

# A Study of Biomass as a Source of Energy in Pakistan

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## ABSTRACT

*Biomass is a major source of energy in Pakistan. However, as in the case of most developing countries, reliable estimates of biomass energy use in different sectors of the country are not available. This paper presents the status of biomass energy use in Pakistan. About 65.07 billion kg consumption has been estimated, which is equal to 22.57 MTOE and accounts for 44% of the total primary energy needs of the country. The share of firewood in the traditional energy is about 56%. The household sector is the major end user and consumes 86% of the total biomass energy. The traditional cookstoves are the major end users of biomass energy, and consume about 80% of the total quantity.*

## 1. INTRODUCTION

Primary conventional energy consumption of Pakistan totaled 28.46 MTOE in 1990-1991 and 34.75 MTOE in 1993-1994 [1]. The shares of oil, gas, LPG, coal, hydro, and nuclear were 14.49 MTOE (41.70%), 13.13 MTOE (37.58%), 0.073 MTOE (0.21%), 2.30 MTOE (6.62%), 4.64 MTOE (13.35%) and 0.12 MTOE (0.34%), respectively in the year 1993-1994. It is estimated that nearly 50% of the total export earnings of Pakistan is spent on the import of oil and the associated products.

Beside commercial energy, substantial amounts of biomass energy is consumed in certain sectors. The main sources of biomass for energy are fuelwood, charcoal, dung, and crop residues [2]. Reliable estimates of such consumption are normally not available. Considering the importance of assessing biomass energy use for energy planning purposes [3], a regional study was carried out on a number of Asian countries within the framework of a project funded by the Swedish International Development Cooperation Agency (Sida). This paper presents a review of sectoral consumption of different types of biomass for energy in Pakistan.

## 2. BIOMASS CONSUMPTION IN PAKISTAN

Being an agricultural country, the majority of Pakistan's population still rely on biofuels, which include fuelwood, charcoal, dung, crop residues, etc. These fuels account for a greater share of total energy consumption in rural areas compared with urban areas.

## 2.1 Fuelwood

There are two main sources of fuelwood supplies in the country: state controlled forests and farmlands. State forests, which cover only 4.8% of the total area, produce a limited quantity of fuelwood. It is estimated that 10% to 15% of the total fuelwood consumption comes from these forests whereas the farmlands supply the remainder [4, 5]. About 65% of the fuelwood is collected mostly by women and children in the rural areas; this indicates the free availability of most of the fuel. However, only about 14% of the urban population collect their needs of fuelwood; and the remaining 86%, 70% of which belong to medium-low income households with an average monthly expenditure less than Rs 2000 (US\$ 1 = Rs 53), rely on purchasing [4].

According to Sheikh [5], the estimated quantities of timber production and fuelwood consumption during the year 1990 were 2.67 million m<sup>3</sup> and 22.4 million m<sup>3</sup>, respectively; fuelwood consumption of 30 million m<sup>3</sup> was projected for the year 2000.

Imtiaz [6], estimated a fuelwood consumption of 19.32 billion kg per year in Pakistan for the year 1991-1992.

UNDP, in collaboration with World Bank, and Energy Wing of the Government of Pakistan, carried out a broad survey titled "House Hold Energy Strategy Study (HESS)" and found that 91% of the households surveyed in rural areas consumed fuelwood at an average rate of 6.7 kg/household/day, while 52% of urban households surveyed consumed fuelwood at an average rate of 5.0 kg/household/day. A total annual fuelwood consumption of 31.38 billion kg has been estimated for the year 1990-1991 [4].

The fuelwood production in Pakistan during 1994 has been reported to be about 22.57 billion kg and has been projected to decrease to about 21.14 billion kg in 2010 [7]. However, the requirement has been estimated to be about 34.69 billion kg in 1994 and is projected to increase to about 52.17 billion kg by the year 2010; this shows a substantial gap between the sustainable supply and requirement. The fuelwood production in Pakistan in 1994 to 2010 is shown in Table 1.

Table 1. Fuelwood production in Pakistan in 1994-2010 [7].

