A Study of Biomass as a Source of Energy in Sri Lanka

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ABSTRACT

The biomass energy potential in Sri Lanka has been assessed. In 1993, biomass consumption for energy was about 11.37 billion kg, which is equivalent to about 3.6 million tons of oil equivalent (MTOE) and accounted for 66% of the total primary energy consumption of the country. The share of fuelwood in the traditional energy supplies is about 88%. The household sector is the major end user and consumes 88.4% of the total biomass energy.

1. INTRODUCTION

In terms of energy sources, Sri Lanka has so far not found any fossil fuel reserves and as such hydropower and biomass are the only substantial indigenous energy resources available. Of the hydropower potential, most of the large resources have been developed, leaving a substantial amount of small capacity plants yet to be developed.

According to Fernando [1], in 1995, biomass, hydropower and petroleum accounted for 57%, 17% and 26% of the total energy supplies, respectively.

Biomass is of crucial importance to the rural people, many of whom do not have access to other energy sources. Apart from fuelwood, the principal agricultural residues available in the country are rice husk and straw, coconut wastes such as husks, shells, fronds, coir dust, and trunks, residues from tea and rubber plantations, bagasse, tobacco stems, cinnamon sticks, cashewnut shells and fruits, citronella grass, cocoa shells, and animal wastes [2].

2. BIOMASS ENERGY SOURCES IN SRI LANKA

2.1 Fuelwood

Fuelwood is the main energy source for many Sri Lankans. In 1993, the share of biomass as compared to the total energy consumption was about 66%; fuelwood accounted for about 88% of total biomass consumption. Total annual fuelwood consumption in the country was about 9 billion kg in 1993 with the energy value of about 3.13 MTOE. More than 90% of the entire population uses mostly fuelwood for domestic cooking [2]. It is also the main thermal energy source for the tea, tobacco, brick and tile and many other industries.

According to a study of the Regional Wood Energy Development Programme in Asia of FAO, the potential supply and estimated consumption of fuelwood in 1994 were 8963 million kg and 5681 million kg, respectively [3].

Wood from rubber plantations is a major source of biomass fuel used in Sri Lanka. Rubber wood is extensively used as fuelwood both in the household and industrial sectors.

Deforestation may have an impact on the future sustainable supply of fuelwood. At present, however, there is no national fuelwood crisis, although in several localities the traditional fuelwood sources have been depleted resulting in adverse environmental impacts and difficulties in meeting the basic energy needs. Individual households usually collect their own fuelwood from the forests or thier own home gardens. About 74% of the fuelwood comes from non-commercial sources such as home gardens, sparsely cultivated croplands and natural forests [2].

In Sri Lanka, most of the biomass used for energy is not purchased. According to the latest national consumer survey [4], approximately 84% of fuelwood used by households was obtained free by users, the balance 16% being purchased. About 86% of the consumed rubber wood and 100% of sawdust and about 41% of fuelwood from forests were reported to be purchased.

The prices paid for fuelwood in various parts of the country vary widely. In rural areas most people do not pay anything for fuelwood, but in Colombo area prices can reach more than 3 Rs/kg (1 US$ = 65 Rs). The price difference demonstrates the difference in access to fuelwood and other energy forms and in relative demand and supply.

The supply of fuelwood and other biomass from coconut, rubber plantations and other sources is given in Table 1.

Table 1. Fuelwood and other biomass supply in 1993 (million kg) [5].

Source	Biomass (million kg)	Percentage (%)
Natural forest	669.35	7
Coconut plantations	1816.80	19
Forest plantations	382.48	4
Processing residues	286.86	3
Rubber wood	669.35	7
Home gardens	2486.15	26
Crop lands	1816.80	19
Others	1434.32	15
Total	**9562.10**	**100**

2.2 Crop Residues

The major crop residues used for energy are rice straw and husks, bagasse, coconut residues and saw dust.

In 1993, paddy production amounted to about 2.6 billion kg. One kg of paddy provides 0.22 kg of air-dried paddy husk [6], accordingly about 572 million kg of paddy husk was available [2]. Rice husk is increasingly being used by paddy millers and tobacco barn owners as an energy source. Paddy straw is not widely used at present as fuel due to its high moisture content and low bulk density, but it is often used as an animal feed or buried as fertilizer in rice fields. In 1993, the use of rice husk by industries and household sectors was about 195 million kg [2].

