SOURCES OF ENERGY AND SECTORAL COMPOSITION OF ENERGY CONSUMPTION IN SRI LANKA

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This paper is one of the 18 papers, published under a special series of publications by the Sri Lanka Economic Association (SLEA) with financial assistance from the United States Agency for International Development (USAID). The objective of these publications is to provide economic literature on current and topical themes on the economy of Sri Lanka to a broad audience that is interested in economic issues, but has little or no background in theoretical economics, while maintaining high analytical standards. Hence, the papers have been written in simple language avoiding the use of sophisticated technical terms, mathematical equations and models etc. which are normally found in economic literature.

SOURCES OF ENERGY AND SECTORAL COMPOSITION OF ENERGY CONSUMPTION IN SRI LANKA

1. INTRODUCTION

Energy and economic activity are closely related because in order to produce output, inputs of some form of energy is required. Further, the level of economic development which is measured in terms of total output produced in the economy depends on the level of energy use. Energy is obtained from different sources and its pattern of consumption is determined by a number of factors such as the socio-economic structure and geographical conditions in the country and the nature and level of technology used in the production activity.

Sources of energy in Sri Lanka can be divided into commercial sources and non-commercial sources for analytical purposes. Commercial energy sources which consist of petroleum, electricity and coal, account for about one-third of the total energy used in the country. A greater proportion of energy is obtained from traditional sources such as fuelwood, agricultural residues, animal wastes and other renewable sources. The entirety of fuelwood and biomass are traditionally considered as non-commercial

energy but approximately 17 per cent of the fuelwood requirement in the country is presently traded through markets. Although quantity-wise, the supply is relatively small, charcoal and bagasse included in the category of non-commercial energy are also traded on a commercial basis.

Primary energy requirement of the country in 1991 was estimated at 6.2 million Tons of Oil Equivalent (TOE). Approximately 1.8 million TOE of crude oil and other petroleum products were used to produce various refined products and secondary sources of energy such as thermal electricity. Approximately, 6 per cent of petroleum is lost in transportation and handling while 20 per cent of electricity produced is not available for use due to losses in transmission and distribution, theft and metering errors. Consequently, in 1991, of the total supply of energy amounting to 6.2 million TOE, energy available for end-users was estimated at 5.9 million TOE showing an annual growth of energy use by 3 per cent over the period of 1977-1991. During the same period, on average, the supply of commercial energy increased annually by 4 per cent while the corresponding growth in the supply of non-commercial energy was 2 per cent.

In Sri Lanka, the level of energy consumption depends mainly on the activities of the household, manufacturing, transportation, commercial and agricultural sectors. The household sector is the largest consumer of energy in Sri Lanka and it accounts for more than 61 per cent of the total energy consumption at present. According to source-wise consumption data, 37 per cent of electricity, 89 per cent of kerosene, 80

per cent of LP gas and 80 per cent of non-commercial energy are consumed by this sector. The main purposes of energy use by the household sector are lighting, cooking and operation of electrical appliances. The practice of using energy for pumping water from wells for use in households and home gardens is negligible.

The industrial sector which uses approximately 20 per cent of energy from all sources put together is the largest consumer of electricity accounting for more than 38 per cent of the total electricity consumption at present. This sector accounts for 20 per cent of the petroleum which is mainly heavy diesel and furnace oil. These fuels are used to provide motive power and heat in the industrial sector. Approximately 17 per cent of non-commercial energy is used by this sector in various processing activities such as tea dryers, brick and limestone kilns, rice mills, bakeries, boilers and distilleries.

The transport sector consumes 13 per cent of the total supply of energy. This includes 61 per cent of petroleum which comprises almost the entirety of petrol and auto diesel. The commercial sector accounts for 5 per cent of the total supply of energy while agricultural and fisheries sector where only a small proportion of diesel and kerosene accounts for approximately 1 per cent of total energy consumption.

This paper attempts to identify the different sources of energy, their relative importance and future prospects while examining the characteristics associated with energy consumption. A separate paper published under the same series of publications discusses

the energy demand and pricing policies of energy elaborately and hence this paper does not intend discussing the issues relating to pricing but, some observations will be made on the demand for energy. However, the main scope of the paper is limited only for discussing the sources of energy and sectoral composition of energy consumption in Sri Lanka. Section 2 of the paper will examine the composition of various sources of energy while section 3 will discuss the future prospects for the different sources of energy. Section 4 of the paper will cover the major characteristics of the various energy consuming sectors with special reference to energy mix and the purpose of using energy at the end-users point. In section 5, a summary will conclude the paper.

2. SOURCES OF ENERGY

Energy is obtained from both primary and secondary sources (See, Figure 1). Primary sources such as hydro power, fuelwood and other sources of biomass are available locally while petroleum and coal are imported. Some of these primary energy products have to be processed locally to obtain energy in different forms to suit the end use. Crude oil is transformed into various forms of petroleum products such as petrol, diesel, kerosene, furnace oil, Liquified Petroleum gas (LP gas), aviation fuel and naptha. In addition to locally refined quantities, certain refined petroleum products are imported in sizeable quantities in order to meet the short-fall in the refinery output specially when the refinery is closed for maintenance. Certain by-products of the petroleum refinery such as naptha are exported as there is no local

demand while bunker and aviation fuel are sold to foreign ships and aircrafts fuelled in sea and airports in Sri Lanka.

Petroleum is transformed into a secondary source of energy viz. thermal power when electricity is generated using diesel and other forms of residual fuel. Thermal power has been a significant source of energy in the past, particularly during drought periods when hydro-power potential was less. Although quantity-wise relatively small, charcoal is another form of secondary source of energy which is produced from wood or coconut shell on a commercial basis for both internal and export markets.

In Sri Lanka, approximately 30 per cent of the primary sources of energy is used to produce usable form of energy such as thermal power and various petroleum-based products. In drought periods, this proportion was somewhat higher than in normal periods. Approximately, 5 per cent of the total energy that is produced is lost in the process of production, transformation, distribution and transportation of energy. A small proportion of energy is consumed by the energy sector itself to operate machinery and equipment in its process of converting energy from primary sources to secondary sources. As a result, only 95 per cent of primary energy is available for end users for their consumption.

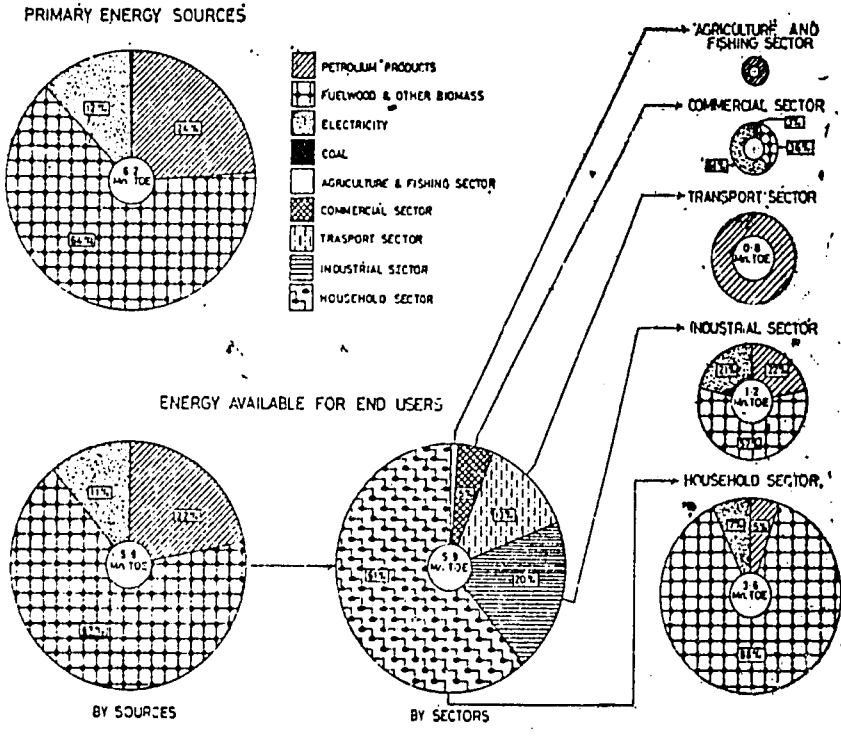
Energy sources are divided into commercial and non-commercial sources mainly on the basis of the characteristics associated with their availability, transportation, convenience of use and efficiency. According to recent estimates, approximately 64 per cent of

the primary energy is obtained from non-commercial sources of energy while commercial sources of energy account for the balance 36 per cent. However, taking into account, the amounts of petroleum and electricity that is lost in transmission, distribution, transportation and handling, the share of commercial energy is reduced to 33 per cent of the total supply of energy at the point of end users consumption. Accordingly, of the net energy available, traditional fuel accounts for 67 per cent while the shares of electricity and petroleum were 11 per cent and 22 per cent respectively. Within the commercial energy sector, petroleum and electricity account for 66 per cent and 34 per cent respectively. Figure 1 shows the supply by various sources of energy and the sectoral composition of energy consumption by different sectors of the economy in 1991.

Although more than a two-third of the energy is from non-commercial (traditional) energy sources, in terms of efficiency petroleum, electricity and other commercial energy sources are superior. This factor is taken into account, when actual availability of useful energy is estimated using a common unit of measurement i.e. Tons of Oil Equivalent (TOE). Losses at the point of consumption is very high in the case of non-commercial energy largely due to primitive methods of using such energy particularly in the household sector. However, the loss of energy due to inappropriate use cannot be measured due to practical constraints. Therefore, it should be noted that most of the technical and practical constraints, may result in over-estimation of the significance of traditional (non-commercial) energy particularly at the point of consumption.

FIGURE I

SOURCES OF ENERGY AND SECTORAL COMPOSITION OF ENERGY CONSUMPTION IN SRI LANKA (1991)



2.1 Commercial Energy

Of the total supply from all sources of energy, the share of commercial energy increased from 27 per cent in 1977 to 30 per cent in 1987 and further to 33 per cent in 1991. This was equivalent to 1.9 million TOE in 1991.

2.1.1 Petroleum Products

Total supply of petroleum which was estimated at 1.3 million TOE in 1991 is the largest source of commercial energy used in Sri Lanka. The energy conservation measures adopted by the authorities and enhanced capacity of electricity resulted in a considerable improvement in the use of domestic sources of energy thus reducing the relative importance of more costly and imported petroleum products in recent years. Of the commercial energy sources, the share of petroleum products declined from 81 per cent in 1970 to 76 per cent in 1977. This proportion which reduced to 72 per cent in 1983 declined continuously and stood at 66 per cent in 1991. However, in terms of quantity, energy from this source increased by an average of 3 per cent annually, over the period 1977-1991 as against an annual average decline of 3 per cent during the period 1970-1977.

The reduction of the relative share of petroleum as a source of energy was due to increased substitution of domestic sources such as electricity and biomass for petroleum. With the expansion of infrastructure facilities of electricity accompanied by a gradual growth in generation, electricity was increasingly substituted for kerosene in activities where such

substitution was possible. This substitution was encouraged by higher relative prices of petroleum products in the domestic market that continued to increase even after 1983 since when the prices in the world market decreased. These price trends were also responsible for increased demand for fuelwood even from urban consumers in spite of the availability of kerosene and LP gas. However, LP gas has become an increasingly popular source of energy in households for cooking due to convenience and efficiency.

At present, the supply of petroleum products constitutes 41 per cent of auto diesel, 17 per cent of furnace oil, 14 per cent each of petrol and kerosene, 6 per cent of aviation fuel, 3 per cent each of LP gas, heavy diesel and small proportions of residual oil, naptha and other products. Except kerosene which declined marginally, the supply of all other major petroleum products increased over the period 1977-1991. During this period, of the total supply of energy from all sources in the country put-together auto diesel, the largest single petroleum product accounted for 10 per cent while the shares of petrol and furnace oil were approximately 3 per cent each. Relative importance of kerosene in the total supply of energy dropped from 6 per cent in 1977 to 3 per cent in 1991 while LP gas which was negligible in 1977 accounted for approximately 1 per cent of the country's total supply of energy in 1991.

Heavy diesel and furnace oil are sources of motive power and heat for the industrial sector. During the periods 1980-1984 and 1987-1988, and in the year 1991, large quantities of heavy diesel and

furnace oil were used for electricity generation. However, in recent years, almost the entirety of power generation was from hydro sources due to favourable rainfall that did not require much thermal power generation. The use of heavy diesel and furnace oil in these periods were therefore, mainly by the industrial sector.