Fuelwood sources	1994			2010		
	million kg	(%)	thousand TOE	million kg	(%)	thousand TOE
Natural forests	1,364	6.04	470	816	3.86	282
Natural forests (wood wastes)	4,598	20.37	1,620	2,578	12.19	915
Plantation	596	2.64	211	645	3.05	235
Other wooded lands	640	2.83	235	640	3.05	235
Agriculture areas	15,371	68.11	5,423	16,465	77.87	5798
Total	22,569	100.00	7,959	21,144	100.00	7465

## 2.1 Charcoal

Charcoal consumption in Pakistan is mainly in the household for ironing and water pipe smoking while small quantities are also used for cooking and space heating [4]. Fuelwood required for making 170 million kg of charcoal consumed annually has been estimated to be approximately 1.3 billion kg which is 4.4% of the total fuelwood consumption in the household sector.

## 2.3 Sawdust

The annual timber consumption in Pakistan is approximately 4 million m<sup>3</sup> [8]. In Pakistan sawdust production amounts to about 3.67% of the timber processed. Nearly 65% of the total sawdust production is used as fuel while the rest is used as bedding material in poultry farms, etc. This gives a total consumption of about 73 million kg of sawdust per year as fuel.

## 2.4 Dung

Dung from buffaloes and cattle is the second largest source of biomass after wood, being consumed as a fuel in the domestic sector both in rural and urban areas of the country. The population of buffaloes and cow in the year 1990-1991 was about 17.8 million heads and 17.7 million heads, respectively, and increased to 19.7 million heads and 17.8 million heads, respectively, by the year 1994-1995 [9].

Considering the dry matter production to be 2.00 kg/head/day [10] for cattle and buffaloes, the total estimated dung production for 1990-1991 and 1994-1995 has been estimated to be about 26.0 billion kg and 27.38 billion kg, respectively.

The dung is used both as fertilizer and fuel in the country. It has been reported that 50% of dung is consumed as fuel [6]. This amounts to an average per capita consumption of at 0.65 kg/day for 1990-1991. In addition, it was also reported that approximately 70% of the population in rural areas and 27% of the population in urban areas use dung as a fuel. Based on a survey, MUCET [11], estimated the average per capita consumption in Pakistan to be 0.55 kg/day at moisture content of 6% to 13%.

The results of HESS showed that 56.3% of the household surveyed used dung as fuel, and on an average the annual consumption has been placed at 13.3 billion kg for the year 1991. About 86% of the dung consumed as fuel is utilized in the rural areas of the country. The major users of dung are cattle owners, 79.5% of whom use dung as fuel. Mostly dung is collected in the rural areas, whereas a majority of households in urban area, 68.2% mostly rely on purchasing, and only 30.3% collect it for their requirement [4].

## 2.5 Crop Residues

Besides firewood, charcoal, and dung, significant quantities of agricultural crop residues are used as energy source. The main agriculture crops of the country are wheat, rice, bajra, jowar, maize, barley, gram, sugar cane, cotton, oil crops, and tobacco. Residues of crops like cotton, sugarcane and rice are of paramount significance from energy point of view. In addition, significant quantities of shrubs and other crop residues are also used as fuels.

The residues of other crops like wheat, bajra, jowar etc. are mostly used as an animal feed. Rice straw is used as an animal feed, and is partly burnt in the fields for disposal.

### *Cotton Stick*

Cotton stick is an important fuel in the domestic sector of the country. It is the byproduct of cotton crop, and is obtained after having picked cotton from the trees. Cotton sticks are then manually harvested and left in the fields for sun drying. After drying these are collected and placed in a pile. It remains in the fields until the next crop plantation, and is taken from there as

per requirement for use as fuel. It is observed that at least one fourth of the sticks generated remains as surplus at the end of year and is burnt in the field for disposal.

Cotton stick production has been found to be nearly independent of the crop yield. As the crop is very sensitive, the yield can be affected because of diseases so that the ration of cotton stick to cotton yield varies. MUCET [11] estimated that cotton stick production was 4,960 kg per 10,000 m<sup>2</sup>. Also, 75% of annual cotton stick produced is estimated to be consumed annually; this corresponds to a total consumption of 9.87 billion kg for the year 1994-1995.

According to UNDP [4] estimates, cotton stick production in 1990-1991 was about 12.46 billion kg, of which consumption was 5.15 billion kg.

### ***Bagasse***

Bagasse is a by-product of sugar cane and is a common fuel in sugar industry. Presently there are 66 sugar mills in the country and the total cane crushing has reached up to 34 billion kg per year. In addition, bagasse is also used as a fuel in treacle (Gur) making process in Pakistan. In the year 1990-1991, about 63% of the total sugar cane was crushed by sugar mills and the remaining was used by farmers in the manufacture of treacle. During 1994-1995 cane milling season, sugar industry crushed nearly 75% of the total cane and the remaining 25% was crushed by the farmers for treacle production [12].

