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Technology issues in the energy sector of developing countries

Small-scale hydropower projects in Nepal

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Study prepared by the UNCTAD secretariat with the collaboration of Dr. Kedar L. Shrestha, Dr. Harendra N. Sharan and Mr. Chris R. Head

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Preface

The present study */ was prepared by the UNCTAD secretariat with the collaboration of Dr. Kedar L. Shrestha (Director, Research Centre for Applied Science and Technology (RECAST), Tribhuvan University, Kathmandu, Nepal), Dr. Harendra N. Sharan (an independent energy consultant based in Seuzach, Switzerland), and Mr. Chris R. Head (Watermeyer, Legg, Piesold and Uhlmann Consultants, Ashford, Kent, United Kingdom). It forms part of the programme of studies of the UNCTAD secretariat on "energy technology issues in developing countries: scope for action at the national level", which has been organized in pursuance of Conference resolutions 87 (IV), 112 (V) and 143 (VI). The programme also represents part of an effort by the secretariat to follow up on the conclusions and recommendations adopted at the UNCTAD Meeting of Governmental Experts on the Transfer, Application and Development of Technology in the Energy Sector (Geneva, 25 October-2 November 1982), **/ as of the General Assembly as contained in paragraph 7 of its resolution 38/151 on the development of the energy resources of developing countries.

The subject matter dealt with in the present study - transfer, adaptation and diffusion of mature renewable energy technologies in developing countries - constituted a principal topic at the meeting of the Intergovernmental Group of Experts on the Transfer, Application and Development of Technology in the Energy Sector, Paying Particular Attention to New and Renewable Sources of Energy, which was held in Geneva from 15 to 24 October 1986. ***/

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*/ A brief report based on the initial findings of this study (TD/B/C.6/116) was submitted to the Committee on Transfer of Technology at its fifth session (3-19 December 1984).

**/ Report of the Meeting of Governmental Experts on the Transfer, Application and Development of Technology in the Energy Sector (TD/B/C.6/94 - TD/B/C.6/AC.9/6), 23 November 1982.

***/ Report of the Intergovernmental Group of Experts on the Transfer, Application and Development of Technology in the Energy Sector, Paying Particular Attention to New and Renewable Sources of Energy. (TD/B/C.6/141).

Chapter I

INTRODUCTION

1. The purpose of the present study is to examine the experience of Nepal in the promotion of small-scale hydropower projects in order to shed light on the conditions for widespread diffusion of mature renewable energy technologies in developing countries. The study addresses the following main questions: (i) where and how have small-scale hydropower projects emerged in Nepal; (ii) what are the alternative technologies actually used; (iii) what are the factors operating in favour or against their use; (iv) what type of domestic technological capacity has been developed for installing, manufacturing and operating them; (v) how has government policy affected the present situation of small-scale hydropower utilization and what kind of policy approaches may be considered for their further promotion.

2. Although much has been written and said about the development and utilization of renewable energy technologies, there is surprisingly little information concerning the conditions for their diffusion. The fact that mature renewable energy technologies 1/ have not spread as quickly as was thought possible several years ago, despite their apparent advantages such as low cost, ready availability and versatility, suggests that it is of great importance to inquire into these conditions. An earlier UNCTAD study 2/ has elaborated, on the basis of existing literature, a conceptual framework for analysing the diffusion of mature renewable energy technologies. Departing from the usual static approach which emphasizes problems of technology adoption (e.g. weak purchasing power of the potential users, unsuitability of the new technology to local conditions and usage, lack of operational reliability of new equipment, problem of maintenance and spare part supply, shortage of trained mechanics, and paucity of infrastructure to support any major new technology application programme), this framework focuses on the working of mechanisms of diffusion over time, including, in particular, the role of local equipment manufacturers. The latter is of special importance in the light of the generally accepted notion that the cost of new technologies to utilise renewable energy resources can only be met through large-scale production and not by further R & D.

3. Small-scale hydropower technology is one of the most mature energy technologies, with a long history of use. Starting from water-driven milling devices, which provided the earliest form of power and which continue to provide relief to women in their household labour, water power harnessed through the introduction of turbines, metallic components and storage dams enabled the massive growth of industries, most notably textiles, to take place in Europe and America in the nineteenth century. Then came the development of hydroelectricity, which constituted the backbone of the industrialization process in many countries. The technological trend in hydroelectricity has, however, been towards large dams and units with high ratings which require heavy investments and long gestation periods and which often constitute part of a large-scale river valley development project.

4. A significant number of developing countries, including several of the least developed countries, have a substantial, if not vast, hydropower potential. 3/ In many of them, like Nepal, which have no other major sources of energy, its exploitation has become an important policy concern, especially since the oil price increases in the early 1970s. The realization of

hydropower potential using large-scale technology is, however, beyond the financial and technological means of many developing countries. Domestic demand for electricity is also in many instances not large or concentrated enough to warrant such investments in the immediate future unless there are export possibilities. Many developing countries endowed with hydro resources have therefore started to emphasize the development of small-scale hydropower projects, in particular in rural regions where energy demand is relatively small and scattered. The small investment requirements favour their application. While these projects would not substitute for large-scale hydropower systems in terms of their impact on the aggregate energy supply, if properly planned, they can play a complementary part in terms of location and time. For example, a mix of a large centralized system and small-scale decentralized hydropower systems can maximize the utilization of potential in a graduated manner.

5. Small-scale hydropower systems occupy an important place in discussions on the introduction of renewable energy technologies, since they are well known, competitive with conventional alternatives and ready for large-scale commercialization wherever water resources are available. They also have other advantages such as the possibility of local equipment manufacture with minimum requirements for industrial facilities, utilization of local manpower for civil engineering work, and little or no adverse environmental impact. Data confirming these advantages in the setting of practical applications in developing countries have started to appear. 4/ It is therefore opportune to direct an empirical study of the diffusion of a mature renewable energy technology to small-scale hydropower technology.

6. The selection of Nepal for the purpose of this study is based on a number of considerations. First of all, since Nepal is a country with no fossil fuel reserves and plenty of water, high priority has been given in its development plans to the development of hydropower resources in general and small-scale hydropower in particular. In spite of its relative technological backwardness, the country started to introduce modern small-scale hydro plants two decades ago to supplement and eventually replace the traditional water wheels called ghattas. A large number of projects have been undertaken, with a variety of technologies and objectives, through different technology transfer mechanisms and supported by various bilateral and multilateral co-operation schemes. The technological progress which has been made during this period in the face of severe financial and infrastructure problems is very significant and worth studying in detail. Nepal's experience also encompasses several other facets of the energy problem which are common to many developing countries that are poorly endowed with conventional energy resources and where the energy sector is yet to be established. Of particular importance is the problem of deforestation, which has reached critical proportions in Nepal as elsewhere. While the cutting down of trees is as much for the development of new farming areas and commercial exploitation as for energy uses (e.g. cooking and heating), harnessing of water resources could, by meeting energy requirements, slow down the deforestation and give reforestation a chance.

7. In this study, Chapter II briefly describes the general energy setting of Nepal and situates the overall contribution of the small-scale hydropower projects. Chapter III identifies three different types of small-scale hydropower technologies and analyses the working of the diffusion mechanisms involved. Chapter IV discusses the role of the Government in respect of the diffusion phenomenon. Chapter V concludes with a consideration of the policy implications of the findings of the study.

Chapter II

SMALL-SCALE HYDROPOWER PROJECTS IN NEPAL'S ENERGY SETTING

A. Introduction

8. Nepal is a land-locked country with a population of around 16 million people whose average income is one of the lowest among developing countries. 5/ The socio-economic and developmental setting of Nepal, including its energy needs, is deeply influenced by its physical and geographic features. Although the country has an area of about 141,000 km^2, almost the size of Bangladesh, much of it is taken up by the mountain ranges which traverse the country from West to East, making the country one of the most land-scarce in the world in terms of cultivated land per person.

9. Topographically, three major geographic regions with distinct human settlement patterns can be distinguished. These regions are: (i) the Mountain Region, including the Himalayan Range, sparsely populated and characterized by an alpine climate with perpetual snow above 5,000 metres; (ii) the Hill Region, with an altitude of 1,500-3,000 metres above sea level, accounting for 33 per cent of Nepal's cultivated land and approximately 60 per cent of the total population; and (iii) the Terai, Nepal's warm and moist sub-tropical lowlands, representing 62 per cent of the total cultivated land and roughly 36 per cent of the total population and producing two thirds of the country's agricultural output. An intense internal rural-rural migration takes place among these regions. People from the Mountain Region and from the densely inhabited Hills migrate to the Terai in search of agricultural land. The rapid depletion of forests beyond their regeneration capability caused by fuelwood consumption and clearing for cultivation purposes has set in motion a vicious circle of erosion, damage to soil, water and other environmental assets, cultivation of marginal land, desertification, flooding and migration.

10. Agriculture is the predominant economic activity in the country, accounting for nearly three-fifths of its GDP and roughly 70 per cent of its total export revenues. More than 90 per cent of the population depend on this activity for their livelihood. Its development, however, has been very slow and has generally fallen behind the population growth, resulting in a declining growth rate of agricultural production per head of population. 6/ Industrial development has not fared any better, as this sector's share in GDP stagnated at around 12-13 per cent and its capacity to create employment remained quite limited throughout the 1970s. There is very little manufacturing activity beyond processing of agricultural products for the domestic market, an activity whose growth is constrained by the limited purchasing power of the population. The country's natural resource endowment is also relatively poor, with the exception of water and forestry resources.

11. The weak economic base of the country manifests itself in a number of ways such as extensive unemployment and under-employment, poverty and shortages in respect of nutritional and other basic needs, a high rate of illiteracy and an absence of skilled manpower, lack of social infrastructure facilities and services, a deteriorating trade balance and heavy dependence on inflows of external resources, mainly through official and other non-commercial channels.

B. The energy setting

12. Nepal's energy picture is characterized by a very low per capita energy consumption (roughly 230 kg of oil equivalent) and the dominance of traditional energy sources for energy supply (about 95 per cent). As shown in table 1, more than 95 per cent of the country's energy consumption is accounted for by domestic or household use, most of it in the form of fuelwood supplemented by other traditional sources such as agricultural and animal wastes.

13. The use of commercial sources of energy is quite limited (i.e., 5 per cent of total energy consumption). A large proportion of these sources are imported - petroleum products for transport and domestic uses and coal for industrial use. Because of the rising prices of these imported energy sources and the general foreign-exchange squeeze, their consumption did not grow during the 1970s. More recently, however, commercial energy consumption has increased through the addition of hydroelectricity generating capacity. Total electricity consumption more than doubled between 1975 and 1983, although electricity reached only around 5 per cent of the population, mostly in the Kathmandu valley and other urban centres in the Terai region.

14. A regional breakdown of traditional energy consumption in the 1970s indicated that while the Terai accounted for approximately 23 per cent of consumption, the Hills' share was 67 per cent. The latter's high share is explained by a combination of factors, including (i) larger population, (ii) the lack of access to petroleum products and coal because of the transport difficulty and the low income of the population, and (iii) the ready availability of fuelwood, which can be procured at no individual cost. The climate in the Hills makes it necessary to heat, and this accelerates the rate of consumption of fuelwood, giving rise to a serious deforestation problem. 7/ It should be mentioned, however, that wood is also cut to open up farm land and also, though to a lesser extent, for commercial undertakings such as the export of timber, and the progressive deforestation is the result of all of these. The forest cover (about 28,000 square kilometers) has been reduced to roughly 20 per cent of the country's total land area. 8/ This situation has a direct effect on small-scale hydropower projects inasmuch as both seasonal drying up of streams and severe flooding adversely affect their performance.