In the long run, the importance of heavy diesel and furnace oil has varied depending on thermal power generation. Heavy diesel, which generally accounts for about 2 per cent of total sales of petroleum products accounted for a higher share of more than 6 per cent in the years when thermal power was largely utilised. However, the use of heavy diesel for power generation decreased with the installation of the Sapugaskanda power plant in 1984 with a capacity of 80 mW where residual oil is also used as a substitute for heavy diesel.

Petrol and auto diesel are the sources of energy for motorised transport in Sri Lanka as in the other countries. Petrol is predominantly a private transport fuel.

Kerosene is the main source of illumination in households particularly in rural areas. Kerosene is also used by the household sector as a source of energy for cooking but, its relative share is very insignificant. The household sector accounts for about 89 per cent of the total energy from this source. The balance 11 per cent of the energy from this source is accounted for by agricultural activities such as water pumping, fisheries activities, light industries etc.

The importance of LP gas, as a source of energy, increased from 1,634 metric tons in 1977 to 37,521 metric tons in 1991, reflecting an annual average growth of 27 per cent over the period 1977-1991. The use of LP gas is predominant in the household sector as a source of energy for cooking and this activity accounts for about 80 per cent of the total supply of LP gas. The commercial sector which accounts for the balance 20 per cent largely comprised of hotels and restaurants where LP gas is heavily used for preparation of food.

The larger quantity of LP gas required for local demand is produced at Sapugaskanda refinery of the Ceylon Petroleum Corporation (CPC) and the shortfall is imported from abroad. The importation and local distribution of LP gas is handled by the Government Owned Business Undertaking (GOBU) of Colombo Gas and Water Company. In 1991, a total 37,522 metric tons of LP gas were consumed in the country while the production in the refinery amounted to only 18,890 metric tons. Salient features of the petroleum sector for two selected years i.e. 1977 and 1991 are given in Table 1.

TABLE 1

Salient Features of the Petroleum Sector

Item	Units	1977	1991
Quantity Imported			
Crude Oil	Metric Tons	1,529,629	1,625,522
Refined Products	Metric Tons	77,939	215,753
Other	Metric Tons	17,810	25,801
Value of Imports	Rs. Million	1,451.69	12,887.20
	SDR million	139.32	227.00
Average Price of Crude Oil	Rs./barrel	113.11	886.76
	US$/barrel	13.15	19.50
Value of Exports	Rs. Million	892.50	3,289.40
	SDR million	85.65	58.10
Production			
Petrol	Metric Tons	103,348	138,074
Auto diesel	Metric Tons	276,620	404,578
Heavy/Super/Marine	Metric Tons	91,708	57,832
Kerosene	Metric Tons	185,447	151,233
Furnace Oil	Metric Tons	545,349	569,949
LP gas	Metric Tons	3,101	18,890
Consumption			
Petrol	Metric Tons	111,491	159,765
Auto diesel	Metric Tons	261,988	539,983
Heavy/Super/Marine	Metric Tons	67,165	52,517
Kerosene	Metric Tons	212,886	173,425
Furnace Oil	Metric Tons	154,292	204,356
LP gas	Metric Tons	1,634	37,522
Local Prices			
Petrol	Rs./Litre	2.93	30.00
Auto diesel	Rs./Litre	1.16	11.00
Heavy diesel	Rs./Litre	1.12	10.60
Kerosene	Rs./Litre	0.76	8.80
Furnace Oil, 500 seconds	Rs./Litre	0.99	6.55
LP gas	Rs./kg.	2.63	17.31

Source : Ceylon Petroleum Corporation.

2.1.2 Electricity

Hydro power is the largest domestic source of commercial energy in Sri Lanka. The first hydro power plant set up in Sri Lanka was old Laxapana in 1950 with an installed capacity of 50 mW. In recognition of the great importance of developing domestic sources of energy and the vulnerability of the high dependence on imported energy, successive governments, particularly in the recent past gave high priority to harnessing the hydro power potential of the country. The hydro power projects that have been installed since 1950 to-date with their capacities and commissioning dates are given in Table 2.

The bulk power generation for distribution in urban areas began in early 1930s using small diesel generators. The maintenance of the electrical system came under the Department of Government Electrical Undertaking with the licenses issued to local authorities who generated and distributed electricity in urban areas covered by the licenses. The large government, business and commercial establishments had their own generators and some of them who had excess capacity, supplied electricity to others institutions that were in the close proximity.

In 1969, the Department of Government Electrical Undertaking was converted to a statutory board, namely, the Ceylon Electricity Board (CEB), which was entrusted with the responsibility of developing and maintaining an efficient, co-ordinated and economical system of electricity supply in Sri Lanka. The then existing power stations with an installed

capacity of 256 mW were vested in the newly formed CEB. Of this total capacity of 256 mW, the hydro power component was 192 mW and the remainder constituted oil fired steam turbines with 50 mW and diesel generators of 14 mW.

In 1984, Lanka Electric Company (Pvt.) Ltd. was set up to take over the function of distribution of electricity in suburban areas in Colombo. The objective of forming this new organization was to overcome the shortcomings experienced in the system when distribution was handled by local authorities. Some local authorities were in arrears of payments to the CEB on account of their bulk purchases and very often consumers experienced low voltages and unreliable supply in areas where local authorities were responsible for distribution.

The significance of electricity as a source of power increased steadily in the past and as a result, its share in the total supply of energy increased from 4 per cent in 1970 to 6 per cent in 1977 and to 11 per cent in 1991. As the government took steps on a priority basis to harness the hydro power potential in the country, the installed capacity of electricity increased from 402.25 mW in 1977 to 1289.65 mW in 1991. Of this increase of 887.40 mW of installed capacity, the hydro power component was 685.20 mW and as at the end of 1991, the shares of hydro and thermal power remained 1017.25 mW and 272.20 mW respectively. However, installed thermal power capacity of 272.20 mW is now derated to 238.2 mW due to technical reasons.

TABLE 2

Installed and Generation Capacity of Hydro and Thermal Power (as at 1992)

Name of the Plant	Installed Capacity (mW) Units X capacity		Annual Electricity Generation (gWh/yr) Long-Term Expected	Commissioning Date
Hydro Laxapana Complex				
Canyon	(2X30)	60	161	Unit 1 Mar. 1983 Unit 2 1988
Wimalasurendra	(2X25)	50	112	Jan. 1965
Old Laxapana	(3X8.33) (2X12.5)	50	289	Dec. 1950 Dec. 1958
New Laxapana	(2X50)	100	491	Unit 1 Feb. 1974 Unit 2 Mar. 1974
Polpitiya	(2X37.5)	75	427	Apr. 1969
Sub Total		335	1480	
Mahaweli Complex				
Victoria	(3X70)	210	726	Unit 1 Jan. 1985 Unit 2 Oct. 1984 Unit 3 Feb. 1986
Kotmale	(3X67)	201	482	Unit 1 Apr. 1985 Unit 2 Feb. 1988 Unit 3 Feb. 1988
Randenigala	(2X61)	12[illegible]	378	Jul. 1986
Ukuwela	(2X20) (now derated to 19mW)	40	177	Unit 1 Jul. 1976 Unit 2 Aug. 1976
Bowatenna	(1X40)	40	53	Jun. 1981
Rantambe	(2X24.5)	49	216	Jan. 1990
Sub Total		662	2032	

TABLE 2 (Cont)

Name of the Plant	Units X capacity		(gWh/yr)	Commissioning Date		
Small Hydro Complexes						
Inginiyagala	(2X2.475+ 2X3.15)	11.25	n.a.		Jun.	1963
Uda Walawe	(3X2)	6	n.a.		Apr.	1969
Nilambe	(2X1.6)	3.20	15		Jul.	1988
Sub-Total		20.45				
Total installed capacity of existing hydro Plants	1017.45	3512				
Under Construction						
Samanalawewa	(2X60)	120	357	Before end		1993
Total hydro plants	1137.45	3869*				
Thermal						
Chunnakkam (Diesel)	(1X14)	14	n.a.			1959
Kelanitissa Gas Turbines	(6X20) (now derated 6X18)	120	n.a.			
				Unit 1	Nov.	1980
				Unit 2	Mar.	1981
				Unit 3	Apr.	1981
				Unit 4	Dec.	1981
				Unit 5	Apr.	1982
				Unit 6	Mar.	1982
Kelanitissa (Steam)	(2X25) (now derated to 2X22)	50	n.a.	Unit 1	Jan.	1962
				Unit 2	Sep.	1963
Sapugaskanda (Diesel)	(4X20) (now derated to 4X16)	80	n.a.	Unit 1	May	1984
				Unit 2	May	1984
				Unit 3	Sep.	1984
				Unit 4	Oct.	1984
Gas Turbine-Cement Factory	(8.2)	8.2	n.a.			1989
Total installed capacity of Thermal	272.2					

*Excluding the generating capacity of small hydro Plants.

Sources : Ceylon Electricity Board Report on Long-term Generation Expansion Planning Studies 1993-2007.

During the period 1977-1991, the hydro electricity generation increased at an annual average rate of 9 per cent. Thermal electricity is mostly used for meeting the shortfall in the supply of hydro-electricity in drought periods and therefore, a clear trend in respect of thermal power cannot be established. At present, in Sri Lanka, thermal power is based on furnace oil, heavy diesel, auto diesel and residual oil. In the past, the importance of thermal power varied with the changes in the weather pattern in the country. In periods of adequate rainfall, generation of thermal power was required only marginally to meet the peak demand.

With the increased availability of electricity more emphasis was laid on improving infrastructure facilities in rural areas. Attributable to the implementation of several rural electrification schemes and expansion of transmission and distribution facilities, of the total households in the country the number of households with access to electricity increased from 10 per cent in 1977 to 16 per cent in 1982 and further to 25 per cent in 1990.

The actual level of consumption does not reflect the actual demand for electricity due to pent-up demand which is very high. The pent-up demand is mainly in the household sector where approximately 75 per cent of the households in the country does not have access to electricity. Further, it should be noted that a sizable proportion of households which are within the reach of electricity lines have not obtained power connections due to their inability to meet the initial costs. Altogether the household sector

accounts for more than 36 per cent of the total electricity provided through the National Grid. This was an increase from 30 per cent in 1977. Salient features of the electricity sector for 1977 and 1991 are given in Table 3.

TABLE 3
Salient Features of the Electricity Sector

Item	1977	1991
Installed Capacity (mW)	402.3	1,289.5
Hydro	332.3	1,017.3
Thermal	70.0	272.2
Electricity Generation (million kWh)	1,216.5	3,376.7
Hydro	1,214.4	3,116.2
Thermal	2.1	260.5
Electricity consumption (million kWh)	1,216.5	3,376.7
Loss in transmission, distribution etc.	180.0	611.7
Electricity Sector	9.9	22.6
Electricity available for end-use (Mn kWh)	1,026.6	2,742.4
Industrial	557.3	1,048.8
Domestic	309.4	1,012.4
Commercial	147.9	639.9
Religious purposes	5.0	19.8
Street lighting	7.0	21.5

Sources : Ceylon Electricity Board ;
Sri Lanka Energy Balance and Energy Data (1991).

2.1.3 Coal

Coal does not form a major source of energy in Sri Lanka and its relative share of the total supply of energy has always been less than one per cent. Coal is imported in small quantities in different forms such as coke and semi-coke, anthracite and lignite. In 1991. 2,425, metric tons of various forms of coal worth Rs. 34 million were imported from seven different countries, mainly Australia, U.K. and Belgium. This will be a major source of energy in Sri Lanka in the future with the commencement of coal fired power generation plants. The first coal plant with a capacity of 150 mW will come into operation in year 2000.

2.2 Non Commercial Energy

The non-commercial energy sources such as fuelwood, agricultural residues and other ligno cellulose matter have been the sources of energy which were approximately 3.9 million TOE in 1991. These sources were responsible for about 73 per cent of energy from all sources put together in 1977 but this share reduced to a level around 70 per cent in early 1980s and further to 67 per cent in 1991. However, in volume terms, the supply of energy from non-commercial sources increased at an annual average rate of 2 per cent over the period of 1977-1991. According to detail estimates, more than 67 per cent of non-commercial energy comes from fuelwood alone and another 18 per cent is from the waste matter of coconut trees,

while the balance comprises of agro-wastes such as bagasse, tea, rubber and minor crop residues, paddy husk, saw dust and animal waste. Relative shares of the various sources of non-commercial energy is given in Table 4.

