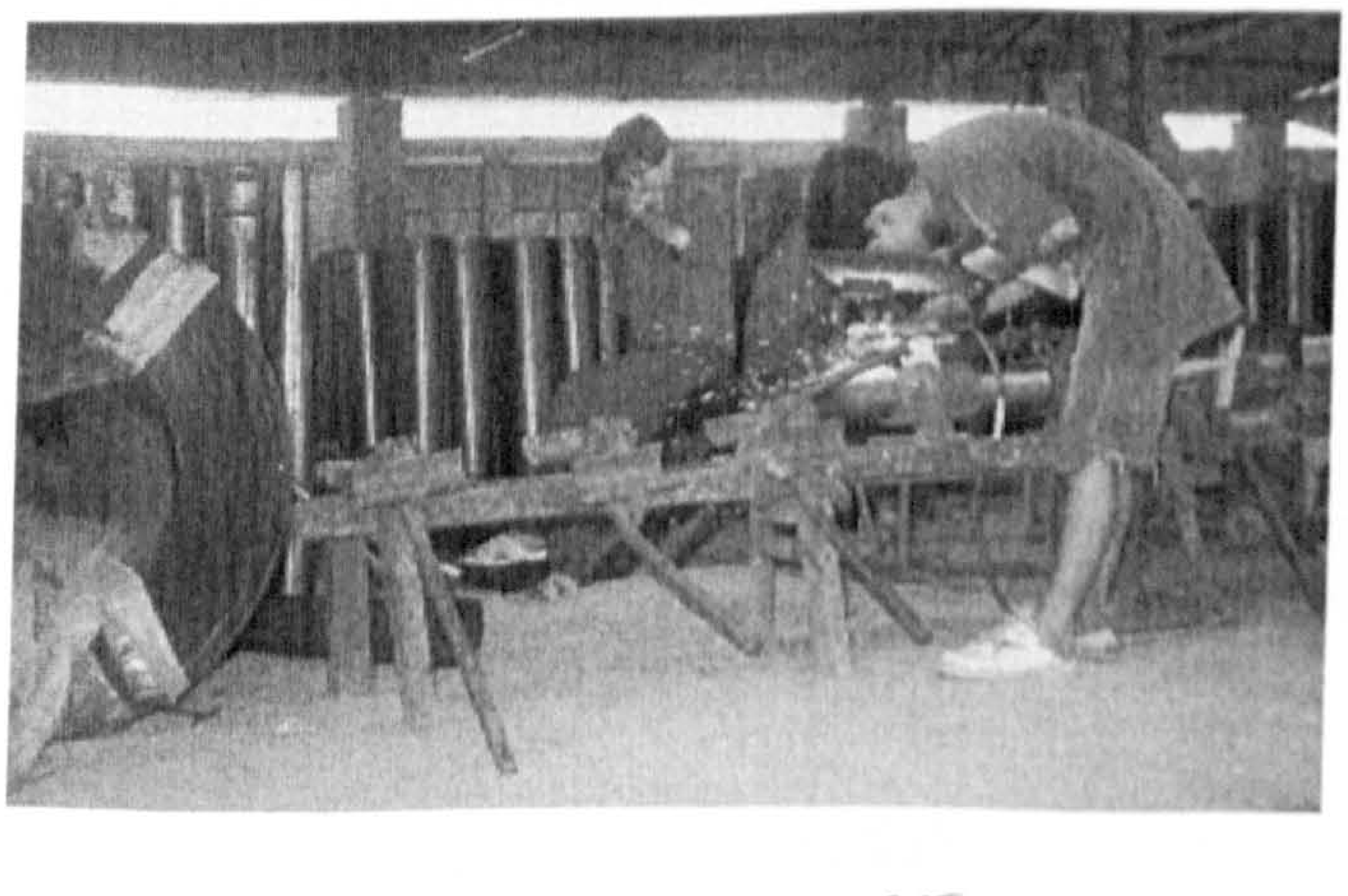
Welding

EQUIPEMENT DEVELOPED LOCALLY

Sheet Roller



Sheet Cutter



