LBL-24688
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Government Policy and Market Penetration Opportunities for U.S. Renewable Energy Technology in India and Pakistan

J. Sathaye and J.M. Weingart

January 1988

APPLIED SCIENCE
DIVISION

Prepared for the U.S. Department of Energy under Contract Number DE-AC03-76SF00098

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LBL-24688

GOVERNMENT POLICY AND MARKET PENETRATION OPPORTUNITIES FOR U.S. RENEWABLE ENERGY TECHNOLOGY IN INDIA AND PAKISTAN

Prepared by

Jayant Sathaye
Jerome M. Weingart

International Energy Studies Group
Applied Science Division
Lawrence Berkeley Laboratory

January 1988

This work was supported by the Deputy Assistant Secretary for Renewable Energy, Director of Solar Electric Technologies, Office of Photovoltaics Technology and Deputy Assistant Secretary for International Affairs, Office of International Energy Analysis of the U.S. Department of Energy under Contract No. DE-AC03-76SF000098.

CONTENTS

ACRONYMS

India

CEL	Central Electronics Limited
DNES	Department of Non-conventional Energy Sources
GEDA	Gujarat Energy Development Agency
GEB	Gujarat Electricity Board
OREDA	Orissa Energy Development Agency
SEB	State Electricity Board

Pakistan

ADBP	Agricultural Development Bank of Pakistan
ATDO	Alternative Technology Development Organization
DGNRER	Directorate General for New and Renewable Energy Resources (within the Ministry of Petroleum and Natural Resources)
KESC	Karachi Electric Supply Corporation
N.W.-FP	North-West Frontier Province
PCSIR	Pakistan Council of Scientific and Industrial Research
UNDTCD	United Nations Department of Technical Cooperation for Development
WAPDA	Water and Power Development Authority of Pakistan

1. INTRODUCTION

Over the last several years the domestic market for U.S. renewable energy products and services has been eroding rapidly. The decline in the size and vitality of U.S. renewable energy markets reflects a number of factors in combination: the demise of the federal and various state tax incentives for investments in renewable energy systems, the decline in oil and natural gas prices, the emerging over-capacity in many electric utility systems, and the suspension of California's long-term standard offer power purchase contracts that provided predictable and attractive revenues for the sale of privately generated power to the state's public electric utility companies.

U.S. firms have been losing domestic market share to foreign competitors in the wind electric, solar thermal electric, and photovoltaic technology fields. In 1982 U.S. firms provided about 80 percent of the domestic installed wind generation capacity. As the annual wind energy systems market grew from 10 MWe in 1981 to several hundred MWe per year after 1982, U.S. wind firms have increasingly lost their competitive advantage, principally to Danish firms.

1.1 Potential Developing Country Markets

Some U.S. renewable energy industries are now looking abroad, especially to the rapidly developing Asia-Pacific region, in order to increase sales and expand markets. The developing world appears in principle to be an important market for renewable energy technologies. These international markets have proven extremely difficult to penetrate, and the U.S. competitive position is threatened by strong, well-organized, government-supported competition from Japan and Western Europe. For example, U.S. photovoltaic manufacturers held 80% of the world PV market in 1980; today their market share is down to 35%.

Less developed countries (LDCs) present a potentially significant but highly elusive market for renewable energy technologies. This market may develop for three major reasons: the shortage of electricity supply and the high cost of grid extension to rural areas, the high cost of oil imports and the scarcity of light oil products, and the gradual replacement of traditional fuels with modern ones.

The cost of extending the electricity grid to meet small loads in remote regions is prohibitive. This, and the shortage of government capital for investment in new supplies of electricity, has stimulated some developing countries to explore the use of privately financed renewable energy for power generation.

The large foreign exchange outflow makes it difficult for many developing countries to import oil and petroleum products. Further, the poor infrastructure in most developing countries adds to the cost of these fuels and often increases their scarcity in remote areas, which can make the use of indigenous renewable energy resources economically attractive.

The renewable energy industries of industrialized countries are just beginning to penetrate the renewable energy market in the LDCs. Obstacles include the high first cost of most renewable energy systems, lack of adequate in-country financing mechanisms, domestic subsidies for kerosene and electricity, high import duties, inability or unwillingness of many developing countries to pay in hard currency, protectionist laws, regulations and attitudes, conflicting advice from external advisors, technology untested in the tropics, lack of availability of foreign exchange, and lack of understanding of government policies.

LDC government policies, tempered by limited availability of foreign exchange, have played an important role in the adoption and selection of technologies. In most countries, the governments have been responsible not only for conducting research and development but also for establishing the initial markets. Some Western industrialized countries are providing the more sophisticated renewable energy technologies. Japan and Denmark are also providing developing countries with attractive financing packages and technical performance guarantees to overcome the resistance resulting from the high first cost of renewable energy systems.

1.2 Focus of the Report

The focus of this report is on the policies and attitudes of national and regional governments in India and Pakistan towards renewable energy technology and how these policies and attitudes affect the potential for penetration of these markets by U.S. industry. We have attempted to provide some useful insight into the actual market environment in India and Pakistan rather than just report on official laws, regulations, and policies. The report also examines the economics of technologies in comparison with more traditional sources of energy. It concentrates primarily on technologies, such as photovoltaics and wind electric systems, that would benefit from foreign participation, but also identifies potential market opportunities for advanced solar desalination and other renewable energy technologies.

1.3 Renewable Energy Programs in India and Pakistan

The governments in India and Pakistan have launched programs to develop renewable sources of energy, recognizing the role that they can play to provide electricity to rural areas and, in the long term, to reduce dependence on oil. The program in India has moved rapidly from research to commercialization. By contrast, a renewable energy program in Pakistan is just being formulated, and previous attempts by the Government of Pakistan to stimulate the development of an indigenous renewable energy capability have had little success.

In India, five major wind farms have been established and several more large scale installations are planned*, large scale use of PV technology is contemplated, urban waste use projects are being investigated, small hydro on irrigation canals is being explored, and hundreds of thousands of biogas units are already operational and more are planned (Table 1-1). Government financial subsidies in support of these programs are numerous. The market for renewable energy systems is relatively large, and wind systems and components of solar hot water systems and equipment to make renewable energy technologies are being imported.

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* A global tender has been issued by the Government of India for 20 MWe of grid-connected wind farms. One U.S. firm has submitted a proposal.

In Pakistan there have been limited experiments with wind pumps, photovoltaic water pumping, and United Nations-sponsored PV installations in a few villages. Micro-hydro projects have been successful and will be expanded, solar desalination is being revitalized for remote communities, and limited production of photovoltaic arrays has begun (Table 1-2).

Privately installed and maintained family biogas units are reported to be operating reasonably well, but the majority of the biogas systems that were installed by the government have fallen into disrepair. In spite of this experience, and the interest of various private and government organizations in renewable energy, there is no well-developed policy towards renewable energy in Pakistan, and the constraints on private sector initiatives in this field, both domestically and by foreign manufacturers, are formidable.

However, government policies in both India and Pakistan *vis-a-vis* renewables are constantly changing within the overall industrial and import policies adopted by the central governments in each country. A principal issue is the necessity for U.S. industry to have an adequate understanding of the present and likely near-term attitudes, actions, and policies of the relevant government agencies and institutions towards renewable energy, and the U.S. renewable energy industry in particular. This means knowing more than the official policies and rules of the target market countries; it means knowing the actual problems as well as opportunities, and being able to use this information to make informed business decisions.

Table 1-1

Renewable Energy Installations in India

Type of System	Number of Installations
Wind Electric (4/87)*	3 MWe in 5 wind farms
Water Pumps	
Wind (1/86)	1,192
Photovoltaic (11/86)	436
Other PV Systems (11/86)	3,584
Solar Hot Water (1/87)	
Industrial/Commercial	1,000 systems, 44,000 m^2
Residential	1,170 systems, 2,600 m^2
Biogas Plants (4/86)	650,000 units

Dates for data shown indicated

Table 1-2

RENEWABLE ENERGY INSTALLATIONS IN PAKISTAN
(1986/87)

TYPE OF SYSTEM	Number of Installations	Financing Mechanism/Source
Wind Energy Conversion		
Wind pumpers	20	Gifts, commercial
Wind electric		
Photovoltaic Systems		
Irrigation (2 kWe)	3	ADBP
Village electricity	4	United Nations DTCD
Cathodic protection	?	Commercial
Electrified cattle fences	?	Commercial
Solar Distillation		
Experimental family units	?	PCSIR
Community system (Gwada)	1	AEC/PCSIR
Biomass Conversion		
Family biogas units	2,000	ATDO, private
MicroHydro Installations		
5 - 50 kWe in N-W F.P.	63	ATDO/N.W.-FP University

Section 2

INDIA

2. INDIA

2.1 Overview

The gross national product (GNP) of India is one of the largest in the world, but with a population of 765 million the country's annual per capita GNP stands at about U.S.$ 270. With the population growing at 2 percent per year and GNP growing at an average annual rate of 3-4 percent, the quality of life in India has improved at a relatively slow pace, although between 1980 and 1985, Gross Domestic Product (GDP) increased at 5.2 percent per year.

Agriculture remains the country's largest employment sector. It employs about 70 percent of the labor force and contributes 31 percent of Gross Domestic Product (GDP). Agricultural production increased at an average rate of 1.9 percent per year between 1960 and 1985. Production surged in the late 1960s and early 1970s due in part to the impacts of the Green Revolution, which made the country self-sufficient in grain production through improved use of hybrid seed, fertilizer and irrigation. During the past two years, the country has experienced a severe drought which will result in slower economic growth accompanied by stagnation in the agricultural sector.

Outside of the agricultural sector, India has created a relatively sophisticated industrial base with a large pool of technically skilled labor. The economy is a mixture of public and private enterprises. Industries in the public sector provide most of India's heavy capital infrastructure. Industry's share of the GDP has increased from 22 percent in 1965 to 27 percent in 1985 and that of private industry from 14.9 percent in 1970-71 to 20.4 percent in 1980-81.

The United States is India's largest trading partner. 10.8 percent of India's imports valued at $2.2 billion came from the United States and 18.1 percent of its exports of slightly lower value went to the U.S.in 1985-86.

The Indian government is actively involved in managing the growth of the economy. A Planning Commission has been established to prepare five year plans for India's economic development. The Sixth such plan was completed in 1985 and the Seventh Five Year Plan is being implemented at present. Annual plans are also prepared within the context of the five year plans and to help achieve the growth targets set forth in the longer plans.

2.2 Energy Background

Substantial reserves of recently discovered off-shore oil and gas combined with the large reserves of domestic coal provide the bulk of modern fuels to the Indian economy. Coal production increased from 103.2 million tons in 1978-79 to 154.2 million tons in 1985-86. The coal has low heating value with 20-40 percent ash content, and its quality is deteriorating; in energy terms it is equivalent to about 77.1 million tons of oil. Coal is used mainly in industry and for electric power generation. Small amounts of coal are also used for cooking. The increase in coal output has been as impressive as that in oil. This has helped the country achieve substantial increases in thermal power generation.

Production of oil increased from 11.9 million tons in 1978-79 to 30.2 million tons or about 600 thousand barrels per day in 1985-86 (Table 2-1). This is sufficient to satisfy about 70 percent of the consumption of petroleum products. Oil reserves and production have not increased much despite substantial investment of funds for exploration and development in recent years.

Table 2-1

Energy Reserves and Production in India

Resource	Reserves 1986	Production 1985-86	R/P Ratio
Coal (Million Tonnes)	14,191	154	92.0
Oil (Million Barrels)	4,200	218	19.2
Natural Gas (BCF)	17,600	286	61.5

Source: Data on reserves from *BP Statistical Review of World Energy*, June 1987. Production data from the Government of India's *Economic Survey, 1986-87*.

Consumption of petroleum products increased by 5.4 percent during 1985-86. It is estimated to have increased by 6.7 percent in 1987 reaching 43.7 million tons or 865 thousand barrels of oil equivalent per day. The rapid increase in consumption of petroleum products is a serious long-term impediment to economic development. Limited reserves have curtailed domestic production of oil which will require increasingly higher oil imports. Foreign currency payments for these oil imports may impede availability of foreign exchange for other development activities.

Middle distillates, kerosene, diesel, etc., constitute about 60 percent of the consumption. Diesel and kerosene use has increased over the long term. Diesel is used primarily for transport and for irrigation pumping, and kerosene is used primarily for cooking in the urban areas and for lighting in the rural areas. Its use increased over the long-term as more families had access to it and moved away from using traditional fuels. Kerosene consumption recorded only a modest growth of 3.3 percent in 1985-86, partly due to the increased availability of LPG, obtained from natural gas, in the urban areas. Renewable technologies can alleviate the shortage of petroleum products, since lighting and irrigation pumping are two activities which can be easily substituted using renewable technologies, such as wind, PV and biogas.

Natural gas is increasingly becoming an important source of energy. Output of associated natural gas has increased with the increase in oil production. Natural gas production reached 8.2 billion cubic meters or about 140 thousand barrels of oil equivalent per day in 1985-86. This is a 25 percent increase in two years. It is expected to increase by the same percentage this year. By 1989-90, natural gas production is projected to reach 14.9 billion cubic meters or about 250 thousand barrels of oil equivalent a day.

A new pipeline is under construction to move the gas from offshore to Northern India. This would make gas available for fertilizer complexes and power plants along the 800 mile route. The first phase of the pipeline was completed recently. Completion of the second phase will virtually eliminate the flaring of natural gas. Because the infrastructure for distributing natural gas tends to be expensive, gas use will be restricted to areas around the main pipeline and along the Indian west coast.

Historically, the acute shortage of electric power has been a pressing problem. This is manifested by frequent power cuts, voltage and frequency fluctuations and frequent load shedding. As of April 1, 1986, Indian public utility companies had 46,769 MWe of installed electrical generating capacity[1]. During 1985-86, India experienced an overall deficit in peak power supply of 24.2 percent and in electric energy supply of 14.9 percent[2], despite the addition of 4200 MWe of new electric capacity. These deficits are projected to improve through rest of the decade. By 1989-90, the end of the current five year plan, deficits are projected to be 19.0 percent and 5.4 percent respectively. Many states, however, experienced significantly higher peak power deficits. Haryana had deficits of 37.9 percent; Jammu and Kashmir had 65.7 percent and Uttar Pradesh, 45.1 percent. Power deficits led to massive industrial cutbacks, the estimated cost of which was several billion dollars in 1985-86.

Widespread power shortages have driven industries to install their own captive power stations, usually small diesel generating sets. These units tend to be operationally and economically inefficient and require increased imports of oil at a time when oil imports are already consuming 40 percent of scarce foreign exchange reserves. Despite its high cost to industry and the Indian economy, captive power capacity increased sharply from 2,859 MWe in 1979-80 to 5,100 MWe in 1985-86. The government estimates that captive power will increase another 40 percent to 7,056 MWe by 1990. Renewable energy sources can help in reducing current and projected power and electricity deficits and in displacing captive diesel generating sets.

2.3 Government Policy

Industrial Policy

Indian industrial growth since independence has been driven overall by the protectionist policies of import substitution. Protection of indigenous industry was justified on the grounds that it would enable industry to become competitive in production and marketing with non-indigenous producers. This policy protects local product manufacturers either by prohibiting the import of competitive goods or by placing a high import duty on goods that make them unattractively priced.