According to the Consumer Finances and Socio-Economic Survey (CFS) 1986/87 of the Central Bank, 25 per cent of fuelwood was obtained from rubber trees while the rest (75 per cent) was from other light and hard wood. Approximately 50 per cent of rubber wood was purchased by users, but more than 88 per cent of the other wood was collected free of charge from forests, own gardens etc, by the consumers. In the urban sector approximately 80 per cent of non-commercial energy is from fuelwood, of which 65 per cent is purchased by consumers from the market. Coconut residues such as husks, shells, trunks etc, contribute approximately 15 per cent of the non-commercial fuel used by the urban sector. These wood residues are obtained from own gardens or vegetation in the neighbourhood. Almost the entirety of tea residues are used by the estate and rural sectors. Consumers in both the rural and estate sectors do not purchase tea residues at all and their needs are collected from nearby tea plantations. However, the consumers in the urban sector have to purchase their fuelwood requirement in the market and therefore, expenditure on fuelwood is a significant component of their household budget. The collection and distribution including transportation and sale of

TABLE 4
Sources of Non-Commercial Energy

(in percentages)

Sources	Household Sector	Industrial Sector	Commercial sector	All Island
Fuelwood and other hard and light wood	69.8	54.6	79.2	67.3
Coconut residues	20.0	9.9	20.5	18.1
Tea plant residues	1.4	—	—	1.1
Rubber plant residues	5.0	2.1	—	4.4
Minor crop residues	1.0	—	—	0.9
Paddy husk	2.3	16.2	—	4.7
Bagasse	—	15.7	—	2.8
Charcoal	—	1.5	0.3	0.3
Saw dust	0.5	—	—	0.4
	100	100	100	100

Note: — Negligible.

Source: Based on primary data provided in Sri Lanka Energy Balance and Energy Data 1991.

fuelwood are handled mainly by the private dealers. Over 47 per cent of fuelwood used in the urban sector is obtained from uprooted rubber plantations. Due to competitiveness in the market, price of fuelwood is largely determined according to market forces. The (all island) average price of fuelwood was Rs. 9.72 per 50 kgs. in 1979 and this has increased to Rs. 60 per 50 kgs. in 1991 according to official sources of price data. The present price of fuelwood is slightly higher than this. The main reasons for high fuelwood prices were high costs of uprooting, logging and transportation.

In addition to the traditional sources of non commercial energy, a fair amount of energy from sun light, wind, human and animal power are used in activities even on a commercial basis to some extent. Direct solar power is used for drying chillie, rice, pepper, cinnamon and other agricultural produce and in the laundry industry and extraction of salt from sea water. In early years human power was used in most of the activities in rural areas while animal power was the most used energy in agricultural work, particularly in paddy fields and rural transportation. However, importance of human and animal power in agricultural activities is diminishing with the adoption of modern technology and hence its share is relatively insignificant today as compared with the other sources of energy.

3. POTENTIAL SOURCES OF ENERGY

The successive governments have taken positive steps to exploit the domestic energy resources particularly since 1973 when the first oil crisis took place.

One objective of this policy was to reduce the dependence on imported energy sources by way of optimising the use of indigenous energy resources. In recognition of this fact, most energy development plans and efforts in the country in recent years centered on new and renewable energy sources with a domestic origin.

The two major indigenous resources of energy already exploited to some extent in Sri Lanka are hydro power and fuelwood. Any substantial fossil fuel resources such as oil, gas or coal have not been discovered as yet and thier availability is not known. Therefore, the country's total requirement of petroleum is imported either as crude oil to be refined locally or as finished products at a considerable drain on foreign exchange earnings. Sri Lanka is generally rated as an attractive area for oil exploration and some efforts have been made in this respect since early 1970s. However, these efforts have been unsuccessful upto now in spite of no strong evidence in favour to rule out the existence of oil and gas deposits. Lack of equipment, expertise and large capital investment required to launch a major exploration has hindered the progress in search of oil in Sri Lanka. Therefore, the dependence of hydro based electric power and other new and renewable sources of energy will increase further in the future. However, to meet the future energy demand, options of coal fired thermal systems and nuclear based thermal systems are also considered.

3.1 Resource Potential of Hydro Power

Sri Lanka has already developed 1137.45 mW (including Samanalawewa with a capacity of 120 mW) of installed capacity of hydro power capable of generating an average of 3869 gWh, per year.

According to the Master Plan Study (MPS), 1989 for supply of electricity in Sri Lanka by, Deutsche Gesellschaft Fur Technische Zusammenarbeit (GTZ) and CEB, a total of 103 rivers and streams in Sri Lanka has a potential for development of hydro power. Due to favourable climate and topographical conditions, the hydro, electric potential is substantially high. The main rivers with a high potential are, Mahaweli including the Uma Oya and Kotmale tributaries, Kelani and its tributaries, Walawe, Kalu, Gin, Nilwala and Maha Oya.

Part of the hydro power potential of Kelani and Mahaweli river basins have been already harnessed but more potential remains specially in Mahaweli and in its major tributaries such as Kotmale Oya and Uma Oya. Taking the cost factors into account, the projects capable of generating electricity with a long term average cost of less than 15 US Cts./kWh (at 1988 prices) were considered. The economically exploitable potential of untapped hydro power resources in Sri Lanka have been estimated to be about 870 mW capable of generating 3,680 gWh per year under average hydrological conditions. It will be required to develop 27 sites to harness this remaining hydropower potential. A list of potential power projects considered in Long Term Generation Expansion Plan — 1993-2007 with their expected installed capacities and generation capacities are given in Table 5.

TABLE 5

Potential Hydro and Thermal Power Plants

Project/Plant	Installed Capacity (mW)	Annual Electricity Generation (gWh)	Total Construction Cost (U$/kWh)
Hydro			
Upper Kotmale	123	539	1,574.1
Kukule	70	305	1,858.1
Ging Ganga	49	205	1,879.6
Belihul Oya	17	71	2,129.7
Broadlands	40	145	2,246.6
Moragolla	27	111	2,660.1
Uma Oya	150	447	1,900.8
Thermal			
Diesel	20	—	1,281.1
Coal Trinco Unit 1 Unit 2	150 150	—	1,616.0
Coal Trinco Unit 3 Unit 4	300 300	—	1,084.9
Gas Turbine	22	—	997.3
Combined Cycle	68	—	586.2
Gas Turbine (rehabilitation)	20	—	130.3

Source : Report on Long-Term Generation. Expansion Planning Studies, 1993-2007.

3.2 Mini Hydro Power

Until the mid 1950s, most of the tea factories in the country depended on power from Small Hydro Power (SHP) plants for their operations. However, with the increased popularity of the use of diesel engines for power generations and availability of electricity from the National Grid, the SHP plants were abandoned.

However, in the mid 1970s several attempts have been made to assess the SHP potential in the country and the latest available study of the GTZ Master Plan has identified 492 SHP sites with a capacity of 88 mW in the island.

The government has taken some steps to encourage the development of SHP projects for independent power applications. Priority has been given to the rehabilitation of abandoned mini hydro-power projects which were previously in operation. A total of about 40 SHP plants have been rehabilitated under a programme assisted by the World Bank and Integrated Rural Development Projects (IRDP) in the various districts.

3.3 Bio-mass Resources

In the past, increased attention has been paid on the conservation and efficient use of fuelwood in the household sector. As an increasingly large quantity of fuelwood which is more than 8.0 million tons at present is consumed by the household sector annually, the growing scarcity of fuelwood has directly become a serious problem. The scarcity of fuelwood

has affected particularly the rural poor who have been depending on collected fuelwood to meet their needs of household energy. The problem has worsened over the years due to the uncontrolled exploitation of forests, denudation by neglect and soil erosion and diversion of forest lands into crop lands and for other purposes.

According to the Forestry Master Plan for Sri Lanka, the present demand for fuelwood is around 9.5 million tons per annum and this is expected to reach 12.2 million tons by the year 2,000. A shortfall of wood resources is expected to occur in the country by this time. According to available forecasts, there will be an increasing scarcity of fuelwood in most parts of the country mainly in the Wet Zone, except in urban areas where more efficient alternatives are available for substitution of fuelwood to other sources such as electricity and LP gas.

Under the replantation programmes, a total area of 151,680 hectares of planting is envisaged during the period 1986-2000. This would include 34,880 hectares of regeneration plantations in existing plantations, 42,600 hectares of new industrial plantations, 27,000 hectares of block fuelwood plantations, 36,000 hectares of farmers wood lots and 11,200 hectares of protection plantations. However, due to the resource limitation and unsettled conditions resulting from periodic civil disturbances in the country, these targets were not reached and only 32,000 hectares of forest plantations have been established upto 1990 and it is expected to plant a further 80,000 hectares during the period 1991-2000. In addition to this,

certain private sector and public sector organisations such as the Janatha Estates Development Board, Sri Lanka State Plantations Corporation, Ceylon Cement Corporation, Sri Lanka Sugar Corporation and Ceylon Tobacco Company etc. have started their own fuelwood plantations.

Shortage of fuelwood will encourage people to shift to commercial energy sources such as electricity, kerosene and LP gas to meet the household energy requirement. With only limited hydro power resources available and high cost of imported fuel, such substitution may not be desirable in the long run. Therefore, the government attention must be focused on conservation possibilities in order to ease the pressure on available forest resources while implementing long-term enhancement measures.

Energy conservation has become an integral part of the energy policy. As fuelwood and kerosene are the major sources of energy used for cooking purposes, significant quantities of domestic fuels can be saved by way of improved stoves and cooking utensils. Fuelwood, agricultural residues and other traditional energy sources are inferior to commercial energy sources in terms of efficiency. It is estimated that the average efficiency of the use of these sources is around 7 per cent. More efficient use of fuelwood and agricultural residues would assist in meeting the growing fuelwood demand to a great extent. Some steps have been taken in this respect and they include—

(i) development of fuel efficient wood stoves for use in households ;

(ii) provision of incentives for using energy efficient cookers ; and

(iii) a programme to encourage energy thrift among consumers through mass media.

To promote efficient use of fuelwood, a wood stove development programme has been initiated in 1984 under the National Fuelwood Conservation Programme launched with the auspices of the Ministry of Power and Energy. According to available information, approximately 300,000 fuelwood efficient stoves had been distributed in several districts under this programme with assistance of the IRDP and Dutch Assistance Programme initially. This programme of popularising efficient wood stoves which has commenced in 1985 has enabled more economical use of fuelwood in households although marginally.

According to the estimates, however, this scheme is expected to reduce fuelwood consumption by 25 per cent by way of increasing the efficiency of fuelwood use by about 20 per cent. If these targets are achieved, this programme would save 9,000 tons of fuelwood annually. This is equivalent to a fuelwood plantation of 900 hectares or preventing complete denudation of 72 hectares of forest land within the life span of the stove This saving can provide annual energy needs of 3,000 average families. This scheme will also provide increased employment opportunities in the pottery industry.

It has been found that further efficiency can be obtained by replacing more efficient design to the present two piece pottery liner. In the urban sector,

the estimated demand for cooking stoves is about 100,000 annually. Several Ayurvedic hospitals, small hotels, cottage industries such as batik and juggery making and bakeries have been installed with improved stoves.

3.4 Use of Agricultural Residues

Agricultural wastes represent a significant potential energy source in Sri Lanka. In some parts of the country agricultural wastes such as rice husk, coir dust, saw dust are available in plenty, but they are either partly or not fully utilised. Other bio-mass wastes such as that obtained from forests, rubber and coconut trees, sugar cane etc. are being used as fuel or put into other uses. Therefore, the possibility of efficiently utilising rice husk, coir dust and saw dust as energy sources could be considered as a significant potential source of useful energy. The annual availability of agricultural wastes is estimated at 5.6 million tons and of this total, only 3 million tons are being used as energy.

3.4.1 Rice Husk

At present rice residues such as paddy straw, and husk are used to generate heat mainly for parboiling of rice, firing of industrial dryers, boilers, etc. and in domestic cooking stoves. Major part of paddy husk is burnt in heaps near paddy mills for disposal.

