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ROLE OF SOLAR AND WIND ENERGY IN NEPAL

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PREFACE

This paper was prepared for, and presented at, the Seminar on 'Rural Energy and Related Technologies' held in Kathmandu from 26 to 28 March, 1991, in collaboration with the Agricultural Development Bank of Nepal and the Water and Energy Commission Secretariate of His Majesty's Government of Nepal.

This paper presents the role played by solar and wind energy to ease the energy constraints of Nepal, and recommends future strategies and policies that need to be taken in order that these two alternative sources of energy can play their rightful role in the context of overall energy development.

CONTENTS

Introduction

Energy is vital for achieving the socioeconomic development of a country. Self reliance dictates that the problem of providing energy must be solved. For a developing country like Nepal, which consumes at least 50 per cent of its total foreign exchange income in the import of petroleum products, this aspect assumes an especially important dimension.

The overall energy situation in Nepal indicates that there is a predominant dependence on traditional energy resources. This in fact constitutes about 95 per cent of the total energy consumed in the country (Rokaya 1990). Among traditional energy resources, fuelwood is the major component and accounts for about 75.5 per cent while agricultural residue and dung account for 11 per cent and 8.5 per cent respectively. Among the commercial energy sources, petroleum products accounts for 70 per cent while coal and electricity account for about 16 per cent and 14 per cent respectively.

The main energy potential of Nepal consists of fuelwood, agricultural residue, animal wastes, solar, wind, and hydropower. As stated earlier, fuelwood is a major source of energy. Unless a viable alternative to fuelwood is found, the demand created by the increasing population growth will result in ever increasing pressure on the existing forests. At the present moment, this pressure is most acute in Eastern Nepal and the Central *Terai* regions.

Nepal has no known appreciable deposit of oil, coal, or natural gas. It has, however, a great potential for hydropower generation. Out of a theoretical potential of 83,000MW, it is estimated that 27,000MW can be economically exploited.

In order to meet the energy demand, it would be beneficial if alternative energy sources, such as wind and solar power, could also be exploited. Wind energy can be used for providing mechanical as well as electrical power. For the scattered and sparsely populated settlements which exist in different parts of the country, the use of smaller, self-contained systems, such as those used for pumping and milling, could prove beneficial. The use of wind energy, however, is site-specific. It depends on factors such as condition of the terrain, the particular season, as well as the range of wind force.

Solar energy is another valuable form of renewable energy. It has the potential to produce electricity through the use of photovoltaic cells, and can be used for providing power to motors, refrigerators, lights, communication equipment, and so on. When concentrated, it can be used for rapid drying, cooking, baking, and heating. The use of these two alternative sources of energy is very limited in Nepal today. It is the purpose of this paper to discuss their role in the overall context of energy development.

Solar Energy

Potential

The average solar energy potential of Nepal, south of latitude 30°N, amounts to around 700 to 800 watts per m^2, or six kilowatt hours per day with eight hours of sunshine (Bassan 1985). Considering the fact that the number of sunshine days is quite significant, especially in the case of Western Nepal, the potential for solar energy generation is quite promising.

Approaches to Solar Energy Use

Basically, solar energy resources can be harnessed through one of three methods:

- o Low grade devices that use heat from the sun.
- o Direct energy conversion devices.
- o Biological conversion of solar energy.

Some of the devices in the first category of low grade thermal devices are solar water heaters, solar cookers, solar pumps, solar stills, solar space heaters, and cookers. Most of these devices depend upon collection of heat either through flat plate collectors or through a concentration system that uses thermal energy to heat a working substance so that it performs a desired function.

Flat plate collectors are used for heat collection for most low grade thermal devices. The efficiency of the collectors depends upon several factors, and these include factors such as the absorption co-efficient of the collector surface for the incident solar radiation, emissivity of the collector surface for longer wave lengths, and heat loss due to conduction, convection, and radiation.

Direct energy conversion occurs through a solar cell which converts solar energy directly into electrical energy. Solar cells are made up of specially treated silicon crystals. Solar cells have a higher power output per unit weight ratio along with a much higher conversion efficiency than any other solar energy converter; at the same time they are also durable.