15. While Nepal lacks commercially exploitable proven deposits of conventional fossil fuels such as coal, lignite, gas and oil, the country's hydropower potential, which is considered to be its major indigenous energy resource, is practically unused. The country's potential includes a large river system, with snow-fed, perennial rivers accounting for 80 per cent of the total run-off and featuring promising sites for large-scale power generation. It also includes hundreds of independent rivers and streams in the southern slopes of the Mahbharat Lekh which originate from the monsoon or from springs, and which are characterized by high flooding in the rainy months and do not dry up in the dry season. They are considered to have feasible sites for power generation on a medium and small scale. These potential sites lie largely in the Hills Region.

16. Out of the country's theoretical hydropower potential of approximately 83,000 MW and an estimated feasibly exploitable generating potential varying between 18,000 and 25,000 MW, 115 MW have actually been harnessed and plant with a capacity of about 90 MW, including small hydro projects totalling 5 kW,

Table 1

Energy end-use pattern in Nepal, 1980/81
(thousands of tons of oil equivalent)

Sector	Traditional sources				Commercial sources				All sources	
	Fuel-wood	Agricultural waste	Animal waste	Total: Traditional	Petroleum	Coal	Electricity	Total: Commercial	Total energy	Percentage share by end-uses
Domestic	3 015.0	53.9	20.5	3 089.4	30.8	-	6.5	37.3	3 126.7	95.1
Commercial	9.0	-	-	9.0	6.7	-	1.8	8.5	17.5	0.5
Industrial	21.1	-	-	21.1	4.8	35.2	4.4	44.4	65.5	2.0
Transport	-	-	-	-	69.1	1.0	0.1	70.2	70.2	2.1
Agriculture	-	-	-	-	5.0	-	0.2	5.2	5.2	0.2
Power generation	-	-	-	-	2.9	-	-	2.9	2.9	0.1
Street lighting	-	-	-	-	-	-	0.3	0.3	0.3	-
Total sectoral consumption	3 045.1	53.9	20.5	3 119.5	119.3	36.2	13.3	168.8	3 288.3	100.0
Percentage share by sources	92.6	1.7	0.6	94.9	3.6	1.1	0.4	5.1	100.0	

Source: Water and Energy Commission, Government of Nepal, Energy Sector Synopsis Report, 1983.

Note: A dash (-) means negligible.

is under construction or has had funds committed (see table 2). The gross production of electricity in Nepal in 1983 was of about 257 million kilowatt hours, of which hydro- and thermal plants provided 80 per cent and 20 per cent respectively. All hydropower production, with the exception of some small-scale hydropower production, is publicly generated, while half of thermal production is privately generated. The same year (1983), Nepal also imported 79 million kilowatt hours of electricity (in net terms), or 24 per cent of total electricity consumption, from India. This import dependence, however, is expected to disappear when four major plants (75 MW hydropower and 10 MW diesel) which have been under construction are commissioned. There are also two very large hydro projects totalling over 4,600 MW which are the subject of feasibility or detailed studies. These projects will provide for the export of electricity to India.

17. In addition to hydropower development, the Government is engaged in the promotion of a national renewable energy programme comprising solar energy for hot water and space heating, wind energy, and biogas plants. Improved efficiency in energy use is also being promoted, for example through the diffusion of improved cooking stoves and by the implementation of a programme to reduce transmission and distribution losses of electricity, which were estimated at more than 30 per cent for the period of 1975-1980.

C. Small-scale hydropower projects

18. Nepal is now pursuing a mixed approach to the supply of energy from water. One component of this approach is the development of large hydropower projects, which are technologically complex endeavours and require substantial financial inputs. This requires huge loans, massive importation of foreign technology on a turn-key basis and regional and/or international co-operation. The second component of the current approach aims at encouraging small-scale hydropower development, which *a priori* could be considered to offer a greater potential for the use of domestic resources.

19. It is difficult to measure the contribution of small-scale hydropower-technology in Nepal to the solution of the energy problem in strictly quantitative terms. In order to give some order of magnitude, it could be estimated that the total expected capacity of small hydel for electricity production in the near future, including those projects currently in operation, under construction and in an advanced stage of planning, would amount to roughly 7 per cent of the total installed hydropower capacity of Nepal in 1983, or, expressed otherwise, to approximately the output of its Sunkosi plant (10.5 MW). It is, however, clearly the socio-economic and technological dimension of small-scale hydropower in the setting of the Hills which can be considered its most strategic contribution to overall development in Nepal.

20. Small-scale hydropower projects in Nepal can be classified into three distinct types according to the kind of technology used. They are (i) traditional water wheels or *ghattas*, (ii) mechanical drive units and (iii) small hydel installations. These projects are owned and operated by different entities, face different problems and offer different long-run development possibilities. Table 3 presents the principal characteristics of the different types of projects. A brief narrative below provides some more ideas about each of them; the mechanisms of their diffusion are discussed in chapter III.

Table 2

Power sector projects under way or for which funds have been committed

Project	Project output	Principal funding source	Total project cost	Expended	Sixth plan	Seventh plan
			(millions of 1980 United States Dollars)			
ULEKHANI NO. 1 HYDRO-ELECTRIC PROJECT	Domestic power 60 MW	World Bank Japan, OPEC, Kuwait	118.0	70.0	48.0	-
DEVIGHAT HYDRO-ELECTRIC PROJECT	Domestic power 14 MW	India	35.0	2.5	32.5	-
HETAUDA DIESEL GENERATION	Domestic power 10 MW	United Kingdom	5.0	4.0	1.0	-
BHARATPUR-POKHARA TRANSMISSION LINE	Extension of power supply grid to Pokhara 132 kV	ADB	6.3	2.3	4.0	-
HETAUDA-BIRATNAGAR TRANSMISSION LINE	Extension of power supply grid to Eastern Region 132 kV	ADB	1.0	-	16.0	2.0
SMALL HYDRO-ELECTRIC PROJECTS PROGRAM	20 regional development projects located throughout Nepal. Total installed capacity 5.185 MW	OPEC, HMG, Switzerland, Austria Yugoslavia, UNDP, ADB	22.2	-	7.8	14.4
		TOTAL	204.5	78.8	109.3	16.4

Sources: Government of Nepal, Water, the Key to Nepal's Development, 2nd edition, Kathmandu, Nepal, 1983, Government of Nepal, Water and Energy Commission Report, 1983.

Table 3

Principal characteristics of small-scale hydropower projects in Nepal a/

	Category	Output range (kW)	Normal turbine type	Indicative unit cost ($US/kW) b/	Promoter (financial)	Purpose	Technology level c/	Local participation
Type I Traditional water wheels	Ghatta	0.5-1	Wooden paddles	Low total cost	Private	Milling of grains	(a) Low (b) Low (c) Low (d) Low	Total
Type II Mechanical drive units	Mechanical and mechanical/ electrical Units	3-10 5-25	MPPU Crossflow	100-500 (plus $US 300 per kW of electrical output in the case of mech/ elec. units)	Private (ADBN)	Agro-industry (and limited lighting in the case of mech/ elec. units)	(a) Low (b) Low (c) Low (d) Low	Total
Type III Small hydel	(i) Micro-hydel	5-100	Crossflow	1 000-4 000	Community/Government (official/private)	Local electric load and lighting	(a) Intermediate (b) Low (c) Intermediate (d) Low	High
	(ii) Smaller mini-hydel	100-500	Francis Pelton (Crossflow) (Propeller)	2 000-8 000	National Agency i.e. SHDB/ED d/ (Government/ official aid)	Electricity supply to isolated towns	(a) High (b) Intermediate (c) High (d) Intermediate	Medium
	(iii) Larger mini-hydel	500	Francis Pelton Kaplan	1 500-4 500	National Agency i.e. SHDB/ED d/ (Government/official aid)	Electricity supply to isolated towns and grid	(a) High (b) High (c) High (d) High	Low

Source : Estimates by UNCTAD study team.

a/ There are inevitably considerable generalizations involved in preparing a table of this sort, particularly as individual scheme characteristics can vary greatly, so it needs to be interpreted with care.

b/ Unit costs, where appropriate, include transmission and distribution.

c/ Technology level is shown for four categories of work: (a) planning and design; (b) civil works construction; (c) mechanical and electrical works; (d) operation and maintenance. (Low - largely undertaken by people trained on-the-job with little formal education; intermediate - largely undertaken by technicians with practical training backing up formal education; high - requiring university engineers or similar).

d/ Small Hydro Development Board/Electricity Department.

1. Ghattas

21. For centuries, Nepalese farmers have been channelling water from small streams using a ghatta - i.e. a traditional water mill - to generate basic energy for the vital task of grinding grains to make flour. Typically, they are horizontal wooden paddles on a vertical shaft, fed by water flow coveyed down an open timber shoot. Their number is estimated at 25,000-30,000 units in the hill areas, using low heads of water of 2-4 metres to develop 1/2 to 1 KW of mechanical power. Without ghattas, women would have to continue grinding on a traditional jhanto, a hand-turned device using two stones.

22. Ghattas often combine with irrigation schemes. Fifty per cent of them still serve this dual purpose, and grinding is done only at peak periods and during the festive seasons. Ghattas do not offer power for any other purpose, such as oil expelling, rice hulling, pumping, lighting, cooking or heating.

2. Mechanical drive units

23. Multi-Purpose Power Units, or MPPUs, are improved traditional ghattas in the range up to 10 kW, which are combined with processing machines. They consist of a horizontal wheel (see Figure 1 in Annex) with cupped metal blades transmitting power to a vertical axle which provides a direct drive for milling or power take-off via a pulley. They operate at heads of water of between 3-10 metres. However, the technological distance between the ghattas and the MPPUs is more important than their similarities. MPPUs are not only more efficient in milling but permit other mechanical operations (e.g., driving several cottage industry machines) and some domestic electricity generation.

24. In another development, during the 1960s, a Swiss-aided mechanical workshop in Balaju, Kathmandu, i.e., Balaju Yantra Shala (BYS), undertook the design, fabrication and installation of crossflow turbines specifically for mechanical power in the villages. The adaptive research and development work on these turbines were initially done mainly by the Swiss technicians at the workshop, but since then a number of other workshops have started producing and marketing crossflow machines in Nepal. The formal training in mechanics conducted by BYS (since 1964) and a general spill-over effect probably explain the spreading of the relevant skills to other workshops. This type of crossflow turbine, which has a multi-bladed cylindrical runner through which the water flows twice, is suited for small power outputs of up to 25 kW. The design has been adapted for local manufacture, which involves simple sheet metal work which can be standardized for batch production, whereas more sophisticated turbines require advanced foundry facilities. They operate at heads of water up to about 20 metres and are increasingly used to provide electricity for lighting purposes in the turbine house. Usually a 12 volt DC car dynamo or a 220 volt AC alternator is attached for this purpose. The voltage is normally regulated by manually controlling the flow of water to the turbine. The owners of these turbines have now received permission, and are in fact encouraged, to sell electricity up to 100 kW per station. This is a part of the "delicensing" policy which has been adopted recently following the Government's recognition of the limited capacity of the public utilities based on small hydel installations to provide services in

many locations still awaiting electricity and also of the generally unfavourable economics of small installations because of the high (fixed) operation and maintenance cost.

