3.2 Energy Supply and Demand Forecast

There are not sufficient statistical information or forecast economic indicators enough to permit forecasting of energy supply and demand based upon them. Some of those available are already deviated from what actually happened. Therefore, this feasibility study supplement necessary information from three existing demand forecasts. This feasibility study examines their basic premises and how projections are derived from these premises. The following sections 3.2.1 analyzes the existing studies and 3.2.2 presents forecast energy supply and demand of this feasibility study.

3.2.1 Analysis of the existing forecasts

The following three studies are analyzed:

1) Study-1: Zambia: Issues and options in the Energy Sector January 1983

   Report of the Joint UNDP/World Bank Energy Sector Assessment program (hereinafter called Study-1)

2) Study-2: Fourth National Development Plan Energy (Draft)

   10th February, 1986 (hereinafter called Study-2)

3) Study-3: The Status and Impact of Woodfuel in Urban Zambia, by Department of Natural Resources, 1984

Major premises of the above three studies are summarized below:

Study-1

1) Two economic scenarios; namely, a high growth scenario and a low growth scenario are assumed as beses for forecasting energy demands during the period from 1980 to 2000. These scenarios are based on the World Bank's country economic model, which assesses the potential for growth based on the likely availability of foreign exchange accruing from exports and external capital flows, the import requirements of the economy and the impact of macro-economic policies.

2) The availability of foreign exchange is the most significant medium to long-term constraint on Zambia's long-term real growth potential. The constraint arises from:

   (a) the value of copper exports, which is determined by the level of production and by the real price of copper;
   and,

   (b) the heavy debt service requirements which have resulted from large increases in external debt since 1975.

3) The high growth scenario and the low growth scenario are based on the following assumptions, respectively:

   (a) High growth scenario:

      (i) Zambia's economy is assumed to be favorable for developments and result in an average real growth rate of 3.2% per annum over 1980 to 2000, on a gross domestic production (GDP) basis.

      (ii) Per capita real income in the country would remain approximately constant.

(iii) Copper prices will increase in real terms by 3% per annum. This will increase the foreign exchange availability and permit the copper mining companies to implement rehabilitation and maintenance programs which are needed to maintain current production levels.

(iv) Overall copper production will remain constant between 1981 and 1995 with some slight variations in production. This is due to the fact that the increase in production derived from the commissioning of the rehabilitation project, and from the bringing into production of a new ore body are expected to offset the decrease in production of economically recoverable ores from existing mines.

(v) Growth in agricultural production of 4% per annum is expected as a result of recent higher producer prices and assuming a continuous and sustained improvement in government policies. If achieved it will provide opportunities for import substitution for current food imports and also allow for export of some agricultural goods.

Foreign exchange earnings and savings from agriculture are necessary to support the activities of other sectors in the high growth scenario.

(b) Low growth scenario:

(i) Zambia's economy is assumed to be less favorable for developments and result in an average real growth rate of 1.8% per annum over 1980 to 2000, on a gross domestic production (GDP) basis.

(ii) Per capita real income in the country would decline

(iii) Copper prices will remain constant in real terms.

(iv) Copper production will be 10 percent lower for all years than in the high growth scenario due to lower levels of rehabilitation and maintenance expenditure.

(v) Slow growth in agriculture would be expected due to less favorable policies.

(vi) Since both (i) and (ii) will result in much less foreign exchange available, there will be a reduction in investment and growth possibily will be lower in the other sectors.

Study-2

1) In assessing future energy consumption, the following two assumptions are crucial:

(a) Future economic activity in different sectors

(b) Future charges in energy prices

2) With respect to economic activity, it is assumed that copper production will decrease slightly from its 1984 level. For the rest of the economy a small increase in the economic activity over the period is assumed. It is further assumed that agriculture and to some extent industry will perform better than transport, commerce, and public sectors.

3) With regard to energy prices, the following is assumed:

(a) Oil product prices will not increase in real terms, i.e. they will not increase more than prices in general; no major charges in the relationship between prices of different oil products are assumed.

(b) Electricity prices are expected to increase significantly in real terms over the period. This is mainly due to the recent devaluation and the expected loss of revenue from electricity export.