The production of bagasse is 340 kg per 1,000 kg of cane crushed at an average moisture content of 50% [12]. The high percentage of bagasse obtained from the cane is due to high fiber content of cane in Pakistan, about 15% to 18%, compared to 12% to 14% in case of most other countries.

The surplus bagasse at sugar mills is about 10% of the total bagasse produced [13,14]. Approximately 90% of the surplus bagasse is used for direct combustion, mostly by brick kilns and the remaining is used in the manufacture of particle boards, etc. The total bagasse consumption as fuel has been estimated at 12.16 billion kg and 15.40 billion kg for 1990-1991 and 1994-1995, respectively.

### ***Rice Husk***

The ratio of the paddy to the husk is about 25%. Normally the paddy milling process involves two stages; the first stage removes most of the husks, whereas the second stage removes the remaining husk along with some broken pieces of rice. The former is normally used as a fuel whereas the latter is mostly used as an animal feed. Based on a survey carried out in rice mills of Larkana Division, the rice husk produced during the first stage of milling is about 12.5% of the paddy, and is used as fuel in brick kilns and bedding material in poultry farms, etc.; about 40% of this total production is consumed as fuel [15].

The estimated rice husk consumption as fuel for the years 1990-1991 and 1994-1995 was around 163 million kg and 168 million kg, respectively.

### ***Other Crop Residues***

Apart from the three common crop residues (cotton stick, bagasse, and rice husk), about 700 million kg of other crop residues like wheat straw, corn cob, rice straw, coconut shells, tobacco sticks, etc. are also used as fuel in the country. In addition, nearly 1.7 billion kg of various local crop residues and shrubs, etc. are utilized for energy [4].

The production and consumption of various biofuels are summarized in Table 2 and Table 3, respectively.

With the assumed values of residue/crop ratio for the selected crops, as shown in Table 4, the theoretical potential of energy from the residues has been estimated to be 25.24 MTOE in 1994, and has been projected to increase to about 41 MTOE by 2010 [7].

Table 2. Production of some biomass residues and wastes in Pakistan (million kg) [4, 11].

Biomass	1990-1991	1994-1995	Use of biomass
Wheat straw	19,830	22,711	Animal feed
Bagasse	12,236	15,524	Fuel
Molasses	1,133	1,712	Ethanol, and being exported
Ethanol	-	28	Exported
Cotton sticks	13,204	13,159	Fuel
Dung	25,915	26,280	Fuel and fertilizer
Rice husk (first stage)	408	419	Fuel and poultry bedding, etc.
Rice husk (second stage)	408	419	Cattle feed
Rice straw	5,729	5,900	Animal feed, packing material and open burning
Total	78,863	86,124	

Table 3. Consumption of various biofuels in Pakistan in 1991 [4, 11].

Biomass	million kg	thousand TOE	%
Fuelwood	31,384	12,648	56.02
Dung	13,300	4,389	19.44
Bagase	12,157	2,407	10.66
Cotton sticks	5,148	2,049	9.07
Charcoal	170	110	0.49
Rice straw/husk	374	129	0.57
Local biomass/shrubs, etc.	1,678	571	2.53
Saw dust	73	29	0.13
Other crop residues	711	242	1.07
Total	64,995	22,574	100.00

Table 4. Energy potential of crop residues in Pakistan in 1994-2010 [7, 16].

Crop	Residue type	RPR	Moisture	LHV kJ/kg	1994 <sup>2</sup>			2010 <sup>2</sup>		
					Production million kg	Residue production million kg	thousand TOE	Production million kg	Residue production million kg	thousand TOE
Rice	Straw	1.757	12.71	13,800	5,170	9,084	2,943	7,718	13,561	4,393
	Husk	0.267	12.37	13,480		1,380	437		2,061	652
Wheat		1.750	17.00	13,900	15,213	26,623	8,687	24,950	43,663	14,247
Milllet		1.750		12,460	228	399	117	113	198	58
Maize	Stalks	2.000	11.50	17,200	1,318	2,636	1,064	1,674	3,348	1,352
	Cob	0.273	7.53	16,280		360	138		457	175
Cotton	Stalks	2.755	12	14,650	4,438	12,227	4,205	8,289	22,825	7,849
Soyabean	Straw+ Pods	3.500	15	14,860	3	11	4	5	16	6
Sugarcane	Tops	0.300	10	15,810	44,427	13,328	4,946	69,710	20,913	7,761
	Bagasse	0.290	49	8,570		12,884	2,592		20,216	4,067
Groundnut	Husks	0.477	8.20	16,860	107	51	20	170	81	32
	Straw	2.300		15,190		244	87		392	140
Total					70,914	79,223	25,240	112,459	107,515	40,732