25. The mechanical turbines were in highest demand from 1983 to 1986. A significant number - approximately 200 - of such units have already been set up, and they are gaining acceptance in the rural areas. 9/. Judging from the above-mentioned changes in government policy, the manufacturers expect that a major marketing effort will be needed to sustain sales of mechanical turbines at present levels. It seems that more efforts may go into the electrification side in the future.

3. Small hydel

26. The third type of small hydro technology is the small hydroelectric systems. These are larger and technologically more complex than the mechanical systems described above and tend to serve larger communities. They are designed to operate at heads of up to 80 metres. They require electrical generators, more sophisticated control systems, and a number of additional auxiliaries. In addition, extensive civil works, transmission and distribution equipment and power lines become major cost factors in their utilization.

27. Table 4 gives a summary list of small-hydel projects in operation, under construction or at advanced stages of planning in Nepal, which add up to a total installed electricity-generating capacity of around 8.3 MW. Of the 35 projects included in the list, 10 are reported operating. The unit rating of equipment employed or planned for installation ranges from 20 kW to 500 kW, with around 65 per cent of the total number of units falling between 100-150 KW and another 20 per cent less than 100 kW.

Table 4

Small-scale hydroelectric projects in operation, under construction or at design and planning stage in Nepal (as of 1985)

Region	Total installed capacity (kW)	Number a/ of projects	Number of small-hydel units (Range of unit rating in kW)	Multi-purpose (MP) or single-purpose (SP) application	Funding agency b/
Eastern Development Region	2 654	11	25 (32-125 kW)	MP: 1 SP: 24	HMG/ADB/UNCDF/ OPEC
Central Development Region	1 315	6	8 (20-250 kW)	MP: 1 SP: 7	HMG/ADB/UNCDF
Western Development Region	2 085	8	15 (40-500 kW)	SP: 15	HMG/ADB
Mid-Western Development Region	1 305	4	11 (100-150 kW)	MP: 4 SP: 7	HMG/ADB
Far-Western Development Region	980	6	12 (40-100 kW)	MP: 2 SP: 10	HMG/ADB
Total	8 339	35	71 (20-500 kW)	MP: 8 SP: 63	-- --

Source: Compiled from a number of materials provided by the Nepalese Government authorities.

a/ Excludes 6 projects (with a total installed capacity of 3,450 kW) which are at various stages of detailed design and 8 other projects which are at the feasibility stage.

b/ HMG (His Majesty's Government); ADB (Asian Development Bank); UNCDF (United Nations Capital Development Fund). Other funding agencies, particularly non-governmental organizations, may not have been accounted for here.

Chapter III

TRADITIONAL WATER WHEELS AND THE DIFFUSION OF "MODERN" MECHANICAL DRIVE UNITS

A. Introduction

28. Introduction of any technology has to pass through several processes before it is accepted widely. For renewable energy technologies, or any other technologies to be diffused, they have to be appropriate to the environment of their users - not only the natural environment, but also the economic, social and political environment. 10/ They are usable only to the extent that they are suited to the requirements of their owners, manufacturers, users and consumers. As they enter the lives of the people, each step brings revaluation, adaptation, negotiation, and adjustment. Often new or "modern" technologies are introduced into societies where there are already traditionally used technologies, and this results in a lengthy social process in which not only technologies are modified or adapted but also the institutional features of the society are altered. The final outcome would necessarily depend on the economic viability and profits for the actors directly involved, but the decision-making process of the actors is itself conditioned by the prevailing social relations.

29. The diffusion of "modern" mechanical drive units in Nepal is one such case. *Ghattas*, traditional waterwheels, have been - and are still - used quite extensively in Nepal. But during the past two decades, efforts have been made to diffuse "modern" technologies to replace them. 11/ The diffusion process, a varied and protracted one, was characterized by the gradual build-up of domestic equipment-supplying capability and the creation of a small but stable market for small-scale mechanical drive units. This chapter discusses this diffusion process, paying attention also to the place of *ghattas*.

B. Ghattas

30. The popular use of *ghattas* by the Nepalese is based on a combination of several factors. There is, to start with, a clear demand for milling and grinding of grains, especially hulling of rice, for local consumption. There is also an abundance of the raw materials needed for a waterwheel - that is, wood to build the wheel, stone to make the grinders and water to run the wheel. The technology for making a *ghatta* is rather simple and within the reach of rural artisans and village craftsmen. The latter are readily accessible to the rural consumers. The wooden waterwheels can also be purchased in some town centres, such as Pokhara and Kathmandu, and transported easily to site. There is usually no problem for operating the *ghatta*, and since there is an ample supply of unused manpower, especially in the hill regions, no need is felt to improve its work efficiency.

31. These water mills are often owned and operated by a local miller, a larger farmer or a community. Payment is received by withholding a proportion of the processed grain. *Ghattas*, therefore, produce a commodity which is a part of a barter economy. As will be seen later, this is also true of the agricultural products processed by MPPUs (Multi-Purpose Power Units) and

mechanical turbines. In this instance, the modern renewable energy technologies which provide mechanical power do not actually upset or alter in its essence the barter trade of the subsistence agricultural sector.

32. Ghatta owners, however, are not without problems. Water resources are becoming unpredictable as flood and drought affect the smooth running of the ghattas. This has forced some more prosperous operators to replace their ghattas with diesel engines. At present, most small hydropower application for direct mechanical agroprocessing in Nepal generates income in kind rather than cash. The ghatta owners do not have arrangements for the sale of their surplus with wholesalers, nor do the average ghatta users. Comparatively richer people in the locality do, and are thus in a better position to acquire and use relatively bigger turbines. The economics and politics of the hill areas are, therefore, influenced by the question of the ownership of larger mills which constitute an important source of profit and influence. It is against this particular socio-economic and political background that the diffusion of "modern" mechanical drive units should be seen.

C. Diffusion of "modern" mechanical drive units

1. Origin of the technology

33. The technology for small water turbines for mechanical power was first introduced into Nepal in the 1960s by missionaries and foreign aid organizations. Already in the middle of that decade, a Swiss-aided mechanical workshop in Kathmandu, Balaju Yantra Shala (BYS), undertook the fabrication and installation of turbines specifically adapted to manufacturing capabilities and conditions in Nepal. At first, propeller-type turbines were tried. But soon the possibilities inherent in cross-flow turbines, such as their capacity for direct mechanical drive or electricity operation, were recognized and their manufacture initiated by BYS. The design of the cross-flow turbines had been perfected and standardized in the early 1970s with the aid of the Swiss organization. Following these activities, a number of other agencies and organizations came forward and started producing and marketing cross-flow turbines in the country. Butwal Engineering Works (BEW), an undertaking of the United Mission to Nepal (UMN), is one such example. Nepal Yantra Shala (NYS), a private enterprise in Lalitpur, was another. Manufacturers like BYS and BEW are still the major companies manufacturing these turbines (see paras. 40-43 below).

34. In order to strengthen the evolving technological capacity in this field, but with a different approach, the Research Centre for Applied Science and Technology (RECAST) of the Tribhuvan University, established in 1977, has been working on the improvement of the traditional water mills and on the development of different water-powered pumps. The power output from such an improved water mill, which has been almost doubled, makes it possible to run a rice dehusker as well as a small electric generator, thus significantly upgrading and diversifying the mill's uses. Recently, the modular construction of the improved water mill with most of its parts, including the runner, made out of steel, was tried and tested. This modular version, popularly called MPPU (Multi-Purpose Power Unit), is now being manufactured by National Structures and Engineering Pvt. Ltd., a local company installed in different parts of the country. The turbine for MPPU is adapted to make it easy for transportation, assembly and maintenance. 12/

2. The demanders

35. The process of diffusion has been different for MPPUs and for the comparatively larger cross-flow mechanical turbines. One difference lies in the type of "demanders". Whereas MPPUs are basically geared to the owner-operator segment of the agro-processing market as an improved replacement of ghattas, the larger cross-flow mechanical turbines are usually installed by a "Seth", a local businessman, and operated by a few employees. The economic base of the two types of demanders can be clearly differentiated. The owner of a mechanical turbine with an installed capacity of around 50 kW can expect to earn NRs 4,300 to NRs 22,000 per annum from milling of grains and other agro-processing jobs, as compared to about NRs 4,000 to NRs 6,000 per year for MPPU owners. 13/ Ghatta owners probably earn about NRs 1,000 per year in cash equivalent.

36. MPPUs with the mechanized hulling and extracting machinery can save the hard work required for agro-processing activities, which women often perform. Oil extraction from mustard seed is increased from 7 per cent by traditional manual means to 29 per cent with their use. 14/ Like ghatta owners, however, most of the MPPU owners are used to processing agricultural commodities in limited quantities for local consumption. MPPU owners do not command sufficient economic power or influence in the national urban and monetized market. The quality of the produce milled with MPPUs, though a clear improvement on that processed by ghattas, is inferior to that obtained from cross-flow mechanical turbines because of the low speed of the MPPU turbines. This sets technical limits to the penetration of their produce into bigger markets. Economic viability for the demanders would seem to depend significantly on the grant elements in the credit scheme made available to them; a number of new MPPU owners interviewed in the course of the study in fact stated that they would not have installed them had it not been for the favourable credit scheme.

37. The relatively larger cross-flow mechanical turbines are usually bought by a particular type of owner - the relatively wealthy businessmen. Although these mechanical turbines had initially been intended for traditional ghatta owners, the credit set aside for their purchases has gone to those who had access to water resources and also commanded other resources such as money, access to transport facilities, and influence. These "rural entrepreneurs" have also been able to secure a larger agro-processing market located further afield (e.g. supply in bulk to a town), and therefore make more profits.

38. In the context of the rural barter economy of Nepal, the differential in the socio-economic positions and the associated control of resources and influence between the owner-operators of MPPUs and ghattas on the one hand and the owners of the larger cross-flow mechanical turbines on the other seems to have had a discernible impact on the working out of the diffusion process. As the diffusion took place in a way to serve rural elites who could concentrate milling capacity, the principal intended beneficiary of the diffusion in the design of the government policy-makers - that is, the poorer agro-processing operators - did not figure as prominently in the process. Ghatta owners often bring their surplus to the diesel or larger hydroturbine mills to be ground to a finer quality. It is also unlikely that the cash income of average MPPU owners will be increased rapidly above their present level if the existing conditions prevail. However, some of the more successful owners have managed to increase their income-earning capacity quite significantly from MPPU

investments. It should also be mentioned, that by installing MPPUs and by being able to talk about the equipment, they can enhance their social standing, especially in the rural setting. This is particularly so when the owners possess technical knowledge. The long-term developmental implication of their rising status on account of such knowledge could be quite significant.

3. The equipment suppliers

39. Because the domestic market is small and local manpower trained in industrial skills so scarce in Nepal, the indigenous manufacturing industry is generally weak. Most small enterprises have difficulty competing with imported goods from India. However, the manufacturers of mechanical drive units are today given contract allocations under the Agricultural Development Board lending programme which protects them to a certain extent from import competition. Although there are some internal rivalries between different manufacturers (especially among the bigger firms), there is no serious competition among them as they were informally allocated different geographic spheres of influence as well as different application areas. It seems that the manufacturers function in a protected, self-contained world, accomodating rather than competing with one another. Thus, for example, when the manufacture of MPPUs started to capture the market of less than 10 kW output range, the larger manufacturers of cross-flow mechanical turbines tended to build fewer small turbines. It should be emphasized, however, that there is foreign competition in the hydel sector (see chapter IV, section B below).