(c) Coal prices are assumed to increase significantly in real terms. This is mainly due to rehabilitation costs the bulk of which is in foreign exchange.

4) The projection for electricity and coal consumption are based on existing detailed studies. Additional information from major consumers has been obtained and some adjustments of the forecasts have been made.

5) No comprehensive studies for future petroleum consumption exist and therefore forecast for petroluem consumption is based on economic assumptions and information from major consumers.

6) Consistency in electricity, coal, and petroleum consumption projections has been achieved by ensuring that total sectoral energy consumption corresponds to the economic assumptions.

7) Because of the anticipated increase in energy utilization efficiency the mines expect a decline of about 5% in their overall energy consumption assuming an almost constant output level.

Detailed assumptions in each energy sector are omitted.

<u>Study-3</u>

This study concerns woodfuel. The demand is forecast mainly in relation with urban population increases supplemented by energy price and local energy situation.

(1) Electricity demand projections

1) Study-1

Table 3-2-1 shows demand for elecricity for 1981 to 1995 projected by Zambia Electricity Supply Corporation, ZESCO. The projection assumes expansion of electrification in the copper mines, ZESCO's increasing sales to non-mining sectors and continuation of the export of electricity to Zimbabwe.

Figure 3-2-1 plots projected demand for electricity shown in Table 3-2-1.

Table 3-2-1 Projected Demand for Electricity (1981-1995) in Gwh

Sectors		1981	1985	1990	1995	Average Growth Rate % 1981-1995
Copper Mines (CPC)		4,120	4,823	5,648	6,390	3.18
Non-Mining:	Copper Belt	577	636	720	814	2.49
	Southern Area	846	914	1,007	1,111	1.97
	Sub Total	5,543	6,373	7,375	8,315	2.94
Export:	Zimbabwe	3,347	3,347	2,003	1,335	
Total		8,890	9,720	9,378	9,650	

Source: Zambia Electricity Supply Corporation (ZESCO)

2) Study-2

Table 3-2-2 indicates a projected electricity consumption for 1990 together with 1984 records. The projected demands incorporate the results of a recent study on the power system in Zambia. The study includes a detailed analysis of future requirements of electric power up to 2004. However, the present projection makes a slight modification to the study in the light of the interviews with major consumers.

Table 3-2-2 Electricity Consumption Projections

Sector	1984 GWh	1984 (%)	1990 GWh	1990 (%)	Annual Growth Rate (%)
Agriculture	119	1.9	167	2.4	5.7
Mining	4,546	72.2	4,546	65.3	0.0
Industry	490	7.8	780	11.2	8.1
Commerce/Public	438	7.0	535	7.7	3.4
Households	583	9.2	804	11.5	5.5
Others	118	1.9	133	1.9	2.0
Total: Domestic Use	6,294	100	6,965	100	1.7
Exports	3,109		300		-32.3
Total: Produced in Zambia*	9,403		7,264		-4.2

* Excl. distribution losses

Zimbabwe is in the process of bringing 920 MW of new thermal generating capacity on stream. The study expects that this will probably reduce the present electricity export to Zimbabwe which is currently one of ZESCO's major sources of revenue. It is expected that this decrease in electricity export to Zimbabwe will become manifest from 1987/88. Figure 3-2-2 illustrates electricity consumption projections shown in Table 3-2-2.