<sup>1</sup> Assumed RPR from Bhattacharya [16]<sup>2</sup> Production estimates by Koopmans [7]

## 2.6 Sectoral Bioass Energy Consumption in Pakistan

Biomass in the country is consumed as fuel in household, commercial sectors, conventional industrial sectors and in the cottage industry. About 93.68% of fuelwood is used in the household sector. Dung, charcoal, and various crop residues, apart from bagasse and rice husk, are used practically only in the household sector. Bagasse and rice husk is used in the industrial sector along with small quantities of fuelwood. The commercial sector uses firewood only, and consumes approximately 6.28% of the total firewood used.

The share of biomass energy in the different sectors of the country is shown in Table 5. The total biomass energy consumption in the country has been estimated at 22.574 MTOE. The consumption in the four sectors are as follows: household 19.38 MTOE (85.84%); commercial 0.8 MTOE (3.52%); industrial approximately 1.6 MTOE (6.94%); and cottage industry sector 0.84 MTOE (3.73%).

### *Household Sector*

The household sector is the major end user of biomass energy (86%) in the country. The quantities of biofuels consumed in this sector are 29.4 billion kg of fuelwood, 170 million kg of charcoal, 13.3 billion kg of dung, 5.15 billion kg of cotton sticks, 1.7 billion kg of shrubs, and 1.29 billion kg of other crop residues.

### *Commercial Sector*

Biofuel consumption in the commercial sector is in the form of fuelwood used in restaurants, bakeries, etc. The sector consumes about 1.94 billion kg of firewood.

### *Industrial Sector*

In the industrial sector, biomass is used in sugar industry, brick kilns, etc. Bagasse is the source of energy for the sugar industry, which consumes about 7 billion kg of bagasse and 4 million kg of fuelwood. About 10 million kg of fuelwood, 700 million kg of bagasse and 163 million kg of rice husk are used in brick kilns which also account for the country's 75% of coal consumption.

### *Cottage Industry Sector*

The cottage industry sector includes the process wherein bagasse is used for sugar cane juice evaporation and concentration by the farmers to produce treacle (Gur). Nearly 4.25 billion kg of bagasse is consumed annually in this sector.

The sectoral biomass consumption in terms of the type of biofuels utilized in each sector is shown in the Table 6, and share of biomass in the total energy consumption is shown in Table 7.

## 3. BIOMASS ENERGY CONSUMPTION IN PAKISTAN BY END-USE TECHNOLOGIES

A wide variety of bio-energy devices are used in the domestic, commercial, industrial, and cottage industry sectors of Pakistan. These range from traditional horse-shoe-type stoves, con-

Table 5. Sectoral biomass energy consumption in Pakistan in 1991.

Sector	thousand TOE	%
Household	19,378.84	85.84
Commercial	794.35	3.52
Industrial	1,567.59	6.92
Cottage industry	842.37	3.73
Total	22,574.00	100.00

Table 6. Sectoral biomass energy consumption in Pakistan in 1991 (million kg) [4, 11].

Sectors	Fuel wood	Dung	Bagasse	Cotton sticks	Char-coal	Rice straw/husk	Shrub	Saw-dust	Other crop residues	Total
Household	29,400	13300	298	5148	170	211	1678	73	711	50916
Commercial	1,970	0	0	0	0	0	0	0	0	1970
Industrial	14	0	7605	0	0	163	0	0	0	7782
Cottage Industry	0	0	4254	0	0	0	0	0	0	4552
Total	31,384	13300	12157	5148	170	374	1678	073	711	65071
(000TOE)	12,648	4,389	2407	2049	110	129	571	29	242	22574
(%)	56.02	19.44	10.66	9.07	0.49	0.57	2.53	0.13	1.07	100

Table 7. Share of biomass in the total energy consumption in Pakistan in 1991.