Range for Penstock
Mould and Welding

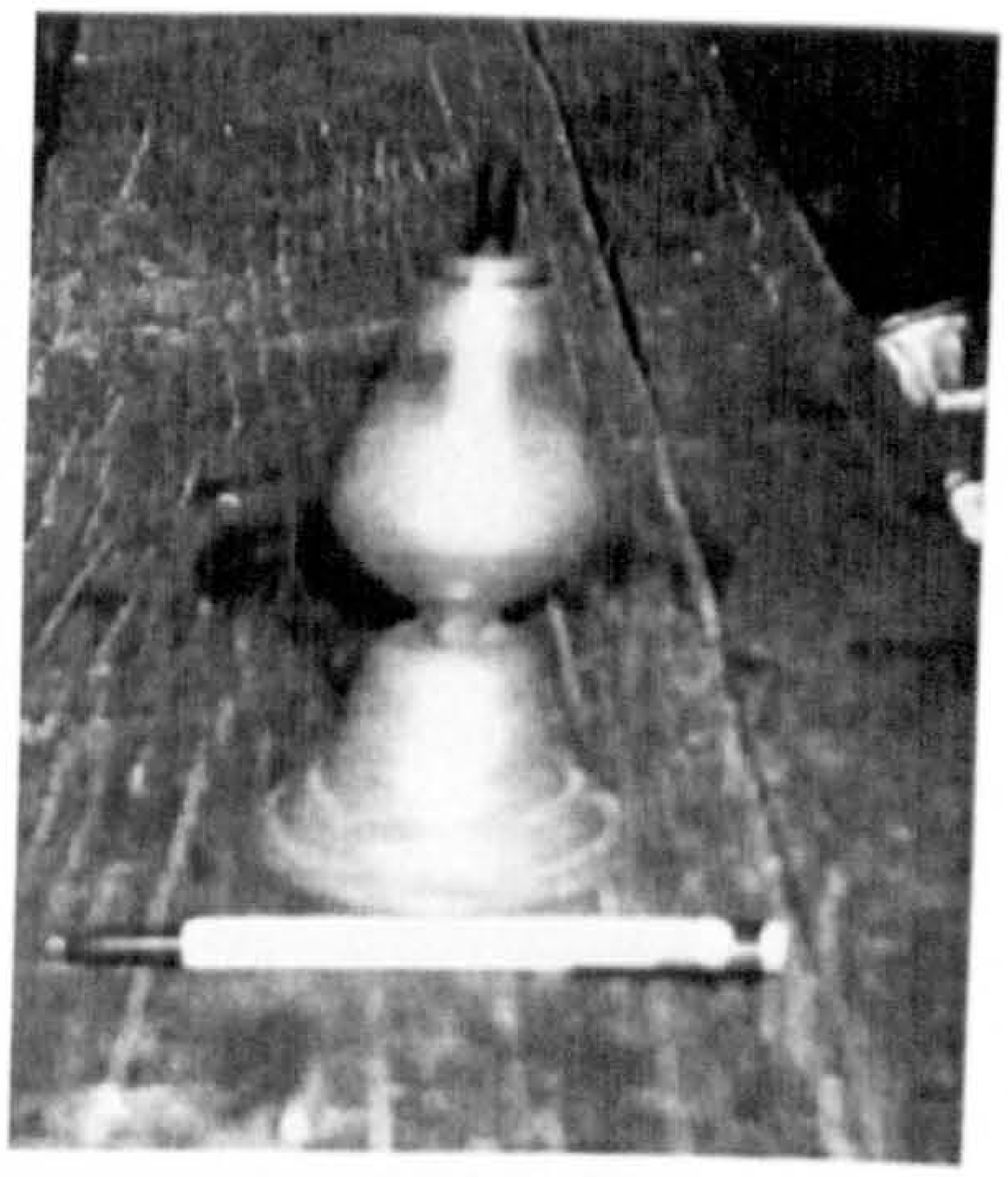
MEANS OF TRANSPORTATION