According to National Renewable Energy Laboratory of the U.S.A., in 1995, large and small mills produced around 560 million kg of husks [7]. About 60% of the rice produced in Sri Lanka is parboiled at larger government mills or smaller private mills. Almost the entire husk produced in parboiling mills, about 330 million kg per year, is used to produce energy.

The area under sugar cane is approximately 110 million m². Sugar cane in 1 m² produces 1.6 kg of air dried bagasse [6], accordingly about 176 million kg of air dried bagasse is available annually. Most of the bagasse is used by the sugar mills to meet the inhouse energy demand [2].

According to Adhikarinayake [8], Sri Lanka has two large sugar factories and they are associated with sugarcane plantations producing 300 million kg annually giving 80 million kg of bagasse. In addition to this, the private plantations also produce about 20 million kg of bagasse annually. It is also estimated that about 12 million kg of tobacco stems are available annually as a source of energy [8].

Sri Lanka has about 4110 million m² under coconut plantation and the average annual production is about 2000 million nuts. The principal waste products from the coconut plantations are trunks, fronds (leaves), husks, and shells.

The annual production of coir dust is approsimately 750 million kg (with a moisture content of 85% on wet basis), while the amount accumulated over the past 50 years is estimated at 22 billion kg [9].

The total quantity of crop residues consumed for energy in 1993 was approximately 1.33 billion kg, of which bagasse, rice husk, coconut husks/residues, saw dust, and other crop residues accounted for 272 million kg, 77 million kg, 984 million kg, 10 million kg, and 54 million kg, respectively [2].

2.3 Animal Waste

The use of animal waste for direct combustion is quite insignificant. However, some amounts are used in biogas digesters. Use of animal waste in digesters amounting to about 1 million kg of wood equivalent has been reported [2].

3. BIOMASS ENERGY CONSUMPTION BY SECTOR

3.1 Household Sector

The household sector accounted for 65% of total national energy consumption in 1995 [1].

Table 2. Composition of energy consumption in the household and industrial sectors.

Type of energy	Household sector(%)	Industrial sector(%)
Bio-energy	87.5	59[b]
Electricity	6.6	25
Petroleum products	5.9[a]	16[c]
Total	100	100

Note: a = Kerosene 4.8% and LPG 1%, b = Fuelwood: 49%, Agro-residues: 10%, c = mainly oil.

Total consumption of biomass energy by household in 1993 was estimated to be about 10 billion kg which is equivalent to about 3.16 MTOE. Table 2 shows the composition of energy consumption in the household and industrial sectors in 1992.

In rural areas, fuelwood is the dominant fuel for cooking. However, in the urban areas LPG, electricity and kerosene are also used for cooking purposes, so that the share of households relying primarily on fuelwood is less. In Colombo, for example the average biomass energy consumption by households is about 30% less than the national average. Biomass energy consumption levels in urban areas in general are lower because urban households have higher incomes, better access to electricity, kerosene, and LPG and less access to biomass resources than rural people.

In the hilly areas, fuelwood is used also to provide heat, especially during the cold season. For example, in the district of Nuwara Eliya, biomass energy consumption by households is more than 20% higher than the national average.

In 1993, the per capita consumption of fuelwood in the household was 1.32 kg/person/day [5]. The per capita consumption of fuelwood has been decreasing over the years. The average reduction in per capita consumption per year is about 1%.

3.2 Industrial Sector

Although no actual statistics on fuelwood consumption by industries appear to exist, the Ministry of Power & Energy uses a model based on past data and simple assumptions to derive annual consumption estimates. During 1982-1992 annual energy consumption in the industrial sector grew on an average by 2.3%. The consumption amounted to 18.2% of total energy consumption in 1992.

Table 3 shows the estimated fuelwood consumption by sectors in 1993. According to Sri Lanka Forestry Sector Master Plan of 1995, the shares of household, industrial and commercial use of fuelwood are 89%, 8% and 3%, respectively [5].