Description	Unit	Value
Primary energy consumption from biomass	MTOE	22.574
Primary energy consumption from conventional sources	MTOE	28.460
Total primary energy consumption in Pakistan	MTOE	51.034
Share of biomass in the total primary energy consumption	%	44.230

suming a major portion of biofuels for cooking, water heating, and space heating in the household sector to brick kilns and bagasse fired boilers in the industrial sector. Mostly, traditional technologies are in common use throughout the country.

### 3.1 Consumption of Biofuels in Pakistan

The biomass presently contributes nearly 44% of the Pakistan's total primary energy consumption. Its use is most prevalent in the household sector where a wide range of biofuels are consumed to meet diverse energy needs.



Consumption of biofuels in the household sector of Pakistan has been estimated as shown in the Table 8 for the year 1991. It is apparent that biofuels are mostly utilized for cooking. Among all biofuels, fuelwood is the most important in the country.

### 3.2 Biomass Energy Technologies in Pakistan

There are a number of energy devices for utilizing biofuels in different applications. The most widely used process for biomass utilization is combustion, in which biofuels are directly burnt to produce necessary heat for a specific purpose.

In the household sector, several types of biomass energy devices are in common use. These are traditional horse-shoe-type stove, tandur oven, space heating fire places, charcoal stove, iron for pressing clothes, and saw dust stoves. The major industrial biomass combustion devices include sugar mill boilers and brick kilns.

Application of other biomass energy systems like improved cookstoves, gasifiers, and briquetting machines, etc. is not significant so far in Pakistan.

### 3.3 Biomass Consumption in Pakistan by End-use Technology

The estimated figures of consumption of biofuels by end-use technology have been summarized in Table 9. Most of the biomass is consumed in traditional energy devices. In the household sector, about 26 billion kg fuelwood is used in the traditional horse-shoe-type stoves, 1.25 billion kg in tandur ovens, and 2.35 billion kg in the space heating fireplaces. Almost the entire quantities of dung and crop residues are used in the traditional horse-shoe-type of stove. Not much of the fuelwood is consumed in the industrial sector. About 4 million kg has been estimated for the boiler start-ups, and about 10 million kg are burnt by the brick kilns, etc. About 7 billion kg bagasse was burnt in sugar mill boilers, 4.25 billion kg in the earth furnaces, and 700 million kg in brick kilns during 1991.

In the commercial sector, about 1.45 billion kg fuelwood was used in the stoves, 500 million kg in the Tandurs, and 30 million kg in the bakeries.

Table 8. End use of biofuels in the household sector of Pakistan in 1991 (million kg) [4].

Biomass	Cooking	Water heating	Space heating	Others/ misc.	Total
Fuelwood	23,814	2,940	2,352	294	29,400
Dung	12,635	665	0.00	0.00	13,300
Cotton stick	4,170	618	360	0.00	13,300
Shrubs	1,510	168	0.00	0.00	5,148
Sawdust	73	73	0.00	0.00	1,678
Charcoal	41	0	0.00	129	170
Other crop residues	640	35.5	35.5	0.00	711
Total	42,883	4,499.5	2,745.5	423	50,480

Table 9. Biomass consumption for energy in Pakistan by end-use technology in 1991 (million kg)[4, 11].

Biomass	Industrial, commercial and agricultural sectors	% of M.C on W.B	million kg per year	Household sector	% of M.C on W.B	million kg per year
Fuelwood	Sugar mill boilers		4.00	Fire places		2,352.00
	Brick kiln		10.00	Stoves	15-21	25,798.00 1,250.00 0
	Restaurants	15-21	1,448.00 492.00	- Traditional		
	- Stoves			- Tandur		
	- Tandurs	Bakeries	30.00	- Improved		
<b>Total</b>			<b>1,984.00</b>	<b>Total</b>		<b>29,400.00</b>
Residues	Bagasse fired boilers	50	6,905.00	Cotton stick stoves	10-20	5,148.00
	Bagasse in earth Furnace (Treacle making process)	50*	4,254.00	- Traditional	15-21	0
				- Improved		
	Bagasse fired brick kilns	50	700.00	Sawdust stoves	15-21*	0
	Rice husk fired brick kilns	6-9	163.00	- Traditional		73.00
				- Improved		
				Shrubs	50*	1,678.00
				- Traditional		0
				- Improved		
				Bagasse	6-9	298.00
			- Traditional	0		
			- Improved			
			Rice straw	10-15	211.00	
			- Traditional		0	
			- Improved			
			Other crop residues		711.00	
			- Traditional		0	
			- Improved			
<b>Total</b>			<b>12,022.00</b>	<b>Total</b>		<b>8,119.00</b>
Charcoal				Charcoal stoves	3-5	0
				- Traditional		41.00
				- Improved		129.00
				- Irons		170.00
				<b>Total</b>		
Animal wastes				Dung cake stoves	6-13	13,300.00
				- Traditional		0
				- Improved		
				<b>Total</b>		<b>13,300.00</b>

\* Assumptions.