The process of biological conversion is similar to the way in which green plants convert solar energy through photosynthesis into carbohydrates from carbon dioxide and water. In biological conversion, for instance, sunlight can be used to break water molecules into hydrogen and oxygen through photochemical reaction. Hydrogen can then be used as a fuel.

While in the process of exploiting solar energy, it is useful to keep in mind its strengths and weaknesses. Some of the advantages offered by solar energy use is that it does not need transportation. Also, it has unlimited production potential and is freely available. On the other hand, the limitations are that it is diffused, intermittent, and that the radiation is variable.

Experiences in Solar Energy Use

Nepal's experience in the use of solar technology is based on the import of solar devices from other countries. This is due to the lack of research and development (R & D) and manufacturing capability in the country. Due to the paucity of data, only some of the activities, from solar devices used in the country, have been outlined here.

Solar Water Heater

A considerable quantity of the energy consumed in Nepal is for heating purposes; either domestic or industrial. If solar energy can be used to supplement other energy sources, it will serve a useful role in overcoming energy constraints.

A lot of headway has been made in the manufacture of solar water heaters in the country. There are, at the moment, about 20 to 25 manufacturers in the country. Solar water heaters are used for domestic purposes as well as for hotels in the urban areas. It is also used by some hotels and lodges along the main trekking routes. Solar heaters are also used for pre-heating water for use in carpet industries.

Since the outlet temperature of solar water heaters is only about 60°C, it falls short of the temperature requirements for certain industries. There is a need to improve performance through the use of superior absorption surfaces and better insulation (Prasad 1981). Therefore, R & D is necessary if solar energy is made more acceptable to industries.

A pioneering organisation, manufacturing solar water heaters in Nepal, is the Balaju Yantra Shala (BYS) Sanitary Engineering Ltd. Annex 1 shows the sales' figures of the commodity over a number of years. The selling price as of the 1st of January, 1991, is shown in Annex 2. It may be mentioned here that the company has been exporting solar water heaters to the neighbouring countries, including Sri Lanka.

Solar Drier

Traditionally, solar energy is commonly used in Nepal for drying agricultural and other products. Commodities such as vegetables, grains, corn, and chillies are spread in the open field to expose them to solar and wind action. One of the constraints of this practice is that the end product tends to be wasted, contaminated, or of inferior quality.

A more scientific approach to solar drying could be introduced through the use of solar driers. Some of the known models for drying fruits, vegetables, fish and grains include - solar cabinet drier-cum-solar ventilated drier (fruits and vegetables), solar box drier (fruits and vegetables), polythene-tent drier (fish), concentrating collector drier (fruit), and solar drier (paddy). The last two types have been especially designed for commercial purposes (Shakya and Chemjong 1988).

The scope for use of solar driers in Nepal is quite considerable. They can be used in tobacco factories, as well as in rice and timber mills. However, the present day use of this technology is quite limited. One of the basic constraints in this respect is its high price. An example can be cited of a herbarium cabinet having a size of $2.7m^3$ (3 racks with stainless steel tray) costing Rs 34,000/-. This cabinet was made by Balaju Yantra Shala on special order. There is hardly any demand for solar driers for daily use on a regular basis. On account of this, the manufacture of driers is minimal.

Solar Cooker

As fuelwood is one of the main sources of energy for cooking in rural areas, any fuel alternative that helps to reduce this dependency will also help to conserve forest resources. One of the ways to meet energy needs could be through use of solar cookers. However, Nepal's experience in this direction at the present moment is almost non-existent.

There are certain constraints to the use of solar cookers in Nepal. One of the main reasons for this is the high cost of production. The cost of production of a box-type solar cooker will come to about Rs 1,000/- (Shrestha 1986). Such solar cookers are sold in the Indian market at less than half the price. This is because the Indian Government provides a subsidy of almost 100 per cent for this type of cooker.

Weather is an important consideration in introducing the use of solar cookers in Nepal. The cloudy weather conditions, in central and eastern Nepal during the monsoon, limit the effective time available to around 1 or 2 hours per day. This means that, perhaps, for six months in a year solar cookers would be of very little use, and, for the remainder of the year, weather conditions may only permit 50 per cent utilisation. This, in effect, limits the scope of solar cookers to only about 25 per cent of the time in any given year. In view of the fact that the monsoon is usually lighter in Western Nepal, the period of use is longer in that region.