India's protectionist policy has not produced a competitive world class industry. After almost thirty years of industrial and scientific investment, India's share of world industrial output has fallen from 12 percent in 1950 to 3 percent in 1980. During that same period, India fell from 10th place to 27th place of ranked industrial powers.

Until recently, trade with and investment by foreigners was discouraged. The Indian Industries Development and Regulation Act (1951) required industry to obtain a license for establishing a new firm and for expansion of capacity and the manufacture of a new product. The allocation of licenses was aimed to disperse industry across the country within the demand limits projected by the government. Further, certain products were reserved for manufacturing by small-scale industries, which often led to sub-optimal scales of production. The investment activities of the foreign-owned firms to which the Foreign Exchange Regulation Act (FERA) applies are confined to selected capital and technology-intensive industries and are subject to more detailed and lengthier reviews in seeking licenses.

These policies are now being modified to provide the private sector and market forces greater freedom to operate. The list of industries in which FERA companies may invest was expanded by 23 industries in 1982. These include alternative energy systems such as photovoltaic and wind energy conversion and associated equipment. Also included were hydro/steam/gas turbines and generators from 20 MWe to 60 MWe. The list of industries has been further expanded in 1985 and again in 1986 (see Renewable Energy Policy). Tax liability of companies has been reduced by 5 percent and bank lending rates have been reduced. Indian firms do not have free access to foreign technology and are primarily restrained by policy[3] restrictions.

Even in the case of collaboration through licenses, which India opted for as the preferred mode of acquisition of foreign technology, the rules governing import have been rather strict and included fairly low ceilings on payments, short periods permitted for collaboration and various restrictive clauses. Although the policy is still one of permitting import of technology only when suitable domestic substitutes are not available, its implementation in practice has been considerably liberalized, as indicated by the sharp rise in collaboration agreements in recent years. Yet the government retains control on decisions regarding what technology to purchase, from whom, under what terms, etc. The number of foreign collaborations and investment approvals increased from 1984 to 1985 with economic liberalization (Table 2-2) but declined in 1986 because of foreign exchange constraints.

Table 2-2

Selected Indicators of Industrial Performance

Indicator	1984	1985	1986
Foreign Collaborations Approved	752	1,024	958
Foreign Investment Approvals	151	238	242

Foreign licensing agreements continue to be subject to a maximum period of validity of five years and to a ceiling on royalty payments of 5 percent, although exceptions are sometimes granted. Foreign firms prefer up-front lump-sum payments since the Indian market is usually small and firms are less inclined[4] for continued commitments over the long term. The Indian government, in its effort to reduce foreign dependence, encourages this by taxing lump-sum payments at half the rate for royalties. However, Indian firms would benefit from longer-term arrangements, which would stretch out the cash flow and guarantee the collaborator's cooperation in the project.

The mix of instruments and institutional mechanisms for technology transfer has until now been strongly biased towards licensing, technical assistance and other arms-length transactions. Direct foreign investment still appears to be viewed in India as an inferior approach to technology acquisition, although international experience in Korea, Brazil and other countries indicates that technology in these countries has modernized significantly from direct acquisition.

Indian trade policy is formulated[5] by senior officials of the government and administered by the Indian Ministry of Commerce. As of April 1, 1985, the official Indian fiscal policy is now issued every three years. The current policy is valid through March 31, 1988. The freer import of renewable energy technologies, such as wind and PV, may change at that time.

Energy Policy

India's response to the increases in international oil prices was similar to that of other oil importing countries. First, the government allocated a large share of resources to development of oil, coal, and power generation, and implemented policies supporting this effort. Second, in order to limit growth of oil consumption, the government implemented measures to better manage oil demand and find substitutes for oil.

The development of indigenous energy resources was accorded a high priority within the Indian government after 1973/74 (Table 2-3). In the Fourth Five Year Plan, the energy sector, petroleum, coal and electric power, received only 18.0 percent of the budget allocation and electric power received 15.4 percent. This allocation increased substantially in the following two plans. In the Fifth Plan, it increased to 25.0 percent and in the Sixth Plan to 27.1 percent. The share of funds going to petroleum increased from 1.9 percent in the Fourth Plan to 4.3 percent in the Fifth Plan, and that to electricity increased in each plan reaching a level of 19.8 percent in the Sixth Plan. In the Seventh Plan the outlay for energy has been increased to 30.1 percent of the budget.

The Indian government administers prices in the energy sector. In addition to setting prices it also levies tax and other duties differentially on each fuel. The pricing policy has multiple objectives of fair return to the energy producing units, encouraging prudent use of fuels, especially oil, and the supply of energy to consumers at lowest possible cost. However, in practice and in the absence of an integrated energy pricing policy, ad hoc changes in prices have resulted in economic distortions. The resulting price subsidies for certain petroleum products (kerosene) and electricity discourage the penetration of renewable energy sources.

In order to manage the demand for petroleum, the government has raised prices of all the fuels continually since 1979 (Table 2-4). The price of petroleum products was raised even as the price of crude oil collapsed in early February 1986. However, prices of petroleum products have not been raised equally. The government subsidized the prices of kerosene and diesel and increased taxes on gasoline and fuel oil. This resulted in rapid increase in the use of kerosene and diesel, causing a mismatch in the mix of refinery products and demand. Compared with international prices, kerosene price is subsidized whereas diesel price have been higher than international prices since 1982. This has led to the renewed use of kerosene as a substitute for diesel in many applications in transport and industry.

Table 2-3

Plan Outlays, Annual Averages
(1970/71 Billion Rs.)

Resource Development	Third Plan 61/62-65/66	Fourth Plan 69/70-73/74	Fifth Plan 74/75-78/79	Sixth Plan 80-85
Petroleum	0.8	0.68	1.95	3.77
Coal	0.67	0.26	1.32	2.51
Electric Power	3.63	5.51	8.09	16.88
Total Plan	**28.82**	**35.81**	**45.35**	**85.41**

Source: World Bank (1985). *India: Structural Change and Development Perspectives.*

Electricity prices, tariff structures, and levels vary across the country. The intent is to set levels to meet certain financial criteria and are structured so as to not penalize consumer groups arbitrarily. Low agricultural tariffs, for example, have been justified on the grounds that they avoid penalizing farmers simply because they are remote users and therefore costly to service. Many State Electricity Boards (SEBs) have only a demand charge based on the size of the installed irrigation pump and no energy charges. The agricultural use of electricity is thus not accurately known. (SEBs often report higher usage by farmers so as to reduce reported transmission and distribution losses.)

Table 2-4

Petroleum Product Prices in India (Rs./liter)

	Gasoline		Kerosene		Diesel		Fuel Oil	
Period	**Domestic**	**CIF**	**Domestic**	**CIF**	**Domestic**	**CIF**	**Domestic**	**CIF**
1973/74	1.82	0.42	0.66	0.39	0.76	0.35	0.28	0.22
1979/80	3.76	1.61	1.26	1.55	1.28	1.50	1.10	0.94
1981/82	5.29	2.60	1.50	2.76	2.56	2.65	2.36	1.72
1982/83	5.40	2.03	1.60	2.21	2.67	2.11	2.44	1.30
1985/86*				2.03	2.67	3.45	2.59	
April 86**		6.77		1.96		3.12		2.90

World Bank (1985). *India: Structural Change and Development Perspectives, Volume. 2*; *R. Bhatia (Oct. 1987), *Energy Pricing and Household Energy Consumption in India: An Analysis of Efficiency and Equity Issues.* Unpublished Report.; ** Government of India (1986-87). *Report of the Ministry of Petroleum and Natural Gas*

The price of electricity increased at about the same pace as the wholesale price index (WPI) between 1971/70 to 1982/81 (Table 2-5). Electricity prices were increased sharply in 1983/82 period and again in 1986/85. In the four years since 1982, electricity price increased faster than the wholesale price index. The price increases were not uniform across sectors.

The agriculture sector is particularly excluded from these price increases, which contributed to 11.1 percent annual increase in electricity demand in this sector between 1970 to 1984 compared to 6.8 percent increase in overall electricity demand. Agriculture's share of electricity demand increased from 10.2 percent in 1970-71 to 19.1 percent in 1985-86. More important, as we show later, the introduction of small wind and PV pumping systems is hampered by the subsidized prices for electricity to the farmer.

Table 2-5

Electricity Price Index in India

Period	Electricity Price Index	Wholesale Price Index
1970/71	100	100
1980/81	238	248
1982/83		285
1985/86		344
1986/87		372

Source: Government of India, Ministry of Finance (1987). *Economic Survey, 1986-87*. p. 48

Several advisory committees have been established over the years to guide the government policy makers in implementing the two-pronged strategy (Table 2-6). Recently a high level Advisory Board on Energy was established; its chairman reports to the Prime Minister of India. Figure 2-1 shows the organization of the various government ministries and departments concerned with development of energy policy and implementation of energy production and management of demand. Although there is no single agency in charge of energy conservation, the government recently appointed a special advisor to the Cabinet for this function.

Table 2-6

Energy Policy Committees

Date	Committee	Remarks
1965	Energy Survey of India Committee	Surveyed energy sources, consumption of commercial and non-commercial energy
1972-74	Fuel Policy Committee	Updated energy resource estimates, energy supply and demand statistics; developed energy demand projections
1977-79	Working Group on Energy Policy	Comprehensive exercise in energy policy; two forecasts developed; policy recommendations developed
1983-	Advisory Board on Energy	Updates earlier committee work, has prepared a perspective on energy issues through the year 2005.

Source: Gururaja, J. (1985). *Policies and Programs on Rural Energy: The Case of India.* Published in *Renewable Energy Planning: Methodological Aspects of Assessment of New and Renewable Sources of Energy and Integrated Planning.* Paper present August 1985, Bangkok, Thailand, UN-ESCAP

Renewable Energy Policy

In addition to increasing the budget allocations for the petroleum, coal and electricity sectors, the government also initiated an ambitious program in renewable energy development and utilization in the Sixth Five Year Plan. It created the Department of Non-conventional Energy Sources (DNES) in September, 1982 under the Ministry of Science and Technology.*

Three years later, along with the Departments of Power and Coal, it was made part of the Ministry of Energy . DNES is charged with implementing the government's renewable energy research, development, demonstration and dissemination program for public education and information. The focus of DNES research is to make non-conventional technologies increasingly competitive with conventional ones by cutting costs and improving operational performance.

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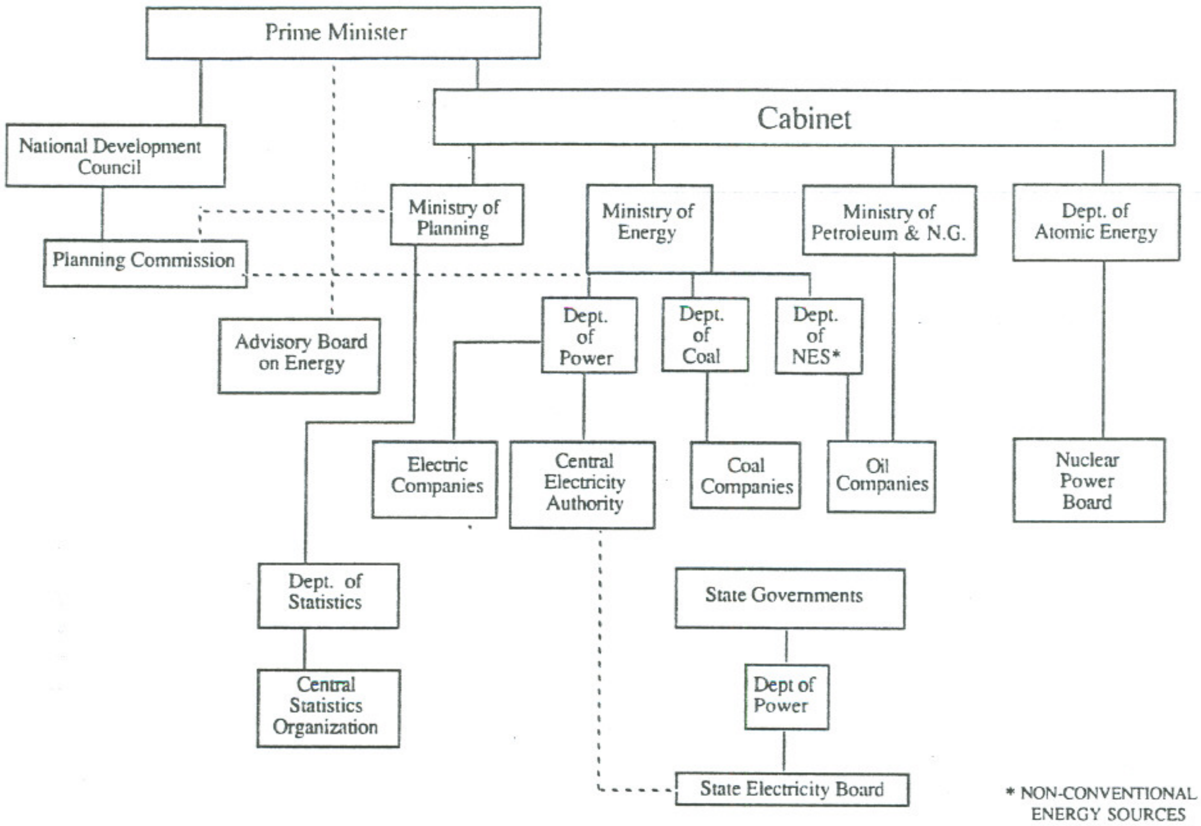
* A Commission for Additional Sources of Energy (CASE) was established in 1981 with membership of offices dealing with science and technology, rural development and energy ministries. CASE now acts as a policy making body for DNES.

Figure 2-1

ENERGY PLANNING ORGANIZATION - INDIA



Source: U. Kohli, Energy Advisor, Planning Commission. Presentation at the ADB/IEA Data Workshop, Tokyo (September 1987)

The high priority accorded to new and renewable sources of energy is reflected in the increasing DNES share of government budgets. The budget for new and renewable sources of energy increased from about $ 4 million in 1980-81 to about $ 88 million by 1984-85, the last fiscal year for the Sixth Plan. Against an approved Sixth Plan outlay of $ 100 million, the actual expenditure was 63 percent higher. In the Seventh Plan, the allocation has been increased to about $400 million or more than a five-fold increase in local currency.

As a fraction of the budget devoted to energy, new and renewable sources of energy accounted for 0.50 percent in the Sixth Plan, which will almost double to 0.95 percent in the Seventh Plan. Not only has the emphasis on these sources of energy not diminished despite lower international oil prices, but the government has increased their importance in the Seventh Plan. Table 2-7 shows the breakdown of government funding for various renewable energy activities.

For the Seventh Plan, DNES has identified the following priority areas for its research and development program:

- Reducing the cost of family sized biogas plants by 25 percent
- Increasing bio-gas production at low temperatures
- Reducing the cost of solar photovoltaics by developing new materials
- Developing efficient pump systems for windmills
- Developing indigenous wind turbine power generation systems

To achieve its research and technology development objectives, DNES has helped establish nodal energy agencies in the states and union territories in India. These agencies will play a pivotal role in the success of renewable energy programs in the country. DNES offers incentives and assistance to industries in the public and private sector. In 1984, there were more than 75 manufacturers, largely in the private sector, engaged in the manufacture/development of various renewable energy systems and devices.