40. As shown in table 5, there exist side by side around 10 manufacturers of the mechanical drive units with varying capacity and capability. The three largest, BEG, NSE and BYS, account for more than three-quarters of the total number of units produced so far. The existence of several smaller firms, which specialize in MPPUs, reflects the policy of the lending body to create broadly-based domestic technological capability in small decentralized technologies.

41. The foreign aid agencies which initiated the small hydroturbine programme believed that for the majority of Nepalese the programme should have an industrial and educational impact, in addition to any economic benefit. The workshops of the National Structure and Engineering Co., for example, offer a course for new or prospective owners of non-traditional equipment to become familiar with, and receive training in, new plant and machinery. In addition, experience in site selection as well as in procedures for obtaining loans, grants and official clearances can be learned by farmers who may often be gaining access to machinery from the modern sector for the first time. The buyers of all turbines have to understand basic installation and maintenance requirements, which they learn from the manufacturers themselves. This knowledge in itself leads to a greater technical awareness, which can be observed on site when boys discuss, for example, the drawbacks of a particular belt system on the agro-processing machines.

42. The operation and expansion of the workshops meant accumulation of varied experience in engineering production by exposing the local managers and workers to manufacture of equipment of different specifications to meet different conditions. Today, the manufacture of small mechanical drive turbines, regulators, valves and penstocks are a part of Nepalese technological capability. Generators and many of the components used in the machines are still imported, as are agro-processing machines such as rice

Table 5

Local manufacturers of mechanical drive units

Name of enterprise	Of which: No of turbines produced	ADBN a/ financed	Financed by others b/
Butwal Eng. Works	126	117	9
National Structure & Eng. Co.	98	83	15
Balaju Yantra Shala	64	50	14
Nepal Yantra Shala	21	19	2
Kathmandu Metal Works	12	5	7
Thapa Eng. Works	10	7	3
Inter Tech.	7	3	4
Agro Eng. Works	6	1	5
Others	3	3	-
Total	347	288	59

Source: G.R. Shrestha, "State of the art of micro and MPPU hydro power in Nepal", paper prepared for a Planning Workshop on Micro and MPPU Hydro in Nepal organized by the Water and Energy Commission, Government of Nepal, Kathmandu, 19 September 1985, Annex I.

a/ Agricultural Development Bank of Nepal.

b/ UNICEF, CARE, etc.

hullers, oil expellers and flour grinders for attachment to MPPUs. The industrial and technological capability built in the industry, however, has been amply demonstrated by the fact that BYS exported turbines to Bhutan, Malaysia and Indonesia. It should also be mentioned that the manufacturing experience with mechanical drive units has had certain spin-off effects for the development of local equipment manufacturing industry. 15/

43. The small hydroturbine industry has thus given some Nepalese men an excellent engineering and mechanical training. A handful of entrepreneurs gained some valuable managerial experience, and some of them are also owners of the firms. Parts of the management of the initially foreign-aided organizations are now Nepalese, and between 1984 to 1988 the ownership of these companies will also be handed over to them. Workshop mechanics, however, do not seem to think their class of persons are rich or modern enough to have a full mastery of the technology, which is regarded as foreign, difficult, and accessible only to men with an English-language training. Nevertheless, mechanics are able to use their skills in the village setting, and thus act to a certain extent as transferers of the technology to the rural areas.

4. Mechanism of project initiation, financing and implementation

44. Many observers of the small-scale hydroturbine diffusion in Nepal have noted that the turbines tend to cluster in certain areas. This is mainly because the diffusion takes place through imitation - that is, a turbine is installed because the owner has seen the benefits of similar equipment belonging to another person. A kind of rivalry seems to develop around this new equipment which intensifies the imitative behaviour, particularly in the Kathmandu valley area and in the eastern area, supplied by BEW. However, as an engineer from Kathmandu pointed out, this pattern of diffusion does not seem to enhance the inventiveness of the individual owner. The turbines are used in the same way, and manufacturers rarely if ever receive visits from individuals wanting a turbine for a very specific application of their own.

45. From an economic or even technical point of view, there is a certain capacity limit which the turbine market should reach in any one geographic area. Although any number of turbines may be installed in any one area through the "demonstration effect", creation of capacity far in excess of the demand will, at least in the short run, lead to scrambling of mill owners for clients. If someone is lucky to get all the jobs, the other mills then stand idle. Or it may be that the clients of the original turbine owner are divided, and neither the new nor the old owners are able to operate at a profit and repay loans. Many cases have been cited of two or three smaller turbines being installed in close proximity, giving rise to an unsatisfactory situation for all the mill-owners concerned. The problem is particularly acute when the water flow, which varies from one season to another, may not be sufficient in the dry season to supply all turbines, and some turbines fall into disuse and are irreparably damaged. One may question why this clustering of turbine installations occurs when it is obvious that it will jeopardize the commercial chances of each. In some cases, non-commercial motivations such as gaining prestige by the fact of having a turbine installed or even obtaining a government loan seem to have a preponderant weight. This should not, however, cloud the fact that the credits provided by the Agricultural Development Bank of Nepal (ADBN) has played a decisive role in the economic installation of the turbines.

46. The ADBN has not only been the major financing agent for mechanical drive unit installations, accounting for about 83 per cent of the total number installed (see table 5 above), but has also acted as a catalyst for the promotion and dissemination of the technology. Its turbine installation finance started in 1974/1975, but it has picked up considerably since 1982 when the Asian Development Bank extended financial assistance amounting to $US 1.98 million for installation of 160 turbines over a three-year period. ADBN maintains a nation-wide network of 362 field offices through which turbine installation and other development projects are carried out. Two Appropriate Technology Units established by the Bank are proving to be a useful channel for the promotion of the technology, and more such units are being planned. 16/

47. A proper site survey and inspection are crucial to the economic installation of small-scale hydro turbine units. If a rural entrepreneur approaches the Agricultural Development Bank of Nepal with a request for a loan, the whole application apart from the site is dealt with by the bank's field officer in the local area. The field staff of the Agricultural Development Bank assess the households to be covered by micro-hydro electrification schemes and the tariff to be collected. In the case of mechanical drive units, they assess whether the owner will be in a position to pay back an ADBN loan. They also assess land ownership, access to water rights, and feasibility of project with regard to potential for future uses. Repayment schedules are worked out according to the feasibility of each turbine. At present the purchaser of a new turbine has to have Rs 200,000-Rs 400,000 for a smaller turbine in order to be able to match the loan from ADBN. Personal contacts with the field officer at the local level are a necessary pre-condition for a successful application for a loan, as his support is needed to mobilize the requisite resources. One or two examples of co-operative ownership of a turbine have been financed by about 60 members raising mortgages on their land to buy shares.

48. As to the site surveys, they are currently done by the equipment manufacturers, at their cost. These manufacturers meet the owners and operators, and can combine these visits with collection of data and information on operation and maintenance of plants operating in that area. This communication between operators and manufacturers is seen to be crucial by both customer and supplier; however, the cost of transport and the lack of a formal budget for such activities limit such exchanges. There is, therefore, a suggestion that the manufacturers should continue to do the surveys but should be paid by the Bank for this service. There is also a suggestion that an independent unit should be established to do the assessment. The site survey is an occasion of frequent conflict as technical criteria can be mixed up with non-technical ones. It is also of much broader importance, in view of the problem of deforestation.

49. Manufacturers usually take the average head of water available during the year, and make a site selection based on the flow of water available to the plant throughout the year. Rivers in Nepal are changing their characteristics, owing to the deforestation of many hill slopes, and this may result in inaccurate information from local people about site characteristics and hence in unpredictable flooding or landslides in a number of sites. Ecological destruction of the Hill and the Terai areas may reduce the number

of small turbine projects which will be installed by impoverishing potential agrarian purchasers and calling in question the usefulness of the technology itself in the eyes of the rural entrepreneurs.

50. At present, neither an independent assessment unit nor hydrological data are available which would allow for external verification of the suitability of a site. For further diffusion of the mechanical drive units and MPPUs, improvement of the information base concerning potential sites and dissemination of the capacity to carry out some basic techno-economic analysis seem to be essential. This is so particularly because the conditions for turbine installations and operations in Nepal vary greatly from site to site owing, among other things, to logistical factors. The ADBN insists on, and trains owners in, recording operational and financial details of mechanical power turbines and their profits. This is no doubt a useful first step. However, more thought would need to be given to evolving joint working mechanisms among the potential owners of turbines, equipment manufacturers and the ADBN, as well as other public agencies that can reach many different locations, if the goal of diffusion on a massive scale is to be seriously pursued.

Chapter IV

SMALL HYDROELECTRIC POWER PLANTS

A. Introduction

51. The third type of small-scale hydro technology in Nepal is the small-hydel technology employed for electrification schemes. These projects, mostly owned and operated by the Government through the Small Hydro Department of the National Electricity Authority, usually constitute isolated power systems in areas remote from the current reach of the grid. They are usually implemented with foreign financial assistance, either private or public.

52. These electrification schemes have enabled people in remote locations to gain access to electricity particularly for lighting. However, there is so far little evidence of increased industrial or other economic activities resulting from the introduction of these hydel schemes. The fundamental problem that arises from this lack of industrial base load is that plant utilization tends to be low, and revenues are insufficient to cover running costs, not to mention amortization of borrowed capital. Table 6 shows summary statistics of operation for two well-established small hydel projects in different parts of the country. In both cases, load factor is low and there is a sizeable operating deficit. It is understood that this is characteristic of most, if not all, of the operating small hydel systems in Nepal. According to a recent paper prepared by the Nepal Electricity Authority, small hydel projects under operation showed a load factor of 15 to 20 per cent at the initial stage of power supply. 17/

53. Apart from the inadequacy of base load, another major cause of the deficient performance of the small-hydel schemes is the high staffing levels needed to operate isolated power systems, which adds to the operating cost. Low tariff levels and high system losses (i.e., difference between generated and sold electricity) arising usually from inaccurate metering and illicit connections, which is evidenced in the case of the Surkhet project, further diminish the economic performance of these stations. As a result, the continued operation of the existing stations depends on perpetual subsidy from the Government.

B. New policy approach to small-hydel development

54. The National Electricity Authority has the following selection criteria for construction of small-hydro power stations: (i) district headquarters; (ii) multi-purpose projects, i.e. electricity combined with irrigation and water supply; (iii) village with cottage industries; and (iv) places of tourist interest. One interesting development which is taking place in Nepal is that the National Electricity Authority is encouraging the private, "rural entrepreneurs" (this phrase is in fact taken from the National Electricity Authority's policy papers) to run small hydroelectric stations up to 100 KW.

55. There is ample evidence that demand for electricity does grow in areas with electricity supply, though at present this is mainly in the urban industrial, government and hotel tourist sectors, and less in, for example, the agro-industrial or rural domestic sector. The Government's new policy is

based on the belief that rural electrification can follow the same pattern of commercialization as in the diffusion of mechanical drive units, the only difference being the longer payback period which has to be managed.