Tea industry is the major consumer of fuelwood, followed by hotels and eating houses, and brick and tile industry. In the tea industry, fuelwood is used to provide heat for withering and drying leaves. Most of the fuelwood requirements in the tea industry are met from rubber plantations. But, with rubber wood getting scarcer for use as fuel, attempts have been made to establish fuelwood plantations in tea growing areas.

In the coconut industry, fuelwood is needed for sterilizing the peeled coconuts, drying of desiccated coconut, manufacturing of coconut oil, and drying copra. The consumption of fuelwood by the coconut industry has decreased in recent years due to the introduction of fuel oil fired boilers in the modernization program and also due to utilization of energy from the coconut shell carbonization process in the largest desiccated coconut factory.

Table 3. Fuelwood consumption by sectors in 1993 (million kg) [5].

Sector	Amount (million kg)
Household	**8260**
Fuelwood for cooking	8260
Agro industry	**532**
Coconut processing industry	42
Rubber processing	72
Tea processing	406
Tobacco processing	12
Manufacturing industry	**199.46**
Bricks and tiles	150
Lime, pottery and others	49
Sugar	0.46
Commercial sector	**269**
Hotels and eating houses	170
Bakeries	99
Charcoal production	**0.41**
Fuelwood for charcoal production	0.41
Total	**9261**

In the rubber industry, fuelwood is used for the manufacture of ribbed smoked sheet (RSS) and crepe rubber. With the establishment of new rubber based industries, the demand for liquid latex has increased and this trend is likely to slightly reduce the demand for fuelwood in the rubber industry. In the tobacco industry, fuelwood is used for curing. Substantial improvements made in the tobacco industry in the form of energy efficient barns and the use of paddy husk has reduced the amount of fuelwood used in the tobacco industry. The other industries using bio-energy are industries such as ceramics, fish drying, lime kilns and distilleries.

Most of these industries are located in rural areas with the tea industry concentrated in the hilly regions. The coconut industries are located mainly in the northern wet zone. Brick kiln industry is located mainly in the central and northern wet zones. The distribution of the various fuelwood consuming industries is naturally reflected in the regional variation in fuelwood consumption.

Total consumption of biomass energy in the industrial and commercial sectors in 1993 was estimated to be about 1417 million kg which is equivalent to about 0.40 MTOE.

3.3 Supply Sources of Fuelwood for Industries

Industries purchase most of their fuelwood requirements. The main sources are estate holdings state owned natural forests, and private non-forest lands. Table 4 provides an estimate of the relative importance of major fuelwood sources to the industrial and commercial sectors.

Rubber wood extracted as a by-product in the rubber industry provides the largest amount of fuelwood to the industrial sector. However, in the recent past, the trunk part of this wood is also used for more valuable purposes such as manufacture of plywood brush handles and wooden toys, thus reducing the amount available as fuelwood.

Improved Cookstoves

A national fuelwood conservation program was launched in 1983 by new and rural sources of energy task force, in collaboration with governmental and non-governmental organizations. Most of these organizations in this task force were already involved in the production and dissemination of improved fuel-efficient stoves. One of the objectives of this task force was the conservation of fuelwood.

In 1979, the Sarvodaya Movement initiated a stove program mainly for rural development. A two pot-Sarvodaya Stove designed by the Intermediate Technology Group (ITDG) of UK and the Sarvodaya Institute of Sri Lanka is currently used in rural and suburban areas, and the CISIR's (Ceylon Institute of Scientific and Industrial Research) single pot stove and the IDB's (Industrial Development Board) single pot (with chimney) are used mostly in the urban areas. During 1987, the Ceylon Electricity Board and the ITDG developed the Anagi stove, which is being popularized throughout the country.

Four types of wood stoves, developed by the Ceylon Institute of Scientific and Industrial Research (CISIR), the Industrial Development Board (IDB), the Ceylon Electricity Board (CEB), and Lanka Jathika Sarvodaya Sangamaya (Sarvodaya) were field tested. It was found that [10]:

1. The CISIR stove is satisfactory on all accounts (average fuel saving 28%): fuelwood saving, durability and acceptability.