Renewable Energy Financial Incentives

There are consumer financial incentives in place for solar hot water (SHW) and biogas systems and for efficient cook stoves, but not for wind, photovoltaic or urban waste systems, which may be the most likely candidates for U.S.participation. Incentives may be extended to these technologies as they mature. Solar technologies are subsidized at rates ranging from 33 to 100 percent (Table 2-8). For example, the Delhi Energy Development Administration (DEDA), subsidizes 75 percent of the price of a residential solar thermal water heater. A consumer buys the unit from an approved company and pays DEDA 25 percent of the price. The manufacturer then collects the full price from DEDA. DNES thus provides a 75 percent subsidy to DEDA to cover the cost of the solar thermal heater.

Several renewable energy technologies or components of such systems are exempt from excise duty. These include PV modules, waste conversion devices, etc. In addition, state governments have exempted renewable energy technologies from state sales taxes and from *octroi* duty (municipal tax).

Table 2-7

Allocation of Indian Central Government Funds
for Energy Technology Development and Application
(percent)

Energy Technology	Sixth Plan (Actual Expenses)	Seventh Plan (Outlay)
Biogas	57.9	48.5
Solar Energy	19.0	14.3
Photovoltaics		6.5
Solar Thermal (non-electric)		7.8
Wind	2.2	4.9
Improved Stoves		9.7
Biomass		6.0
Urban Waste		3.4
Others	20.9	13.2
Total	**100.0 %**	**100.0 %**
Total (U.S. $)	$163 million	$400 million

As a general rule, technical products that ensure import savings or generate export earnings are given favorable consideration for import licensing. Equipment for exploitation of alternative energy sources such as solar insolation, wind power and geothermal energy are exempt from this licensing requirement. In addition, the production of amorphous silicon solar cells is one of the eight designated technology missions of the Indian government.

The principal tax incentive for manufacturers of renewable energy systems is enhanced depreciation. Normal depreciation available to industry is 30 percent. Manufacturers of new and renewable energy systems qualify for an additional 15 percent during the first year. Institutional credit is available at a lower interest rate which in 1985 was 12.5 percent. For some technologies manufacturers may qualify for as much as 100 percent depreciation in the first year.

Table 2-8

Financial Incentives for Renewable Energy
Government of India, 1985

System	Incentive	Comments
Domestic Solar Hot Water	50%	Up to a maximum of Rs. 3,000
Industrial/Commercial	33.33%	
Water/Air Heating Solar Cookers Desalination		
Government Enterprises	75 - 100%	
Solar Desalination	100%	
Solar Crop Drying	50%	
Urban Waste Systems	20%	DNES to pay loan interest

Source: DNES (1987). *1987 Annual Report*

2.4 Wind Energy

During the Sixth Plan, an outlay of about $ 1.5 million was targeted by the government for the development of wind energy systems. The actual expenditure exceeded this target and was about $ 3.3 million. The program included development and demonstration of wind pumps for irrigation and drinking water. About 1000 small wind pumping mills were installed under demonstration programs.

The focus in the Seventh Plan[6] will be on technology development of wind electric systems, and for improvements and cost reduction in the utilization of wind pumps for irrigation and drinking water. Programs will also include strengthening of the national wind energy data base and setting up pilot projects on wind monitoring, R&D of medium and large wind electric generators and demonstration and field testing of wind pumps, small battery chargers as well as setting up of wind farms. During this Plan, the government plans to spend about $ 15 million on wind energy programs, half of which will be spent on research, development and demonstration. DNES plans to install 25 MWe of demonstration windfarms during the Seventh Plan.

DNES wants to promote local capacity to assemble and manufacture wind systems and has therefore encouraged joint ventures with Indian companies. Previously, total wind turbine systems were exempt from customs duty, but individual components were not. Now components are also exempt, which will encourage the use of local components and enable manufacture of hybrid systems using appropriate foreign components. This would allow U.S. manufacturers to enter the market with technology which is best suited and appreciated in India.

Wind manufacturers enjoy several tax exemptions and subsidies. Capital equipment can be depreciated 100 percent in the first year and until March 1988 wind technology imports are exempt from customs duties. The India Renewable Energy Development Bank provides 5.5 percent financing with 7 year repayment and interest moratorium in the first two years. Direct grants are available from DNES for 10 to 75 percent of the cost of the project. The Industrial Development Bank also makes 5.3 percent loans and several state finance corporations offer 10 year loans with a moratorium on the interest payments for two years.

Penetration, Economics and Financing

There are five major windfarms in operation in India with a total capacity of 3.3 MWe. The location, name of the manufacturer, size and number of units in each windfarm are shown in Table 2-9. Among these windfarms, the Mandavi, Tuticorin and Okha windfarms have been the better performers with plant factors ranging from 0.17 to 0.22; those at Puri and Deogarh have performed less well. The Mandavi system is producing electricity at the rate of 1.7 million kWh a year. The installation cost[7] of the Mandavi system is about $1,300 per kW.

The Okha windfarm was set up using funding from DNES, the Gujarat Energy Development Agency (GEDA) and the Gujarat Electricity Board (GEB). It has reportedly performed very well with only a 0.9% down time during the past 15 months. The system was expected to generate 1.21 million kWh per year, but because of load shedding which cut off electricity to the feeder thus interrupting the windfarm, it generated 0.95 million kWh of electricity between April 1986 and March 1987.

Electricity from the system was expected to cost* Rs. 1.24 per unit in the first year declining to Rs. 1.08 in the tenth year but the actual cost in the first year will be higher because of lower than expected generation of electricity. GEB has agreed to buy the electricity at Rs. 1.25 per kWh although this is more than their cost of generation (Rs. 0.8 to 0.9 per kWh., of which the fuel cost is estimated at Rs. 0.45.) The marginal cost of electric power bought from the neighboring state of Maharashtra is Rs. 0.94 per kWh.

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* Rupee is the currency used in India. Its value has decreased relative to the dollar over the last few years. In this report, we have used an exchange rate of US$ 1 = Rs. 10 for the Sixth Plan period, 1980-85, and US $1 = Rs. 13 for the Seventh Plan period, 1985-90.

Table 2-9

Major Windfarms in India

Location	Capacity (kW)	Manufacturer	Size No. x kW.	Date of Commissioning	Generation 1986, Mn.kWh	Plant Factor
Mandavi, Gujarat	1159	Micon Micon Windane Windane	2 x 110 14 x 55 6 x 22 2 x 18.5	Jan.16, 1986	1.74	0.18
Tuticorin, Tamil Nadu	550	Windmatic	10 x 55	Jan.18, 1986	0.80	0.17
Okha, Gujarat	550	Vestas	10 x 55	March 8, 1986	0.87	0.22
Puri, Orissa	550	Vestas	10 x 55	May 1, 1986	0.20	0.06
Deogarh, Maharashtra	550	Vestas	10 x 55	May 23, 1986	0.33	0.11

Source: Derrick A. (1987). Renewable Energy Market Survey, India.
Prepared for U.S. Dept. of Commerce, and
DNES, Annual Report, 1987.

A recent economic analysis by the World Bank[8] indicates that electricity from wind farms is only marginally attractive. At an installation cost of $1,300 per kW and a plant factor of 0.25 percent electricity cost amounted to Rs. 1.53 per kWh. If the installation cost is reduced to $1100 per kW, the electricity cost declines to Rs. 0.92 per kWh. These may be compared with coal base generation cost of Rs. 0.80 per kWh and the cost of supply to rural/remote areas of Rs. 1.01 per kWh. The existing wind farms have operated at a plant factor ranging from 0.22 to 0.06. Using these figures would increase the wind generated electricity cost by 14 to 400 percent. This analysis indicates that grid-connected electricity from wind may be economically marginal at best, unless the installation cost is reduced or the plant factor is higher.

The machines installed in the 5 windfarms are primarily of Danish origin. For example, at Puri, Orissa, a consortium of Danish manufacturers, banks, and the aid agency prepared an introductory technical and financial package that virtually guarantees the stipulated performance of the machines. The terms included a 10-20 % down payment by the nodal agency, such as the Orissa Energy Development Agency (OREDA), or the state electricity boards. The remaining loan was to be paid in 7 years.

The operator of the machine was *insured by Danish banks against failure to generate the stipulated amount of electricity.* For example, if the machine did not generate sufficient electricity because of technical problems, such as the breakdown or overloading of the generator, or even because of lack of adequate wind speed then the insurance company makes up for the loss of revenue incurred by the operator. In order to provide such a complete coverage the Danes conducted the initial feasibility study to ensure adequate wind resource conditions for the generation of electricity, and trained operators in Denmark to ensure adequate capability to provide on-site maintenance and repair. There are no Danish staff at the site once the trials are completed.

Despite Danish efforts, their wind machines have faced start-up problems. For example, in Orissa, these have included siting of the machines at low-wind regime sites, burning out of the small 5 kW generators on 8 of the 10 machines and unanticipated, though minor, corrosion because of higher humidity and temperature conditions in India. The machines are being moved to a new site and more generators are being shipped to India.

The complete guarantees were offered as an introductory package and the Danes are no longer providing complete coverage of the machines. This affords the U.S. manufacturers an opportunity to enter the market. However, the Indians perceive that the U.S. machines are designed for a higher cut-off wind speed than the average found in India while the Danish machines are designed to operate at lower speeds. This perception will have to be overcome to enter the Indian market.

The Danish government recently allocated 250 million kroner (about $75 million) in foreign aid funds to finance several additional wind and solar projects[9] in India. DANIDA has asked Danish manufacturers to submit bids for the projects.

In addition to the large windfarms, there is also a substantial market for small windpumps in the country. In March 1985, there were 3.5 million diesel irrigation pump sets and 5.7 million electric pump sets installed in the country. There were 1192 water pumping windmills and 343 photovoltaic units as of January 31, 1986. The Seventh Plan calls for 3 million new pump sets to be installed at an estimated cost of $2.5 billion. The corresponding investments in electric power will be around $15 billion to supply electricity to these pump sets. Windpumps can meet a small fraction of this demand and 500 to 1000 units per year can be expected. Although only indigenously manufactured units are expected to be installed, the need for more efficient pumps and other components presents an opportunity for U.S. manufacturers of small windpumps. Bergey Wind Power recently entered into a licensing agreement to produce 1 kWe wind generators in India.

Judging from the rapid growth of wind farms, the establishment of nodal agencies and the removal of import restrictions on renewable energy equipment, the government appears committed to providing the incentives necessary for rapid commercialization of wind systems. Financial and import licensing incentives are substantial for domestic production and collaboration with foreign manufacturers. There is as yet no legal framework analogous to PURPA that would force the state electric utility boards to purchase electricity from private and para-statal producers of electricity, although DNES is presently pushing the adoption of such a statute in the Indian parliament. Until that happens, the best markets will be in the states where the SEBs have progressive attitudes towards sharing the generation of electric power with other producers. SEBs in Gujarat and Orissa seem better disposed towards allowing non-SEB renewable power generation.

2.5 Solar Energy

During the Sixth Plan, the government spent $ 12.6 million on about 2,000 solar hot water (SHW) systems and the sale on a subsidized basis of 30,000 solar cookers. Another $ 15 million was spent on reducing costs and improving photovoltaic (PV) production technology. Two public sector undertakings (parastatals), Central Electronics Ltd. (CEL) and Bharat Heavy Electricals Ltd. (BHEL), started producing crystalline PV cells. Solar pumps for drinking water supply and irrigation and PV street lighting in villages were installed for demonstration purposes. An extension program was also established under the National Solar Energy Development Programme (NASPED).

The government plans to spend about $25 million on the solar thermal program, and $20 million on the PV program in the Seventh Plan, about two-thirds of which will be spent on RD&D. The solar thermal program will focus on the field demonstration and testing of refrigeration, air-conditioning, power generation centralized systems, etc. The emphasis will be on manufacture of amorphous silicon cells and ribbon silicon cells, and the development of system components.

The Seventh Plan calls for electrification of 118,000 villages in the country. It also recognizes that remote villages will be too expensive to electrify using grid connected electricity and recommends the use of PV and other renewable technology for 10,000 of these villages. The market for PV technology for street and community lighting and water pumping in rural areas is thus extremely large in India, on the order of 20 - 100 MWe.

Penetration, Economics, and Financing: Photovoltaics

CEL, BHEL, and Rajasthan Electronics and Instruments Ltd. are the three manufacturers of crystalline PV cells in India. Their combined manufacturing capacity is 2.5 MWp per year. Of this, CEL is the largest with a capacity to produce 2 MWp per year, expected to expand to 6 MWp.

Table 2-10 shows a breakdown of the types of applications that CEL has supplied PV systems for. CEL is one of the largest producer of photovoltaics in the world. Sales increased by 124 percent from 1985-86 to 1986-87. Sales in 1986-87 were Rs. 12.64 crores* or about $10 million. A total of 3540 systems were sold amounting to about 700 kilowatts of power. Production is expected to expand around 50 percent next year.

A controversy was generated[10] on the proposed technology import by the National Silicon Facility (NSF) for the production of polysilicon in November 1984. The government's final decision on the contract with a U.S. company, Hemlock Semiconductors, was kept pending for more than two years till Metkem Silicon, an Indian company, could prove its technology. In October 1986, Metkem started supplying photovoltaic-grade silicon.

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* 1 Crore = 10 million

Table 2-10

Photovoltaic Systems Supplied by the Central Electronics Laboratory (CEL) of India (As of mid-November 1986)

Systems	Number
Rural Water Pumping	436
TV/Lighting Systems	258
Rural Lighting Systems	52
Stand-Alone Street Lighting	3,191
Offshore Platforms (PV Power Sources)	17
Other	66

Source: *Urja Update*, Vol. IV, No. 2, June 1987.

The government has now terminated the contract with Hemlock. The Metkem product has been approved by BHEL and CEL. CEL agreed to purchase all the silicon produced by Metkem during 1986-87, despite the quoted price being double the international price. The Metkem price for polysilicon is about Rs. 850 per kg.

In order to protect the new domestic industry, the government has levied a customs duty of 30 percent on the import of silicon wafers. This along with the lower value of the rupee has resulted in an increase in the market price of PV cells and modules by 10-15 percent. During the controversy it was argued that the capital cost of the Metkem plant will be less than that of the NSF facility. The higher price of silicon does not bear that out.

Bhatia[11] has estimated the total costs (capital costs and present value of operating costs) for providing irrigation to a 2.5 acre and a 1 acre farm in Northern India using a variety of power systems (Table 2-11). For smaller farms, against market (subsidized) prices of grid electricity and diesel fuel, a PV system currently available in India (costing $11.75 per peak watt and having 3.4% efficiency) is twice as costly as a diesel engine and over three times as costly as grid electricity. A future PV system costing $4.50 per peak watt and having 4.6% efficiency is projected to be 35% less costly than the diesel engine and only 22% more costly than grid electricity.