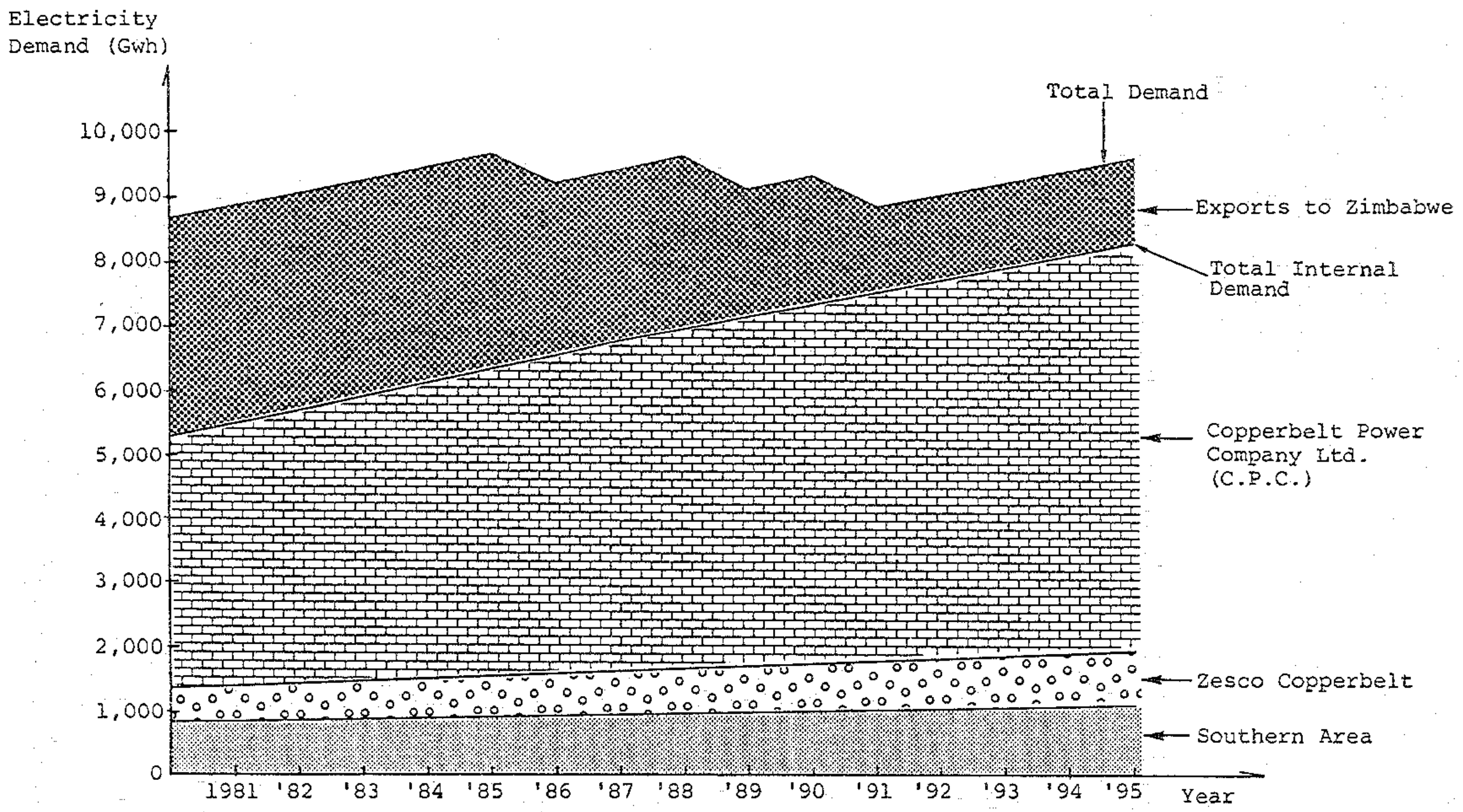


Figure 3-2-1 Projected Demand for Electricity (1981-1995)