IN THE RURAL AREAS

Transportation by Yak in the Mountain Regions

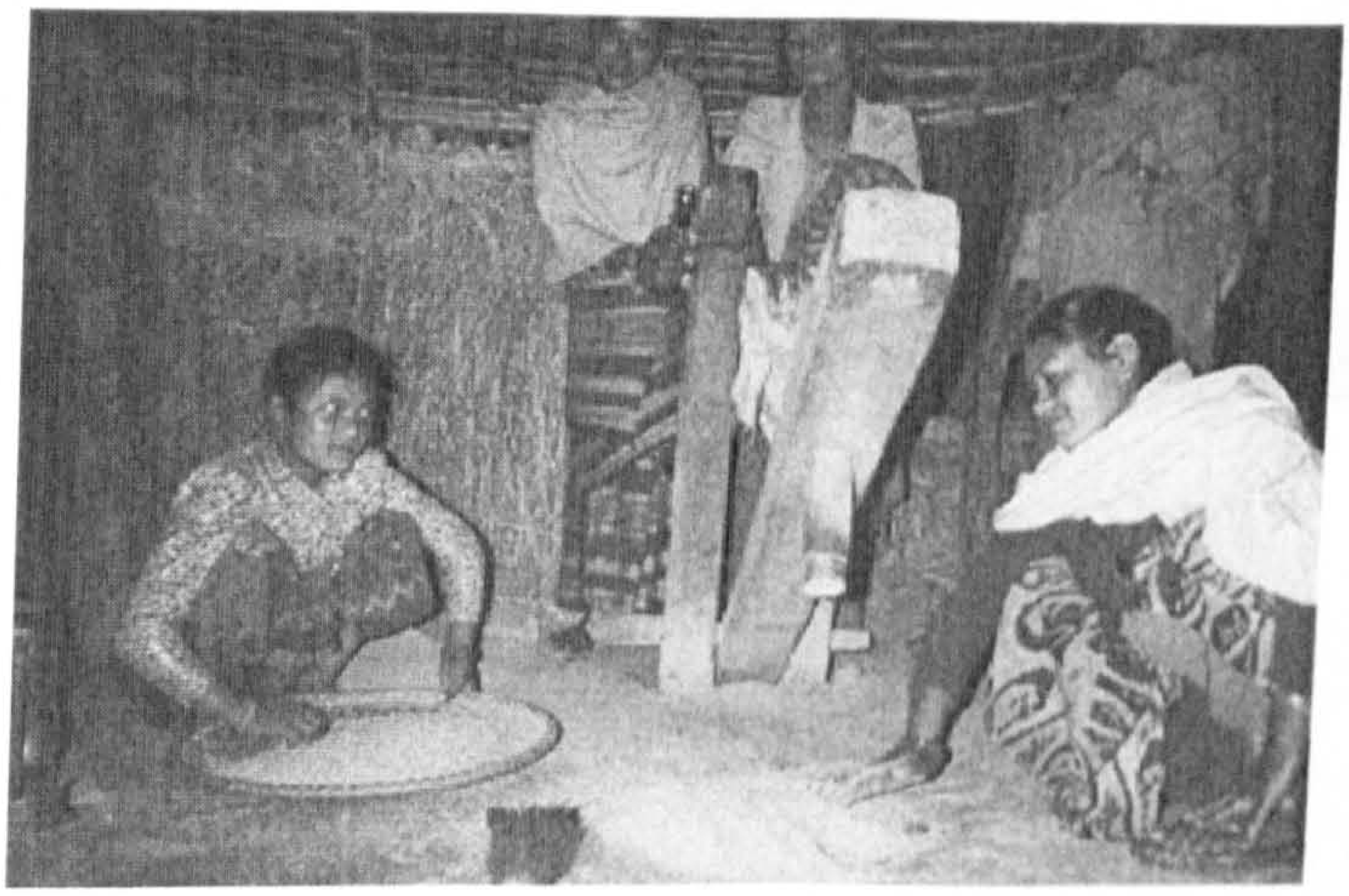