Table 2-11

Present Value of Energy Costs for Irrigation in India
(1986 U.S. $)

	2.5 Acres		1 Acre	
	Shadow Price	Market Price	Shadow Price	Market Price
Grid	2,277	626	1,697	601
Diesel[1]	1,789	1,401	1,371	1,135
Photovoltaic				
Current[2]	5,000	5,000	2,110	2,110
Future (Increased Eff.)[3]	3,740	3,740	1,610	1,610
Future (Eff., Costs)[4]	1,550	1,550	730	730
Windmills	4,960	4,960	1,980	1,980

Source: Bhatia. R. (1986). *Economic Evaluation and Diffusion of Renewable Energy Technologies: Case Studies from India.* Draft Report.

Notes for Table 2-11

1. Shadow price is the CIF import price of diesel fuel increased by 25% to reflect its overall scarcity plus the internal transport costs

2. Cost of $\$11.75/W_p$ and 3.4% overall system efficiency (AM0). Cost includes $\$9.75/W_p$ for the arrays and $\$2/W_p$ for the balance of system

3. Cost of arrays in $\$/m^2$ same as in Note 2, but with 4.6% AM0 system efficiency

4. $\$4.5/W_p$ for overall system

Removing subsidies for electricity and diesel fuel changes the results dramatically. The currently available PV system is still not competitive, but decreasing the installed cost to $4.50 per peak watt and improving the efficiency to 4.6% would make it less expensive than grid electricity and competitive with the diesel engine. Some combination of cost reduction and efficiency improvement would thus make the PV system less costly than either of the two conventional options. The windpumps were shown not to be competitive at unsubsidized prices with grid-connected electricity.

In a similar comparison of grid extension versus the use of stand-alone PV systems for street lighting and other smaller loads in villages, Bhatia concludes that for villages as close as 5 km. from the grid, if the total demand is of the order of 2 kilowatts, PV systems are clearly economic at current costs and efficiencies (Figure 2-2).

A recent World Bank/UNDP study[12] compared the cost of PV with other options for supplying electricity for village applications. It concluded that both small PV and wind pump sets present lower cost options for village water supply than diesel or wood gasifiers in low lift (8 to 15 meters) applications. The main reason is that PV and wind pump sets can be sized to meet a constant daily demand and do not need to be over-sized to meet a peak demand.

In its comparison of costs of various energy systems, the World Bank/UNDP study assumes installed cost of PV arrays, excluding installation cost of about $2 a peak watt, to be $12 per peak watt. However, a recent assessment[13] of different options for rural water supply quotes comparable cost of arrays installed in 1986 at $7 per peak watt. This would make PV options substantially more cost effective and improve their economic viability for irrigation pumping.

Penetration, Economics, and Financing: Solar Hot Water Systems

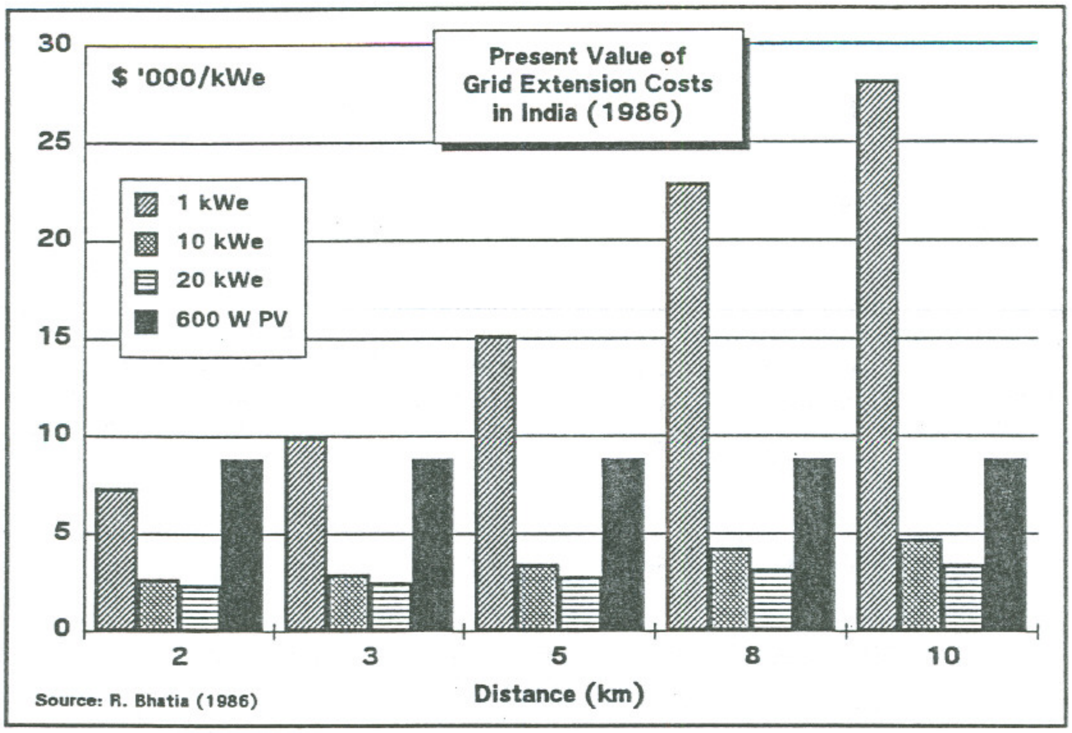
A large market is anticipated in India for solar hot water (SHW) systems. By January 1986, there were 760 systems installed in the country. A year later, these had grown to 2,170 installations, about 1,000 of these[14] were for commercial and industrial applications. In terms of collector area, the residential systems amounted to 2,600 m^2 and the commercial and industrial systems to 44,400 m^2.

With the active participation of some of the nodal agencies and DNES financial subsidies channelled through these agencies, the market potential is large. In actual practice, since money is transferred from the customer through the nodal agency to the manufacturer, who has to procure a certificate to validate the operation of the installed water heater system, the opportunity for corruption is substantial. The fear is that this may destroy the fledgling industry before it has a chance to take off.

An economic analysis of a SHW system compared with an electric geyser, each delivering about 100 liters per day of 60 degrees centigrade hot water, shows that without subsidies for either electricity or the SHW system, an advanced SHW system would have a payback period of about 5 years. With market price of electricity and a 50 percent subsidy for the SHW system, this reduces to 3 years.[15]

Although the Indian government restricts the import of SHW systems, private Indian companies are importing components to assemble SHW systems in India. One such company, Solar Energy Conversion Devices, is importing absorber panels made by Furukawa of Japan, and Tedlar glazing made by Dupont of the U.S.

Figure 2-2



Present Value of Grid Extension Costs in India (1986)
$ '000/kWe
30
25
20
15
10
5
0
1 kWe
10 kWe
20 kWe
600 W PV
2
3
5
8
10
Distance (km)
Source: R. Bhatia (1986)

2.6 Energy Efficient Lighting - A Potential Market Entry Opportunity for Photovoltaics

Although, the main focus of this report is on renewable energy technologies, high luminosity low wattage lamps as replacement for incandescent lamps will be a major and much larger new market in the energy arena. As described earlier, the peak demand for electricity is not fully met in most parts of India. Peak load on most utility systems occurs between 5 and 9 pm when there is a sharp increase in the use of lighting by domestic and commercial customers. The Seventh Plan projections indicate that even with new capacity additions, peak loads will not be fully met during the next few years.

A recent study[16] concluded that the introduction of low-power high-luminosity fluorescent lamps, which are commercially available in the U.S. and Europe but are not made in India, would reduce the need for 10,800 MW or 23 percent of presently installed capacity. The annual rate of return on expenditure for lamp substitution in electricity saved would range from 45 to 55 percent.

The market for incandescent lamps in India is very large; about 300 million lamps are produced annually. At $10 for a low-power high-luminosity lamp the market is about $3 billion. At present, the import of capital equipment for production of these lamps attracts heavy customs duty. The study shows that it is in the interest of the country to reduce this duty. Packaged with PV systems, such lamps would provide at least a three-fold advantage over the cost figures cited in Figure 2 for PV systems. Even at the low efficiency levels and high cost of PV systems in India, such packages would become attractive for villages close to the grid. The introduction of such lamps not only in India, but in other countries as well, offers a strong opportunity for U.S. manufacturers.

2.7 Urban Waste

The Seventh Plan allocates $10.8 million dollars for the urban waste area. About 70 percent of the funds will go for RD&D. Electric power generation from municipal waste and agricultural residue and forest matter has been determined to be economical. DNES will provide 20 percent of the investment cost as an outright grant to the developer.[17] It will assist the developer in seeking financing for such a project from local banks and request that these projects receive a low interest loan which DNES will reimburse the developer. These loans are generally reserved for the priority sector. Essentially the developer will receive an interest free loan.

A recent study[18] by Blevis and Shrivastava for the U.S.Trade and Development Administration (TDP) concluded that this was one of the priority areas for U.S. participation. Accordingly, TDP plans to conduct a feasibility study in the major urban areas to select a location for a possible 10 to 50 MWe generation plant. Westinghouse has a process for using low-Btu materials which may be amenable to using municipal waste from LDC urban areas. These have a higher organic content compared to those in a developed country. The location choice will depend on the attitude of the local SEB. Tamil Nadu state appears to have a more progressive SEB which may be willing to purchase electricity from a private power developer.

2.8 Conclusions

Our review of the renewable energy activities and the Indian government's policy reveals that there are several opportunities for U.S. industry to participate in the Indian renewables market. However, the better opportunities are in the sales of system components, manufacturing equipment and end-use devices rather than in sales of complete renewable energy systems.

The Indian government policy has been to indigenize the production of renewable energy technology, consistent with its overall policy to discourage outright joint investment in Indian companies and to encourage short-term licensing agreements. Past experience shows that the government has opted for indigenous technology in most industrial arenas even at the cost of sacrificing efficiency and quality of the product.

Conversations with Indian officials reveal that the market for single-crystalline PV cells is closed to foreign manufacturers although that for polycrystalline cells is unclear. The manufacture of amorphous silicon presents an opportunity for U.S. manufacturers to collaborate with Indian counterparts. However, Hemlock Semiconductors' unsuccessful and costly experience in marketing crystalline silicon manufacturing technology in India indicates a degree of caution.

The experience with Hemlock may be repeated in the amorphous silicon area. Recent pronouncements from one of the national laboratories claim that the technology for making amorphous silicon cells is being readied for commercialization in India. The government is likely to be wary of foreign collaboration because of internal pressures to adopt indigenous technology.

Foreign competition from Danish, Dutch and French consortia for tapping the Indian renewable, especially wind, energy market is quite strong and needs to be overcome. The Danish aid agency, DANIDA, was instrumental in providing an attractive introductory financing package, including machine performance guaranteed by Danish insurance companies in order to gain a foothold in the Indian market. It has withdrawn this complete coverage since then which affords U.S. manufacturers an opportunity to enter the market. The U.S. government would have to match or exceed the terms and conditions set forth by the European competitors. Indian government officials indicate that this may have to include financial assistance to the program established by DNES.

A different opportunity arises from comparing the experience with solar thermal collectors assembled by an Indian company in New Delhi. Two important components, Tedlar for glazing and absorber panels, are imported for assembly in India. The use of Tedlar for solar thermal hot water systems is an example of the use of U.S. components in a technology which is relatively simple and not open for direct U.S. participation.

Finally, the market for low-wattage fluorescent lamps is large in India. Their benefits are evident and accepted by the government. A combination of these lamps with PV cells could prove to be a major new market for U.S. industry.

Section 3

PAKISTAN

3. PAKISTAN

3.1 Introduction

Pakistan[19] is a developing country of 93 million people, with a per capita GNP of roughly $300. Adult literacy is well below 50%, and less than 10% of the rural population has access to electricity; two-thirds of the total population have no reliable access to clean water. Moreover the population growth rate is close to 3%/year, diluting the benefits of economic growth. The Government of Pakistan is planning to accelerate the development process, including electrifying all of the non-electrified settlements over the coming decade.

The energy sector has become a major area of concern and a target of new investment, lending, and assistance by the Government of Pakistan, bilateral agencies such as USAID*, and the multilateral development banks. During the period 1982 - 1987 (corresponding to the Sixth Five-Year Plan period) almost 40% of all public sector investments were made in the energy sector, and commercial energy supply grew at 8.6%/year. Energy demand, especially during the peak winter months, has continued to outstrip supply, resulting in growing shortages of natural gas and electricity, (with shortfalls of 1,000 MWe in a system of 7,000 MWe), and increasing imports of petroleum products. During this period energy imports increased from $0.5 billion in FY78 to $1.5 billion in FY84, equivalent to 23% of total imports and 55% of total exports.

Growing energy imports and the need for continued expansion in commercial energy supply is a considerable concern to the Government of Pakistan. As the draft Seventh Five-Year Plan[20] points out:

> The energy needs of the country are mounting at an exponential rate and are bound to do so for an indefinite period of time. ... It is, therefore, imperative to evolve a viable national energy system -- a system which overcomes the energy shortage of today, has the potential to cope with the vastly expanded requirements of tomorrow, relies chiefly on indigenous resources of energy, but does not involve a level of dependence on fuel imports which enfeebles the national economy, nor taxes it so much that other sectors are deprived of requisite investments. This, in short, is the energy challenge which has to be met adequately for a self-reliant and prosperous Pakistan.

The indigenous resources referred to here are principally coal, hydropower, and natural gas. However, there is a growing interest by the Government of Pakistan in the potential of renewable energy resources[21] (besides hydropower) to make an important long-term contribution to the nation's energy supply, and in the near term, to contribute to improvement of the quality of life and to economic development in rural areas of the country.

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* The United States, through USAID, provides the largest bilateral support to Pakistan.

3.2 Energy Resources

Pakistan is endowed (Table 3-1) with a variety of commercially exploitable energy resources, primarily hydropower and natural gas, and to a lesser extent crude oil and coal. In addition, the country uses substantial amounts of firewood, crop residues, and animal waste. Although Pakistan's commercial energy resources remain underexploited, it is likely that in spite of government efforts, the gap between energy demand and supply will continue to widen. Pakistan now imports 30% of its commercial fuels. The goal of the new Five-Year Plan is to reduce this to 24% by 1992.

Hydropower

The full hydropower potential of Pakistan is estimated at about 30,000 MWe distributed among several sites on the Bydus, Jhelem, and Swat rivers; less than 3,000 MWe are developed. The small-scale hydropower potential[22] in Pakistan is estimated to be 150-300 MWe. Over 60 microhydro plants in the range of several kWe to 50 kWe have been built at low cost ($200 - $300/kWe) by ATDO (Alternative Technology Development Organization of Pakistan), and more are being developed.

Oil and Natural Gas

Remaining recoverable oil and condensate reserves are estimated at 154 million barrels. Current production is 43,000 barrels per day or 15.7 million barrels per year. The present reserve to production ratio stands at roughly 10, but the reserves in a number of known oil fields are yet to be estimated. Production is projected to expand to 71,000 barrels per day by 1992/93, which will cover about one-third of total domestic demand for petroleum products, with a net imports liability of $ 1.5 billion (1987 dollars). An accelerated program of exploration and development is included in the Seventh Plan.

The remaining recoverable reserves of natural gas (as of July 1986) were estimated to be 19.5 trillion cubic feet, equivalent to 15.2 trillion cubic feet of purified gas at 975 Btu/cf. The production of natural gas is expected to rise to 2,300 million cubic feet per day (CFD); current production is 1,270 million CFD. New discoveries are expected to add only 200 million CFD by 1992/93.