The main problem of utilising rice husk for industrial heating is the high cost of briquetting and transport. Briquetting of rice husk has not been very successful due to high wear and tear of briquet-

ting machines. An effort should be made to utilise rice husk as a fuel in industries which are in the close proximity to paddy mills. Rice husk can be burnt efficiently in cyclone furnaces for firing of boilers and generate steam and may be electricity for industries. Therefore, to utilise rice husk as an energy source mainly in rural industries, should be encouraged. Improving the efficiency of cooking stoves, development of gasifiers should be pursued. The annual availability of paddy husk is estimated to be around 500,000 metric tons in 1991.

3.4.2 Coir Dust.

About 150,000 metric tons of coir dust is produced annually as a by-product of the coconut fibre industry. The unutilised stock of coir dust which is accumulated over the past years is estimated to be about 4 million metric tons at present. Coir dust contains about 90% moisture when discharged from fibre mills. Before use as a fuel, coir dust has to be dried but it is uneconomical to do so in conventional dryers due to substantial waste of net energy. Sun drying is a problem due to lack of space suitable for the purpose. However, trials carried out by certain private firms by mechnical dewatering and solar drying of coir dust before briquetting have proved successful. Coir dust briquettes which can be used effectively as an industrial fuel is an attractive alternative for fuel oil. Another possibility is to palletise after sun-drying and use in cement factories for firing of the kilns as a pulverised fuel as a substitute for imported oil or coal.

3.4.3 Saw Dust

Saw dust is used as an energy source in industrial activities and as a domestic cooking fuel. This source of energy can be utilised more efficiently with marginal improvements in stoves and in the designing of furnaces for firing as an industrial fuel. As in the case of coir dust, saw dust has to be processed before use as an effective source of energy. Experiments carried out in briquetting have proved successful but, the net energy loss in the process of briquetting and drying is quite large.

3.5 New and Renewable Energy Sources

Solar radiation, bio-gas, ocean thermal energy and wind power are the other major sources of energy that are generally available but these require large capital investments and hardware for collection and conversation into useful forms. The cost of these processes of transformation is higher in comparison with conventional sources, except in special applications.

3.5.1 Bio-gas

In the search for cheap indigenous sources of energy, many countries (both developing and developed), have recognized the need to advance bio-gas technology. A great potential remains in developing agro-based bio-gas in developing economies. Bio-gas is obtained from decomposing animal and vegetable waste matter and the process should be carried out in specially built air-tight compartments. Cattle dung, either alone or mixed with cattle urine is the

most common input used. A few of the plants use human excreta or other animal waste such as poultry or pig dung and leaves of ipil ipil. These plants are capable of prevailing sufficient power for lighting, cooking and for small scale industries. Waste material in bio-gas plants has a high content of fertilizer while the environmental problems associated with the process are minimal.

As an agriculture based economy with a farming tradition, Sri Lanka can take advantage of bio-gas potential as an alternative household fuel. In the early 1980s, an effort was made to popularize bio-gas plants to provide energy for lighting and cooking. In addition, attempts have been made to introduce bio-gas plants at community level for providing electricity to model villages. However, in a recent study carried out by the Ministry of Power and Energy it has been found that bio-gas plants are not successful at community level even for the purpose of recharging batteries and the existing bio-gas plants are negligible in terms of energy requirements at national level. Most of these plants are not in a position to be operated regularly due to maintenance problems and also lack of raw material.

There are a few common problems faced by households with bio-gas plants such as the non-availability of a suitable gas tap. Although recently cheap and very efficient gas taps have been manufactured and were made available in the market the other connected problems such as the lack of repair and maintenance facilities for bio-gas operated cookers and lamps continued to prevail. According to a sample survey (Wijesinghe, 1986), the average cost of

constructing a 6m fixed dome plant in 1984 was Rs. 3,200 and at today's price this ranges between Rs. 4,500 to Rs. 6,000. The costs of construction of most of the household bio-gas plants were totally or partly subsidised by state institutions as a part of their promotional activity.

It is evident from available information that even in households where sufficient dung for a bio-gas plant is available, most people cannot afford the capital costs required to construct a plant. Subsidies for construction are therefore, necessary for household bio-gas programme to expand. Evidence (Wijesinghe, 1986) suggests that operating costs of lighting and cooking with bio-gas is substantially lower than kerosene and LP gas.

3.5.2 Solar Photovoltaic

Solar energy for lighting and operation of electrical appliances is one of the major potential sources of alternative energy for electricity. Solar power is universally available as a clean, free and abundant source of energy and can be harnessed through Solar Photovoltaic (SP) technology. The average solar insulation over Sri Lanka is around 5 kWh per square metre per day. Photovoltaic panels can convert solar radiation directly into electricity and electric power which is generated from this source can be used for battery charging, water pumping, lighting of dwelling houses and drying purposes. However, photovoltaic technology is not a cheap method that can be adopted to meet the energy needs of the poor at least for the next decade. Yet it has developed to a stage where

photovoltaic panels can be used in rural areas to provide electricity to large entities such as hospitals, schools, and community centres.

Certain steps have been taken to encourage the use of photovoltaic based rural electrification systems in recent years. The Ceylon Electricity Board and the Ministry of Power and Energy have initiated a programme to popularize the solar photovoltaic systems in rural areas as a source of energy for lighting and to operate TVs and radios and other small scale applications. The government action has resulted in popularizing and commercialising this technology to some extent. A large number of private sector firms have ventured into solar photovoltaics module production. Vendors also have found this to be an attractive business activity. Solar photovoltaic panels are used mainly in areas where electricity from the national grid is not available.

In an evaluation on the use of photovoltaic systems, it was observed that more than 75 per cent of the users have found that the system is a worthwhile investment while the other users were satisfied with the performance of the solar panel but they have encountered problems in the quality of lamps and batteries available. A major problem in popularizing solar photovoltaic among the average consumer is the high initial cost which varies from Rs. 6,000 - 20,000 depending on the type of the panel. The National Engineering Research and Development centre, the Ceylon Electricity Board and some other public and private sector institutions have conducted a great deal of research and development work on the use of solar thermal power for meeting energy requirements.

3.5.3 Windmills

Sri Lanka is exposed to two monsoons with strong reliable winds and therefore, the utilisation of wind energy is a promising sources of renewable energy in Sri Lanka. Use of wind energy for irrigation water pumping and small scale electricity generation appears particularly attractive.

A wind energy development programme with the assistance of the Government of Netherlands has been implemented to introduce suitable wind mills for water pumping for lifting irrigation in the dry zone areas of the country. Around 200 wind mills with a pumping capacity of about 10,000 gallons of water per day have been installed under this project.

A feasibility study, has been conducted to ascertain the wind and solar energy resource potential in some selected areas in the country with the objective of developing wind energy for large scale power generation. The initial results of the study have shown favourable prospects for large scale utilisation of wind energy in Sri Lanka.

3.5.4 Ocean Thermal Energy

The existence of deep sea close to the Island with a established temperature profile contributes to the potential for the ocean thermal energy. Further, the strong winds and wave action could contribute to useful energy exploitation from this resource. However, the technology available on the exploitation of these resources is still at experimental stages.

3.6 Fossil Fuel Based Thermal Power

At present, the thermal power plants ; Chunnakam (Diesel based - 14 mW), Kelanitissa (Steam 50 mW), Gas Turbines (120 mW), Sapugaskanda (80 mW), Kankesanturai (8.2 mW) are connected to the National Grid.

Owing to the limited hydro power potential in the country, the installation of thermal plants has been considered in the long-term power expansion plan. Thermal options which were already considered include diesel power plants (20 MW), gas turbines (22 mW), coal fired power stations (900 mW) and combined cycle - power plants (68 mW). The existing gas turbines (20 MW) are scheduled to be rehabilitated in about six to seven years time and therefore, the power system requires new plants with short-term capacity to meet the peak demand. Hence, diesel operated gas turbines with a similar capacity have been considered in the expansion plan.

Low sulphur residual oil will be used in the proposed diesel power plant while the proposed combined cycle power plants will be operated on light or heavy oils. Among the sites evaluated in the Master Plan, Trincomalee offers the cheapest location for installation of the coal power plant. All fuel oil and coal based thermal generation in Sri Lanka will continue to depend on imported primary sources of energy. The CPC enjoys the monopoly of importing, refining and distribution of petroleum products. During the periods when the refinery output falls short of the demand, certain products (mainly auto diesel) in refined form are imported. When coal power plants are installed, the entirety of coal inputs needs to be imported.

4. SECTORAL COMPOSITION OF ENERGY CONSUMPTION

The pattern of energy consumption is associated with characteristics exclusive to different sectors. Therefore, in order to enable the analysis in this section, sector-wise energy consumption will be examined. Standard sectoral classifications are used for this purpose and the analysis will cover the period 1977 through 1991.

The household sector is the largest energy consumer in the country. This sector accounts for about 70 per cent of the total energy consumed in the country in 1977, but this share which reduced gradually over the years reached a much lower level of about 61 per cent in 1991. However, the energy consumed by this sector in volume terms increased at an annual average rate of 2 per cent over the same period 1977-1991. The industrial sector energy consumption increased from 18 per cent of the toal in 1977 to about 20 per cent in 1991 indicating a 4 per cent annual average growth rate over the period 1977-1991. As an energy consumer, the relative importance of the transport sub-sector which is part of the services sector remained more or less unchanged over the period 1977-1991. The commercial sector which was responsible for approximately 1 per cent of the total energy consumption in late 1970s has become a major energy user since the 1980s due to the expansion in service and commercial oriented activities following the economic liberalisation steps since 1977. As a result, the commercial sector now accounts for more than 5 per cent of the total energy consumption in the country. The agricultural and fisheries sector is a consumer of diesel and kerosene although its relative share is quite small.

4.1 The Household Sector

The household sector consumption of energy in 1991 comprised approximately 7 per cent of electricity, 5 per cent of petroleum and 88 per cent of non-commercial energy. In aggregate terms, this sector consumes more than 22 per cent of commercial energy and 80 per cent of non-commercial energy.

However, as these figures include losses of energy in transportation, distribution and losses due to inefficient use, the relative share of non-commercial energy tends to be over estimated. In terms of efficiency, petroleum and electricity are much superior sources to non-commercial energy. Owing to the use of primitive methods of using energy particularly by the household sector a sizeable proportion energy from non-commercial energy is lost.

With the expansion of activity, the total consumption of energy by the household sector increased by a moderate rate of 2 per cent per annum over the period 1977-1991. During this period, changes in the consumption pattern in this sector was mix as the consumption of non-commercial energy increased by 2 per cent while electricity increased by 9 per cent annually. Although marginally the consumption of petroleum products declined over the same period and evidence available suggests that this was due to increased substitution.

Fuelwood and other traditional sources of energy are used for cooking by the household sector while commercial energy sources i.e. kerosene and electri-

city are mainly used as sources of lighting. The entirety of LP gas and relatively small quantities of kerosene and electricity are used as energy for cooking in households. Apart from the use for cooking, electricity is used for operating household electrical appliances such as air conditioners, televisions, radios, refrigerators, washing machines, and electric irons etc. Use of energy for water pumping and cleaning is negligible in this sector.

According to the CFS 1986/87 about 95 per cent of the households in the country used fuelwood for cooking while 3 per cent used LP gas. Only 2 per cent of the households used either kerosene or electricity for cooking. However, 6 per cent of the households which used fuelwood as the main source of cooking fuel, used either electricity, LP gas or kerosene as an alternative source of energy for cooking.

According to CFS data during the periods between 1981/82 and 1986/87, number of households using kerosene and electricity for cooking dropped considerably from 8 per cent to 2 per cent of the total households in the country. This may be due to the higher relative cost of kerosene and electricity. As an efficient and easy mode of household energy, LP gas has become increasingly popular mainly in urban areas since recent years.

Of the total households in the country, the use of kerosene and electricity for lighting accounts for 73 and 25 per cent respectively. Balance 3 per cent of the households, use electricity (including privately generated power), solar power, bio-gas or a battery connected power supply system (Prashakthi) for

illumination of their houses. However, CFS 1981/82 data shows that only 16 per cent of the houses in the Island had access to electricity from the National Grid and 84 per cent of the households used kerosene and other sources for lighting. The increase in electricity consumption is mainly in the urban sector where infrastructure facilities for electricity expanded considerably over the recent years. Improvements in electricity infrastructure facilities in the rural areas are mainly associated with the introduction of more rural electrification schemes particularly since late 1970s.