Transportation Using Twin-System

ACTIVITIES TO BE REPLACED WITH THE USE OF MMHP

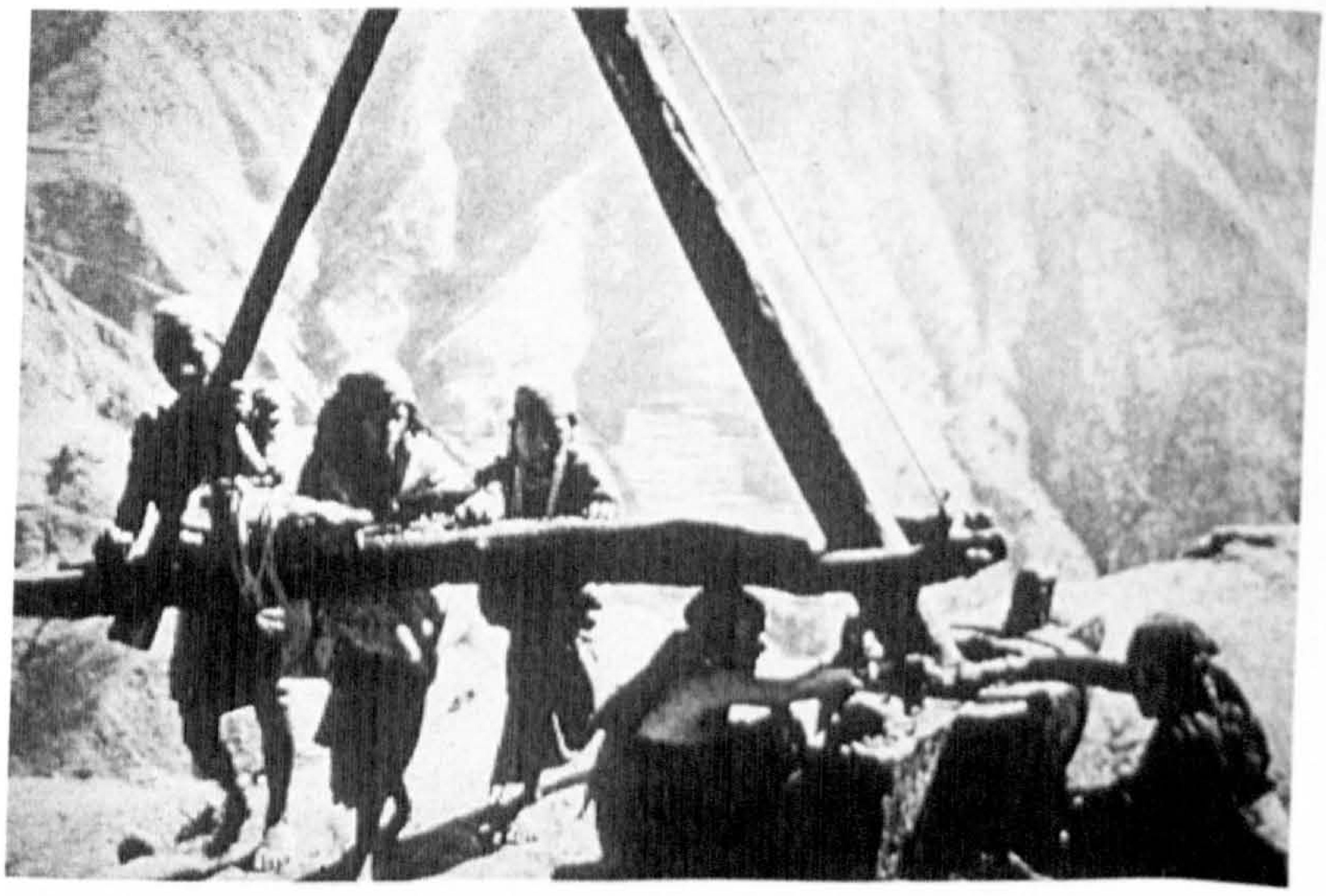
Threshing



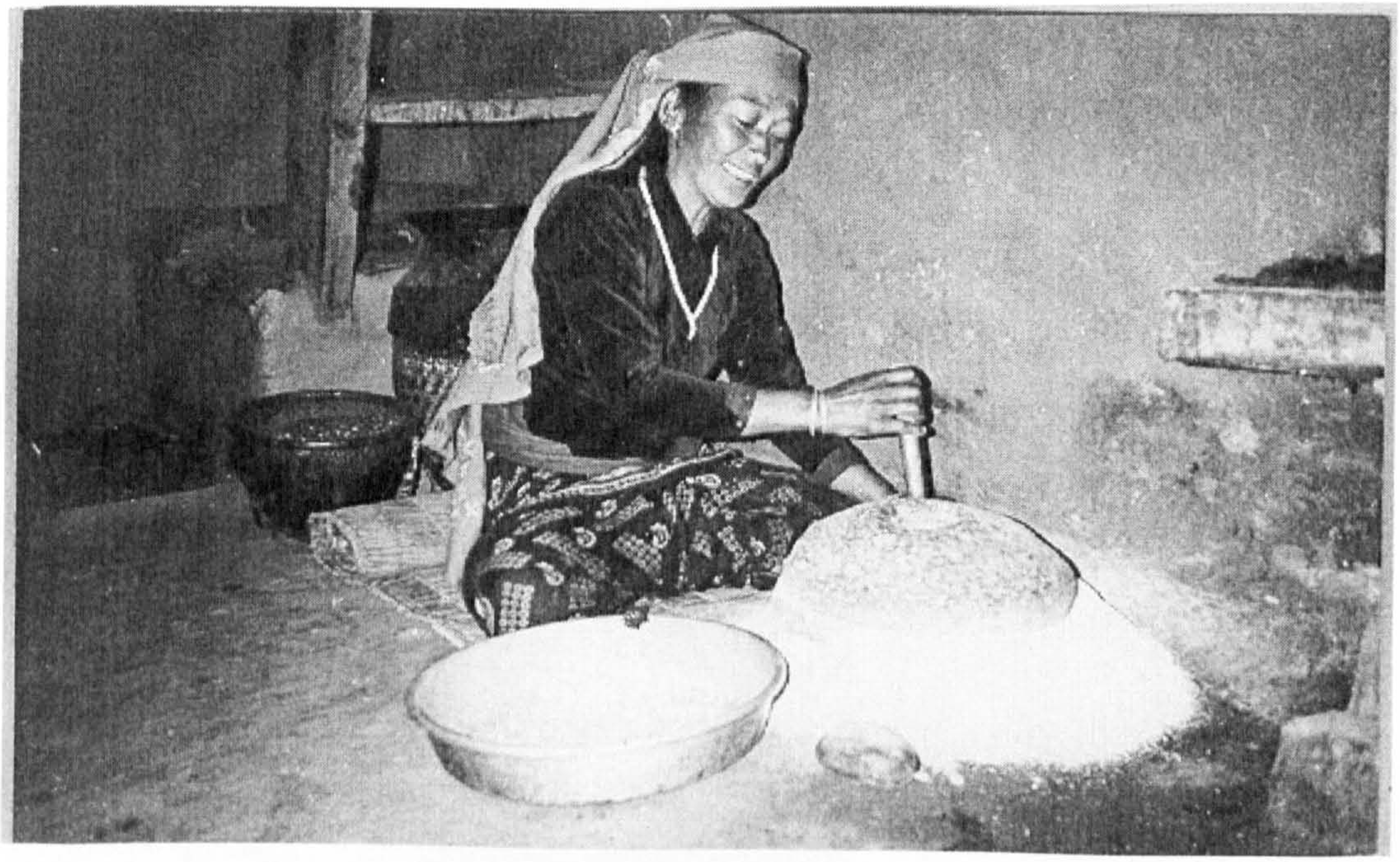
Kerosene Lamps