Coal

Domestic coal could become a major resource for power generation, and the Seventh Plan provides for the establishment of initiatives to develop this potential. Total estimated coal reserves are 1.25 billion tons, comprised of 197.5 million tons (measured), 187.8 million tons (indicated), and 863 million tons (inferred). The coal ranges in quality from lignite (5,300 Btu/lb) to sub-bituminous (9,500 Btu/lb). The current production of coal is market-limited. In 1985/86 the reported production was 2.2 million tons and unreported production was estimated at 1.86 tons. Coal production is expected to increase to 9 million tons annually by 1992/93 by extending coal use to the cement industry and for power generation.

Table 1

ENERGY RESERVES AND PRODUCTION
(1985/86)

Resource	Reserves	Production	R/P Ratio
Coal (Million tons)			
Measured	198		
Indicated	187		
Inferred	863		
Total	1,250	4.1	305
Oil (Million Barrels)	154*	15.6	10
Natural Gas (BCF)	15,200	464	33
Hydropower Potential	30,000 MWe	2,547 MWe**	

* As of July 1987

** As of 1984

Solar Radiation

Pakistan is a sunny country, with annual global insolation of 5-6 kWh/m^2-day. Figure 3-1 shows the results of measurements reported over a 3-year period in the mid-1970s for Karachi. While not definitive, the numbers are representative for most of Pakistan.

Wind Energy

There are some regions of Pakistan where there is sufficient wind energy during at least four to five months of the year to justify use of wind systems for water pumping, for shaft energy, and in some cases for power generation. In particular the windy coastal areas of Pakistan in the South and South-west are extremely dry and lacking in power for pumping groundwater. During the 1960s the Pakistan Water and Power Development Authority (WAPDA) supported a pilot windmill project using six wind mills provided by the Government of Australia. Three of the mills were set up in Baluchistan and three in Sind. Wind data for Sind are shown in Figure 3-2. The wind conditions shown[28] would be considered economically marginal at best for power generation in California but may be economic for water pumping in Pakistan.

Figure 3-1

Typical Insolation Conditions in Pakistan

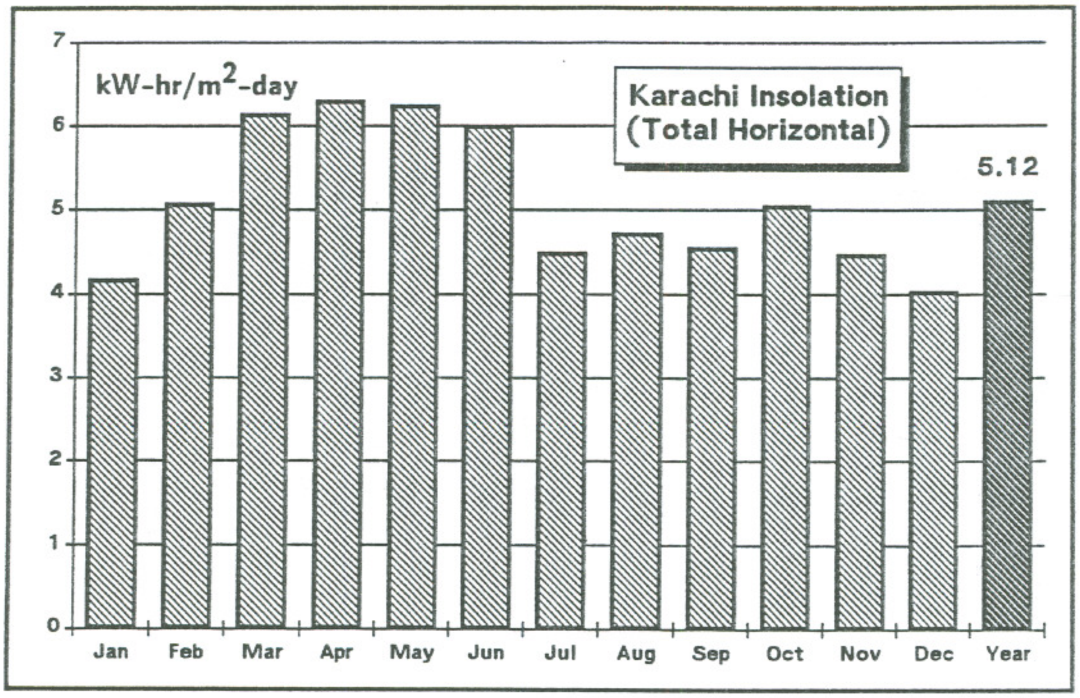
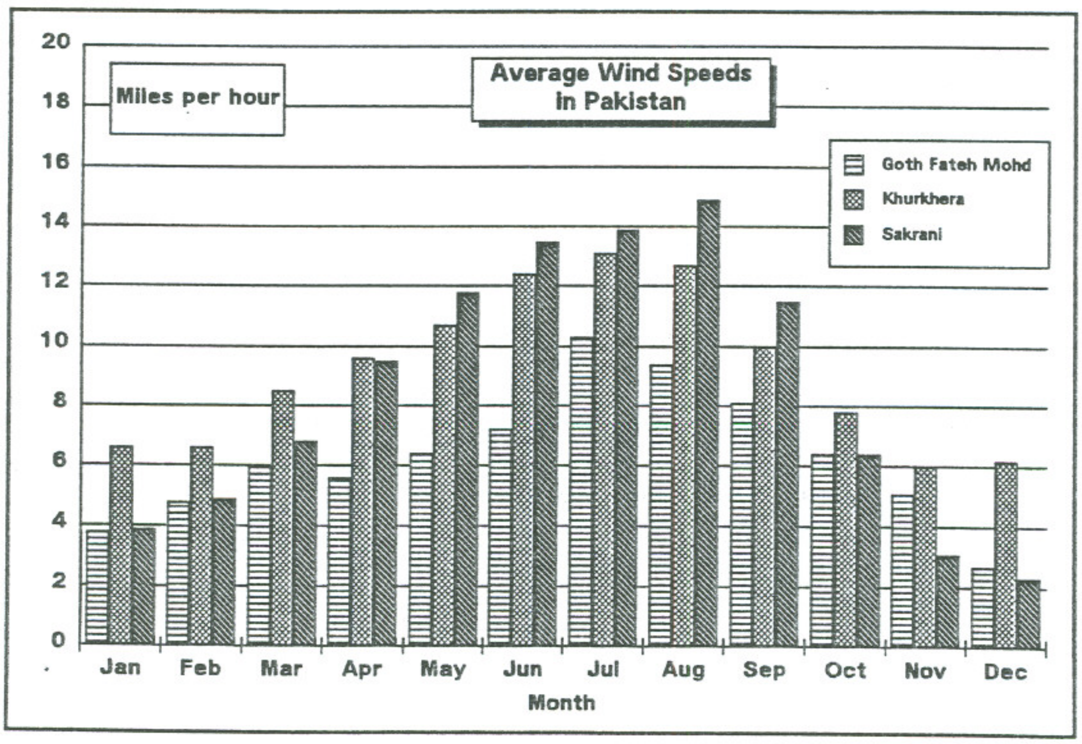


Figure 3-2



Biomass Resources

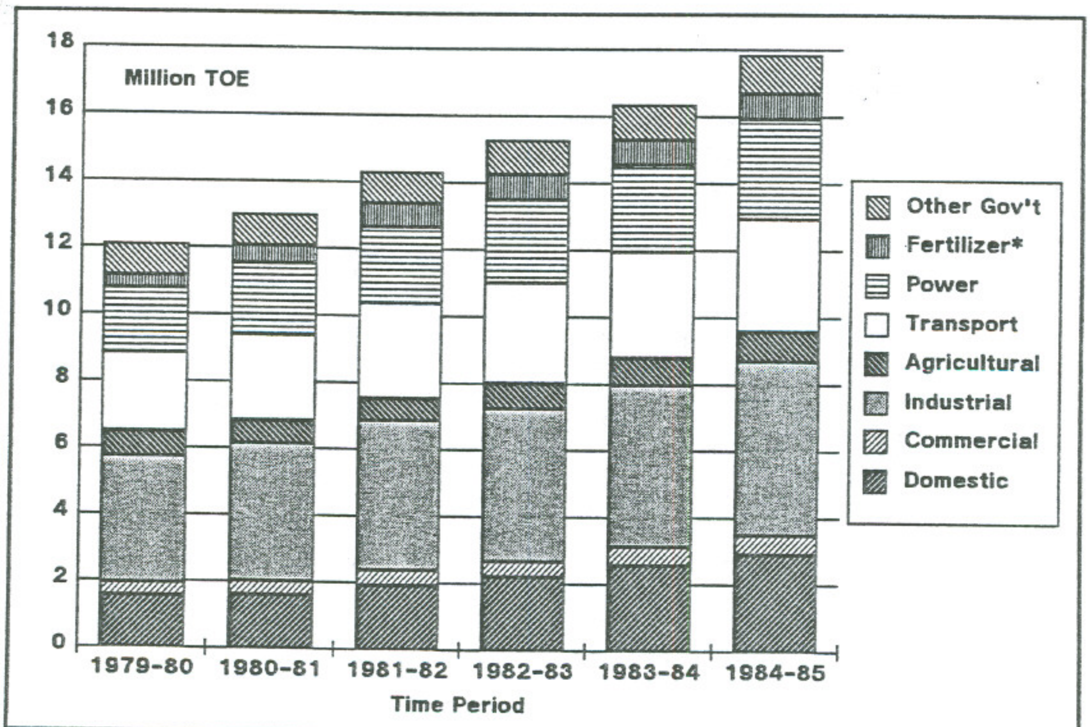
Cow dung, firewood, and crop residues are widely used in rural areas for cooking. The most significant agricultural residues in terms of biomass production are sugarcane, wheat (straw), and rice (hulls). Annual production of rice paddy in Pakistan was 3.4 million metric tonnes in 1982 and yielded about one million metric tonnes of rice hulls. These can be used effectively as a rural fuel source for rice mills even though their overall contribution to commercial energy consumption would be at best on the order of 0.25 million tonnes of oil equivalent annually, equivalent to 1.5% of national energy use.

3.3 Energy Supply and Demand

In 1982/83 the total primary energy consumption[24] in Pakistan was estimated at 23 million tons of oil equivalent (MTOE), of which roughly one-third was in the form of non-commercial energy including firewood, charcoal, agricultural crop residues, and cow dung. Commercial energy consumption was divided among natural gas (39%), oil (39%), coal (5%), hydropower (17%), and a small amount of nuclear and other energy sources (0.6%). In the five-year period from 1979-80 to 1984-85 overall commercial energy consumption has increased at 7.8% per year (9 year doubling time). This corresponds to a *per capita* commercial energy consumption of 0.16 toe per year, or approximately 225 W(th) per person. By contrast, the world per capita consumption is roughly 2 kW(th), for Western Europe is in the range of 3 - 6 kW(th), and for the U.S. is about 12 kW(th). Sectoral energy demand from 1979-80 to 1984-85 is shown in Figure 3-3.

Figure 3-3

Sectoral Structure of Energy Demand in Pakistan



Imported energy, virtually all of it petroleum, accounts for 29% of the commercial energy in the period 1987-88. This share is expected to decline slightly to 24% by the end of the Seventh Plan through increased use of domestic coal, hydropower, and natural gas. The share of natural gas in commercial energy supplies is projected to rise from 38% currently to 42% in 1992-93, and that of coal from 12% to 20%.

Renewable Energy

Renewable energy resources, excluding hydropower installations over 5 MWe, provided the equivalent of 11 million tons of oil in 1987-88 or roughly 40% of the total energy consumption in Pakistan. Virtually all of these renewable energy resources are firewood, crop residues, and animal waste, consumed primarily for cooking. According to the most recent major biomass use survey in Pakistan, 99% of rural households and 61% of urban households use biomass for cooking, water heating, and space heating. Although non-commercial fuels play an important role in the overall energy supply picture, the current share of 31.3% is expected to decrease to 26.9% by 1992-93. However during that period that absolute amount of commercial fuel use is expected to increase from 11.5 MTOE in 1987-88 to 13.5 MTOE in 1992-93.

3.4 Power Generation

Pakistan is in the takeoff stage for electric power generation. The recent history of installed generating capacity in Pakistan is summarized in Figure 3-4. Electricity consumption has grown significantly (Figure 3-5), with a 30-fold increase since 1960, and with a major spurt in growth beginning in 1968. During the Sixth Plan period the supply of commercial energy grew at an average rate of 8.6%/year. Installed power generation capacity grew by 2,018 MWe, against a target of 3,795 MWe. Figure 3-6 shows the projected generating capacity through the year 2000.