4.1.1 Energy Consumption by Sectors of the Economy

On the basis of socio-economic characteristics, the economy is traditionally divided into three main sectors namely urban, rural and estate sectors. According to the CFS 1986/87, of the total population, approximately 74 per cent lived in the rural sector, while the urban and estate sectors accounted for 19 per cent and 7 per cent, respectively.

A large proportion of the people who live in the rural sector are engaged in subsistence agriculture or agro-based activities. Employment opportunities available to rural masses in industrial and commercial activities are very minimal. Use of energy in manufacturing activity in this sector is therefore, very limited, due to the low level of industrial activity and the use of more labour intensive technology. Most of the large industries and commercial complexes are located in urban and suburban areas and in rural areas only small scale and cottage industries can be found. With the exception of rice milling which is associated with

paddy production, other small scale and cottage industries are based on labour intensive and age-old technology. Therefore, the consumption of energy in the rural sector is basically confined to household purposes such as cooking and illumination. Use of energy for operation of electrical appliances, water pumping for household purposes and other irrigation work is negligible in the rural and estate sectors mainly in activities of low income groups of the population.

The estate sector consists mainly of tea, rubber and coconut plantations, where advanced technology is used in processing activity and this sector accounts for more than 6 per cent of the total energy consumption of the country. However, plantation agriculture is mostly labour intensive and almost the entirety of the estate sector population consists of plantation workers whose living conditions are somewhat similar to that of rural people. Therefore, in so far as energy demand is concerned, rural and estate sectors are associated with somewhat similar characteristics which are exclusive from the urban sector.

Of the total energy consumed by the household sector, 73 per cent was utilised by the rural households while the urban and estate households account for 17 and 10 per cent, respectively.

4.1.1.1 Per Capita Energy Consumption by Sectors

Based on the information obtained from the CFS 1986/87 of the Central Bank and the energy balance compiled by the CEB for 1987, the per capita consumption of households in the rural and estate sectors was estimated at 209 and 281 Kilogrammes of

Oil Equivalent (Kg. OE) respectively. This was 196 Kg.OE in the urban sector. Although the urban and rural sectors indicate more or less similar per capita energy consumption levels, significantly different characteristics can be observed in the energy consumption pattern of these two sectors. Per capita annual energy consumption by sources and sectors of the economy are given in Table 6.

The increase in per capita energy consumption in the urban sector is due to the increased utilisation of electricity and LP gas resulting from the expansion of economic activities and improved quality of life; Reasons for the increased per capita energy consumption is quite the opposite in the estate sector where the consumption of traditional fuel is substantially higher. As observed in field work, the higher quantity of per capita fuelwood consumption in the estate sector gives the inference that fuelwood used in this sector is of a lower quality comprising mainly of branches or twigs of uprooted tea bushes which are relatively lower in efficiency.

According to the CFS data the all-island figure of per capita fuelwood consumption increased by 4 per cent during the period 1981/82 — 1986/87. In both the urban and rural sectors, per capita consumption of fuelwood increased by 3 per cent each, while the corresponding figure for the estate sector was 6 per cent.

In terms of absolute volumes, per capita fuelwood consumption is much higher in the estate and rural sectors than in the urban sector. This is due to the reason that the urban sector uses more hard wood while other two sectors use low quality firewood such as agricultural residues which are fired in low efficiencies. The proportion of useful energy obtained from

TABLE 6

Per Capita (annual) Energy Consumption

Source	Urban		Rural		Estate		All Island	
	1982	1987	1982	1987	1982	1987	1982	1987
Fuelwood (Kg.)	335.98	345.12	505.40	520.67	659.30	701.10	483.03	503.51
Kerosene (Lit.)	9.43	3.19	15.70	10.33	18.76	17.74	14.69	9.64
Electricity (kW)	197.39	241.90	4.00	10.34	0.46	1.34	40.90	51.30
LP Gas (Kg.)	1.81	4.24	—	0.01	—	—	0.35	0.77
(KgOE)	184.63	196.30	205.78	208.74	265.90	281.17	205.69	212.30

Note : Conversion factors
Kerosene 1 Kg. = 1.291 litres
Kerosene 1 Kg. = 1.05 Kg. OE
Fuelwood 1 Kg. = 0.38 KgOE
LP Gas 1 Kg. = 1.06 KgOE
KgOE is Kilograms of oil equivalent.

Sources : The Report of Consumer Finance and Socio Economic Survey 1981/82, Energy Balance and Energy data.

fuelwood is lower in the rural areas despite the high consumption in gross energy. Further, a number of houses using fuelwood is much higher in these sectors than int he urban sector. When compared with 1982, per capita consumption of electricity by the urban sector increased substantially by 23 per cent in 1987. Although only a marginal improvement could be seen in absolute terms, per capita electricity consumption trebled in the rural and estate sectors. Per capita electricity consumption is higher in the urban sector where power is consumed to operate electrical appliances and for cooking and air conditioning etc., in addition to lighting. The households in the rural and estate sectors use electricity mainly for lighting.

4.1.1.2 Consumption of Energy by Income Groups, Fuel Types and the Purposes of Using by End-Users

Approximately 67 per cent of the Urban sector energy needs are satisfied by non-commercial sources. According to CFS 1981/82, i.e. in early 1980s, this proportion was around 70 per cent. In contrast, 95 per cent of the energy requirement in the rural and estate sectors at present are satisfied by non-commercial sources of fuel. Availability, cost and household income are the main factors responsible for the divergences in the composition of energy consumption between the sectors.

According to the CFS 1986/87, poor consumers who earn less than Rs. 700/- per month, depend entirely on fuelwood for cooking while in the income groups between Rs. 701 — Rs. 2,000, the dependence was as high as 99 per cent. Ninety five per cent of

the households having income between Rs. 2,001 — Rs. 5,000 used this source for cooking. The income cut-off-point of Rs. 700/- is important because food stamp holders and Janasaviya recipients (from 1989) fall into this income group.

Even in higher income groups earning Rs. 5,001 or more per month, 80 per cent of the households used fuelwood for cooking. On an average 79 per cent of the households in the urban sector obtain their entire energy requirements for cooking from fuelwood and other sources of bio-mass, of which 58 per cent was obtained on a commercial basis. Of the total households in the urban sector, 10 per cent used fuelwood as an alternative source to the main source of energy they use for cooking.

In 1986/87, in the urban sector, 13 per cent of the total households used LP gas for cooking while the proportions of electricity and kerosene used for cooking were 3 per cent and 2 per cent respectively. Another 3 per cent of the households used timber coal, bio-gas and other renewable sources of energy for cooking. The main source of energy for cooking in the urban sector however, was fuelwood which accounted for 79 per cent of the total households. As an alternative source of cooking fuel, in the urban sector, 16 per cent of the households used electricity where 3 per cent each used kerosene or LP gas. In this sector, almost all the households having kerosene, electric or gas cookers belonged to the income groups earning more than Rs. 2,000 per month. In the urban sector, the number of households using kerosene and electricity for cooking dropped substan-

tially from 29 per cent to 5 per cent while LP gas increased from 5 per cent to 13 per cent within a time span of about 5 years from early 1980s to mid 1980s, according to CFS data. Importance of kerosene and electricity as a cooking fuel has diminished in recent years mainly due to the higher cost of those fuels when compared to that of fuelwood and LP gas. Although 58 per cent of fuelwood requirements are purchased from the markets in the urban sector, its relative price is much lower than that of electricity as a source of cooking fuel. Further, LP gas which is a very close and efficient substitute for other sources of cooking fuel is available more conveniently in the urban sector. The initial cost of using LP gas is also lower compared to that of electricity. Kerosene is more costly and on the other hand, it is less efficient and inconvenient to use in comparison with electricity or LP gas due to strong smell and high carbon content in the smoke.

Only 2 per cent of the households in the rural sector use either electricity, kerosene or LP gas as a source of fuel in cooking. The use of alternatives for fuelwood is negligible in lower income households both in the rural and estate sectors. Only a negligible proportion of commercial energy for cooking is seen in households of higher income groups in the rural sector. According to CFS 1986/87, approximately 84 per cent of fuelwood used by all households in the country was obtained free by users, while the balance was purchased on a commercial basis. The free availability of fuelwood is much higher in the rural and estate sectors where approximately 88 per cent and 98 per cent respectively of their fuelwood requirements were obtained from free sources. According

to CFS data, when compared with 1981/82 availability of free fuelwood and other bio-mass increased marginally in 1986/87. Although a considerable time has to be devoted for collection of fuelwood, this activity is a part of the day-to-day life of women and children in rural households. The percentage shares of household energy used for cooking by sources, sectors and income groups are given in Table 7.

Of the total, 73 per cent of the households in the country use kerosene for illumination of their homes, while 25 per cent use electricity for this purpose. Only 2 per cent of the households use other sources of energy for lighting. In the urban sector, of the total households, 35 per cent use kerosene for lighting, while the source of lighting in the other households was electricity. The share of households in the urban sector using electricity increased from 47 per cent in 1981/82 to 64 per cent in 1986/87. However, in the urban sector where infrastructure facilities are adequately available, 73 per cent of the households in income groups of less than Rs. 2,000 per month did not have electricity. Within the income group Rs. 2001 — Rs. 5,000, only 66 per cent had electricity. Of the total electrified households in the urban sector, 88 per cent belonged to income groups earning more than Rs. 2,000 per month. This information suggests that household income is an important determinant of the use of electricity for domestic purposes.

About 35 per cent of the total urban households do not have electricity either due to non-availability of lines or financial inability and most of these households use kerosene or other sources for lighting.

TABLE 7

Percentage Share of Household Energy Used for Cooking by Sources, Sectors and Income Groups

Income Group	Urban					Rural					Estate					All Island				
	K	E	LPG	FW	OS	K	E	LPG	FW	OS	K	E	LPG	FW	OS	K	E	LPG	FW	OS
0 — 700	—	—	—	100	—	—	—	—	100	—	—	—	—	100	—	—	—	—	100	—
701 — 2,000	—	—	—	99	1	—	—	—	100	—	—	—	—	100	—	—	—	—	99	1
2,001 — 5,000	3	4	7	83	3	—	—	—	99	1	—	—	—	100	—	1	1	2	95	1
Above 5,000	2	6	31	59	2	—	—	3	97	—	—	—	—	99	1	1	3	15	80	1
All Income Groups	2	3	13	79	3	...	...	1	98	1	—	—	—	99	1	...	1	3	95	1

Note : K — Kerosene
E — Electricity
LPG — LP Gas
FW — Fuelwood
OS — Other Sources
... — Negligible

Source : Consumer Finance and Social Economic Survey 1986/87.

However, the proportion using kerosene in the urban sector is as high as 72 per cent of the total households in the lower income group of less than Rs. 2,000 per month. This percentage is as low as 6 per cent among the households of whom average income is over Rs. 5,000 per month.

At present, the rural and estate sectors are not adequately served by the National Electricity Grid (NEG). As a result of this, kerosene continues to remain the main source of lighting in households in these two sectors. Approximately 80 per cent of the rural sector and 96 per cent of the estate sector households use kerosene as the only source of lighting. Eighteen per cent of the rural households and 4 per cent of estate sector houses obtain electricity from the NEG. The number of households having access to electricity in these two sectors has increased in recent years due to the expansion in the transmission network and rural electrification programmes. Accordingly, the share of households using electricity in the rural and estate sectors doubled from 9 per cent and 2 per cent in 1981/82 to 18 per cent and 4 per cent respectively in 1986/87. A small number of rural sector households use solar power, Prashakthi and biogas for illumination of their homes. The percentage shares of household energy used for lighting by sources, sectors and income groups are given in Table 8.