Rice Pounding

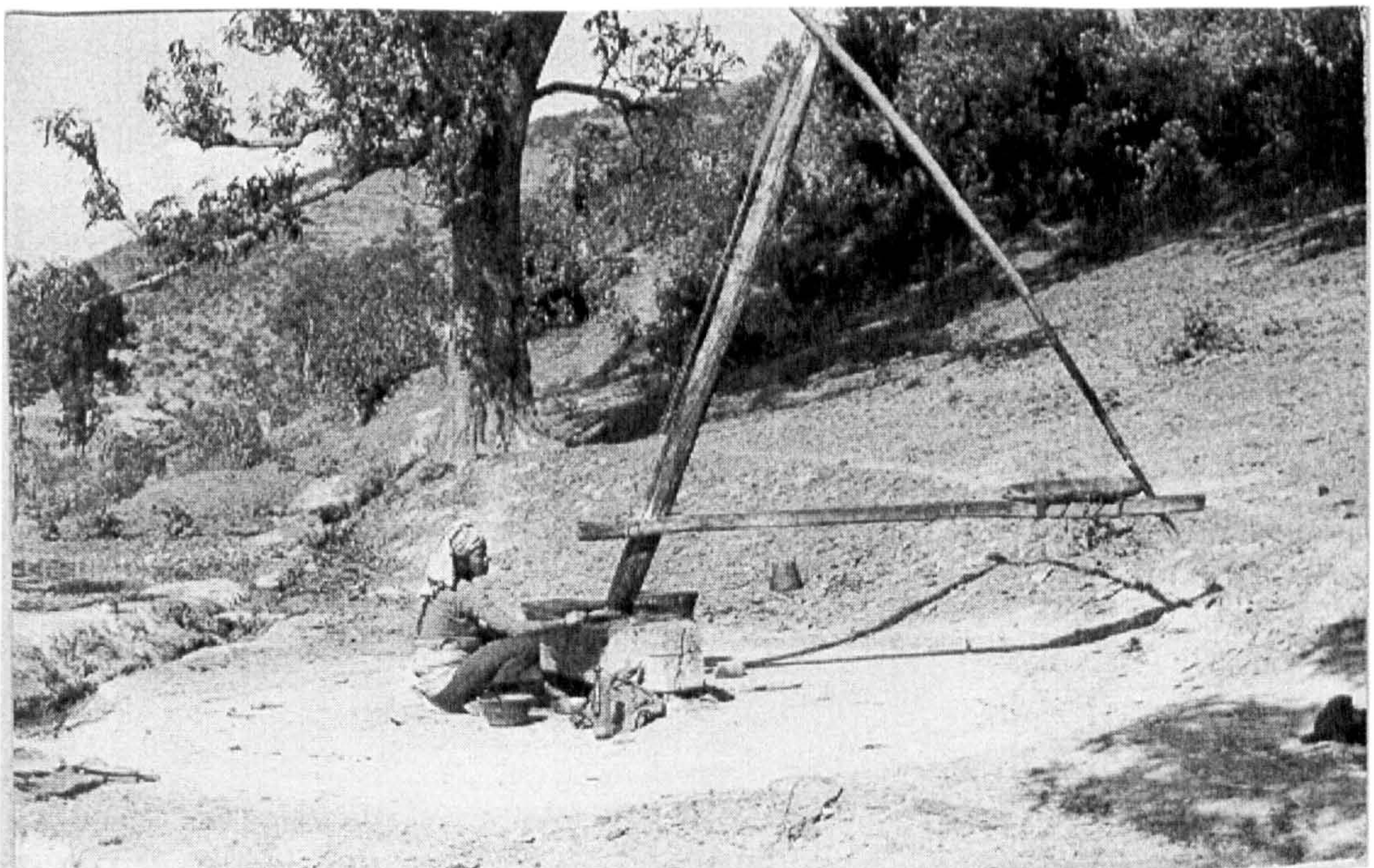


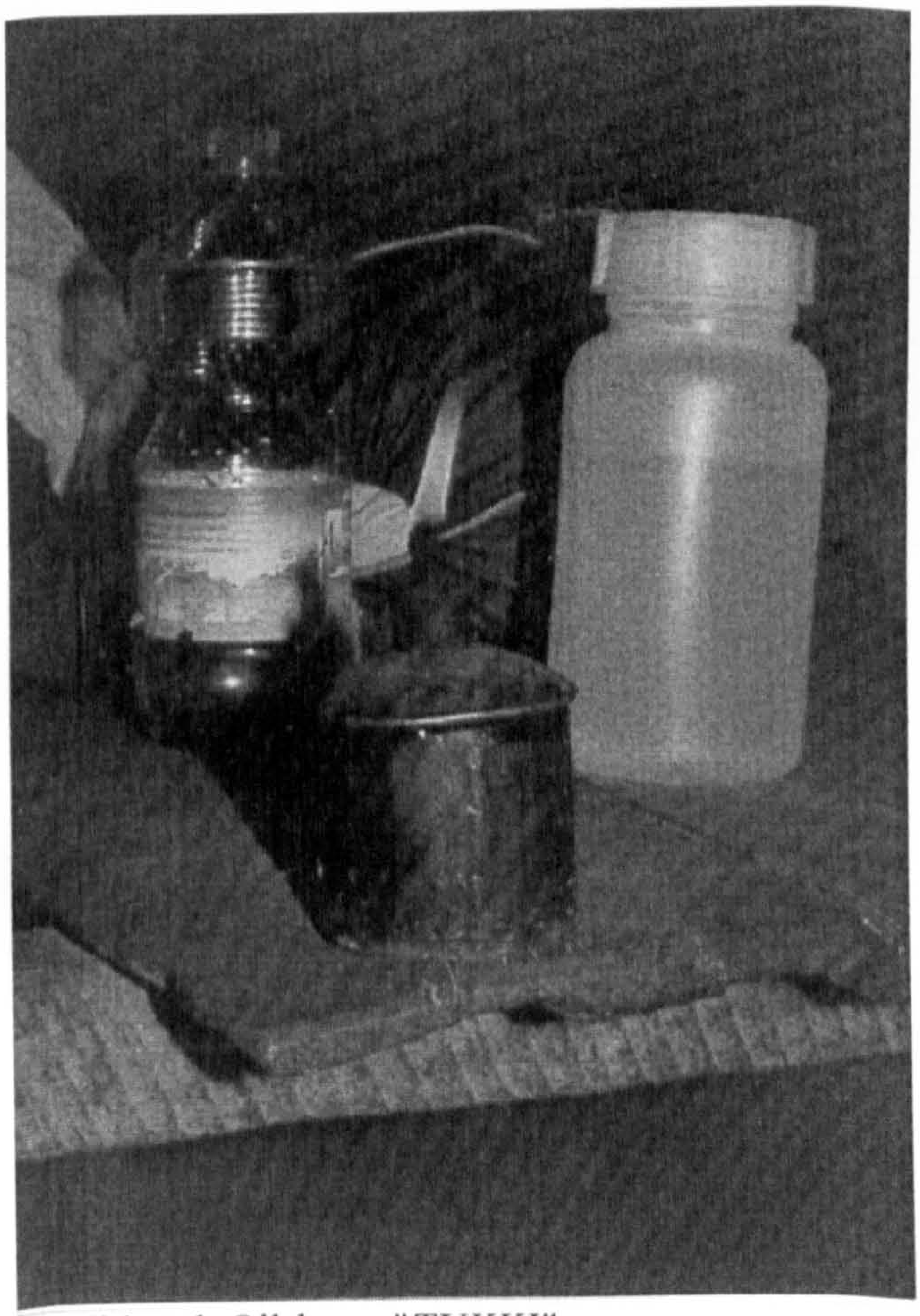
Kol



Traditional Grinding Stones "*JANTO*"

Traditional Oil Expellor "*KOL*"





Traditional Oil-lamp "*TUKKI*"