Figure 3-4

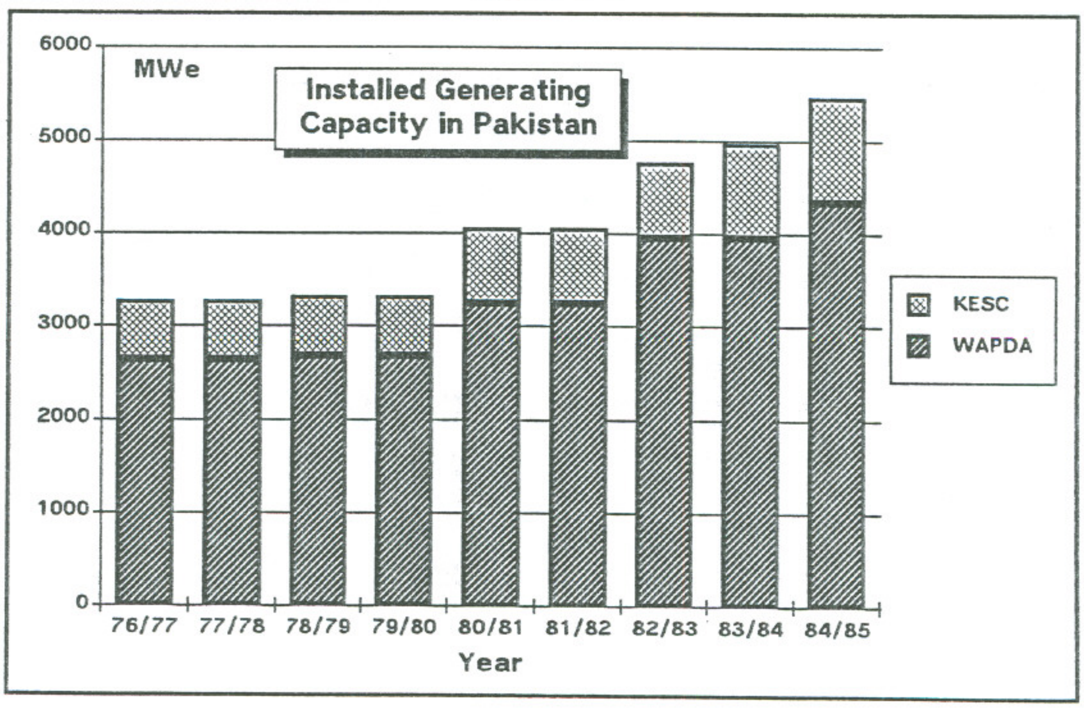


Figure 3-5

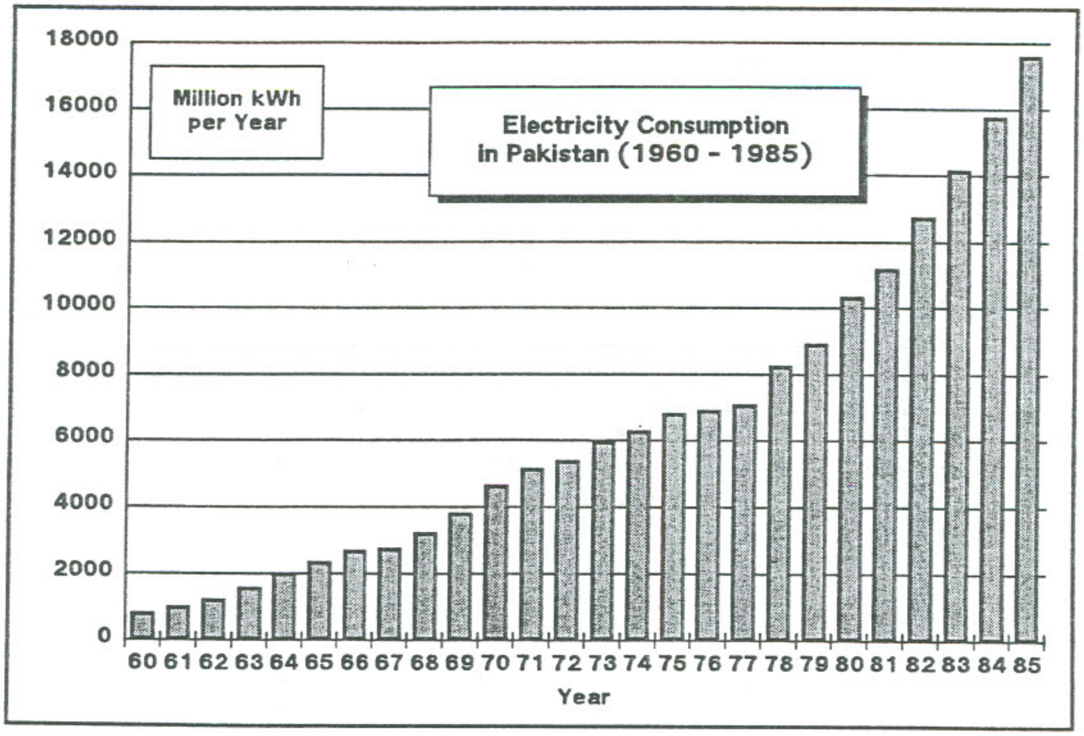
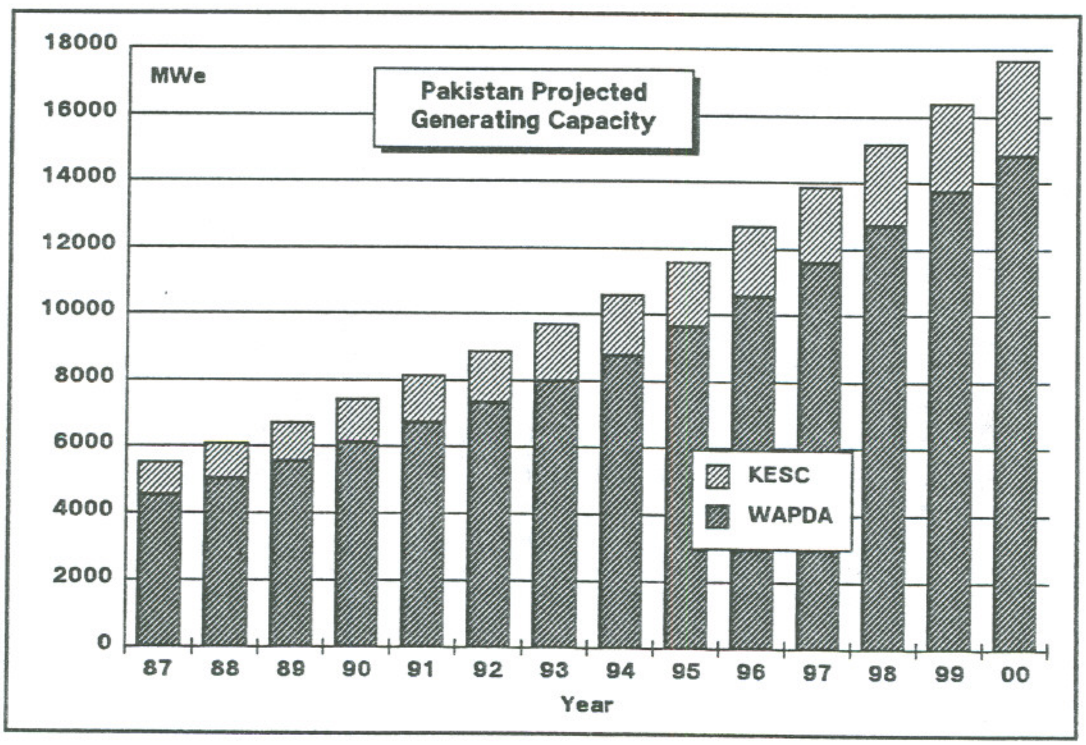


Figure 3-6

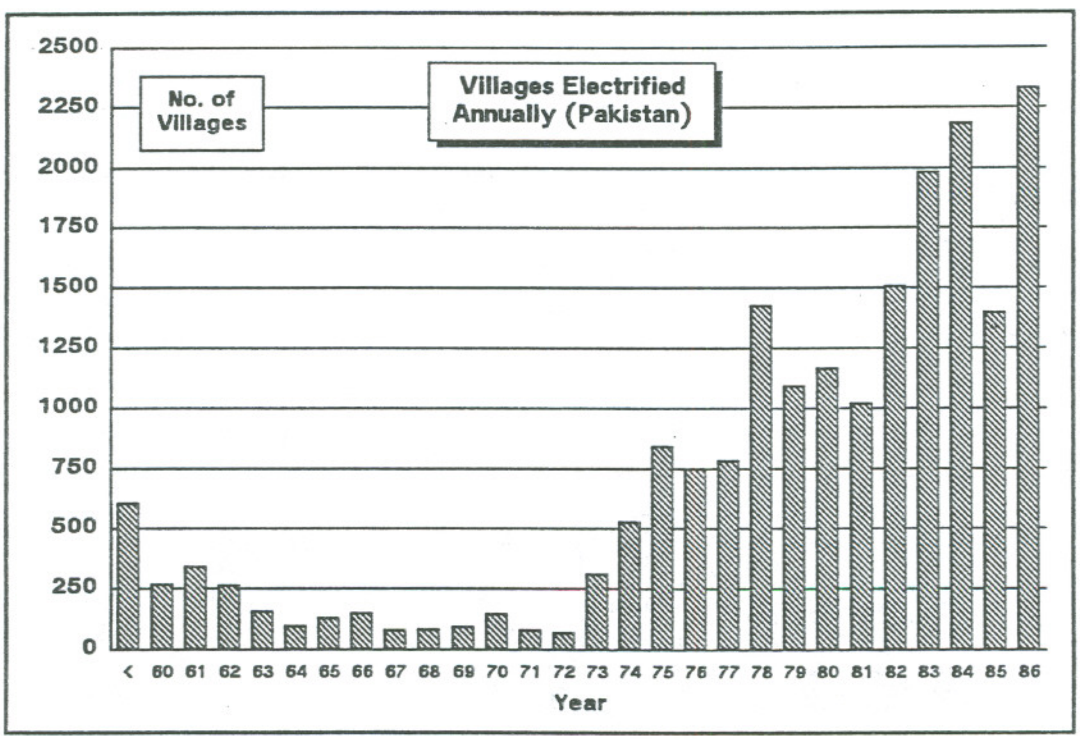


Rural Electrification

The Prime Minister's 1986 directive ordering electrification of 90% of the villages by July 1990 has been incorporated in the 7th Plan. According to the 1981 census there are 47,074 villages in Pakistan. By June 1988 about 32,100 will be electrified under current plays, with an additional 14,902 to be electrified* during the 7th Plan period.

Rural electrification resulted in a total of 15,487 villages being electrified against a target of 20,000. (Electrification of a village can mean provision of electricity to just a few individuals, or just for street lighting and other community purposes, without availability for individual household use. According to one recent report, only 25% of the rural population of the electrified villages are using electricity). As Figure 3-7 demonstrates, between 1,000 and 2,000 villages have been electrified each year since the early 1970s. Figure 3-8 shows the cumulative growth in electrified villages, with the total number of villages officially set at 45,000. (The total number of small settlements that are without electricity is considerably greater than this.) The major focus on rural electrification reflects Pakistan's long-term commitment to transforming the conditions of rural life in the country. It also provides major opportunities for mobilizing renewable energy resources.

Figure 3-7



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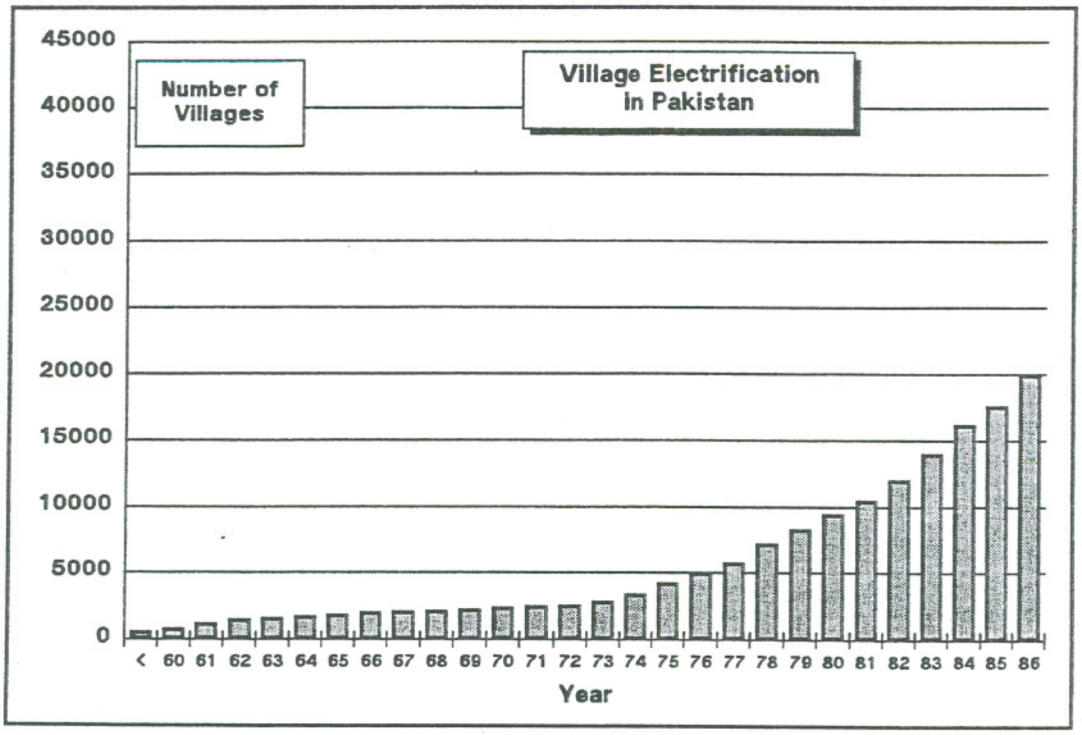
* According to informed authorities in Pakistan, there is little chance that these rural electrification goals can be fully achieved given the present pace of implementation of rural electrification.

Figure 3-8



Diesel Power Systems in Pakistan

Diesel power is used in Baluchistan, but diesel units have many problems. The units used are high-speed diesel engines; they require maintenance facilities and only last a few years. Pakistan's experience with diesel power has not been very satisfactory. In Baluchistan, with units in the range of 100 - 200 kWe (and a few at the level of 500 kWe) the unsubsidized kilowatt-hour price of electricity is greater than Rs 2. There are also some gas turbines producing electricity at Rs 2.35/kWh. Small diesel units, in the range of 10 - 500 kWe, are produced in Pakistan. Medium-size diesel generators, in the range of 300 kWe to several MWe are generally Japanese, with some German (Siemans) and Chinese units as well. These larger units cost Rs 14,000/kWe ($800/kWe) and the total cost of electricity production is in the range of Rs 2 - 3, including capitalization of the equipment.

3.5 Energy Policies and Practices

Pakistan's energy plans and policies are embedded within the framework of national planning, which centers on the Five-Year Plans. The Sixth Plan period, from 1982/83 to 1987/88, is almost ended, and the Seventh Five-Year Plan is being drafted.

Seventh Plan Objectives and Targets

The opportunities for U.S. energy industries in Pakistan will reflect to a significant degree the plans and objectives of the new Seventh Five-Year Plan. The principal energy-related objectives of this plan are:

1. To substantially increase electricity supply, eliminate loadshedding, and electrify most rural areas.

2. To accelerate the exploration and development of domestic energy resources, notably coal, oil, gas, hydro, and renewable energy resources.

3. To make conservation and efficient use of energy a common practice in all sectors of the economy.

4. To reduce power system losses.

5. To establish an efficient load management system, to reduce peak demand, and to decrease the need for loadshedding.

6. To draw on the resources and expertise of the private sector, to a far greater degree than in the past, for energy development and production.

7. To rationalize oil, gas, and electricity prices to generate funds for new energy investment; to establish incentives for energy conservation and fuel subsidies.

8. To increase the capacity of government organizations to self-finance their investment programs and reduce the burden on government resources.

9. To develop Pakistan's energy sector manpower, and to improve the effectiveness of its institutions for energy planning, development, and service.

In the power sector the targets include:

1. Elimination of load shedding by 1990

2. Electrification of 90% of the villages (1981 census basis) by 1990, with the remaining 10% to be electrified by 1992/93.

3. Addition of 6,868 MWe of new generation capacity (2,188 MWe hydro and 4,680 MWe thermal plants)

4. Private sector installation of 970 MWe of power generation capacity.

The private sector's involvement in power generation is expected to expand substantially, with an estimated 600 - 1,500 MWe of privately developed, financed, and operated generation capacity added during the 7th Plan period. This is to be accomplished by establishing a new set of incentives for the private sector (Table 3-2). For the nominal installation of 970 MWe of private power generation, it is projected that 20 MWe will be hydro, 850 MWe steam and diesel, and 100 MWe as gas turbines.

Table 3-2

PROPOSED INCENTIVES FOR PRIVATE SECTOR POWER GENERATION IN PAKISTAN

- o Designation of specific areas for private power sector projects
- o Definition of power purchase conditions by WAPDA
- o Assignment of a major portion of the Lakrha coal fields for private power generation
- o Designation of selected dormant gas fields for private sector power development

Rural Uplift Program

In October 1987 the Minister of Planning announced that Rs 23 billion ($1.4 billion), spread over three years, would be spent on the rural uplift program. The components of the program are summarized in Table 3-3. According to the plan, electricity will be provided to 4,208 villages. Clean water will be provided to an additional 8 million people. Thirty-five new rural health centers will be established. However the means to accomplish this are unspecified.

Conversations with Pakistani planners charged with developing the implementation plan for the rural uplift program indicate that they would be very interested in advice from U.S. renewable energy industry and government experts regarding the post effective ways to use renewable energy technologies to help achieve these goals.