There are also certain problems relating to popularisation. One problem is that a solar cooker needs a certain minimum period of direct sunlight in order to achieve minimum cooking temperature inside the cooker. In view of the low angle of incidence of sun rays during the winter months, minimum temperature is often difficult to obtain with a horizontal box-type solar cooker. With a glass reflector type, an adjustment is required in the position from time to time according to the direction of the sun. The possibility of cloud formation further adds to its unreliability. The high cost of glass and its susceptibility to breakage is another constraining factor in promoting the use of box-type solar cookers.

Solar Pumps

For an agrarian country like Nepal, solar pumps have a lot of potential for replacing diesel pumps in small-scale irrigation. They can also be used to lift water for drinking and irrigation purposes.

Even though solar pumps have been used in other countries, such as the U.S.A. and France, they have not been all that popular in Nepal. One of the main constraints is its high cost. An approximate idea of costing and the number of units installed by the Agricultural Development Bank of Nepal are shown in Annex 3.

Solar Generators

In 1982, photovoltaic systems were responsible for the generation of 7MW throughout the western world, and this had already risen to 17MW by 1984. It is estimated that the output from such plants will have risen to 8,500 MW by the turn of the century (Benemann 1986).

The prospects for use of the photovoltaic system are excellent in remote areas where there are no power structures, where fuel for diesel generators is difficult to obtain, and where suitable operating and maintenance personnel are also lacking. Telecommunications is one field where the solar photovoltaic system could be profitably used. The unique advantage of the photovoltaic system has been optimally used in Nepal where 64 out of the 75 remote-area wireless stations are equipped with solar panel back-up equipment (Prasad, personal communication, BYS).

As far as the use of photovoltaic systems for rural electrification are concerned, the Small Hydropower Department (Nepal Electricity Authority) has implemented four solar projects. The details of these units are shown in Annexes 4 and 5. The estimated cost for implementing these projects are also indicated therein.

The performance of these photovoltaic plants has been found to be satisfactory. Only one of the installed units has a problem with the inverter, i.e., the device that converts the direct current (D.C.) into the alternating current (A.C.). One of the interesting features of these generators is that electricity is supplied to the consumer in A.C. form.

As shown in the Annexes, the cost of generating electricity by solar plant is many times more expensive than electricity generation by micro-hydropower. Further, the generating cost of electricity for smaller units is higher than for larger units. Brief descriptions of the photovoltaic systems installed at Kodari and Tatopani have been given in Annex 6. Salient features of Simikot SPP and Gumgadhi SPP are shown in Annexes 7 and 8 respectively.

Wind Energy

The topographical features of Nepal are extremely heterogeneous. Within a span of about 200 km, the altitude ranges from a few hundred metres in the *Terai* region to over 8,000m in the High Himalayas. The topography from east to west features many discontinuities, due to the presence of gorges and deep valleys.

It is, therefore, difficult to generalise upon wind potential in this country. Collection of wind data on a national scale has been conducted by various departments of His Majesty's Government, including the Department of Hydrology and Meteorology and the Department of Civil Aviation. However, the information is quite inadequate, and, hence, no assessment of wind potential on a national scale is yet available.

Some studies were conducted in the past to assess the wind energy potential. A study conducted by the Energy Research and Development Group (1978) in Palpa, Tansen, and Lho Mantang in the Mustang Region reported that wind could be used for generating electricity on smaller scale. According to the study, wind energy at Palpa amounted to 1.8 kW hr/day/m^2 during April, while for the months of July to September, it was 0.2kW.hr/day/m^2. The average monthly reading at Lho Mantang, Mustang, showed 1.4 kW hr/day/m^2, in February, and 0.3kW hr/day/m^2 during most other months.

A report to the World Bank (Heln 1977) indicated that the prospects of wind power exploitation in the Khumbu Region of Nepal were excellent. The average wind velocity in the area measured amounted to a little over 5m/sec. The same study indicated that wind energy would be much cheaper than wood or kerosene.