2. The IDB stove makes the highest fuelwood savings (37%), but is less acceptable. It is in fact suited to smaller families (about four adults)

3. The Sarvodaya stove can save 16% fuelwood and has good durability but has some drawbacks.

Among the improved stoves, the Sarvodaya stove and the Anagi stove are the most commonly used at present, while the others are also used to a lesser extent. The number of Sarvodaya/CEB stoves and the Anagi stoves sold up to 1995 were 350,000 and 500,000 respectively [11].

Sawdust/Paddy Husk Stoves

This is a very simple stove for burning sawdust or paddy husk. This is made out of an open drum or any other metal can, which is open on one side. Before filling the drum with sawdust/paddy husk, a stick is placed horizontally near the bottom and another vertically in the centre of the drum. Sawdust-paddy husk is filled and pressed with another stick or wooden pole. Before firing, the two sticks are removed leaving a passage for air circulation. When the stove is fired it provides heat for about 3 hours. This type of stove is commonly used by gram sellers and at small tea boutiques situated near and around saw mills as the stove can be easily moved.

The Rice Processing Research and Development Centre (RPRDC) has newly developed a low cost efficient husk stove, in which unbroken husk from improved rice mills could be used as a fuel. This stove is smokeless, portable and keeps a stable flame. This can be fabricated to different sizes and capacities as required. This development enables the use of non-pulverized husk. It can be used for cooking as well as for thermal energy generation for agricultural processing, such as parboiling of paddy. Heat is generated from the combustion of gas generated from the husk.

4.2 Biomas Energy Combustion Systems in Industrial and Commercial Sectors

The major industries using biomass as a source of energy are tea, coconut, rubber, sugar, bricks & tiles, tobacco and commercial concerns such as bakeries, hotels and eating houses. Other small scale industries which use biomass as a source of energy are pottery, ceramics, lime kilns, small food processing units, chemical, metal, leather, textile, soap industries, road tarring, distilleries, crop and fish drying, laundries, and paddy parboiling.

The rubber processing industry uses wood fired furnaces (80%), and to a lesser extent wood fired industrial boilers (20%). Brick and tile, lime pottery and bakeries use wood fired furaces (100%) in their production process. The distilleries use wood fired furnaces (80%) and paddy husk fired boilers (20%) in the manufacturing process.

The technology for the use of biomass as a source of energy by the industrial and the commercial sectors are given below by the type of industry.

Tea Industry

The tea processing industry is the largest consumer of biomass for energy purpose. On an average, 3 kg of wood (i.e. about 0.7 kg for withering and about 2-2.5 kg for drying) is required to produce one kg of tea [8]. The production of tea is characterized by the region where the tea is produced; high grown, medium grown and low grown tea. The high grown tea, which is grown in the hilly region often requires more heat for withering purposes.

All biomass-fired furnaces used in the tea industry are of fixed grate type with batch loading of fuel. The combustion chambers are under negative pressure, because of induced draught fans. The induced draught fan discharges into underground ducts and these ducts lead to brick chimneys at some distance from the plants. Process air heaters are of cast-iron construction with some refectory lining in the combustion chamber. The furnaces of the air heaters are assembled from a large number of sections with asbestos rope between the joints to provide sealing.

The Natural Resources Institute (NRI) of the United Kingdom developed a new type of furnace/heat exchanger system for the tea industry. The efficiency of this heater is 20%-30% higher compared with conventional systems [12].

In some tea factories, attempts were made for drying tea using paddy husk also [12].

Coconut Industry

The desiccated coconut (DC) industry has a variety of furnace/heat exchanger systems and these can be divided into two main categories: (i) multiple furnace system, where each dryer has a furnace/heat exchanger, and (ii) single furnace system where the mill is equipped with only one furnace/heat exchanger system which suplies drying air to several dryers. Systems of first and second category are used in approximately 20% and 60% of the DC mills respectively. The balance 20% of these factories use oil fired steam boilers and radiators to produce the hot air required for drying. One such factory is using carbonization gases as fuel.

The coconut industry uses coconut shell fired copra kilns (40%), wood fired furnaces (45%), wood fired industrial boilers (12%), and carbonization gas fired furnaces (3%) to meet its energy requirements.