Table 6

Summary operating statistics (1982/83) for the Surkhet and Dhankuta Small Hydel System

Scheme region	Surkhet Mid-Eastern region	Dhankuta Eastern region
Established installed capacity (KW)	1978 3x115 a/	1972 2x120
Staff	47	42
Running Costs (NR/yr)	450 000	772 600
Tariff income (NR/yr)	193 840	504 000 b/ (228 000)
Income/running cost	43%	65% b/ (30%)
Energy sold (kWh)	389 021	667 585
Consumers (Percengage energy sold)		
- Domestic	391 (82%)	711 (89%) c/
- Industrial	6 (17%)	9 (10%)
- Street Lighting	- (1%)	- (1%)
Energy generated (kWh)	503 381	716 067
Losses	22.7%	6.8%
Load factor	16.7% d/ (25.0%)	34.0%

Source: Compiled during an UNCTAD mission (1983).

NRs - Nepalese rupees

a/ One set inoperative at Surkhet over full period.

b/ Figures for Dhankuta are before and after recent tariff increase.

c/ Dhankuta percentages estimated from L. Krayenbuhl and E. Ledergerber, Small Hydel Development Programme -- Programme Evaluation Final Report. Direktion fuer Entwicklungs-und Humanitaere Hilfe, Bern, Kathmandu/Zuerich, January 1981.

d/ Higher Surkhet load factor based upon two sets only.

56. In areas where people are able to acquire capital and mobilize their social influences to break out of stagnating agricultural production, electricity appears to be in demand. One example of this is the Jomsom station, which has a maximum capacity of 260 kW and supplies 15 villages as well as Jomsom itself. The villages are connected by 19 km of distribution lines which cover a population of 3,500 people. They use the power for two wood workshops, some wood mills, and a distillery. In Jomsom, the hotel owners have lighting, room and water heating and power for other equipment. The Small Hydro Power Department is about to install another 50 KV transformer and the load factor will then be increased to approximately 40 per cent.

57. According to the new policy, in 1985/1986 20 private rural electrification schemes were to be given a subsidy of 50 per cent on the cost of the generating system. Hydroturbines for mechanical power are also being encouraged to generate electricity with ADBN credits. The new "rural entrepreneurs" who will run the small electricity stations will receive some technical assistance from the Government. They will run on a commercial basis, as have the mechanical ones hitherto. Delicensing of hydel plants will give their new owners the monetary incentive of tariff charges to install turbines for rural electrification. Observers expect that these new owners will be either "pradhanpanj" or local wealthy people who will install such stations to support their particular activity, be it running a saw mill or a hotel.

58. In order to overcome some of the problems of private running of micro hydel stations under 100 kW, the Small Hydro Department of the National Electricity Authority is setting up a special unit which will ensure the continued full integration of private stations into the national programme. The policy is thus based on the assumption that the very small private grids will create the initial demand for electricity, and once the demand exists these grids can be linked up to form a larger one. The critical question is: will the rural entrepreneurs find enough consumers to make private electricity generation profitable? Such a station will probably have to have a utilization factor of more than 75 per cent - i.e., 18 hours per day, to break even. An electric stove costs 225 Nepalese rupees in a country where the minimum wage is 250, and the average income of a very small farmer, 100 Nepalese rupees per month. In rural areas without tourism it is unlikely that enough domestic consumers will be found to reach a constant full load, in which case one industry, one saw mill, or one ropeway will have to be a constant consumer.

59. Part of the reasons for the delicensing has been that mechanical drive units installed privately seemed to have a better return on investment than the small-hydel electric stations which only generated electricity. As many of the mechanical turbines started generating their own electricity, the "rural entrepreneurs" gained experience in supplying electricity and the National Electricity Authority became willing to allow this group of people to own electricity generating stations.

60. Other small-hydro electric stations which are larger than 100 kW will be either integrated into larger projects in the long run or perhaps not built unless they have sufficient existing load demand. Out of 10 small hydel stations in operation, two will be integrated into grids running from new larger units in the near future. There is a need felt increasingly to couple

existing electricity-generating capacity with demand-generating projects of the private or public sector. 18/ While this does not necessarily mean immediate and strict application of "economic efficiency" criteria to the planned construction of larger stations, there will be an increasing pressure that adequate load planning be carried out for those projects.

C. Equipment and related services supply from domestic sources

61. The foregoing discussion of the installation of small-hydel plants has an important implication for the development of the domestic technological capability for supplying the equipment and related services. Table 3 above shows some of the qualitative and quantitative differences to be found in diverse small-hydel units in the degree of local participation, the planning and design, civil works, mechanical and electrical works, and functions of operation and maintenance. Planning and design, civil works, mechanical and electrical works and the operation and maintenance of micro-hydro projects up to 100 kW have in most instances been undertaken by people trained on the job with little formal education, or by technicians with practical training to back up formal education. In larger units beyond 100 kW the domestic inputs and participation decreases very rapidly, as technology is beyond the reach of local capacity and skills.

62. This raises an important issue relating to the relative advantages of domestically produced versus imported equipment. A study of this question concerning Nepal compared the costs of local technology to those of imported technology in similar cross-flow turbine projects. The local technology was based on a Nepalese design and construction, and supply of local components such as step-up transmission, coupling, base frames, gate valves and penstock; only the alternator was supplied from abroad. 19/ The results showed that Nepalese equipment cost approximately 30 per cent less than the imported equipment. Domestic technology proved not only to be less expensive, but had the immense advantage of not using up scarce foreign exchange. Although for reasons of enormous project diversity and site-specificity in the case of small-scale hydropower projects such an interpretation should be considered with care, it appears that the domestic capacity to supply the equipment and deliver the project has an important impact on the economies of the application of small-hydel technology.

63. Turbines up to 60 kW have already been produced in Nepal and, on the basis of the acquired experience, one could assume that the technological capacity for building units up to 100 kW of the cross-flow variety would go up relatively quickly. Considering that the small-scale projects under construction or at an advanced stage of planning in 1983 could be indicative of the existing market for such equipment, available data on such projects would point to a potential of 24 units of up to and including 100 kW. Out of these, 11 had already been explicitly defined as units in projects employing domestically produced turbines. Most of the other planned projects considered the use of international bidding for the procurement of equipment. This would mean that the national manufacturers for this range of turbines have already doubled their participation in schemes under construction and being planned, and that, owing to the lower costs of their turbines, they could presumably participate competitively in some of the international bidding for other such micro-units.

64. The two larger equipment manufacturers, Balaju Yantra Shala (BYS) and Butwal Engineering Works (BEW) are the mainstay of technological up-grading efforts in this area. In fact, the two co-operate with each other on technical matters regarding turbines even though they are commercial competitors. Nevertheless, they are following different approaches for further development.

65. BYS continues to draw on the R & D input for turbines from SATA, the technical assistance wing of Helvetas, as it did with the initial mechanical drive units. Relying on such support, BYS has recently designed and produced a cross-flow turbine of 150 kW capacity, and has also developed a new design with greater efficiency, termed "split-flow" turbine. BYS also offers management advice and is trying to boost its capability to offer a total service and equipment system through close contact with Swiss technical assistance. At the same time, for turbines over 50 kW, BYS will collaborate with an English company for a technical license in order to gain access to new designs. This commercially-based agreement is expected to help BYS to compete more effectively in the small-hydro electrical turbine market. Although the original mechanical turbine purchasers still constitute its main clients, it envisages its future to lie in the new and larger markets, including the export market, as it has already exported mechanical turbines to Bhutan, Malaysia and Indonesia.

66. As for BEW, the designer and producer of the cross-flow turbine, it has entered into a license agreement with a Norwegian manufacturer and seems to be seriously contemplating the production of Francis turbines up to 2 MW, which could theoretically allow the manufacture of equipment beyond mini-hydro range. In view, however, of the constraints from the demand side as discussed earlier, and also of the vastly more complex nature of the technology, such steps would have to be considered very carefully.

67. For both BYS and BEW, foreign competition is quite keen, and any significant upgrading of product range would have to be backed by some measure of protection and support from the Government. Without the latter, they will also lack incentives to attempt such upgrading. Because of the small size of the domestic market and the proximity to Indian industries, the firms almost inevitably depend on the Government's protective policy for their growth. The influence of the latter can be witnessed, for example, in the work of the electrical section of BYS to fabricate transmission lines and other electrical components for rural electrification schemes rather than to take up the manufacture of generators and ancillary equipment on its own.

Chapter V

FACTORS AFFECTING FURTHER DIFFUSION OF SMALL-SCALE HYDROPOWER TECHNOLOGY

A. Development of the market

68. The foregoing discussion shows that the spread of small-scale hydropower technology in Nepal has taken place on the one hand through private, commercial channels (i.e., small mechanical drive units) and on the other hand by way of public intervention for rural electrification (i.e., micro- and mini-hydro electricity generation by utilities). There is some measure of convergence between these two channels as the new government policy of delicensing allows private entrepreneurs investing in turbines (mostly below 100KW) to supply electricity publicly. Corresponding to this development on the demand side, there has also evolved a domestic industry that supplies equipment and related services in the area of small-scale hydropower technology. Further diffusion of the technology in the country will obviously depend on the present and future shape of this market.

69. It should be specified at the outset, however, that the present small-hydro power market in Nepal does not exactly approximate the economics textbook concept of a market. The key actors in it, the National Electricity Authority and principal equipment suppliers, are deeply dependent on foreign sources of capital and technology and are far from "maximizing profit" and "mobilizing resources according to market signals". 20/ What is referred to as "market" here is, in fact, parallel and differently organized trades with no clear linkages, even though some of the entities on the supply side operate in more than one area. The demand side, in particular, is quite fragmented along socio-economic groupings which are formed by skewed income distribution, social and geographical differentiation and, most decisively, varying accessibility to means of production and marketing of output. Thus, for example, if the small-scale farmers have no way of selling increased milled produce or expanded output from cottage industry operation, it would not make sense for them to acquire the means (e.g., small-scale hydro turbines) to increase or improve output.

70. Furthermore, in considering the development of any market in Nepal, one should remember the existence of two constraints, of rather general and overriding character, on the country's development process. One is the disadvantages of being a land-locked economy, which are manifested, for example, in the high costs of trade on account of high transit costs and additional costs from delays and damages. The other is the difficulty of having an open border with a much larger economy (i.e. India), which has a well-established industrial base. The latter's industrial development policy, in particular its trade régime, has a deep impact on Nepal's corresponding policy, depriving Nepal of effective control over market development strategies. 21/ It is against such a background that some factors affecting the future development of the small-scale hydropower market are discussed below.

71. As mentioned earlier, apart from investment costs, the economics of small mechanical hydro turbines depends critically on the utilization factor. Generally, such a plant has to operate for 18 hours per day to break even, and the water and other site conditions should permit its running throughout the year. For 100 kilograms of milled rice, 4-5 kW of power is needed. A perfect

installation, the manufacturers claim, would earn NRs 100,000 in the peak season. One operator and two employees can earn NRs 1,000 per day, and thus could have a return of 30 per cent per year. This may not always materialize, but as mentioned before, the small mechanical turbines have been installed predominantly through the commercial mechanism, thus indicating a certain financial benefit to the owner.