A three year wind assessment study at Jomosom, Mustang, is being carried out by Royal Nepal Academy for Science and Technology (RONAST) (G. R. Shakya, 1990). The programme, which started in 1989, will be completed by the end of this year. The study uses modern wind classifier techniques to record wind data.

On a national scale, a record of the mean monthly wind speed data for 1983, as compiled by the Department of Hydrology and Meteorology, is shown in Annex 9. Even though the average monthly wind speed data may not tell us much about maximum speed and its diurnal nature, it is possible to draw some general inferences from these figures. The wind speed at higher altitudes is fairly high throughout the year. Thus, wind could be a potential source of electricity generation. At lower altitudes, in the *Terai* region, the wind is stronger during March to September, and could be used for lifting water for drinking and irrigation purposes.

Experiences in Wind Energy Use

There have been attempts in the past by individuals and organisations to introduce wind generators into the country. However, because of lack of information only some of these activities have been documented here.

An example of an early wind installation is the windmill erected at Rampur Agricultural Farm (Chitwan) about two decades ago. The unit, funded by the USAID, was short-lived. Another windmill based on an Indian prototype was installed at Ramechhap. The unit lasted one day only. Another windmill was installed on the outskirts of Kathmandu, some years ago, through international assistance. This structure has since been dismantled. The Balaju Yantra Shala had also installed a wind generator in Jomosom some years ago. This too was unsuccessful as the unit broke down shortly afterwards. It appears from the above-mentioned cases that one of the reasons for break-down may be the lack of proper understanding of wind patterns.

Among more recent cases, the Research Centre for Applied Science and Technology (RECAST), of Tribhuvan University, has been experimenting on windmill programmes under the sponsorship of the United Nations' Financing System for Science and Technology for Development (UNFSSTD). This work has included field testing of Indian prototype models Apoly 12 PU 500 and Apoly 12 PU 350. These are products of the Institute of Engineering and Rural Technology, Allahabad. Apparently, these prototypes have been used successfully in various parts of India.

Annex 10 gives information on the performance of Apoly 12 PU 500 in terms of power generation, while its windspeed characteristics are shown in Annex 11. Some of the salient features of the Apoly 12 PU 500 windmill include its capacity to convert 38 per cent of the wind's kinetic energy into mechanical power and its working limits of 2.5 m/sec and 10m/sec as cut-in velocity and cut-out velocity respectively. The windmill has an automatic security device which protects the wind generator by turning the rotor to 75° out of its plane of operation when the wind velocity exceeds 10m/sec. The experiences of RECAST during field testing of the Apoly 12 PU 500 windmill have been dealt with in detail in Annex 12.

In order to promote the use of wind energy, the Nepal Electricity Authority (NEA) has also installed a 20kW. unit at Kagbeni, Mustang, on a pilot project basis. The success of this project is yet to be seen. The initial indication is that this unit too is facing some problems.

In order to promote wind energy technology, there is much ground to cover. Apart from the functional aspects of windmills, the cost of installation is exorbitant. It is estimated that the cost of generating electricity through this method could be many times that of micro-hydropower per kilowatt power generation. There is an urgent need for support from international agencies, both in terms of finances and technology transfer, if any headway is to be made in popularising this technology.

General Recommendations

There is a need to formulate a suitable national policy which will facilitate the promotion of solar and wind technology. As most of these devices are expensive, subsidies are needed to make these products competitive in the market. Subsidies could include soft loans to manufacturers as well as the removal of high taxes and custom duties during the import of raw materials.

Efforts should be made to promote the free flow of information among scientific and technological organisations at the national as well as at international levels. This would ensure information exchange and dissemination of technological options while at the same time minimise the duplication of efforts. The holding of meetings/seminars on a regular basis could provide a forum for this purpose.

National human resource development should form an important component of the promotion, development, and dissemination strategy for solar and wind technologies. Adequate training materials and audio-visual aids should be used, and training should be conducted regularly for groups such as:

- agency personnel, researchers, technical assistants, and trainers,
- energy end use device manufacturers, and
- end users (including women).