A main reason for lower access to electricity is the non-availability of infrastructure facilities in most rural areas. The availability of electricity supply lines in close proximities to hoseholds is a more important determinant rather than the income

TABLE 8

Percentage Share of Household Euergy Used for Lighting by Sources, Sectors and Income Groups

Income Group	Urban			Rural			Estate			All Island		
	K	E	O.S.	K	E	O.S.	K	E	O.S.	K	E	O.S.
0 — 700	78	22	—	96	4	—	100	—	—	94	6	—
701 — 2,000	72	28	—	92	7	1	100	—	—	91	9	—
2,001 — 5,000	33	66	1	67	30	3	91	7	..	72	27	1
Above 5,000	94	6	—	43	52	5	82	18	..	28	70	2
All Income Groups	35	64	1	80	18	2	96	4	..	73	25	2

Note : K — Kerosene
E — Electricity
O.S. — Other Sources
.. — Negligible

Source : Consumer Finance and Socio Economic Survey 1986/87.

of the household itself. The high cost involved in obtaining a power connection and wiring of houses including the costs of switches, bulbs, fittings etc. and monthly charges in proportion to the household income are the major constraints faced by the poor in obtaining electricity in both urban and rural areas. The unsuitability of houses for electricity connection is also a problem in areas where infrastructure facilities are available. For domestic power connections, the cost to the consumer on account of fuses, insulators, posts and the connecting wire from the main line varies between Rs. 2,700 for a 10 metre length to Rs. 14,500 (including 3 electricity posts) for 100 metres at 1993 rates. The cost of wiring of a house with 5 lamps is about Rs. 2,000. The initial cost for obtaining electricity for a small house is, therefore, in the range of Rs. 7,500.

As the initial capital cost required for use of electricity is high, the use of kerosene is more economical from the point of view of the poor consumer. On the other hand, kerosene is available for purchase conveniently at retail outlets or from co-operative stores. The co-operatives supply kerosene to the consumers either on payment of cash or in exchange for Kerosene Stamps. The consumer can purchase as little as 100 ml. at a time depending on the capacity of his household budget.

Kerosene which is the main source of energy for lighting plays a major role in the rural and estate sectors as lighting is a necessity for human life. Kerosene can be used with no initial cost in a naked flame bottle lamp (Kuppi Lampuwa). According to

a survey (Wijesinghe, 1983), 43 per cent of the households which used kerosene for lighting used only this type of lamps, while the other 56 per cent used both bottle lamps and standard lamps such as the table type chimney lamps, suspended chimney lamps, hurricane lamps and mantle type pressure lamps. The balance 1 per cent did not use bottle lamps at all. However, in terms of efficiency, kerosene is very much inferior as compared with electricity at the point of end use for lighting. In another study (Ranatunga, 1987), it has been found that the widely used naked flame bottle lamp which is not fitted with a chimney produces 0.5 per cent of light produced by a 40 watt standard light bulb for the same cost to the consumer. In other words, one cent's worth of energy put into a naked flame bottle lamp gives only about one-two hundredth (1/200) of light as would a 40 watt bulb produce at the same cost. When computed on the current cost of kerosene and electricity, in terms of efficiency, the fluorescent lamp is superior to the standard bulb and both these electricity based lighting systems are much superior to kerosene as a source of illumination. Nevertheless, due to the underlying problems with regard to electricity, the high cost involved in infrastructure facilities together with financial constraints and social and behavioural patterns in households, electricity is not an easy and cheap substitute for kerosene for both the urban and rural poor.

Of the total electrified households in the urban sector, 75 per cent had televisions, while 44 per cent and 6 per cent of them used refrigerators and washing machines respectively. However, 52 per cent of the

televisions, 68 per cent of the refrigerators and almost the entirety of washing machines were used in households which are in higher income groups of more than Rs. 5,000 per month. In the rural sector, 80 per cent of the electrified households used televisions while almost all the electrified households in the estate sector use televisions. Approximately 20 per cent and 14 per cent of the electrified households in the rural and estate sectors used refrigerators. A very small number of households in the rural sector used washing machines but, none of the households had such facilities in the estate sector.

4.1.2 Potential for Improving Efficient Use of Energy in the Household Sector

4.1.2.1 Kerosene Lamps

A major problem involved in the use of kerosene for lighting is the use of inefficient lamps. An inevitable solution to this lies on improving the efficiency of the existing bottle lamp and the use of other lamps which are more efficient. However, even if the efficiency is increased without keeping the cost very low, the average consumer would not be able to afford the additional cost. Even at present, the available mantle type pressure lamp and the chimney lamp are more efficient than the bottle lamp. In terms of efficiency, as compared to chimney and mantle type pressure lamps, the bottle lamp gives only about 30 per cent and 7 per cent of light respectively, for the same cost. The average chimney lamp costs about Rs. 30/- to Rs. 40/- while a hurricane lamp costs around Rs. 150/- to Rs. 200/- and a mantle type

pressure lamp is priced within the range of Rs. 900/- to Rs. 1,100/- today. Due to the high cost of efficient lamps, most of the rural households (43 per cent) use only bottle lamps.

The Ministry of Power and Energy has made an attempt to improve the bottle lamp by changing the design and improving the efficiency with the help of improved technology. The intention is to introduce a low cost kerosene oil lamp which is simple in design and gives better light output for the energy it consumes. Altogether 30 working models have been produced and it is worthwhile for the authorities to evaluate these alternatives to find the right balance between the lower cost and higher efficiency. Steps are also deemed necessary to improve efficiency, minimize wastage and reduce wanton consumption of electricity. Some options that could be considered in this respect are discussed below.

4.1.2.2 Use of Fluorescent (tubelight) Bulbs

Encouraging the consumers to use fluorescent (tubelight) bulbs will achieve two objectives viz. providing power in an efficient way to the consumer and safeguarding the national objective of conservation of electricity. According to the estimates made by the CEB, a reduction of 130 mW of consumption could be achieved if fluorescent lighting is used by all domestic consumers. This would be equivalent to a reduction of Rs. 6,000 million in the investment on power generating plants and transmission and distribution systems. Eventhough, an additional investment of Rs. 300 million would be necessary for

conversion of incandescent lamps to fluorescent lighting, the reduction in consumption will be equal to a one-fourth of the total investment in the power sector for the next five years. From the consumer's point of view too, the fluorescent bulb is more efficient and economical than the conventional bulb. However, the price of fluorescent bulb is higher than that of the conventional bulb. The price of a 40W fluorescent bulb is around Rs. 50/- to Rs. 90/- while a conventional bulb costs Rs. 25/-.

4.1.2.3 Use of Prashakthi

An efficient source of providing electricity to consumers for lighting is Prashakthi where the light is obtained from a re-chargeable battery connected to flourescent bulbs. However, the main constraints for popularizing this method have been the high initial cost of the battery and the tube lights and the distance the consumers have to travel to find battery charging places for re-charging. One problem in the battery charging system is that although the actual cost of electricity for charging a battery is around Rs. 4/- per turn, the charges the consumer has to pay range from Rs. 10/- to Rs. 30/- per turn. This high cost is beyond the reach of most villagers as a regularly used battery needs to be recharged 2-4 times a month. This system of utilising electricity can be popularized through a low cost facility of battery charging system and providing financial assistance or loans to poor consumers who wish to install this equipment for lighting.

In general, it was observed that most of the consumers do not have the option of using more efficient alternatives due to lack of awareness on energy conservation and their financial inability to obtain more efficient alternatives because of higher initial cost. On the other hand, due to normal habits of consumers such as keeping porch and exterior lights on during the night and the wrong notion that frequent switching on and off reduces the life span of the bulb etc., tend to increase wanton consumption of power.

It may be possible to improve efficient use of electricity by ways of providing incentives and implementing an appropriate pricing policy to encourage the use of equipment which are energy-efficient and low cost. Furthermore, by way of increased consumer awareness to avoid wasteful habits and wrong practices, wastage of useful energy can be reduced a great deal.

4.1.2.4 Rural Electrification

Rural electrification is considered vital for socio-economic upliftment in the rural sector. This programme has the objectives of promoting economic development and improving the quality of life of people in rural areas. In order to ensure that the benefits of electricity reach the poor, the provision of electricity in more rural areas has also been identified as an important part of the national energy policy in recent years. Special emphasis has been laid on electrification in remote areas and as a result, the rural electrification schemes have made a substantial headway since late 1970s. Capital cost of these projects

is provided by the government or donor agencies while operational cost is met by the CEB. Number of rural electrification schemes completed over the period 1977 to 1991 was 10,121.

It should be noted that the success of these schemes depends largely upon the socio-economic conditions of the areas served. The domestic sector is the main beneficiary of rural electrification, yet approximately 55 per cent of the prospective domestic consumers within the reach of distribution lines have not obtained electricity due to various reasons such as lack of finance and unsuitable conditions of their houses for electrical wiring and power connections. However, 90 per cent of the consumers who have access to electricity in these areas are domestic consumers while the balance 10 per cent belongs to the industrial and commercial sectors.

It was found that unequal consumer density per kilometer in project areas, lack of financial resources, non-suitability of houses for power connection, deficiency in layouts of distribution systems are the main reasons for sub-optimal performance of certain rural electrification schemes. As a result of lower utilisation of available facilities, a large proportion of these schemes is not economically viable. It is also important to note that the cost of rural electrification has been relatively higher because of the high initial costs of installation of distribution lines over long distances, high losses in transmission and distribution and very low load factor.

4.2 Energy Consumption by the Industrial Sector

Industrial sector which contributes nearly 25 per cent of the GDP accounts for approximately 20 per cent of the country's total energy consumption. The energy consumption by this sector increased from 726,000 TOE in 1977 to 1,183,000 TOE in 1991 registering an annual growth of 4 per cent.

Fuelwood, bio-mass and other traditional sources of energy are responsible for nearly 57 per cent to the total industrial energy. Trends in the consumption pattern of different types of energy sources in the industrial sector indicate a shift from Petroleum products and fuelwood to electricity. During the period 1977-1991, use of petroleum and bio-mass in this sector increased annually by 6 per cent and 4 per cent respectively, while that of electricity increased by 5 per cent. Of the consumption of diffierent petroleum products, the use of fuel oil increased by 4 per cent per annum while that of LP gas and residual oil increased substantially. However, the relative shares of these two products in total industrial energy are very small. Of the different sources of energy the share of petroleum decreased marginally from 23 per cent to 22 per cent, while that of fuelwood and other sources declined from 59 per cent to 57 per cent during the period 1977-1991. As an outcome of these changes that have taken place over the years since 1977 the relative importance of electricity as an industrial energy increased from 18 per cent to 21 per cent. Product-wise consumption of energy by the industrial sector in 1977 and 1991 are in table 9.

TABLE 9

Energy Consumption by the Industrial Sector

(in '000 TOE)

Year	Electricity	Commercial Energy			Non-Commercial Energy			Total
		Fuel Oil	Heavy Diesel	Other Petroleum	Charcoal	Bagasse	Fuelwood and Other	
1977	133.8 (18.4)	113.7 (15.7)	48.5 (6.7)	0.3 (..)	1.0 (..)	28.0 (3.9)	400.8 (55.2)	726.0 (100.0)
1991	251.7 (21.3)	194.2 (16.4)	34.2 (2.9)	35.6 (3.0)	10.2 (1.0)	110.8 (9.4)	546.8 (46.0)	1,183.4 (100.0)

Percentage shares are given in parenthesis.

Sources : Report on Sectoral Energy Demand in Sri Lanka, Energy Balance and Energy data.

The value added in the industrial sector (in constant 1982 prices) increased from Rs. 15,839 million in 1982 to Rs. 27,490 million in 1991 indicating a growth rate of 5.5 per cent per annum. However, the energy consumption increased only by 2 per cent during the same period indicating a reduction in energy intensity. Accordingly, energy inputs required to add Rupees 1 million worth of out-put to GDP reduced from 56 TOE in 1982 to 43 TOE in 1991. This showed the increased efficiency of energy use in the industrial sector and this improvement may be attributable to increased use of more energy efficient technology and adoption of conservation measures. This improvement is also partly due to the shift of some activities from petroleum to electricity which is a more efficient source of energy with minimum wastage in consumption.

4.2.1 Mining and Quarrying Activities

A broader definition is used for the industrial sector, in this analysis to include mining and quarrying activities, which accounts for about 3 per cent of the country's GDP. However, in terms of energy consumption, this sector is insignificant. According to available estimates the energy consumption by this sector amounted to about 2,000 T.O.E. in 1991. The main activities in this sector such as graphite mining, stone quarrying, clay and sand pits and sand mixing require low energy inputs. In mining and quarrying industries, electricity accounts for more than 90 per cent of energy inputs.