72. Because of the fluctuating character of the load demand in remote locations, it is generally difficult to select a small hydro turbine. For a stand-alone plant, there are thus operational problems either of obtaining high utilization factors, if a large unit size is chosen to reduce specific costs, or of meeting peak demands if a small unit rating is chosen. Most of the existing plants in Nepal usually face one or the other problem. This problem exists even for a grid-connected plant in Nepal since, in the absence of fossil fuels, a thermal/hydro mix to balance the load daily or seasonally is out of the question.

73. The economic viability of small hydel plants is currently unfavourable. They are not viable on strictly commercial terms. Capital costs are quite high - between 27,000-73,000 Nepalese rupees per kilowatt. On average, a small hydel station seems to have an income of about 11,000 per month, which is not even sufficient to cover salary, maintenance costs and capital servicing. Thus the electrification of all district headquarters, 27 of which will be supplied by small hydel schemes, is difficult to justify on a purely commercial basis. The Small Hydro Power Department of the National Electricity Authority is, of course, aware of this and explicitly states that the small hydro power projects "should not be evaluated purely on commercial basis or on the profitability of the investments". 22/

74. Careful load planning and management can alleviate the demand-supply matching problem inherent in isolated small hydro power plants. An example from Namache Bazar is quite instructive. 23/ Here, electric cooking and space heating in tourist lodges are connected to a small hydroelectric plant, leading to resonably high load factors. However, if electric cooking and space heating were allowed to be used at the time of peak loads, the Namache Bazar plant would have needed too large a turbine to allow transportation to the site. They had, therefore, to introduce a novel switching system to which a limited number of tourist lodges are attached and peaking can be thus controlled. As a foreign aid project, Namache Bazar could afford to introduce experimental techniques for load planning, a crucial first step to an efficient use of the plant, if not its financial viability. Similar load planning is crucial to the viability of most hydel projects but similar innovative solutions are not often to be found.

75. On the side of equipment supply, at present there are 10-12 turbine/MPPU manufacturers with a combined capacity for small turbine production and installation of approximately 200 units per year. Though the manufacturers complain of slackness in demand for mechanical turbines and a need for a marketing campaign, "rural entrepreneurs" have on the whole taken up the offer of loans to improve the agro-processing sector through hydro turbines, albeit on their own terms. The response of two of the manufacturers to the volatile atmosphere of the mechanical turbine sector has been to move into the market for larger turbines (over 100 KW) for small-hydro electricity generation. Only one small company seems to have gone out of business, the reason for which seems to have been primarily managerial.

76. The international tendering system for small hydel stations over 100 kW, which the Nepal Electricity Authority introduced in 1983, could drive domestic suppliers out of the market. They are not able to offer complete systems competitively owing to the cost, including taxes and duties, of imported raw materials and components. Six tenders were so far out for small hydel turbines, but none will go to local manufacturers, whereas out of the preceding 10 units installed, six were supplied by them. Whereas previously small-hydel stations were built with the Government to a certain extent relying on the aid agencies and the manufacturers for technical information (in the range up to 80 KW local manufacturers were more or less given a free hand on the technical side), the new programme of the National Electricity Authority at the higher end is likely to be handled entirely by foreign manufacturers.

77. This new situation is also a result of the recent trend in the policies of industrialized aid-donor countries towards utilizing aid for the benefit of their own equipment industries. The aid policies of the donor countries involved in small hydropower in Nepal at present make it difficult for local manufacturers to participate in projects or organize a consortium to maximize local participation. Out of 17 new small hydro power stations currently under construction, six are being built by the Chinese with no local participation on the electro-mechanical side. The Japanese contractors in Tatopani will only use penstock pipes manufactured in Nepal if steel can be released. Such practices have a direct impact on the ability of manufacturers to build up their infrastructural resources. For Salleri Chialsa, a combined mechanical and electrical power project to supply existing local industry and adjoining villages, the Swiss agency, Helvetas, imported (air-freighted) Italian turbines, the indicated reason being the high cost of Indian steel and the cost of training existing Nepalese manpower.

78. In short, continued market development with increasing technological capability may not be assumed. The equipment manufacturers seem to be squeezed for the moment between the weak economic base of some of their potential rural customers on the one hand, and the increasingly complex technology and capital-requiring production methods required for potential contracts from the Government and aid agencies on the other. To break out of this binding situation, these firms would have to take measures to consolidate and further strengthen the manufacturing as well as supplying capability of turbines up to 100 kW. As already discussed earlier, they would have to work closely with other entities engaged in the promotion of the small hydro technology at the lower end to improve the scope of its diffusion. They may also have to diversify into other areas of equipment manufacture in a more serious manner than in the past.

B. Problems of infrastructure and management

79. The development of the market, and the manner in which this takes place, is influenced by the extent of formation of physical and economic infrastructure, and this is nowhere more evident than in Nepal. Take the ghatta market for example. Its formation in dispersed and remote locations has to do at least partly with the underdevelopment of physical infrastructure (e.g., transportation, communication) which has permitted rural artisans in different communities to exercise their skills without much competition with one another. The shaping of the markets for more "modern" turbine technologies on the other hand has relied heavily on the supply of foreign

inputs of capital, technology and materials and, therefore, on the functioning of the economic infrastructure (e.g., markets for capital, skilled labour) in and around Kathmandu. One peculiarity of this development, however, is that the latter has been developed in a rather ad hoc manner. Thus each industry or workshop has to carve out for itself a network of contacts and resources in the foreign sector, so that it may be provided with capital and skill training opportunities and assured of a continued supply of raw materials and finished and semi-finished components through imports. Governmental procedures for imports of materials and components are quite cumbersome and slow, and manufacturers can directly import their requirements only to a limited extent. Moreover, the existing system of taxes and duties does not favour small industries. However, even without such procedures, the security and reliability of material supply would be far from guaranteed.

80. In the case of mechanical and electrical engineering work, firms need testing facilities. Only two of the equipment manufacturers have them; most, however, find the price of testing equipment too high and possess access only to limited testing facilities at RECAST. The situation is complicated especially since in 1982 the Government added a stipulation in the tenders of the National Electricity Authority that X-ray of certain components is essential. This requires expensive equipment and facilities as well as trained staff at the manufacturing plant. Local manufacturers, even the two leading ones, do not have such facilities. Questions are being asked whether this requirement could be dropped, at least for a certain range of small turbines, without adversely affecting their performance or whether investment incentives could be given to the local industry with commitments regarding future orders so that they can install the required facilities.

81. The insecurity of the entire system of production and supply lies in that products could only be made and sold to the extent that their producers could maintain the infrastructure linked to their industry. However, as was seen in the discussion of the market development, the industry's infrastructure building effort has been rather segmented. Different bodies involved in the industry are acting independently, driven by their own institutional logic. Thus, some of the managers in the two larger manufacturers want to upgrade their technology, while the ADBN is interested in promoting MPPUs. The National Electricity Authority, however, appears to be interested in establishing much larger small-hydro electricity plants (at least 500 kW) which are beyond the technological and industrial capability of the local equipment makers, leaving only delicensed below 100 kW plants for the latter. The Government has recognized the need to find a common thread to weave together these seemingly disparate efforts, and is calling for a master plan for small hydropower development as an "urgent necessity". 24/

82. One important reason for the continued emphasis on the role of small hydropower technology lies in the fact that considerable experience and skills have been gained through accumulation of projects and training programmes, as well as related education. At the most general level, there are more than 10 education and training centres for engineers and technicians which come under the jurisdiction of the Training Directorate and the Ministry of Education. 25/ The importance of on-the-job training is also universally recognized. Apart from training for employees in the workshops, the newness of turbine technology requires people who use it to be trained in operation

and maintenance. Manufacturers train operators at the installation stage, and give training for two weeks to one month in their own workshops and again during the time of commissioning and load testing. Usually manufacturers feel that nothing much can go wrong if operators follow instructions. The Agricultural Development Bank also provides help to new operators by showing them how to manage the mills. In all these ways, though not necessarily adequate especially in the rural areas, the knowledge and skills relating to the small hydropower technology are spread in the country.

83. As to the skill base of the equipment suppliers, managers and engineers of BYS and BEW have generally had some foreign education, on government scholarships or other sponsored programmes. Through mechanical training programmes organized by these workshops at BYS and BEW their skills have been transmitted to a wider segment of the industry personnel. The men who run Nepal Yantra Shala and other newer workshops were mechanics who took the opportunity to start a workshop of their own after leaving BYS. It is important to point out, however, that, because of the relative insecurity of the small-hydro turbine market, there are genuine fears that the established know-how base in both the technical and managerial areas might be weakened as experienced people leave the industry, for example, to take up jobs on the big hydroelectric dams. The proposed exercise to prepare a master plan for small hydropower development should, therefore, encompass a programme for further development of the skilled manpower for the small hydro sector.

C. The role of Government

84. The Government plays an important role in the diffusion of small-scale hydropower technology in Nepal. As was seen in the preceding discussion of the market structure and general economic infrastructure, the Government in many ways forms an integral part of the market itself, and there appears to be a corresponding expectation on the part of all the actors involved in the market. However, the exact nature of the Government's role, as well as the extent of its impact, differs from one segment of the market to another.

85. In the area of small-hydel electrification schemes, the involvement of the Government has been total. The Small Hydro Power Department of the National Electricity Authority (which used to be the Small Hydel Development Board) plans, negotiates with foreign donors, and implements as well as operates the mini and micro-hydro schemes designed mostly for remote hilly areas and district headquarters. As mentioned earlier, the economic performance of these small-hydro power stations has not been satisfactory. Part of this has been attributed to the lack of expertise and experience in the planning, siting and designing of plants and deficiencies in administration and management of the operation, which are internal to the national organization concerned. However, part also is said to be due to the eagerness of outside donors to finance such projects, which tends to reduce the need for more rigorous planning and standards of financial performance. 26/ There is general acceptance of continued subsidy of the operation in the remote stations based on social considerations, which is reinforced by the lack of competitiveness of alternative means of energy supply (e.g., diesel-engine generated electricity). 27/

86. One obvious area for improvement is the alteration of the electricity pricing policy. Demand is growing for lighting; in the case of Surkhet and Dhakuta stations cited earlier, 100 to 150 applications for connection were pending in 1983. Although increased tariffs would probably not solve the financial problem, they would certainly improve the situation.

87. More fundamentally, however, the financial problem arises from the Government's over-dependence on domestic lighting as the principal load. It is well known that the economics of small-hydel schemes improves with the scale of the electricity-generating operation, and spontaneous growth of industrial load is implicitly assumed to justify the installation of a unit larger than the lighting demand permits. There is no evidence that the introduction of electricity has significantly triggered development, especially industrial activity, in the areas concerned. 28/ There has been no co-ordinated attempt, at either the planning or operational level, to integrate new productive demands with small-hydel development. There seems to be an ongoing debate, especially in the Alternative Energy Cell of the Water and Energy Commission and the Small Hydro Power Department of the National Electricity Authority, for incorporating small-hydel development schemes into the country's Integrated Rural Development Programme, but no concrete development has come about mainly because other ministries directly concerned with the latter are yet to be involved. There seems, therefore, to be a preponderant need to improve the policy-making and implementation machinery relating to the small-hydel development. 29/

88. With the new delicensing policy for the small hydel electrification schemes up to 100 KW, the Government assumes a new role. The private entrepreneurs are to carry the main burden for managing and running the small hydel installations, including the small grids, which has already been done on a small scale with MPPUs and small mechanical turbines and which may be carried out on a larger scale even without delicensing. The Government is endorsing and promoting such schemes. A central part of the new role would consist in the provision of credits to the entrepreneurs through the Agricultural Development Bank of Nepal and of the 50 per cent subsidy incentive on the cost of the electricity generating system. Even with these schemes, however, the entrepreneurs would have to assume considerable amount of risks in making the investments for the small-hydro electricity units. The Small Hydro Power Department of the National Electricity Authority would, therefore, be expected to provide advice concerning the technical, engineering and economic aspects of such schemes. The unit to be established within the department would also have to ensure the integration of these private grids into the national programme.