There is an urgent need for R & D into solar and wind technologies. The approach should focus on application rather than basic research. Thus, action research programmes that emphasise users' level demonstrations in a broad context, R & D, and training should be encouraged. Further, R & D programmes should test the performance of each technology under field conditions (including physical, environmental, and socioeconomic set-ups) for different segments of society so that appropriate models of the prototype (or modified) technology can be identified and standardised for large-scale diffusion.

In order to promote and disseminate cost-effective and environmentally sound solar and wind technologies, the role played by international donor agencies cannot be over-emphasised. Such a role will also be beneficial for advanced nations as it will create markets for innovative technologies. At the same time, innovative technologies will serve to improve living conditions in rural Nepal, by promoting sustainable mountain development.

Summary

Solar and wind energy could be exploited in order to ease the energy constraint in Nepal. Due to the paucity of data, the potential of these two alternative sources of energy is yet to be ascertained on a national scale. However, Western Nepal has a greater potential for solar energy exploitation because of its being less influenced by the monsoon. The wind potential in the northern belt of the country could be used for electricity generation while, in the southern region, it could be used for pumping drinking water as well as for irrigation purposes for many months of the year. Past efforts in the use of solar and wind generators have been very limited and on an ad hoc basis. Careful technological as well as economical considerations are needed in order to promote the use of these alternative sources of energy.

ANNEXES

Annex 1

Table 1
Sale of Solar Water Heaters (B.Y.S.)

Sl. No.	Period	Sale of Solar Collectors
1.	1978 - 79	65
2.	1979 - 80	75
3.	1980 - 81	129
4.	1986 - 87	59
5.	1987 - 88	44

Source: B.Y.S. 1991

Annex 2

Table 2
Retail Price of Solar Water Heaters (B. Y. S.)
(with effect from 1/1/91)

Sl. No.	Capacity	Cost per Set
1.	200 litres, with double collector (1.90 m by 1.68m)	Rs. 22,250.00
	200 litres, with triple collector (1.90 m by 2.38m)	Rs. 26,500.00
2.	300 litres, with 2 double collectors	Rs. 38,000.00
	300 litres with one double and one triple collector	Rs. 42,000.00
3.	400 litres, with one double and one triple collector	Rs. 44,500.00
	400 litres with two triple collectors	Rs. 49,000.00
4.	500 litres with two triple collectors	Rs. 53,000.00
	500 litres with two double collectors and one triple collector	Rs. 61,500.00
5.	600 litres with two triple collectors and one double collector	Rs. 70,000.00
	600 litres with three triple collectors	Rs. 74,000.00

Source: B.Y.S. 1991

Annex 3

Table 3

Cost of Solar Devices and Units Established by the ADB/N

Sl. No.	Place	Solar Pump Installed (Unit)
1.	Birendranagar, Chitwan	1
2.	Letang, Morang	1
3.	Arghauli, Nawalparashi	1
4.	Surkhet	2
	Total	5

Cost of solar panel (47W)	=	US $ 235 (FOB Price)
Solar pump system (500W, centrifugal pump)	=	Rs 125,000
Submersible pump system (90 ft head 2000 U.S. gallons/day)	=	U.S $ 4,527.00
Submersible pump system (90 ft head 4000 U.S. gallons/day)	=	U.S. $ 7,244.00

Source : K. M. Singh, February 1991.

Annex 4

Table 4

N.E.A. Established Solar Generators

Sl. No.	Place	Capacity	Estimated Project Cost (in million Rs)	Cost per Installed kW (U.S. $/kW)
1.	Gumgadhi	50 kW peak	24.561	22,328
2.	Simikot	50 kW "	24.465	22,241
3.	Tatopani	20 kW "	10.737	24,402
4.	Kodari	1o kW "	06.067	27,579

Source: Small Hydropower Department (NEA) March 1990.

Annex 5

Table 5

Sl. No.	Project	Total Project Cost (Eqv. NRs.)	LC/TPC (%)	FC/TPC (%)
1.	Simikot Solar Power Project	2,01,11,240	36	65
2.	Gumgadhi Solar Power Project	1,89,89,241	74	26
3.	Kodari/Tatopani Solar Power Projects (Combined)	1,34,85,512	66	34

Source: Small Hydropower Department (NEA) November 1990.