4.2.2 Manufacturing Industries

The manufacturing industries are generally subdivided into nine categories according to the United Nations Standard Classification of All Economic Activities (ISIC). Important characteristics of the categorywise energy consumption in the industrial sector for 1982 and 1988 are given in Table 10. The energy consumed by manufacturing industries remained more or less at same level during the period 1982-1988. However, the composition of energy consumption by sub sectors changed considerably due mainly to the rapid expansion of textiles and leather products industries and non-metallic mineral products industry which includes, construction activities. The energy consumption by these two categories of industries increased by 12 per cent and 4 per cent per annum respectively during the same period.

The sources of energy in the manufacturing sector are commercial sources such as electricity, and petroleum and non-commercial sources which constitute mainly fuelwood. The use of fuelwood and other non-traditional sources of energy by manufacturing industries increased continuously over the last two decades but, their relative importance among the other sources of industrial energy remained more or less unchanged at around 58 per cent. This sector accounts for approximately 17 per cent of the total non-traditional fuels in the country at present.

Manufacturing industries obtained approximately 25 per cent of their energy requirement from electricity. The consumption of electricity by this

TABLE 10

Percentage Share of Energy Consumption by Sources of Energy in the Manufacturing Sector (1982-1988)

Category	Electricity	Furnace Oil	Heavy Diesel	Renewable Energy	Total	Total Energy	Contribution to the GDP
Food and Beverages	13	3	2	82	100	48	45
Textile and Leather	76	17	4	2	100	9	12
Wood Products	58	14	4	23	100	1	3
Paper Products	58	37	5	—	100	3	3
Chemical and Rubber	24	34	2	40	100	15	14
Non Metallic	21	21	2	55	100	21	7
Metal Products	51	49	—	—	100	1	2
Fabricated Metal	68	25	6	—	100	1	6
Others	11	1	—	88	100	1	8
Industrial Sector	25	14	2	58	100	100	100

Sources : Report of "Sectoral Energy Demand in Sri Lanka 1992 ;
Central Bank of Sri Lanka.

sector increased by 21 per cent during the period 1982-1988. The relative importance of furnace oil which accounted for approximately 25 per cent of industrial energy in early 1980s reduced due to the closure of the fertilizer manufacturing corporation in 1985 which was the largest single consumer of furnace oil.

4.2.2.1 Food, Beverages and Tobacco Industries

Food beverages and tobacco industries contributes the highest share of value added to the manufacturing sector output and this has averaged around 45 per cent during the period 1982-1988. This sector is also the largest consumer of energy among the manufacturing industries accounting for nearly 50 per cent of the energy consumed by all manufacturing industries put together. Energy consumption by food, beverages and tobacco industries has shown an increase from 408,500 TOE in 1982 to 435,900 TOE in 1988. Of this total energy consumption by this sector, 82 per cent was from fuelwood and other bio-mass, 13 per cent was electricity and petroleum accounted for the remainder.

One reason for higher consumption of energy from traditional sources by this sector is that the tea and sugar industries which are major sub-sectors satisfy almost 75 per cent of the energy requirement from fuelwood and bio-mass. The main sources of energy in the tea industry is fuelwood and this is about 75 per cent of the total energy consumed by this industry. Sugar industry itself produces bagasse as a waste material which can be used for meeting its own energy requirement to some extent.

4.2.2.2 Textile and Leather Products

The place occupied by the chemical and rubber products which was the second highest in the manufacturing sector output in early 1980s has been gradually overtaken by the rapidly expanding textile and leather industry since 1985. Its contribution to the GDP increased from 7 per cent to 16 per cent during the period 1982-1988. Energy consumption by this sector also increased from 54,500 TOE in 1982 to 103,100 TOE in 1988 at an average rate of 12 per cent. These industries account for approximately 9 per cent of the total energy consumed by the manufacturing sector.

Electricity is the main source of energy in the textile and leather product industries. This source accounts for more than 75 per cent of the energy requirement of this sector today. Balance 25 per cent is from petroleum which is mainly heavy diesel and furnace oil. However, importance of these two fuels decreased considerably over the years owing to the substitution of electricity for petroleum. This also has resulted in a decrease of energy intensity from 57 TOE/Mn. Rs. to 32 TOE/Mn. Rs. during the period between 1982-1988 or by an average rate of 8 per cent.

4.2.2.3 Chemical and Rubber Products

Chemical and rubber products sub-sector which includes the production of chemicals and manufacture of chemical products, rubber and plastic products, paints, soaps, drugs, perfumes and fertilizer contributes approximately 14 per cent of the value added

in the manufacturing sector today. The proportion of energy consumed by manufacturing industries also amounts to about 15 per cent of the total energy consumption by the industry sector. However, in volume terms the consumption of energy by this sector declined considerably after the closure of the Fertilizer Manufacturing Corporation in 1985 and as a result, the percentage share of energy consumed by this sector declined from 22 per cent in 1982 to 8 per cent in 1988. On average 40 per cent of the energy requirement of this sector is accounted for by fuelwood and biomass while the proportions of petroleum and electricity are 34 and 24 per cent respectively.

4.2.2.4 Non-metallic Products

This sub-sector accounts for approximately 22 per cent of the energy consumed by the industrial sector. The activities in this sub-sector consists mainly of the production of ceramic and potteryware, cement, brick and tile, glass and glass products and construction work. The contribution to the total industrial sector value added by this sub-sector was 10 per cent in 1982 but, this figure dropped to about 6 per cent in late 1980s, due to the disturbances in the North that affected production of the cement industry. However, the energy consumption by this sub-sector increased at an average of 4 per cent annually over the period 1982-1988. As a result, energy intensity has increased from 130 TOE/Mn. Rs. in 1982, to 215 TOE/Mn. Rs. in 1988. One reason for this was the use of coal and petroleum instead of electricity in certain industries due to the interruptions experienced in the supply of electricity from the National Grid in late 1980s. A break-

down of energy use by this sub-sector by source of energy indicates that more than 55 per cent of energy is obtained from non-commercial sources. A significant proportion of energy consumed by brick, tile, ceramic and pottery industries is from fuelwood. Electricity and petroleum account for about 45 per cent of the energy used in addition to natural sunlight which was substantially used for drying purposes.

4.2.2.5 Paper and Paper Products

This sub-sector consumes approximately 3 per cent of the total energy used by all manufacturing industries put together while contributing 3 per cent to the industrial sector value added. Electricity is the main source of energy which provided 58 per cent of the energy while the balance was accounted for by petroleum.

4.2.2.6 Basic Metal Products

The activities that fall into this sub-sector make a contribution of about 2 per cent to the total value added of the manufacturing industries accounting for approximately 1 per cent of the energy consumption by the sector, The energy mix of this sub-sector changed to a certain extent over the years and a shift from electricity to petroleum was observed. This was evident from the percentage share of electricity in the energy mix that dropped from 65 per cent in 1982 to 53 per cent in 1988.

4.2.2.7 Fabricated Metal, Wood Products and Other

These three categories of industries put together contributes approximately 17 per cent to the value added of the manufacturing sector while accounting for

only 3 per cent of the energy consumed by the sector. Electricity and petroleum are the main sources of energy for fabricated metal and wood product industries.

4.3 Energy Consumption by the Transport Sector

The transport sector which is the largest consumer of petroleum accounts for approximately 13 per cent of the total energy consumed in the country. Auto diesel, petrol, aviation gasoline and marine diesel are the petroleum products used in the transport sector accounting for about 60 per cent of the total petroleum consumed in the country in 1991. Some information on energy consumption by the transport sector is given in Table 11.

This sub-sector constitutes transportation by road rail, air and waterways. In Sri Lanka inland water ways and domestic air transport are insignificant. Therefore, main transport activities comprises of road and rail transport together with international air transport and sea transport by both passenger and freight modes.

Domestic passenger transportation consists of private and public transport. Private passengers use cars, taxies, motor cycles and tri-shaws while public transport is mainly by bus and rail. As in most countries in the world petrol is predominantly used for private transport in Sri Lanka. Although conventionally auto diesel is a public transport fuel its use for private transportation increased due to the sharp increase in diesel vehicles for private use resulting from relatively low auto diesel price in recent years.

TABLE 11

Transport Sector Energy Consumption

Source	Unit	1977	1991
Petrol	Metric Tons	111,500	166,350
Diesel	Metric Tons	262,000	482,840
Fuel Oil	Metric Tons	18,800	21,000
Aviation Gas	Metric Tons	400	211
Aviation Turbine	Metric Tons	16,500	72,700
Coal	Metric Tons	4,000	890
Total fuel consumption	TOE	435,600	786,055
Transport sector energy consumption as a percentage of total energy consumption		10.8	13.4

Source : Ceylon Petroleum Corporation.

The domestic freight transport is handled mainly by road and rail. The road freight transport constitutes motorised modes such as trucks, lorries, trailers and non-motorised modes such as bullock carts. All these motorised modes use petroleum as the energy while a small quantity of coal is used by the Sri Lanka Railways to run its remaining steam engines. Transport of crude oil from Colombo Harbour to the Refinery at Sapugaskande is by a pipeline system. This system is called the Single Point Boying Moring Discharge facility and does not involve any loading and unloading of cargo like in other modes of freight transport.

4.3.1 Road Transport

Sri Lanka has a network of about 10,400 kilometres of national roads and 15,300 kilometres of provincial roads. According to the Registrar of motor vehicles, road vehicle population as at the end of 1990 included 320,452 motor cycles, 54,954 lorries and trucks, 57,235 buses, coaches and vans, 92,962 cars, 10,425 taxies and approximately 37,436 other land vehicles. Of the total number of vehicles about 50 per cent was owned by individuals and the balance 50 per cent was by public sector organisations and private firms.

Public passenger transport in Sri Lanka was owned and managed by both private and public sector until recently but the Government has taken steps to privatise all passenger bus services owned by the Regional Transport Boards in 1990. Approximately 80 per cent of passenger transport today is by buses. According to CFS 1986/87, of the total households in

the country approximately 3 per cent owned private cars while 5 per cent owned motor cycles. However, all the privately owned vehicles are not used regularly for travel as some private car owners depend largely on public transport.

More than 80 per cent of freight transported by road is handled by private hauliers. As the private sector is more sensitive to cost, the efficiency of operating private sector vehicles appears to be higher than that of the public sector. A survey conducted for the Transport Sector Master Plan has found that the cost of operation per passenger kilometre of a public bus in urban routs was about 25 per cent higher than that of a private bus operating on comparable routes. This was partly due to higher energy intensity of public sector buses.

At present, of the total energy consumed by the transport sector, road transport accounts for approximately 85 per cent. Of this, 71 per cent was diesel and 29 per cent was petrol. Only 3 per cent of the total transport fuel is consumed by rail transport while air transport and sea transport account for 7 per cent and 4 per cent respectively.

Consumption of diesel by the transport sector increased by 5 per cent per annum from 262,000 metric tons in 1977 to 482,840 metric tons in 1991, mainly as a result of increased diesel vehicle population and the expansion in the demand for freight and passenger transport. Number of large buses operated increased from 4,551 in 1977 to 6,387 in 1990 while other passenger transport type buses and vans increased rapidly from 1,255 to 50,848 during this

period. These increases were mainly due to the liberalisation of vehicle imports and private sector participation in public transport. The rapid expansion in the activity level resulted in a higher demand for passenger and goods transport since liberalisation.

The consumption of petrol decreased from 111,500 metric tons in 1977 to 107,700 metric tons in 1980 and this may be partly due to higher energy efficiency in new vehicles compared to older ones. However, since 1980 as the vehicle population continued to increase the petrol consumption increased at an annual average rate of 5 per cent from 107,700 metric tons in 1980 to 166,350 metric tons in 1991. During this period passenger cars and taxies increased from 63,225 to 103,387 while the number of motor cycles increased from 42,095 to 320,452.

4.3.2 Railway

Rail transport in Sri Lanka is owned and operated by the Sri Lanka Railways (SLR) which is a government department under the Ministry of Transport and Highways. The rail transport infrastructure constitutes among other things 1944 kilometres of rail track and over 1,000 steel bridges to provide the railway services in the country. As at end of 1991, the effective available fleet comprised of about 200 diesel electric and diesel hydraulic locomotives, 4,000 wagons, 1,300 coaches and 46 power sets used exclusively for commuter traffic within the Greater Colombo area.