89. In contrast to these electrification schemes, the spread of the small mechanical turbines and MPPUs has taken place with much more limited involvement by the Government apart from the credit from ADBN, as mentioned earlier. The incentives provided by the latter were sufficient to induce the private agro-processors in rural areas to make the investments. It should be mentioned, however, that RECAST, a government-funded research organization, played an important part in the development of MPPUs, and continues to provide a useful technical service, including the information dissemination function, for the promotion of small mechanical turbine and other renewable energy technologies. A more recent example of its work includes development of a lightweight sheet metal ghatta. Development of appropriate technologies to be used with the spreading mechanical energy sources may also be envisaged.

90. The social, economic and geographical conditions surrounding the market for mechanical drive units are such that the initial rounds of adoption of such technologies may not necessarily lead to dynamic chain reaction between increased income and investment. As was already explained, the market and economic structure is too fragmented in rural Nepal for such a process to take place spontaneously. The Government may, therefore, have to rethink the further spread of the small mechanical turbine technologies in a broader framework of rural development policy. If, for example, the diffusion of such technologies is slowed down in any area because of the perception of heavy risks by individual families, some institutional innovation at the community level may be needed to make up for the gap. A successful example of a village co-operative to run a mechanical power plant is already known. The Government may be in a good position to encourage such institutional arrangements in places where rural entrepreneurs do not emerge in spite of favourable conditions for installation.

91. The role of the Government would also have to be reviewed from the point of view of requirements for further development of the small-scale hydropower equipment-supplying sector. There is, to start with, the need to define the R & D requirements. If there was a strong institutional arrangement which regularly followed up on the performance of existing turbines and their end-use applications, consumer oriented improvements based on the experience of the owners and the actual operation and maintenance could be recommended to manufacturers for incorporation in designs or could lead to productive research by RECAST. Suggestions have also been made regarding the creation of an extension service to constitute a feed-back mechanism for technical information, which could simultaneously cover a part of the training needs.

92. In the past decade, smaller manufacturers have gained their know-how essentially from BYS and BEW. If no new developments or improvements come from them in the smaller turbine range, there is a danger of some serious lacuna arising in this field. The Government might want to take into account suggestions that smaller manufacturers specifically could be supported and encouraged to undertake their own developmental work on the small-scale end of the technology. This could comprise encouragement through financial incentives to improve the quality of components; to standardize further and reduce costs; to achieve import-substitution by manufacturing finished and semi-finished components as well as machines such as generators; to manufacture locally other consumer end-use equipment and gadgets; assess field performance of machines and plants and introduce improved designs, materials and quality in order to increase plant reliability; to test new materials; and so on. In fact, the awareness of this problem is already there and Akal Man Nakarmi and the National Structure and Engineering Pvt. Ltd. have provided a good example of how this can be done on the technical side.

93. The Government's role in respect of equipment manufacture at the more advanced technology end, involving BYS, BEW and a few other older, technologically established companies, may need reconsideration. These firms seem to be losing a part of the market to MPPUs and also experiencing a certain market saturation for their mechanical turbines, but at the same time seem unable to take a larger share of the market for larger size plants owing to high cost of imported raw materials, components and generators. They may be rationalized taking into account the possibility of import substitution of critical equipment and components, standardization and means to promote volume production.

94. However, the present policy of most aid agencies which finance the small-hydel projects to support their home industries to the maximum possible extent without any significant involvement of local industry (e.g., turn-key supply) is a serious constraint for the process of consolidation of the accumulated domestic technological and engineering capability. This situation may, therefore, call for elaboration of a national policy of "unpackaging" of small-hydel plants supplied through aid schemes and the institution of suitable guidelines, including setting down of "minimum local contents" to ensure the participation of the domestic firms in the supply, erection and commissioning of the projects. Without such support, the technological and industrial capability of the firms already operating in the country, which can reduce capital costs (and foreign exchange bills) for future installations, assure continued supply of spare parts and repair services for all types of units, and generally serve as a principal diffusion mechanism for any other technology, may be seriously impaired.

Chapter VI

SUMMARY AND CONCLUSIONS

95. Nepal has a relatively long history of utilizing small-scale hydropower technology. From time immemorial the rural population has used *ghattas*, or traditional waterwheels, for milling of grains; 25,000 such units are said to be still in use today. "Modern" small-scale hydropower technologies have been introduced into the country since the 1960s for mechanical energy and for electrification schemes. During the 1970s an improved version of the traditional waterwheel was developed and diffused in the rural area. Although the energy produced by all these means accounted for only a small share of the total energy consumed in the country, the use of these technologies had a particular significance in that (a) it provided energy for the rural population who did not have access to grid electricity and imported oil and who suffered from increasing fuelwood crisis, and (b) it was accompanied by considerable development of domestic technological and industrial capability in the supply of equipment and related services, especially at the simpler end of the technology.

96. The most encouraging development has been the spreading use of small-scale mechanical drive units, both MPPUs and larger mechanical power units (up to 50 kW), for agro-processing activities. These units have been purchased by private individuals with the aid of credits provided by the Agricultural Development Bank of Nepal (ADBN). The generally favourable financial results of their installations is witnessed by the low rate of defaults on the loans. While these units are primarily used for mechanical energy generation, they can provide lighting and limited electricity load. The economics of these mechanical-*cum*-electrical units has also been good.

97. The role of the Government in the diffusion of these units, has mainly been in the provision of the credit facility. The principal mechanism for their diffusion has been the domestic manufacturers of equipment which not only make the units but also carry out the initial site surveys, installation and training of operators. The ADBN has also played an important promotional role, though its co-ordination with the manufacturers can still be improved. The equipment manufacturers originated in a few workshops established by foreign aid organizations, mostly non-governmental, and have been growing by mutual sharing of technology and market accommodation.

98. In contrast to the dynamic development of mechanical and combined mechanical electrical turbines, the small-hydel power plants (ranging from 25-500 KW) established, owned and operated by the public power authorities have encountered problems. Their economic performance has been generally poor on account of low load factors and operation costs, in particular for maintenance coupled with low, subsidized tariff rates. The installation of these plants, nevertheless has been promoted by a combination of factors including the Government's policy of providing decentralized electricity and the willingness of foreign aid donors to supply such plants. To the extent that the problems faced by the existing plants are internal (e.g., problem of management), their resolution should receive priority attention. For the many projects under preparation, a thorough review may need to be carried out on the basis of more complete data about potential sites, using systematically

elaborated criteria including in particular the economic potential beyond lighting. The need for such a review and a master plan for further development has been acknowledged by the Government earlier. 30/

99. The recently-instituted Government policy of "delicensing", allowing the private ownership of small-hydel plants up to 100 KW not only for their own agro-processing and lighting use but also for sales of electricity in the locality, has opened up a new perspective for further development of the small-hydro electricity sector. These arrangements offer the possibility for increasing the economic viability of small-scale electrification schemes by reducing the specific costs of equipment as well as site works and increasing the load factor of the installation for the structure and the absence of developed infrastructure (e.g., transport, repair and maintenance service), continued dynamic development of such a market may not be assumed.

100. Apart from the expanded credit facilities, the Government may have to take a more active part in the propagation of the mechanical drive units, especially in the development regions where they have not yet been introduced, for example, through an extension service which could guide both the equipment manufacturers for potential orders and possible establishment of production facilities and the potential clients in their choice of technology.

101. Finally, it should be stressed that the further development of the small-scale hydropower sector needs to be considered in an integrated framework of the Government's development policy as a whole so that investments in the former could be coupled with profitable and employment-generating activities for which energy is to be provided. The development of physical infrastructure, like transport, to support the latter activities should also be considered. Such an integrated approach is particularly needed in the rural areas. The exact composition of demand for energy and the types of technology required would, of course, vary from one location to another. The integrated approach, therefore, would need to be pursued for individual regions and localities.

102. The experience of Nepal demonstrates that a developing country, even with relatively limited general industrial and technological capability, can develop the domestic capacity necessary for reproducing and diffusing some small-scale hydropower technologies. Although it may generally be thought that the technology for small-scale hydropower is mature and ripe for use anywhere and the necessary equipment readily available from numerous manufacturers in the industrially advanced countries, the Nepalese example indicates that equipment import alone would not lead to effective application of the technology and that to ensure a widespread use of such a technology a domestic mechanism of diffusion has to be put in place, including a local source of equipment and related services. The role of equipment manufacture in the diffusion process should be carefully considered in any developing country considering the large-scale utilization of a mature renewable energy technology. 31/

103. The Nepalese experience is also instructive concerning the role which the Government has played in the diffusion process. In many developing countries, especially in their rural areas where the "market" development is limited (in the sense that goods and information do not flow freely and much commercial transaction still takes place in kind rather than in monetized form), the

Government is often expected to play an important part in bringing new products and new technologies to the population. This seemed also to be the general perception of the people in Nepal. However, the actual role played by the Government differed in the diffusion of different technologies. For the small-scale mechanical drive units, its role has been centred in the provision of credit facilities, whereas in the small-hydel electrification schemes its role has been all pervasive. This, however, may be expected to change. For further diffusion of the mechanical turbines, the Government may have to be more involved to promote coupling of such investments with income and employment-generating opportunities.

104. For the electrification schemes, the Government has already decided on a delicensing policy, to permit sales of electricity by private owners of mechanical-*cum*-electrical turbines and of small-hydel plants. What all this indicates is the importance of matching the market to technology. To the extent that the matching is not done in a spontaneous manner by the market, the Government may have to intervene to bring about the appropriate matching solution by a combination of measures on the demand side (e.g., provision of credits, electricity tariff policy, demonstration projects, information for users) and on the supply side (e.g., R & D support for the domestic industry, equipment import policy). In the latter connection, the importance of the build-up of domestic technological and industrial capability over time should not be lost sight of, since it improves the working of the diffusion mechanisms.

105. Finally, the particular way in which the foreign, non-governmental agencies assisted in the development of the small-scale hydropower sector needs to be underlined. Had it not been for the workshops they were instrumental in establishing or for the turbine designs they helped develop, the diffusion of the small-scale mechanical drive units would probably not have occurred in the dynamic way it did, if at all. The experience of these agencies may suggest that, for the diffusion of mature renewable energy technologies in developing countries, external co-operation could more usefully be directed to the generation of local technological and industrial capability for reproduction and diffusion of the equipment than to the shipment of equipment.

Notes

1/ The definition of mature technologies in the renewable energy field can be given in different ways with varying nuances. In this study, a technology (i.e. equipment, plants and systems) is mature if it: (i) has passed various stages of design and of operational and manufacturing feasibility; (ii) is capable of operating within prescribed technical operations; (iii) has been sold, even in limited quantities, under diverse local conditions; and (iv) has demonstrated the potential of achieving economic feasibility within a reasonable time frame and a set of defined boundary conditions.