N.B.

LC = local cost component borne by HMG, Nepal.
FC = foreign exchange component borne by the French Government.
TPC = total project cost.

Annex 6

Photovoltaic Plants at Kodari and Tatopani

As part of the rural electrification scheme, the Small Hydropower Department (N.E.A.) had initiated installation of two solar plants in 1986 at Tatopani and Kodari. These were subsequently commissioned in 1989. These systems, based on French manufacture, supply A.C. for electrification.

The process of power generation consisting electricity produced by solar panels are regulated and stored in a battery bank. This 120V D.C. current is subsequently converted to 380V A.C. through means of an inverter. In order to minimise transmission loss, the 380V A.C. is stepped upto 11kV for distribution. Finally, it is stepped down to 380V through means of a step down transformer. The supply of electricity at the end point is maintained at 220V.

Salient Features of Tatopani/Kodari SPP

1.	Type of generator	:	Photovoltaic
2.	Number of generators	:	2
3.	Generator output voltage	:	20kW + 10kW
4.	Type of PV cell	:	Multicrystalline
5.	No. of cells per module	:	36
6.	Module peak power	:	40W
7.	Module voltage	:	12V
8.	Generator output voltage	:	120V
9.	Number of modules per generator	:	500 + 250
10.	Number of regulators	:	2
11.	Battery type	:	Lead-acid, Stationary
12.	Output voltage	:	120V D.C.
13.	Capacity at C 100 discharge rate, per generator (5 days)	:	4320 Ah + 2176 Ah

14.	Number of inverters	:	2
15.	Type	:	Electronic
16.	Rated output	:	25 kVA + 12 kVA
17.	Input voltage	:	120 + 15% V D.C.
18.	Output voltage	:	380 + 5% V AC
19.	Output frequency	:	50 + 1% Hz
20.	Load centre	:	Tatopani Bazar Area, Kodari and Liping
21.	No. of people benefitted	:	780
22.	No. of households	:	130

Source: PV Solar Power Projects in Nepal (NEA) November 1990.

Salient Features of Simikot SPP

1.	Type of generator	:	Photovoltaic
2.	Number of generators	:	2
3.	Generator output voltage	:	25kW
4.	Type of PV cell	:	Multicrystalline
5.	No. of cells per module	:	36
6.	Module peak power	:	40W
7.	Module voltage	:	12V
8.	Generator output voltage	:	120V
9.	Number of modules per generator	:	625
10.	Number of regulators	:	2
11.	Battery type	:	Lead-acid, Stationary rate
12.	Output voltage	:	120V D.C.
13.	Capacity at C 100 discharge rate, per generator (5 days)	:	4050 Ah
14.	Number of invertors	:	2
15.	Type	:	Electronic
16.	Rated output	:	25 kVA
17.	Input voltage	:	120 + 15% V D.C.
18.	Output voltage	:	380 + 5% V A.C.
19.	Output frequency	:	50 + 1% Hz
20.	Load centre	:	District headquarters and by villages
21.	No. of people benefitted	:	1260
22.	No. of households	:	200

Source: PV Solar Power Projects in Nepal (NEA) November 1990.

Salient Features of Gamgadhi SPP

1.	Type of generator	:	Photovoltaic
2.	Number of generators	:	2
3.	Generator output voltage	:	25kW
4.	Type of PV cell	:	Multicrystalline
5.	No. of cells per module	:	36
6.	Module peak power	:	40W
7.	Module voltage	:	12V
8.	Generator output voltage	:	120V
9.	Number of modules per generator	:	625
10.	Number of regulators	:	2
11.	Battery type	:	Lead-acid, Stationary rate
12.	Output voltage	:	120V D.C.
13.	Capacity at C 100 discharge rate, per generator (5 days)	:	4050 Ahr
14.	Number of invertors	:	2
15.	Type	:	Electronic
16.	Rated output	:	25 kVA
17.	Input voltage	:	120 + 15% V D.C.
18.	Output voltage	:	380 + 5% V A.C.
19.	Output frequency	:	50 + 1% Hz
20.	Load centre	:	District headquarters and by villages
21.	No. of people benefitted	:	1150
22.	No. of households	:	185

Source: PV Solar Power Projects in Nepal (NEA)November 1990.