This program, if it can be implemented, should provide significant opportunities for renewable energy technologies. However, the development and effective implementation of this effort will require cooperation with and support from the U.S. and other donor nations. In this area, the U.S. renewable energy industry and the relevant U.S. Government agencies (e.g. USAID, Department of Commerce, Department of Energy) can work together with the Government of Pakistan to develop effective renewable energy-based packaged systems that can couple renewable energy sources of electricity to end-use needs for remote settlements. These needs include reliable access to clean water, illumination systems for street lighting, community centers, dispensaries, and homes, irrigation pumping, and communication.

Table 3-3

PAKISTAN'S RURAL UPLIFT PROGRAM

ACTIVITY	Billion Rs	Million $
Rural education	5.54	317.6
Rural health	1.41	80.6
Rural water supply and sanitation	1.25	71.4
Rural roads	1.98	113.1
Improvement of slum areas	0.73	41.7
Small housing	0.50	28.6
Village electrification	5.27	301.1
Anti-water logging and salinity	2.52	144.0
Generation of additional employment	2.00	114.3
Local development programs	1.62	92.6
TOTAL	**22.82**	**1,305.0**

Renewable Energy

The physical targets for renewable energy are shown in Table 3-4. The total budget (Table 3-5) for renewable energy during the 7th Plan period is Rs 610 billion (ca. $36 million), of which slightly less than half will be in foreign exchange, provided primarily by the United States. This corresponds to 0.5% of the total 7th Plan energy sector investments of Rs. 133 billion ($ 7.6 billion). The energy impact of all the 7th Plan renewable energy projects is estimated at approximately 1 million TOE.

During the 7th Plan the emphasis will be on promotion of commercialization of renewable energy technologies, with 65% of the renewables budget going for this. The remainder will be spent on demonstrations, feasibility studies, data collection, training, and institutional strengthening. Most of the resources will be managed by the Directorate General for New and Renewable Energy Resources (DGNRER), an organization without the technical or managerial resources to pursue this effort.

The institutional support for renewable energy has been meager, most of it through the Pakistan Council of Scientific and Industrial Research (PCSIR). PCSIR organized a solar energy division in Lahore in 1978. An international solar energy workshop was held in Lahore about 1979/80. An extensive plan was developed conceiving of a $50 million renewable energy institute. This amount was reduced to $25 million, and the institute was almost funded. Late in the process the Finance Minister decided that the funds were better spent on more immediate needs.

Table 3-4

RENEWABLE ENERGY TARGETS FOR PAKISTAN DURING THE 7TH FIVE-YEAR PLAN PERIOD (1988 - 1993)

TECHNOLOGY	TARGETS
Fuelwood augmentation	30 - 50,000 hectares
Mini and micro-hydro plants	Total of 10 MWe
Improved cooking stoves	1 million units
Photovoltaic installations	
Dispensaries	125 units
Households	1,000 units
Water pumping*	20 units
Demonstration solar water heaters	500 units
Other solar thermal installations	
Water purification & desalination	Not specified
Crop drying	Not specified
Biogas installations	4,500 units

Source: Government of Pakistan (August 10, 1987). **Energy Chapter of the Seventh Five-Year Plan (DRAFT).**

* This is listed elsewhere in the draft Plan as 20,000 units; 20 (twenty) seems to be the correct figure.

3.6 Renewable Energy Activities and Market Opportunities

Introduction

Renewable energy research and development has been pursued at a very modest level in Pakistan over the past twenty years. In spite of the potential for rural applications in regions where the grid is unlikely to extend for a decade or more, the development of an indigenous capability for production of renewable energy equipment has been essentially ignored. The effort supported by the Government of Pakistan, until recently, has essentially been at the level of "tinkering" with simple devices such as solar cookers, water heaters, and primitive wind turbines. Only in one renewable energy area -- that of photovoltaics -- has there been an attempt to develop relatively modern facilities for the production of silicon solar cells and photovoltaic arrays. In addition, a substantial one time investment was made in the development of a large-scale solar distillation unit for community fresh water supply in Baluchistan.

Table 3-5

PRELIMINARY BUDGET ESTIMATE FOR
PAKISTAN'S 7TH PLAN RENEWABLE ENERGY PROGRAM

(Millions of Rs - Nominal)

PROJECT ACTIVITY	Foreign Exchange	Local Currency	Total Costs	Percent
Data Collection, Evaluation & Dissemination of Information	7.14	6.00	13.14	2.2
Research & Development	7.65	5.17	12.82	2.1
Feasibility Studies	1.53	3.66	5.19	0.9
Demonstration Projects	56.70	45.98	102.68	16.8
Commercial Projects	148.75	251.70	400.45	65.3
Technical Assistance	39.22	7.57	46.79	7.6
Training	16.83	10.00	26.83	4.4
Strengthen Institutions	5.10	0.00	5.10	0.8
TOTAL (Rs.)	**282.92**	**330.08**	**613.00**	**100.1**
TOTAL (US $)	**16.17**	**18.86**	**35.03**	

Rs 17.5 = $1.00 (in 1987)

Source: Government of Pakistan (August 10, 1987). **Energy Chapter of the Seventh Five-Year Plan (DRAFT).**

There is virtually no renewable energy industry of any kind in Pakistan, although there are a few foreign companies in Pakistan with subsidiaries that produce solar equipment (solar thermal panels, photovoltaic arrays). High import duties and restrictions affect the ability of consumers, manufacturers, and others to purchase renewable energy and related equipment. Current GOP policies do not take into account the benefits that would accrue from development of a domestic renewable energy industry. Policy instruments such as preferential interest rates, longer repayment periods, and relaxed collateral requirements are not available to local industry or end users.

A few companies have attempted to market renewable energy products and services in Pakistan, but with very limited success. BP Solar, a subsidiary of British Petroleum, has mounted an aggressive marketing and sales program in Pakistan, selling photovoltaic units for rural electrification and battery charging. BP is working closely with the

Government of Pakistan to develop inroads into the rural electrification and rural uplift programs. With the exception of a few ARCO Solar panels purchased by the Government of Pakistan for test purposes, BP Solar presently has the PV market to itself. Other areas in which there are cottage industries are microhydro power plant components and improved cook stoves.

In October 1986 one of the authors (JMW) conducted an extended mission[25] in Pakistan for the United Nations, to assess the requirements for a renewable energy institute being proposed by the Government of Pakistan. In consultation with a number of local officials and energy experts, a list of priority areas for rural and commercial applications of renewable energy technologies was drawn up. Priority areas for application of renewable energy technologies are shown in Table 3-6 for decentralized use and in Table 3-7 for commercial applications. In none of these areas are there well-established markets, and those that do exist are essentially government markets.

Only with micro-hydro development and family biogas systems has there been real success in diffusion of the technology, and this has been due to the capabilities and energies of a very small number of skilled individuals working with local communities and artisans rather than to a major government-supported R&D and commercialization effort.

Solar Desalination

Pakistan has extensive regions where the local population has no reliable access to clean water. Consequently there has been a strong interest in solar desalination for several decades. Pakistan has one of the largest solar distillation units in the world. It was designed and installed at Gwadar, Pakistan with United Nations support, under the direction of the Pakistan Atomic Energy Agency in collaboration with Greek experts. The system was designed to produce 6,000 gallons per day of fresh water. Although it was to be maintained by the Pakistan Coast Guard, the unit has fallen into disrepair, and is now being refurbished and recommissioned by the PCSIR Solar Energy Centre in Hyderabad. Simple family-sized solar distillation units have been developed by the PCSIR Solar Energy Centre in Hyderabad and will soon be test marketed.

There are many situations in which much larger units are needed to serve whole communities. More advanced systems could also be introduced in Pakistan, similar perhaps to the sophisticated system in operation[26] in Abu Dhabi. Completed in October 1984 the plant provides an annual average production of 80,000 liters per day on a site 100m by 105m. The plant was built as a joint project of the Ministry of International Trade and Industry (MITI) in Japan and the Ministry of Petroleum and Mineral Resources in the United Arab Emirates. The system incorporates evacuated glass tube solar collectors to maximize solar energy collection. Unlike the simpler distillation units built in Pakistan the plant also requires electricity - about 20 kWe (7 Wh/liter).

The opportunity for U.S. industry reflects the need for reliable access to clean water, not the explicit need for solar desalination units. Integrated PV or wind-electric and wind-mechanical powered systems for pumping, filtration, purification, storage, and delivery of clean water, at the community level from small villages to large towns, are a potentially significant commercial option.

Table 3-6

PRIORITY RURAL DECENTRALIZED APPLICATIONS OF NEW AND RENEWABLE ENERGY TECHNOLOGIES IN PAKISTAN

Micro-Hydro

- Conventional Microhydro (5 kWe - 50 kWe)
- Low-head (run of stream) hydro
- Underground rivers of Baluchistan

Solar desalination

Wind energy (where the resource is sufficient)

- shaft energy for irrigation, machine tools, etc.
- power generation

Integrated Photovoltaic Systems for

- Potable water (pumping and purification)
- Lighting (street lighting, health centers, residential)
- Communications (e.g. village television, radio telephone)
- Shaft energy (grinding and milling, small machine tools)
- Battery charging
- Refrigeration of medicines and vaccines (compression refrigeration and solid state Peltier cooling, phase-change salts for thermal control)

Solar Thermal Systems

- Dehydration of fruit and other crops
- Sterilizing grains (killing insect larvae)
- Cooking
- Water heating (rural health centers)

Biomass

- Densification and briquetting for cooking fuels
- Improved cookstoves (higher efficiency, less smoke)
- Methane generation from agricultural and animal wastes
- Gasification and combustion of agricultural wastes (e.g. rice hulls)
- Energy cane (transformation of the sugar industry)

Table 3-7

PRIORITY COMMERCIAL APPLICATIONS OF NEW AND RENEWABLE ENERGY TECHNOLOGIES IN PAKISTAN

Climate-appropriate building design, including passive solar architecture (residential, institutional, etc.)

Solar thermal systems

- Water heating (hotels, hospitals, residences)
- Space heating (room air heaters)
- Desiccant cooling
- Absorption refrigeration
- Industrial process heat and preheating

Solar thermal electric (grid-connected power generation)

Photovoltaics

- Communications (e.g. microwave repeaters)
- Cathodic protection
- Other small-scale, high-value markets
- Grid-connected bulk power (if price goals can be achieved)

Wind energy conversion

- Wind electric (grid-connected)
- Wind pumpers for irrigation and draining water-logged areas (e.g. in lower Sind where major investments in drainage are underway)

Microhydro Power Plants

The installation of small hydropower plants in Pakistan is organized by the Appropriate Technology Development Organization (ATDO). ATDO is concentrating on high-head medium discharge sites and low-head high discharge sites. To date ATDO has installed 63 plants in northern Pakistan. These installations range from 3 to 20 kWe. Twenty five new sites have been identified, and work is on progress on twelve of these.

ATDO also provides technical guidelines with regard to assessing the potential for the sites selected, meets 25 - 50% of the initial costs, and trains the operators. Maintenance is the responsibility of the village cooperatives that operate the plants. They collect (monthly) Rs. 1 - 2 per bulb (40 - 60 watts). The installed cost of the plants is in the range of Rs 4,000 - Rs 5,000/kWe ($230 - $275/kWe). The extremely low cost reflects the virtually total local content in labor, materials, and equipment. Additional work is being conducted by the National Institute of Power on low-head high discharge plants. The extensive irrigation canals in Pakistan are characterized by a combination of very low heads and high discharge rates. One 30 kWe plant has been installed on a canal and four more plants of 50 kWe capacity are planned. These plants are expected to have a cost of Rs. 7,000 - Rs. 8,000/kWe ($400 - $460/kWe).

The implementation of small scale hydropower units in the North-West Frontier Province (N-W F.P.) of Pakistan is rare success story[27] that demonstrates an effective systematic approach to introduction and diffusion of small scale energy technologies in a rural environment in a developing country. Prof. Abdullah of the N-W F. P. Technical University, working with a group of 4-5 others, has been responsible for the installation of 62 micro- hydro plants in the region. All of the plants are in operation, although at any given time roughly 10 percent of them are down for repairs (e.g. flood damage). Because the plants are small and the unit costs are low, the overall financial risks are very low.

The microhydro systems are in the range of 5 - 50 kWe, with the average plant size in the range of 10 - 15 kWe. These plants have cost about Rs 7,000 - 10,000 per kWe, or roughly $400 - $600 per kWe. By contrast some microhydro plants built by the Government of Pakistan in the 1970s cost Rs 50,000 - 100,000 per kWe, an order of magnitude higher!

The approach taken by Dr. Abdullah and his team has been extremely successful. The members of his team are provided on a full-time basis by the Alternative Technology Development Organization (ATDO). They involve the local villagers in all aspects of the project, from site selection to operation and maintenance. Although villagers do not understand the technical details of measurement of stream flow, they do know from experience where the better sites are, and have never been wrong in their reports of the maximum flood height of the streams involved.

Because the plants are built by donated local labor, using local materials, the capital costs for the civil works are minimal. The turbine, controller, and other equipment installed by the team are given to the villagers at no charge. Local skills for operation and maintenance and repair of the plants are developed and upgraded over time. The work is carried out by the local people under the supervision of Dr. Abdullah and the ATDO team.

The turbines are fabricated in a small workshop in Peshawar. This operation and the overall design and construction of the equipment other than the civil works is centralized. They do not want to experiment in the field. The generator and parts are all purchased in local markets. The cost of (imported) mechanical governors to control the speed of the turbine is very high. Prof. Abdullah has developed an electronic load controller that puts a constant load on the turbine. Excess power is dumped into a resistive load!

Electronic controllers were developed using locally available components, replacing expensive and less reliable mechanical controllers imported from the U.K. The total cost for a 10 kWe controller is about Rs 10,000 or less ($60/kWe or about 10% of the unit installed cost). The ATDO/N-W F.P. University group is also working on a zero--head hydro unit, using run of river where the flow is about 1 - 2 m/s with very significant volumes of water flowing.

An essential aspect of this work is that an integrated technology package, not just the power plant, is provided to the local villagers. This means that integrated end-use items must be developed, both electrical and mechanical, the latter directly coupled to the shaft horsepower developed by the plant. This approach is directly relevant to the establishment of photovoltaic-based rural micro-grids in rural settlements, and an innovative program to establish such systems in Pakistan could be developed in concert with Prof. Abdullah's group.

Conversion of Human, Animal, and Agricultural Wastes to Methane

There is extensive and decidedly mixed experience[28] with the use of methane digestors to convert human, animal, and agricultural wastes to methane. The Government of Pakistan has invested in thousands of biogas plants. Most of these plants are no longer working. On the other hand, privately built plants (over 450 in Sind alone) are nearly all operating. In the latter case there is a technician who provides ongoing technical assistance to these plants.

The further development of effective plants to make use of animal wastes, both in rural areas and at centralized livestock facilities appears worthwhile, both in terms of public health and environmental considerations, and economically as well. Strong interest has been expressed by the USAID office in Islamabad supporting a program to develop and commercialize such technology for use at these centralized feedlots, poultry farms, and other similar installations.

Commercial opportunities for U.S. industry are in modern systems to convert animal wastes at centralized livestock facilities rather than in small scale biogas plants. Industries interested in pursuing this areas should contact USAID/Islamabad directly to determine the extent to which AID will support commercial initiatives.