Source: ZESCO

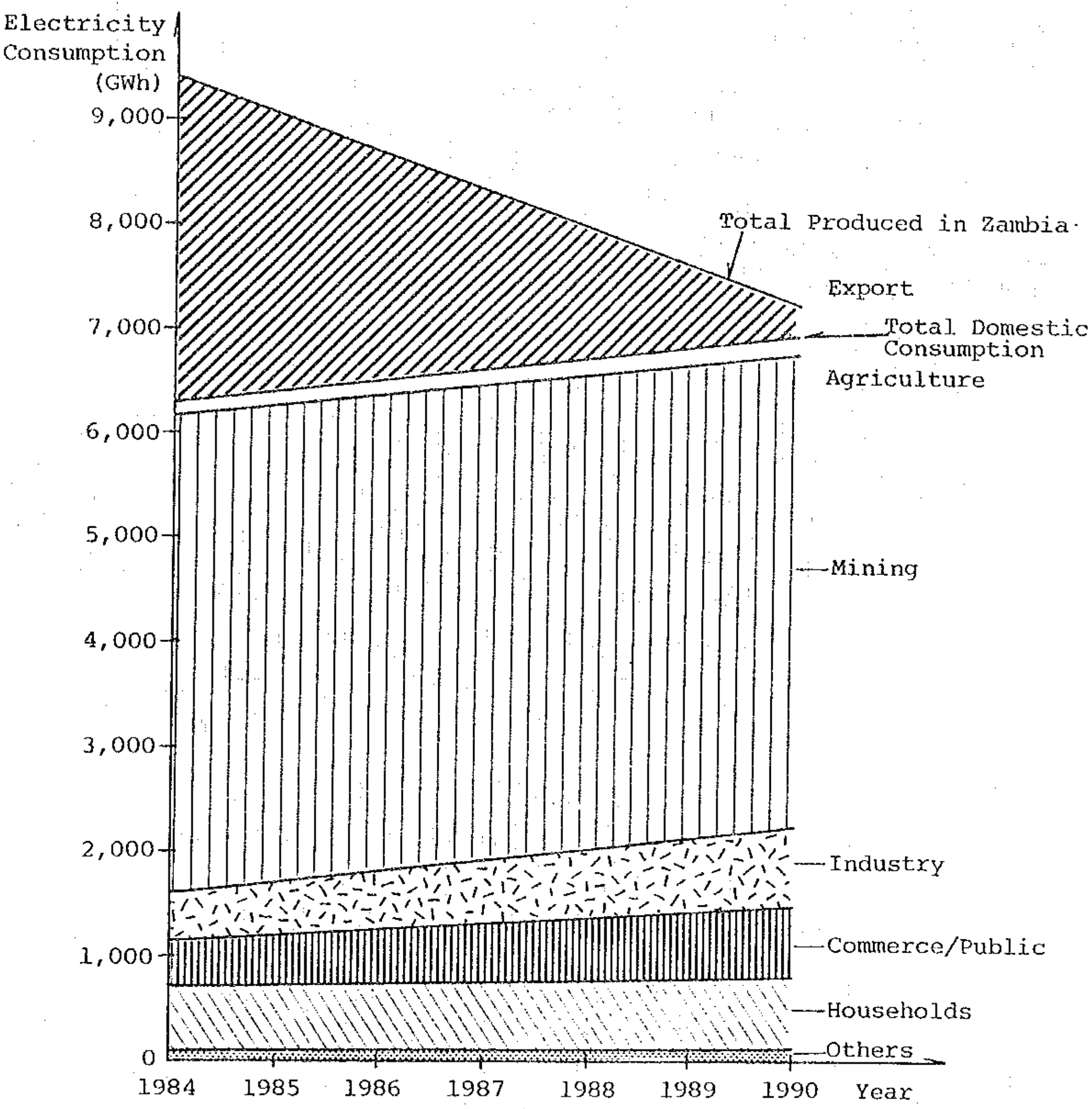


Figure 3-2-2 Electricity Consumption Projections

(2) Petroleum demand projections

1) Study-1

Table 3-2-3 shows projections for petroleum demand in Zambia. The projections assume that there will be a major change in the relative price structure of energy products and in particular petroleum products. The projections for petroleum demand from 1980 to 2000 are made based on three economic growth scenarios; namely, high growth scenario without fuel oil substitution and low growth scenario. The high growth scenario with fuel oil substitution. The high growth scenario with fuel oil substitution assumes fuel substitution will proceed after 1985; e.g., electricity for diesel oil chiefly in the copper mining sector. It also assumes rehabilitation of Indeni Refinery. These assumptions have already deviated from the reality and should be re-examined. Therefore, the demand projections of Table 3-2-3 for the high growth scenario without fuel substitution and the low growth scenario are illustrated in Figure 3-2-3 and 3-2-4.

Table 3-2-3 Demand Projections for Petroleum
(in 1,000 Metric Ton)1/

	1980	1985	1990	1995	2000	Growth Rate(%) 1980-2000
High Growth Scenario	723	758	874	980	1,135	2.28
Annual Growth Rate (%)	-	0.9	2.9	2.3	3.1	-
High Growth Scenario	723	758	645	752	891	1.05
(with Fuel Substitution)2/	-	0.9	-3.2	3.1	3.4	-
Low Growth Scenario	723	717	789	840	916	1.19
Annual Growth Rate (%)	-	0.2	1.9	1.2	1.8	-

1/ Projection excludes the possibility of substantial exports to neighbouring countries which are currently being discussed between the various parties concerned.