Table 6

Wind Speed Data

Regions	Place	Evaluation in metres	Anemometer height in M +	Monthly Mean Wind Speed in Km/hr in the Year 1983 JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Eastern Development Region	Dhankuta	1160.0	2.13	7.8	9.3	9	9.6	8.8	8.8	8.2	7.3	8	7.3	7.4	7.2
					2.17 m/s										
	Tarahara	200.0	4.50	2.2	2.4	3.8	6.1	6.0	6.8	5.3	5.2	6.1	3.4	2.6	2.3
Central Development Region	Khumaltar	1350.0	4.20	4.0	5.2	5.9	5.2	4.8	5.8	5.3	5.1	4.5	3.5	3.0	3.1
	Rampur	256.6	5.20	1.0	1.8	3.4	5.5	4.3	4.1	3.3	3.3	3.2	2.3	1.1	1.0
Western Development Region	Thak marpha	2566.0	2.57	17.4	14.7	18.5	15.7	16.4	18.3	18.3	17.2	15.8	14.6	14.2	15.9
	Bhairawa	120.00	2.70	2.3	3.3	4.7	6.2	6.7	5.4	5.3	5.0	4.3	2.2	1.7	2.0
Mid-Western Development Region	Jumla	2300.0	1.50	10.9	12.9	15.3	15.5	15.3	16.2	16.7	13.6	11.6	12.1	13.4	10.0
	Birendranagar	720.0	4.0	4.2	5.0	6.6	6.9	6.2	6.3	4.8	4.2	3.9	3.7	3.7	3.7
Far-Western Development Region	Dipayal	617.0	2.0	1.3	1.8	2.2	3.3	3.3	3.5	2.8	2.4	1.8	1.8	1.6	1.1
	Mahendranagar	176.0	2.50	1.3	1.5	2.4	2.3	2.1	2.2	0.9	0.6	0.6	0.9	0.8	0.9

Source: Data Acquisition Unit, Department of Irrigation, Hydrology and Meteorology, Ministry of Water Resources, Babar Mahal. In Shrestha et al. 1985.