Tobacco Industry

Some R & D work on the use of paddy husk for tobacco curing have been carried out in Sri Lanka. Initially the furnace was introduced to small barns, but was later expanded to large barns as well. The furnace is made of 13 clay slates each 100 mm wide placed in a stepwise manner forming a step grate furnace, which is 1.2 m wide and approximately 1.35 m in height. In a new design, two hot air sucking tubes on either side are connected to the central hot air diffuser [13]. This curing system reduced the fuel usage by 30%. The fuel system in the barn was further modified into multiflues thereby increasing the area of radiation. The furnaces are converted into venturi systems minimizing the heat losses from the furnaces [14]. The tobacco industry uses wood fired barns (80%) and to a leser extent rice husk fired barns (20%).

Ceylon Tobacco Company (CTC) was successful in introducing a curing system called the warm air furnace that reduces the fuel usage by more than 35%. Subsequently, with modifications to the flue systems and the furnace it was possible to reduce fuel wood usage by a further 10%. Thus an overall saving of approximately 45% was derived.

Parboiling of Paddy

The normal fuel for parboiling and drying of paddy in many medium and large size paddy processing mills is paddy husk. The technique of using paddy husk ranges from manual feeding to mechanically operated blowers. In manual feeding, paddy husk in small quantities is thrown into the furnace. The husk catches fire instantaneously. The heat is controlled by increasing or decreasing the quantity of husk fed. This method is useful where diesel or electrical power is not available. In cases where electricity or mechanical power is available, husk is blown into the furnace over which is the parboiling tank or to a steam boiler.

In more effective burning/boiler operations, paddy husk is fed from a hopper at a controlled rate on to a grate arranged in a step formation through which a draft of air passes, providing the oxygen for combustion. Ash is removed from the bottom at intervals and the system provides efficient burning and heat generation. Similar technology is also being adopted for tobacco curing.

Bagasse Fired Boilers

The use of bagasse for steam and/or power generation is a common practice in Sri Lanka's sugar industry. A sloping grate furnace is used for burning of bagasse in an as-received state. The sloping grate forces the bagasse to move from the feeding point to the ash outlet. The bagasse is fed either mechanically according to the need for heat from the boiler or from already filled chutes. The ash is normally extracted from the bottom of the grate by means of screws to a water tank.

The heating surfaces are divided into sections of different water of steam temperature. The feed water is first sent to the economizer in the end of the flue gas duct. The low temperature heat of the gases will preheat the feed water on its way to the boiler.

Sawdust/Paddy Husk Fired Oven/Furnace

An oven which uses sawdust/paddy husk is currently being used by some bakeries in the country. The sawdust/paddy husk is placed in tins or barrels beneath the oven. The heat generated by the burning of sawdust/paddy husk is transferred to the oven. The number of tins/barrels to be used depends on the capacity of the oven.

The National Energy Research and Development Center has developed a bakery oven operated with agro-waste such as paddy husk or saw dust and these bakery ovens are compact. The hot air is circulated without any contamination, and with minimum smoke unlike the traditional bakery ovens.

The Energy Development Systems (Pvt) Ltd has designed a direct combustion furnace to suit locally available biomass, such as saw dust, rice husk, coir fiber dust and straw. In association with the Industrial Development Board (IDB), they have produced and successfully fired two of the smaller size furnaces using rice husk as fuel. The smaller of the two is suitable for generating heat for the conventional types of bakeries, tobacco barns, and large kitchens, while the other is ideal for use in rubber factories [15].

Ceylon Institute of Scientific and Industrial Research (CISIR) developed and demonstrated a paddy husk cyclone burner. The heat generated in this process can be utilized for heating ovens (bakeries) and boilers [16].

At the Department of Agricultural Engineering, University of Peradeniya, a husk fired furnace for grain drying has been developed and demonstrated. The furnace consists of a used oil drum with compacted paddy husk leaving a center passage for forced primary air entry. Secondary combustion takes place at the outlet of the drum. The fumes leaving the drum ar mixed with regulated air to give the desired temperature for grain drying. The total quantity for batch feeding is 50 kg paddy husk which is sufficient to dry 2000 kg of grain within 8 hours [16].

4.3 Biogas Digesters

The traditional biogas generator is built based on the Indian or Chinese design. Both types use animal waste as feed. Daily feeding and maintenance work involved in these designs have been a major barrier faced by the users and for dissemination of the method.