Note: M.C. on W.B. stands for moisture content on wet basis.

#### 4. CONCLUSIONS

The estimated biomass energy consumption in Pakistan during the year 1991 was 65.07 billion kg amounting to 22.57 MTOE. The share of various biofuels in the total biomass energy consumption was: fuelwood 56.02%; dung 19.44%; bagasse 10.66%; cotton stick 9.07%; and other crop residues, etc. 4.81%.

The biomass energy consumption in the different sectors was: household sector 85.84%; commercial sector 3.52%; industrial sector 6.94%; and cottage industry sector 3.73%.

Most of the biomass energy is consumed in traditional stoves in the household and commercial sectors, accounting for 81.33%; the remaining consumption takes place in sugar mill boilers (6%), furnaces in cottage industry sector (3.73%), tandur ovens (3.11%), fire places for space heating (4%), and other combustion systems.

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#### 6. REFERENCES

1. Ministry of Petroleum and Natural Resources (MPNR). 1994. *Pakistan Energy Year Book*. Islamabad: MPNR.
2. Amur, G.Q., and Bhattacharya, S.C. 1997. Biomass as a Source of Energy in Pakistan. A Synthesis Report prepared for the project on Study on Biomass as a Source of Energy and Technical Options for Green House Gases Emission Reduction for the Asian Regional Research Program in Energy, Environment and Climate (ARRPEEC), Energy Program, Asian Institute of Technology, Bangkok, Thailand.
3. Sharma, M., and Bhattacharya, S.C. 1998. A study of biomass as a source of energy in Nepal. *Energy for Sustainable Development*.
4. UNDP. 1993. House Hold Energy Demand Consumption Patterns. Pakistan Household Energy Study Survey, Energy Wing, Government of Pakistan.
5. Sheikh, M.I. 1990. Background Paper. Wood Producers Users Seminar Souvenir. Office of the Inspector General of Forests, Islamabad. 3-10.
6. Imtiaz, A. 1993. State of art of the utilization of agricultural residues and other biomass and identification of priority projects in Pakistan. In *Proceedings of Regional Workshop on HRD for Utilization of Agricultural Residues as an Energy Source*. China. 236-248.
7. Koopmans, A. 1998. Biomass Energy Resources for Power and Energy. Regional Wood Energy Development Program. FAO Bangkok, Paper Presented at the Expert Consultation on Options for Dendro-Power in Asia, Manila.
8. Ministry of Planning and Development, Eight Five Year Plan 1994-1998. Government of Pakistan, Islamabad.
9. Government of Pakistan, Finance Division. 1994. *Economic Survey of Pakistan*. Islamabad: Finance Division, Government of Pakistan.

10. Bhattacharya, S.C. 1993. State-of-the-art of utilizing residues and other types of biomass as an energy source. *RERIC International Energy Journal* 15(1): 1-21.
11. Mehran University College of Engineering and Technology (MUCET) Nawabshah. 1995. Database of Biomass Estimations.
12. Pakistan Society of Sugar Mills Association (PSMA). 1994-1995. Annual Reports and Summary of Laboratory Reports.
13. Amur, G.Q. 1994. Assessment of the Export Power Options for Habib Sugar Mills in Pakistan. Thesis No. 23. Asian Institute of Technology, Bangkok, Thailand.
14. Amur, G.Q. 1996. Energy Efficiency Study at Sugar Mills in Pakistan. Report submitted for the ARRPEEC project. SERD-Energy Program, Asian Institute of Technology, Bangkok, Thailand.
15. Rice Mills in Larkana Division (RMLD). 1995. Personal Communication.
16. Bhattacharya, S.C.; Venu, M.S.; and Salam, P.A. 1996. *Assessment of Bio-energy Potential in Asia*. Bangkok: Asian Institute of Technology.