Table 7

Power Generation of Apoly 12 IU 500 Windmill

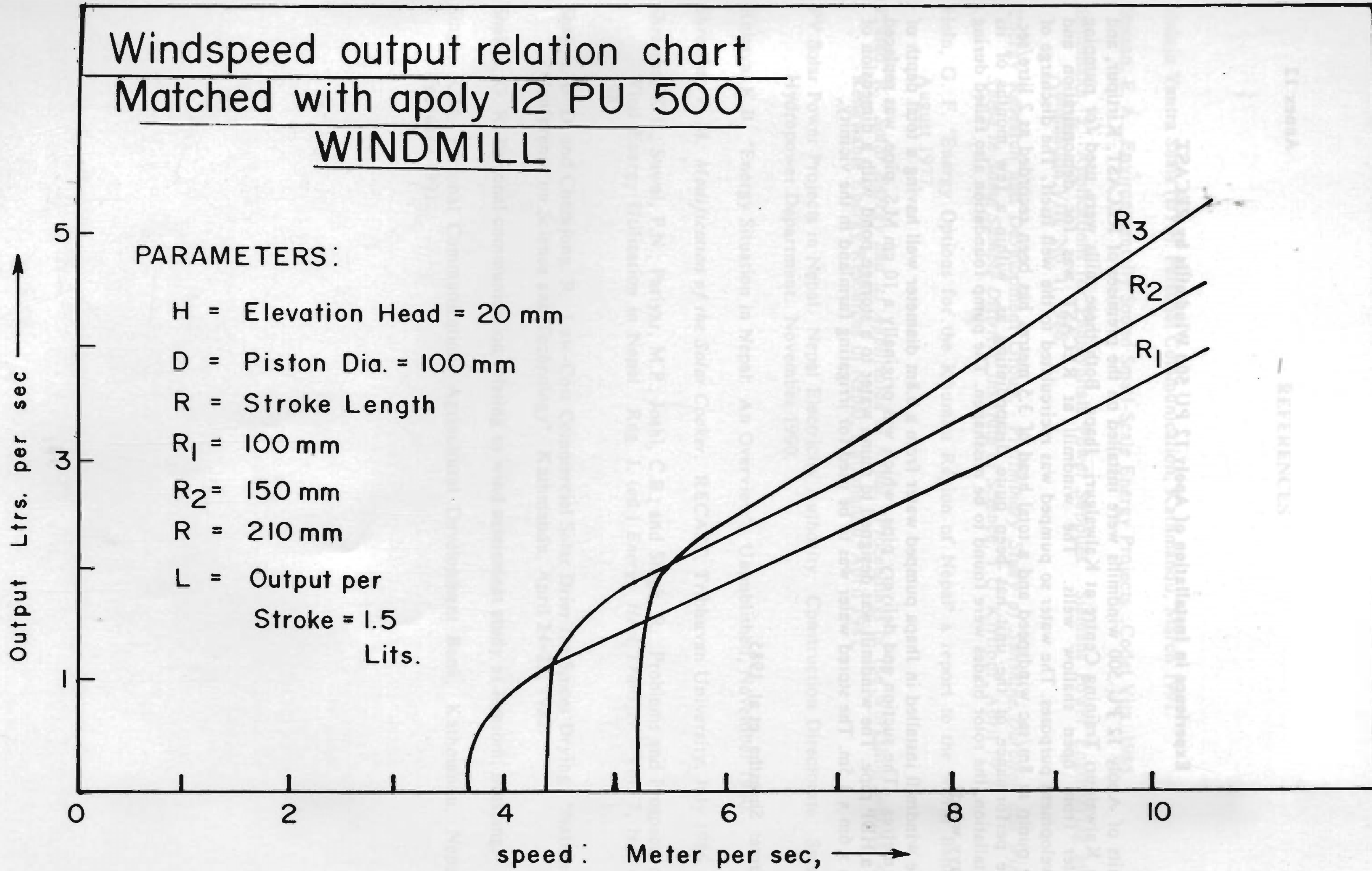
Wind Velocity in m/sec	Rotor LPM	Power Output in watts
2	15	20
3	24	120
4	31	280
5	40	560
6	46	970
7	53	1520
8	61	2250

Source : Shrestha et al. 'Problems and Prospects of Wind Energy Utilisation in Nepal'. In Reg, J. (ed.) *Energy Heat Transfer*, Vol. 7. No. 4, 1985.

Numerous operational problems were encountered with this installation. Even fixing the pump inside the well was difficult because of the narrow diameter of the well. The seepage of water from the storage pond caused land settlement around the well to a depth of about 0.3m. The windmill blades became misshapen a number of times because of strong wind. On one occasion, a heavy storm of unknown magnitude uprooted the whole rotor blade assembly, possibly because of non-functioning of the automatic security device.

FIGURE 1

ANNEX 11



Source: Shrestha et al 1985

Experience in Installation of Apoly 12 PU 500 Windmills by RECAST

Units of Apoly 12 PU 500 windmills were installed on the premises of RECAST, Kirtipur, and the Kalwalguri Training Centre at Kalwalguri, Jhapa. Both these mills were used for pumping water from open shallow wells. The windmill at RECAST was for demonstration and development purposes. The water so pumped was recirculated to the well itself. The discharge of the pump at 8m/sec windspeed and a total head of 3.5 metres has been recorded as 2 litre/sec. The performance of the unit has been quite disappointing as, within a few months of its installation, the rotor blades were found to be misshapen. The pump foundation also failed during heavy winds.

The windmill installed in Jhapa pumped water from a 0.8m diameter well having a total depth of 10 metres. The suction and delivery pipe, which was originally a 10 cm M.S. pipe, was replaced by a HDP pipe. The windmill was designed to pump water to a storage pond with a dimension of 3m x 6m x 1.5m. The stored water was to be used for irrigating farmland in the vicinity.

Source: Shrestha, et al. 1985.

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The Centre was established in 1983, and commenced professional activities in 1984. Though international in its concerns, ICIMOD focuses on the specific, complex, and practical problems of the Hindu Kush-Himalayan Region which covers all or part of eight Sovereign States.

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