2/ "Transfer, adaptation and diffusion of mature renewable energy technologies in developing countries", study prepared by Dr. C. Hurst in co-operation with the UNCTAD secretariat.

3/ See, for example, the World Bank, "A survey of the future role of hydroelectric power in 100 developing countries", Energy Department Paper No. 17, Washington, D.C., August 1984.

4/ See, for example, United Nations ESCAP, "Small hydropower development", 1982; and R.E. Holland, "Economics of micro-hydro power plants", paper submitted to the Joint Seminar of the United Nations and Agence française pour la Maîtrise de l'Energie on Economics of Small Renewable Energy Systems for Developing Countries (Sophia Antipolis, France, 31 May-6 June 1986), May 1986.

5/ For an extensive discussion of the state of socio-economic development in Nepal, see R. Islam, et. al, Employment and development in Nepal, ILO: Asian Employment Programme (ARTEP), Bangkok, 1982; and S. Sharma, "Nepal's economy: growth and development", Asian Survey, vol. XXVI, No. 8 (August 1986), pp. 897-908.

6/ Annual rate of increase of total and per capita agricultural production for different periods was as follows:

Annual rate of increase in agriculture production (per cent)

	1961-1970	1970-1980	1981-1982	1982-1983	1983-1984
Total	1.6	1.0	-8.9	20.0	1.2
Per head of population	-0.8	-1.3	-10.9	17.4	-1.1

Source: FAO data contained in Handbook of international trade and developmenmt statistics; 1985 supplement (United Nations publication: Sales No. E/F. 85 II.D.12).

7/ According to an estimate by the Government, in 1977 the deficit in the availability of fuelwood was 5 million cubic metres and it was expected to increase. (Government of Nepal, "Country Paper of Nepal", paper submitted to the United Nations Conference on New and Renewable Sources of Energy" (Nairobi, 10-21 August 1981), pp. 8-9.

8/ The rate of forest depletion seems to be alarmingly rapid. According to an estimate by a private consulting firm, "the comparison of maps and analyses of aerial photos show that the Nepalese forest area has declined from 60 per cent to 30 per cent within 30 years". See Integrated Development Consultants (Heidelberg, Federal Republic of Germany), "The exploitation of the energy potential in Nepal: possibilities and limitations", in Renewable energy resources in Nepal, proceedings of a workshop seminar on the subject sponsored by the Water and Energy Commission and National Council of Science and Technology, Government of Nepal, and organized by the Research Centre for Applied Science and Technology, Tribhuvan University, Kathmandu, 1-4 April 1981, p. 59.

9/ United Mission to Nepal, Small Turbine and Mill Project, Development and Consultancy services, Socio-economic evaluation study of small-turbines and mill installations: summary, Volume I, Final report, Butwal, Nepal, May 1982.

10/ For an illuminating discussion on the background to agricultural change in developing countries, particularly the issue of the accumulation of capital, see J. Harris et al, ed., Rural development, Hutchinson University Press, Hutchinson, 1982.

11/ Replacement of ghattas could be considered in a boarder framework of rural energy improvement scheme. Ghattas and wood-burning stoves, another traditional technology, could both be replaced by local electrification with mechanical/electrical turbines. In fact, the Alternative Energy cell of the Water and Energy Commission is trying to construct such an integral energy development plan for rural areas, including solar energy options.

12/ For a detailed description of MPPUs in comparison with ghattas, see C.B. Joshi, "Improved water mills: traditional micro-hydro industries for modern society" in Renewable energy resources in Nepal, the Proceedings of the Workshop Seminar (Kathmandu, 1-4 April 1981) published by RECAST, Tribhuvan University and Sahayogi Press, Kathmandu, 1981, pp. 193-210. See also A.M. Nakarmi and A. Bachman, MPPU, Multi-purpose power unit with horizontal water turbine: basic information, Volume I, Sahayogi Press, Kathmandu, 1983.

13/ G.R. Shrestha, "State of the art of micro and MPPU hydro power in Nepal", paper prepared for a Planning Workshop on Micro and MPPU Hydro in Nepal organized by Water and Energy Commission, Government of Nepal, Kathmandu, 19 September 1985, p.3.

14/ Ibid., p.4.

15/ See, for example, K. Niitsu, et al., "The capital goods sector in Nepal: present position and prospects", ILO World Employment Programme, WEP 2-22/WP.113, Geneva, March 1983.

16/ G.R. Shrestha, op. cit., p.5.

17/ G.B. Shrestha and P.M.S. Pradham (Nepal Electricity Authority), "State of the art of small hydro power development in Nepal", paper prepared for a Planning Workshop on Small Hydro Development in Nepal organized by the Water and Energy Commission, Government of Nepal, Kathmandu, 12 September 1985, p. 17.

18/ Peter Molinari, "The need for an integrated approach in rural electrification in Nepal", (document ID.WG.305/41), UNIDO-RCTT Seminar-workshop on the Exchange of Experiences and Technology Transfer on Mini-Hydro Electricity Generation Units, September 1979.

19/ Ueli Meir, Harnessing water power on a small-scale: Local experience with micro-hydro technology, Schweizerische Kontaktstelle für Angepasste Technik (SKAT), St. Gallen, 1981.

20/ See K. Bharadwaj, Production conditions in Indian agriculture, Hutchinson University Press, Hutchinson, 1982, for a discussion of difficulties in conceptualizing market conditions prevailing in rural South Asia. The problem associated with "under-development" of a market mechanism is, of course, a more general one; for an illuminating discussion of this subject, see Shigeru Ishikawa.

21/ For an illuminating discussion of these issues, see R. Islan, et al., op. cit., pp. 77-97.

22/ Shrestha and Pradham, op. cit., p. 7.

23/ See B. Oettli, "Namache Bazar Manufacturers Report", Schweizerische Kontaktstelle für Angepasste Technik, St. Gallen, Switzerland, 1984.

24/ Shrestha and Pradham, op. cit., p. 22.

25/ These include: (i) Mechanical Training Centre (SATA); (ii) Jiri Technical School (SATA); (iii) Sanothemi District School (DANIDA 7 HMG); (iv) British Training Centre; (v) United Missions Training facilities; (vi) Utterpani Technical School (HMG); (vii) Thapattali Engineering College Training Centre (HMG); (viii) Junior Technical School (HMG); (ix) Institute of Engineering, Tribhuwan University; (x) RONAST research centre; and (xi) ILO Scheme for Skills Testing and Standardization covering mechanical, plumbing and electrical skills.

26/ L. Krayenbulh and E. Ledergerber, "SHP/Nepal: Small Hydel Development Program : Program Evaluation", paper prepared for the Swiss Direktion für Entwicklungszusammenarbeit und humanitäre Hilfe (Swiss Development Co-operation), Berne, 1981, pp. 7-8.

27/ D.L. Wright, An economic appraisal of six typical micro hydroelectric projects in Nepal, Conference on Appropriate Technology in Civil Engineering organized by the Institute of Civil Engineers, London, April 1980.

28/ Krayenbuhl and Ledergerber, op. cit.

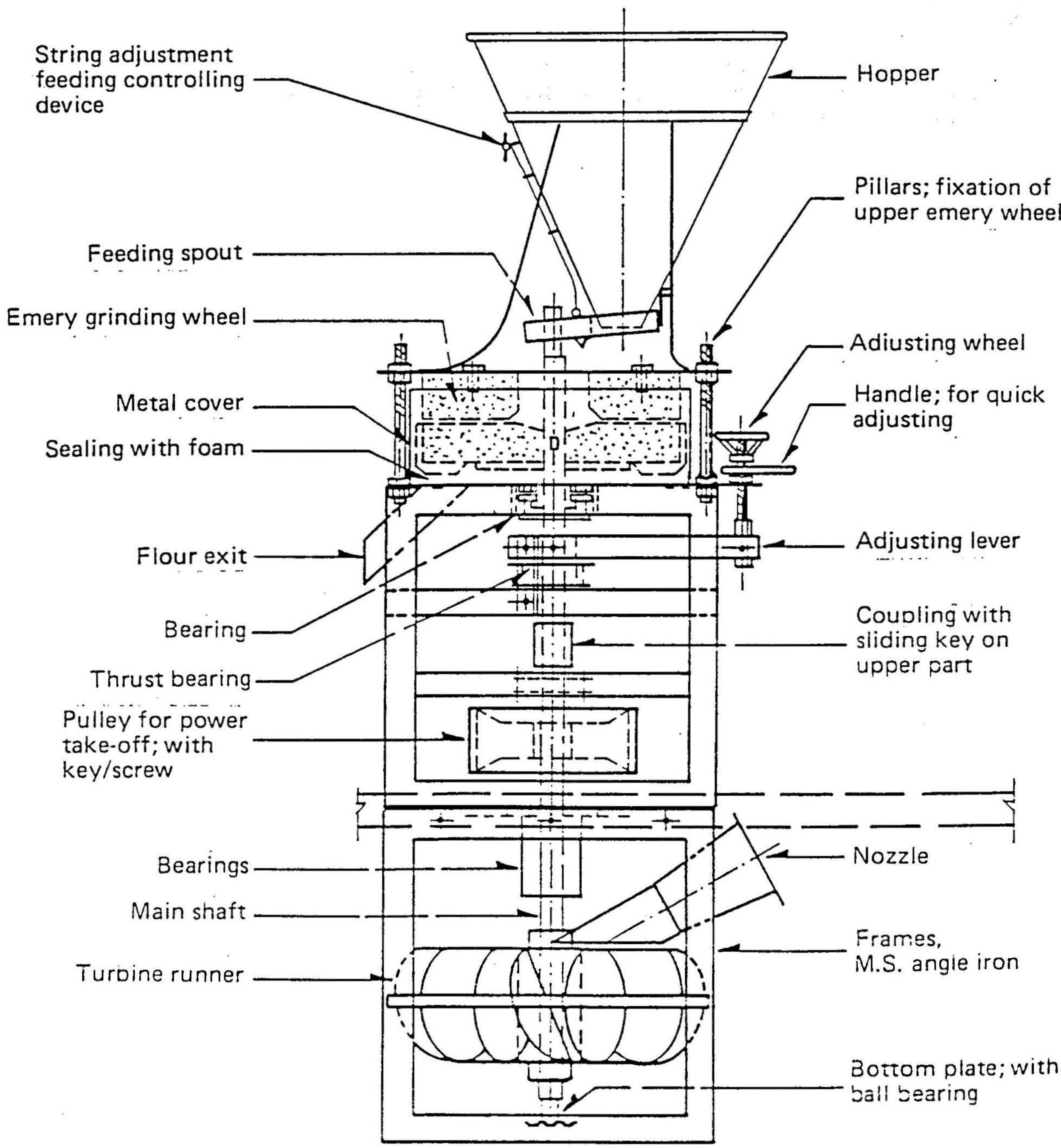
29/ The Joint UNDP/World Bank Energy Sector Assessment Mission to Nepal, which took place in November 1982, addressed these institutional questions.

30/ Ministry of Water, the Government of Nepal, Water, the Key to Nepal's Development, Kathmandu, Nepal, 1981, p. 19, and Shrestha and Pradham, op. cit.

31/ On the approaches to equipment manufacture in the renewable energy technology field, see United Nations ESCAP, Local manufacture of energy equipment, Bangkok, 1985.

Annex

Figure 1
MULTI-PURPOSE POWER-UNIT



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