In view of these problems, the National Energy Research and Development Center developed a new method of biogas production using the patented "Sri Lankan Semi-Dry-Batch Biogas System". The process does not need the daily feeding of raw material and overcomes the problems of daily maintenance encountered in the traditional Chinese and Indian models. This has been adopted successfully for straw and market garbage. The gas production is 1 m^3/day per 1000 kg of material. This gas has a calorific value of 12 MJ/m^3 [1].

4.4 Gasification

A prototype down-draft gasifier was designed and constructed by the National Energy Research and Development Centre during 1980-1981. Various fuels like wood charcoal, coconut husk and coconut charcoal were tested. The project made headway when it was later diverted into two directions: (i) Stationary Bed Down-Draft Gasification, and (ii) Fluidized Bed Gasification. The NERD successfully demonstrated water pumps, generators and vehicles running on individual gasifiers [17].

4.5 Densification

Until recently, densification or briquetting technology has been found to be economically not feasible as firewood is available at a cheaper price. But the present situation is different and the country appreciates the importance of introducing briquetting technology as a solution for the prevailing energy crisis. Several companies have already engaged in briquetting of biomass like husk and coir dust for export and for the local market [8].

A commercial briquetting machine was adopted by the Ceylon Tobacco Company Limited after modifications to produce briquettes with a density of about 1200 kg/m³. These briquettes are about 75 mm in diameter, adjustable in length and could be stacked to have a bulk density of about 800 kg/m³ [17]. However, as the cost of densification was found to be excessive, this technology has not been commercialized.

A project supported by the European Union to manufacture low density briquettes from coir dust was developed by the Ministry of Power and Energy in 1992.

4.6 Carbonnization

Carbonization of Wood

The State Timber Corporation (STC) started carbonizing charcoal from firewood and wood residues such as branchwood, slash produced from Mahaveli Accelerated Development Program areas. Charcoal was produced using steel kilns. Charcoal was introduced to the market in 3 kg packs with the trade name "Timco". However, with the declining supply of wood from natural forests, the production of charcoal has declined. The STC was able to produce only 119,000 kg of charcoal during 1993, indicating an 81% decrease over the previous year [18].

Carbonization of Coconut Shell

Charcoal production is done using both traditional and improved methods. Circular pits of diameter of 1 m to 3 m and a depth of 2.3 m are lined with bricks to prevent contamination of the charcoal with soil and to stop erosion of the walls. Shells are sun-dried to a moisture content of approximately 14% (dry basis) and a layer of shells spread on the bottom of the pit. A fire is lit at the base of the pit and shells are added progressively as the fire spread upwards. Eventually the shells form a mound standing above the pit, which produces a large volume of smoke. At this time the mound of shells is covered with palm fronds and then with soil and ash. When the last traces of smoke disappear, the soil is checked for cracks, caused by contraction and movement of the charcoal bed, and any holes are filled in. When the pit has cooled the charcoal is unloaded.

The traditional carbonization method has many shortcomings e.g. energy loss due to the combustible gases rejected to the atmosphere, heat loss during the process, environmental pollution etc. To overcome these shortcomings, the Tropical Development and Research Institute (TDRI) of the UK developed a technology, which is called the Waste Heat Recovery Unit (WHRU). This works as a coconut shell carbonization unit with waste heat recovery for application in the coconut industry.

WHRU method of carbonizing has the following advantages over the traditional method:

1. the energy usually wasted in the traditional method is recovered and utilized for productive purposes;

2. the hazardous smoke generated during carbonization is totally trapped;
3. since carbonization is carried out in a metallic kiln, the product is free of any grit;
4. as no water is used in the process, the charcoal produced is very low in moisture; and
5. the yield of charcoal is increased to 30% from 25% obtained in the traditional method.

If this technology is used by the entire desiccated coconut industry, it will result in a saving of 50 million kg of fuelwood annually. Moreover, the 50% of the shell used as fuel in copra manufacturing will also be converted into charcoal [12].

Coconut shell charcoal is mostly used as the raw material in the manufacture of activated carbon where micro-pore structure of the carbonized shell is particularly useful for gas filtration applications. Almost all the activated carbon produced in the country is exported. A small percentage of coconut shell charcoal is used locally, especially for desiccated coconut (DC) mills. Currently there are at least eight activated carbon plants in Sri Lanka.