Photovoltaics

It appears that PV power systems, if centrally financed, can make economic sense now in programs such as Pakistan's village uplift efforts. The challenge will be to develop the procedures and infrastructure that will result in socially acceptable introduction and diffusion of the technology and in reliable and effective installations that can be operated and maintained by local communities with the assistance of a rural energy extension service. This development will require joint efforts between the Government of Pakistan and commercial industry from abroad.

The United Nations has sponsored the establishment of four photovoltaic installations in villages in Pakistan. The project, although well-funded, suffered from lack of continuous in-country commercial and technical expertise, and only one of the four villages has a fully operating system. However, Pakistan's mixed experience with previous PV-powered village installations should not discourage the development of such a program. The work of Professor Abdullah and Professor Shaw in successful implementation of some 60 microhydro plants in the N-W F.P. provides an example of a carefully orchestrated, socially sensitive, and technologically appropriate approach to providing electricity and motive power to a rural community in Pakistan. A few examples are discussed below.

Photovoltaic-powered water pumps are ideally suited for pumping water for human consumption in rural Pakistan. In areas without access to the electric grid, PV-powered pumps in the range of 300 - 700 watts are actually competitive with diesel powered pumps. The Agricultural Development Bank of Pakistan (ADBP) has purchased 15 photovoltaic pumpsets and provided them to farmers in order to evaluate their performance. Minimum requirements were a pumping rate of 4 - 5 liters/second with a 25' lift. The preferred system that emerged from the tests was an ARCO Solar PV panel (60 volts DC, 9.9 amps or ca. 600 watts) combined with a Jacuzzi submersible pump. The performance was 6 liters/second from a 35' water depth. Based on this selection and a year of successful operation on a farm ADBP has imported ten additional ARCO/-Jacuzzi systems for test and later sale.

At present the PV panels selected by the ADBP cost $7/watt, and the entire system costs Rs 100,000. Even with the present Rs 40,000 subsidy from the government the price is too high for farmers. It will require centralized financing, analogous to the financing of central station power and the transmission and distribution system to open the market and bring down the costs of photovoltaic pumping systems in Pakistan.

Such pumping systems can be incorporated in village water systems to provide reliable sources of clean water. Use of filtration, chemical treatment, and sanitary sealed storage tanks, coupled with the PCSIR-developed passive system for sterilizing water in transport jugs could help Pakistan meet its recently announced goal of bringing clean water to an additional 8 million people over the next 3 years.

It will also require in-country manufacture of photovoltaic arrays, pumps, and other system components, to reduce the total cost as well as the foreign exchange component. The prospects for this are uncertain; if a proposed joint venture between Chronar Corporation (USA) and SUN Ltd. (Lahore) can be implemented, this would result in 1 MWe/year (equivalent to 1,500 PV-pumpsets per year) of photovoltaic panel production capacity in Pakistan.

A major PV pumping system evaluation[29] was performed from 1980 to 1983 by Sir William Halcrow and Partners together with Intermediate Technology Limited. The study, which was funded by the United Nations Development Programme (UNDP), resulted in the 1984 *Handbook on Water Pumping*. The study concluded that photovoltaic pumping systems were on the verge of being competitive with diesel pumping systems for water requirements of a few liters/second or less. The key issue is the extent to which the capital cost of the solar pumping system can be financed so that the users pay a monthly charge (similar to ongoing payments for fuel and O&M for diesel pumpsets).

A recent detailed review[30] and analysis by the Meridian Corporation of PV-powered systems for rural application concluded that, in the case of development agency financing, PV-powered water pumping systems are the least-cost option at demands of up to 40 m^3/day (1.4 liters/second for a pumping period of 8 hours/day) at a head of 25 meters, even under unfavorable financial assumptions. When the financial conditions are more favorable, PV-powered systems are competitive up to 320 m^3/day (11 liters-/second, 8 h/day)

PV-powered water pumping appears to have a significant potential in Pakistan provided the appropriate means for financing the initial stages of commercial application can be put in place and PV production facilities can be established in Pakistan. As discussed earlier, the rural development program of the Government of Pakistan may provide the best environment for sales and service of U.S. supplied equipment.

Photovoltaic Refrigeration

The World Health Organization (WHO) and UNICEF are spearheading a program to immunize children and women of child-bearing age throughout the developing world. WHO studies have also shown that as much 80 percent of vaccines in Africa are impotent (spoiled) by the time they are applied. This is generally due to the breakdown in the refrigeration chain from production to end use.

Photovoltaic refrigeration units appear to be especially suited to high value applications for storage of medicines and vaccines. U.S. studies indicate that the overall cost of delivering a dose of potent vaccine is less for a PV systems than for a kerosene--powered refrigerator, not including the reliability problems associated with possible occasional unavailability of kerosene. Many countries are now using such refrigerators on a trial basis. These should be considered routine equipment for all rural health centers, including those on the grid, since interruptions of power for extended periods can also lead to spoilage of vaccines and medicines. The 35 new rural health centers mentioned in the new Five-Point Socio-Economic Program (rural uplift program) would be obvious candidates for such systems.

Solar Thermal Electric Power Generation

Solar thermal power plants have been fully commercialized in the U.S. by Luz International Limited, a California corporation that will have installed over 500 MWe of grid--connected facilities by the early 1990s in California. These plants are built as 30 MWe modules, and produce most of their output during the local utility's peak demand period (noon to 6 PM during the summer). Costs have declined steadily to about $2,500 per kWe, with projected costs declining to about $2,000 per kWe. Similar manufacturing facilities and solar thermal power plants could in principle be built in Pakistan under joint venture and/or licensing agreements if the economics appeared attractive.

Recently Texas Tech University offered to provide the Crosbyton solar thermal electric bowl system to the PCSIR Solar Energy Centre of Pakistan, if funds could be made available to disassemble, transport, re-erect, and commission the system. While this technology does not represent the most promising of the long-term commercial solar thermal electric options, the Crosbyton Bowl system provides an excellent facility for training graduate students and engineers in the engineering principals of solar thermal electric conversion. However, USAID has recommended against funding this transfer and the issue is now being discussed in Congress.

Passive Solar Design of Buildings

The design of buildings that mitigate the effects of intense sunlight and wide temperature extremes is an ancient art, well-established in the Middle East and the Subcontinent in ancient times. Only recently has the art of design with climate[31] been re-established, and this time with the aid of scientific analysis and modern building materials. Sometimes referred to as "passive solar design", climatically appropriate building design is badly needed throughout the world.

In Pakistan and other developing countries, where the need to maximize the economic use of electricity is especially urgent, the design of buildings that minimize the requirements for air conditioning and heating can play a significant role in freeing up capital and power generation capacity for more productive uses. For buildings where the owners cannot afford such luxuries as air conditioning, the use of external insulation, night-sky radiative cooling, and other techniques can mitigate the effects of high temperatures, especially in dry climates.

Solar Cooling

Technology has been developed in the U.S. to combine solar heat collection with desiccants to dehumidify air. Solar dehumidification could significantly increase comfort in those areas, especially Karachi, that are hot and humid much of the year. In buildings with central air conditioning, the dehumidification of the air prior to its cooling would considerably reduce the amount of refrigeration required to achieve the same comfort level in the building. This technology would be especially appropriate in combination with the use of energy-efficient climatically-sensitive building design.

3.7 Institutional Responsibilities for New and Renewable Energy

U.S. industry will have to establish close ongoing ties with government agencies in Pakistan in order to develop the necessary markets and business arrangements. An overview of the most important agencies is provided below.

Ministry of Petroleum and Natural Resources, Directorate General of New and Renewable Energy Resources (DGNRER)

The official responsibility for research, development, and promotion of new and renewable energy in Pakistan rests with the Directorate General for New and Renewable Energy (DGNRER) within the Ministry of Petroleum and Natural Resources. DGNRER has virtually no professional staff and no laboratory or test facilities, and there appears little likelihood that these will be established in the near future. The present focus of the DGNRER is on rural energy applications.

According to meetings held in October 1986 with the acting Director of DGNRER, seven photovoltaic systems ranging in size from 7 kWe to 58 kWe have been installed to provide electricity for drinking water, residential lighting, and lighting for Mosques. There are demonstration units only. The Director of DGNRER believes that there is a real need for a cost breakthrough in order for PV technologies to be relevant to rural energy development needs.

Future renewable energy technology development and implementation activities conducted by the Pakistan Council of Scientific and Industrial Research (PCSIR), ATDO, and other government bodies will be done under the direction of DGNRER.

Pakistan Council of Scientific and Industrial Research (PCSIR)

The Pakistan Council of Scientific and Industrial Research is a semi-autonomous body established in 1953 to coordinate and support scientific and engineering research and development in the country. The important government-based capabilities in renewable energy rest with PCSIR. PCSIR operates a network of national laboratories, and for the last decade or so has supported a modest program of renewable energy technology research and development. Most of this work has focused on solar desalination, solar cooking, water heating, and biogas production.

Until last year this work was scattered among several different PCSIR facilities throughout the country. Most of the work and much of the staff has been brought together in a new Renewable Energy Resources Centre in the city of Hyderabad, about 100 miles from Karachi. The staff of approximately 40 professionals is currently based in modest temporary quarters. A permanent modern laboratory and office facility is being designed and will be built on the outskirts of Hyderabad over the coming several years.

Appropriate Technology Development Organization (ATDO)

The Appropriate Technology Development Organization, headquartered in Islamabad, is a small organization that provides energy extension services to rural communities and small businesses. The ATDO has been in existence for 14 years. ATDO has been responsible for the installation of about 60 microhydro installations with an average capacity of 10 kWe, ranging in size from 3 - 50 kWe. Some 36 additional microhydro facilities are scheduled to be installed in the near future. These have been the most successful of the ATDO projects.

The ATDO is also working with very small wind turbines, ranging from 0.5 - 5 kWe for water pumping (for human consumptive uses and irrigation). They are interested in the design and manufacture of small wind machines. The designs, which are being executed in Pakistan, are based on those of the Intermediate Technology Development Group in London.

National Institute for Semiconductor Technology (NIST)

The National Institute for Semiconductor Technology has been recently established to act as the country's leading center for silicon technology. A new facility has been completed recently in Islamabad, and contains good facilities for growth of single crystal silicon and preparation and characterization of silicon solar cells and solar arrays.

Solarex, Inc. helped in the design and establishment of NIST. Solarex trained five people (each for 6 months at Solarex) and helped design the laboratory and prepare specifications. After Solarex's founder Dr. Joseph Lindmayer left Solarex, the new management decided to terminate the relationship with NIST. The United Nations

Development Programme also supported the establishment of NIST with a grant of $1.27 million. These funds were used to support a professional training program. Currently NIST scientists are being trained in Europe, Japan, the United States, and Korea.

The silicon single crystal growing capability at NIST is representative of solar cell fabrication in the U.S. 25 years ago. However the facility is providing valuable training to local scientists, engineers, and technicians. Present pilot line module production capacity is about 20 kWp per year.

Agricultural Development Bank of Pakistan (ADBP)

The Agricultural Development Bank set up PV systems for irrigation approximately 3 years ago. These were not accepted by the farmers. In a subsequent meeting with the ADBP it became clear that even with a subsidy of Rs 40,000 for a small (500 watt) PV-powered pumpset that cost Rs 115,000 there was no way a farmer could afford it. The ADBP was not looking at creative financing or the larger national economic implications of the widespread diffusion of this technology. Under the present ADBP program there is no possibility of these systems being widely used.

The Agricultural Development Bank (ADB) of Pakistan was provided $500,000 for installation of 100 PV shallow well pumps (for drinking water). They charge the farmers about 15% of the capital cost of the PV system (equal to the full costs of a diesel pump of equivalent capacity. The ADBP obtained about 15 PV pumpsets and provided them to farmers in order to evaluate their performance. The requirements were 4 - 5 l/sec for a 25' head. In the near future ten systems for water lifting will be installed, together with ten systems (5-500 W(p) and 5-1,000 W(p) units) for electrification. The latter use inverters and provide 220 VAC , and hence will use the inefficient lighting and appliances available on the local market.

ADBP decided that the best combination of components was ARCO Solar panels and Jacuzzi submersible pumps. The systems are rated at 640 W(p), 60 VDC, 9.9 amps (16 modules, 36 cells/module). The panels cost about $7/watt. The ADBP has imported ten additional units (ARCO/Jacuzzi) for test and for sale.

Presently there is a Rs 40,000 subsidy available for each PV pumpset, but the actual implementation mechanism and procedures for this subsidy are still not settled. The easiest way would be for the GOP to simply credit the ADBP with this subsidy and the ADBP would sell the units at a reduced price. There is currently no import duty on PV arrays.

Many farmers are requesting the PV units but the present (and likely future) prices are too high. No farmers are willing to purchase the units at the present price. The ADBP will provide loans for such equipment, at the present commercial rate of 12% with an 8-year loan term. Clearly a creative financing approach is needed by the ADBP in order to have a centralized investment and financing of the PV units.

These units may be especially interesting in parts of Baluchistan (lower Baluchistan coastal area - Makra District) where people have money but no central electrification from the grid.

Electric Utilities

Pakistan has two electric utility companies - the national Water and Power Development Authority (WAPDA) and the Karachi Electric Supply Company (KESC). The view of senior officials within WAPDA is that WAPDA can have no real interest in renewables until they are capable of providing competitive power in Pakistan in the 10 - 100 MWe range in grid-connected WAPDA officials have stated that the grid will soon serve all but a few percent of the population of Pakistan; hence there is little need for a major emphasis on renewable remote power generation options.

3.8 Present Renewable Energy Technology Markets

The government has been the only significant market for modern renewable energy technologies, and virtually all of the foreign exchange has come from international assistance, primarily USAID. In FY 85 $2.87 million was allocated by USAID for hardware to equip PCSIR laboratories and the National Institute for Semiconductor Technology (NIST). More recently another $1.5 million was allocated by USAID for purchase of laboratory, test, and demonstration equipment for the PCSIR Solar Energy Research Centre at Hyderabad. Only a portion of these funds were for renewable energy equipment per se.

USAID Energy Commodities and Equipment Program

In August 1984 a three-year program was signed between the Government of Pakistan and the U.S. Government for the import of energy-related equipment and commodity. $100 million was obligated (50% loan, 50% grant) during the period FY 1984-86. The main purpose of this program was to support the Government of Pakistan's 6th 5-Year Plan in energy production from indigenous resources and adopt energy conservation measures. The program was aimed at providing fast-disbursing foreign exchange resources for the importation of energy commodities and equipment.

Under this program a "private sector window" was established to provide foreign exchange loans to Pakistan's private sector. According to USAID, the effective demand for U.S. equipment will reflect three factors: technological advantages of U.S. equipment, quality advantages of this equipment, and price competitiveness. The Government of Pakistan set up the mechanism to disburse these funds late in 1985. However the $50 million program has had negligible disbursements.

The problems include the higher prices of U.S. products relative to those of other countries, the financial terms of the private sector loan window, and the Government of Pakistan's import policies. The interest rate for the financing was set by the State Bank of Pakistan at 11 percent, plus 3 percent for foreign exchange risk coverage. The total rate of 14% provides no incentive for importers with supplier credits or other concessional financing elsewhere. Recently the GOP reduced the total interest rate (including the exchange risk coverage) to 10% and eliminated all transaction limits. The GOP import approval and eligibility under the import policy order have also been a constraint on the program.

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