The SLR accounts for approximately 5 per cent of the total diesel consumption of the country. The fuel consumption by the SLR declined continuously due to reduced railway operations in the recent past.

Volume of cargo transported declined form 263 million ton kilometres in 1985 to 170 million kilometres in 1991. Rail passenger traffic reached a peak of 4.1 billion passenger kilometres in 1979 but this had steadily fallen to 1.7 billion in 1988. Rail passenger traffic reached a somewhat higher level of 2.7 billion kilometres in 1991.

4.3.3 Marine Transport

The Port of Colombo handles 90 per cent of Sri Lanka's marine tonnage and of this about 70 per cent is containerised transhipment. The two smaller ports in Galle and Trincomalee also can accommodate ocean going ships while other ports handle only coastal shipping and fishing vessels.

The loaded and discharged cargo in all three main ports together increased continuously from 1.1 million tons and 20 million tons in 1977 to 4.5 million tons and 7.0 million tons in 1991 respectively. Energy consumed by this sector consisted of 21,000 metric tons of fuel oil and 1,080 metric tons of gas oil in 1991. The consumption of marine fuel oil increased although marginally since 1980 due to the expansion of activity in colombo Port and Sri Lanka's international trade.

4.3.4 International Aviation

The total number of passenger arrivals and departures increased from 0.5 million in 1977 to its highest level of 1 million in 1982 and declined since 1983 due to the slump in tourist arrivals. Traffic carried by the national carrier in terms of passenger kilo metre increased from 1952 million to 3424 million while freight ton kilometerage increased from 21.3 million in 1982 to 91.2 million in 1990. This sector consumed 72,715 metric tons of aviation turbine fuel and 211 metric tons of aviation gasoline which was around 10 per cent of total transport fuel in 1991.

4.4 Commercial Sector

The commercial sector for the purpose of this analysis includes activities of shops, supermarkets, banks and hotels etc. These activities put together account for approximately 5 per cent of the total energy consumption in the country at present. Electricity is the main source of fuel accounting for 60 per cent of the total energy consumption by the commercial sector followed by fuelwood and petroleum which account for 37 per cent and 3 per cent respectively.

Electricity is used mainly for lighting, air-conditioning and operating electrical appliances while petroleum which is mainly LP gas used to generate heat for preparing food in hotels, guest houses etc. Heavy diesel is used for private electricity generation where elctricity is not available and also as a back up source of power for use when necessary. Fuelwood and charcoal are used in tea kilns, eating houses and

in other small scale service activities such as blacksmiths. Most of the commercial centres such as banks, commercial sector office complexes and super markets are concentrated mainly in urban areas. Influenced by this dualistic characteristic in the economy, consumption of commercial energy is confined mostly to the urban sector, while non-commercial sources such as fuelwood and other sources of biomass continued to be the largest source of energy in rural areas.

4.5 Agriculture and Fisheries Sector

Output in this sector has a relatively lower level of energy inputs as compared to many other sectors of the economy. This is evident from the fact that this sector contributes 20 per cent to the GDP while consuming only 1 per cent of the energy consumed in the country.

Activities in rural areas are largely based on subsistence agriculture and technology used in these activities are very labour intensive. As manpower is freely available at a relatively low cost and funds for procuring more sophisticated equipment are limited, the use of new technology in agricultural activities is relatively insignificant in the rural sector. Use of energy in typical rural agricultural activity is therefore, very limited. The main users of energy are in activities such as water pumping in commercial cultivation of crops like potatoes, chillies, onion, betel leaves etc. and for operating winnowing machines.

The other main purpose of using commercial energy in agricultural sector is the use of diesel for operating agricultural vehicles such as tractors, trailers

etc. In recent years an average of 500-800 agricultural vehicles per year were imported and this compares with a much lower level of such vehicles imports in the period prior to liberalisation in 1977. Use of oil based fishing crafts is also becoming increasingly popular since the recent past. As a result, the consumption of kerosene by agriculture and fishing industry increased by an annual average rate of 2 per cent during the period 1982 to 1991. The consumption of kerosene by the agriculture sector is around 8 per cent of the total consumption of this product in the country.

The use of commercial energy by the agricultural sector depends on the size of the activities and extent of application of the modern technology. Although the use of mechanised equipment, tractors and modern technologies can enhance the productivity of the agricultural sector, benefits emanating from these improvements have not yet reached the majority of the poor due to a number of reasons. As the small farm sector has not yet developed to afford expensive machines and modernized equipment they have to continue with primitive technology. Buffaloes and cattle are commonly used animal power in the agriculture sector for ploughing of paddy fields, threshing the harvested paddy and for drawing carts. The bullock cart plays a very important role in small scale transportation activities in the rural sector where the road system of both inter-village and intra-village has not been fully improved upto the standard required for motorized vehicles. The small farmers often transport small loads of farm products to market and farm inputs and consumables to the village.

When the poor quality of available infrastructure, inadequate facilities for repairing and maintenance of the transport system, economic disabilities of the farmers, working habits of rural people and availability of the large stock of animals are considered, animal power appears to be an appropriate and economically viable source of power for the small farming sector. Although comparatively lower use disqualifies animal power from being a main part of modern agriculture, it has a considerable potential to be developed as a significant source of energy in the rural sector.

According to available information, total buffalo population is 0.8 million and 55 per cent of them are used for drought purposes. Total cattle stock is 1.3 million but only 15 per cent of them are used for drought. While the cattle are used in both farm activities and drawing carts, buffaloes are used only for farm activities. It has been estimated that a pair of cattle can provide one horse power and on an average can work 6 hours per day. The economic life of cattle is 6-10 years. A pair of buffaloes can provide 1-6.5 horse power but they work at a slower speed. Their economic life is 12-13 years.

Although the use of tractors have gathered momentum since 1940s, considerable extent of paddy fields is still tilled by the animals. This proportion is as high as 64 per cent and 55 per cent in the intermediate zone and wet zone respectively. In the dry zone where paddy cultivation is largely mechanized only 26 per cent of the paddy lands are tilled by the animals.

It has been found that there is a great potential to promote animal power through the improvements in the feeding system, animal training, yoking, harnessing and improvement of bullock carts. In many other Asian and African countries, research and experiments are being conducted and encouraging results have been found in this respect. Although not included in data a significant proportion of traditional energy such as animal power, manpower, solar power and wind power etc. are used mainly in non-commercial economic activities.

5. SUMMARY AND CONCLUSIONS

5.1 The sources of energy in Sri Lanka can be divided into commercial and non-commercial energy sources. Commercial energy sources which consist of petroleum, electricity and coal account for approximately one third of the country's total supply of energy while the larger proportion of energy is based on non-commercial sources such as fuelwood, agricultural residues and animal wastes. Within commercial energy at present petroleum accounts for 66 per cent while the share of electricity is 34 per cent. Very small proportion of the total commercial energy is contributed by coal. Fuelwood and other sources of bio-mass are traditionally considered as non-commercial energy but approximately 17 per cent of fuelwood is traded through the market today. In addition to traditional sources of non-commercial energy, a significant proportion of energy is obtained from solar, wind, man and animal power although such sources of energy are only marginally used.

5.2. The energy is obtained either through primary sources or transformed sources of energy. Primary sources such as hydro-power and bio-mass sources have a domestic origin while crude oil and coal are imported from other countries. In Sri Lanka, approximately 30 per cent of energy from primary sources are used to produce usable form of energy such as thermal electricity, and various petroleum products. Approximately 5 per cent of the total energy is lost in the processes of transmission, distribution, transportation and handling.

5.3. Within the commercial energy sector, the relative share of petroleum, which is the largest source of commercial energy declined continuously from 76 per cent in 1977 to 64 per cent in 1991. This reduction was due to increased substitution of domestic sources such as electricity and bio-mass for petroleum products. Petroleum is used mainly in the industrial and transport sectors. Of the different petroleum products, heavy diesel and furnace oil are used to provide motive power and heat in industrial activities. However, in the past, the importance of heavy diesel and furnace oil depended on the level of thermal power generation as these two fuels were used to operate oil fired thermal power plants. The other main consumer of petroleum, the transport sector is responsible for the entirety of petrol and auto diesel consumption. Kerosene is largely used for illumination of houses particularly in rural areas and marginally as a source of cooking fuel and for water pumping in agricultural activities.

5.4 The generation of electricity increased steadily and as a result its share in the total supply of energy increased from 6 per cent in 1977 to 11 per cent in 1991. The installed capacity of electricity increased from 401 mW in 1977 to 1,286.65 mW in 1991. With the increased availability of electricity and improved infrastructure facilities in more areas, the number of households with access to electricity increased from 10 per cent in 1977 to 25 per cent in 1991.

5.5 Fuelwood which is the major source of energy in households in the rural and estate sectors for cooking is also used as an industrial fuel in small and cottage industries and plantation crop processing industries ; although kerosene, electricity, LP gas, bio-gas etc. are substitutes for fuelwood, the degree of substitutability between fuelwood and these products is very limited. Further, a larger proportion of fuelwood is obtained free of cost by consumers and therefore, a shift from fuelwood to kerosene or electricity is not taking place at any significant level as far as the rural sector is concerned. Substitution of fuelwood for petroleum or electricity is not possible in the short run in the industrial and commercial sectors due to the initial cost involved in changing the technology and the long time lags involved in shifting to new technology. In the case of small and cottage industries, lack of finances is the major problem that has restricted the substitution. However both in the estate and rural sectors, use of all petroleum for domestic and industrial purposes

declined marginally while that of electricity and fuelwood increased. This may have been due to the shift from petroleum to electricity which has occurred consequent to the increased infrastructure facilities such as rural electrification schemes and improvement in the distribution and transmission net work in rural areas. The pricing policy of both petroleum and electricity would also have played a significant role in discouraging the wanton consumption of these sources of energy.

5.6 Electricity can be substituted for kerosene in both cooking and illumination purposes in households. However, on most occasions, substitution of kerosene was low due to the fact that electricity was not always available for domestic kerosene consumers for easy substitution. The cost of kerosene and the level of consumer income were the main factors that determined the demand for kerosene in the rural and estate sectors. The higher relative price of kerosene has led to the use of fuelwood for cooking in low income households while high and middle income households have resorted to the use of LP gas for cooking due to convenience of use and lower relative price as compared to that of electricity.

5.7 Today, the household sector, the largest consumer of energy in Sri Lanka consumes more than 61 per cent of the total supply of energy. This comprises 7 per cent of electricity, 4 per cent of kerosene, 1 per cent of LP gas and 88 per cent

of non-commercial energy. The main purposes of energy use by the household sector are lighting, cooking and operation of electrical appliances. Although energy is used for pumping water from wells to overhead storage tanks in households in the proportion of energy used for this purpose is quite marginal.

Fuelwood and other sources of bio-mass are the major sources of energy used to generate heat for cooking. Approximately 95 per cent of the households use fuelwood for cooking and this proportion was much higher in rural and estate sectors. LP gas, electricity and bio-gas are the other fuels used for this purpose. Kerosene is mostly used by the rural sector for illumination of houses. Other sources such as solar energy, bio-gas, Prashakthi (battery connected power supply systems) electric generators etc. are used by relatively a small number of households.

5.8 The industrial sector which accounts for approximately 20 per cent of total supply of energy in the country is the largest consumer of electricity and was responsible for more than 38 per cent of the total electricity consumption. Energy consumption by this sector constitutes petroleum viz. heavy diesel and furnace oil, electricity and non-commercial sources which account for 22 per cent, 21 per cent and 57 per cent respectively.

5.9 The transport sector which consumed 13 per cent of the total supply of energy in the country which includes 61 per cent of total petroleum products. Petroleum and auto diesel are used almost entirely by this sector

5.10 At present, commercial activities consume approximately 5 per cent of the total energy consumption in the country. In this sector 23 per cent of the total supply of electricity is used for lighting, air conditioning and for operation of electrical appliances. Small quantities of LP gas, fuelwood and charcoal are used to obtain energy for cooking.

5.11 Agricultural and fisheries activities account for approximately 1 per cent of the country's total consumption of energy mainly for purposes such as operating of tractors, water pumps in cultivation of crops, such as potatoes, chillies, onions and betel leaves.

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