4.7 Technology-wise Biomass Energy Use in Sri Lanka

Table 5 shows the technology-wise use of biomass energy in Sri Lanka [19]. The major use of biomass is for household cooking which accounts for about 9.96 billion kg or 88.4% of the total biomass utilized. The total quantity of fuelwood consumed by the household sector is

Table 5. Technology-wise use of biomass for energy in Sri Lanka in 1993 (million kg).

Type of biomass	Industrial and commercial sectors	MC@	Amount (million kg/year)	Residential sector	MC	Amount (million kg/year)
Wood	- Industrial boilers	24.4	10.9	- Space heating	25.0	1.0
	- Furnaces	42.1	790.0	- Stoves		
	- Commercial stoves	50.0	99.0	- Traditional	25.0	4,480.0
	- Hotels etc.	50.0	164.0	- Improved	25.0	4,480.0
	Total		**1,063.9**	**Total**		**8,961.0**
Residues	- Bagasse fired boilers	53.9	272.0	-Coconut	25.0	974.0
	- Rice husk fired boilers	10.8	50.0	plantation	40.0	
	- Rice husk fired		17.0	residues	10.6	
	furnaces	10.6	3.0	- Saw dust	50.0	10.0
	- Waste veneer fired			- Rice husk		10.0
	boilers	45.7	10.0	- Openpile		
	- Coconut husk/shell			burning		50.0
	fired furnaces	30.0	1.0			
	- Carbonization gas					
	fired furnace	12.0				
	Total		**353.0**	**Total**		**1,044.0**
Coconut shell and charcoal	- Blacksmiths	5.0	0.1			
	Total		**0.1**			
Animal waste				- Biogas digestors		1.0*

Note: 1) All industrial furnaces are of the static grate manually fed type with over and under air supply. 2) The bagasse fire boilers are of the suspension burning type with static grate. Ash removal is manual. 3) A system has been developed to recover and utilize the waste combustible gases in the coconut shell carbonization process. 4) @ = Percentage of moisture content on wet basis, 5) * = wood equivalent.

8.961 billion kg, accounting for 90% of the total quantity of the biomass used by households. Agricultural residues account for 994 million kg comprising approximately 10% of the total quantity of biomass consumed by the household sector. About 1 million kg of fuelwood equivalent of biogas is also used by the household sector.

The industrial sector consumed about 1.417 billion kg or 9.1% of the total quantity of biomass used during 1993. As in the case of the household sector, fuelwood is the main bioenergy used by the industries. The industrial boilers, furnaces and commercial ovens use 1.064 billion kg of fuelwood which accounts for 75% of the total quantity of biomas consumed by these industries. Agricultural residues account for 353 million kg or 25% of the total biomass consumed by industries. Coconut shell charcoal used by blacksmiths accounts for about 100,000 kg of the total industrial consumption.

The sugar industry is the only consumer of bagasse. Bagasse is used in sugar mills to generate steam and electricity for sugar processing. Small manufacturing industries such as bakeries, brick and tile, lime, pottery and agro-industries such as copra, desiccated coconut, tea, rubber, etc. consume fuelwood to a large extent. Fuelwood and coconut shells are also used to produce charcoal some of which is further converted into activated carbon.

5. CONCLUSIONS

The total biomass consumption in Sri Lanka in 1993 is about 11.37 billion kg or about 3.6 MTOE. The share of firewood, bagasse, coconut, and other crop residues was 91%, 1.29%, 7.05%, and 0.67% respectively. The share of biomass in total primary energy consumption is envisaged at 66%. Biomass energy consumption in the household, and industrial and commercial sectors was 3.16 MTOE (88.4%) and 0.41 MTOE (11.6%), respectively.

About 89% of the total firewood consumed in the country is utilized in cookstoves, and nearly equal amounts are used in traditional and improved cookstoves. Approximately 11 million kg firewood is consumed by industrial boilers, and 272 billion kg bagasse is utilized by sugar mill boilers. In addition, 790 million kg coconut residues are utilized in industrial furnaces along with other residues.

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