2/ Total fuel oil substitution is projected to occur after 1985 for the high growth scenario only.

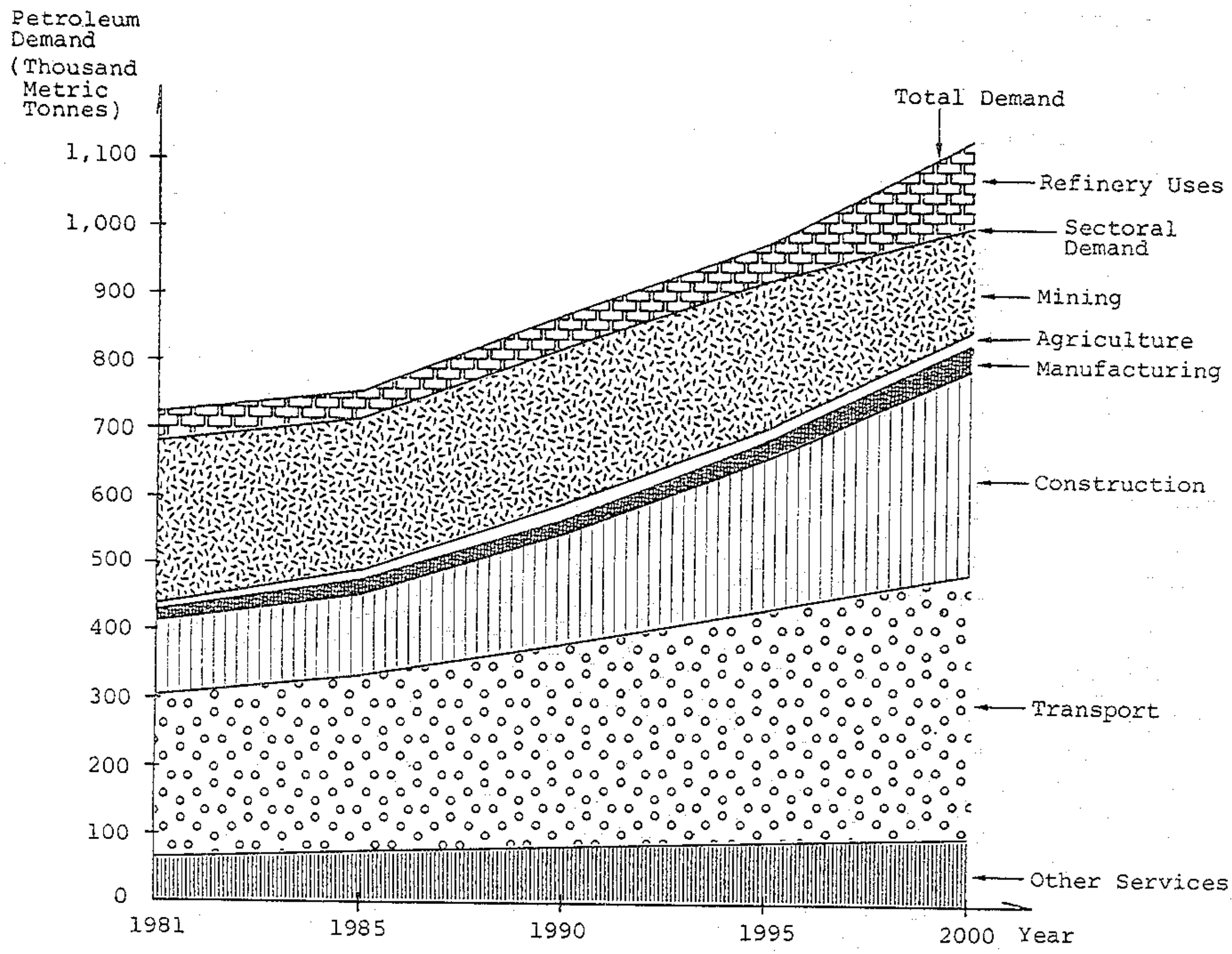


Figure 3-2-3 Demand Projections for Petroleum
(High Growth Scenario without Fuel Substitution)

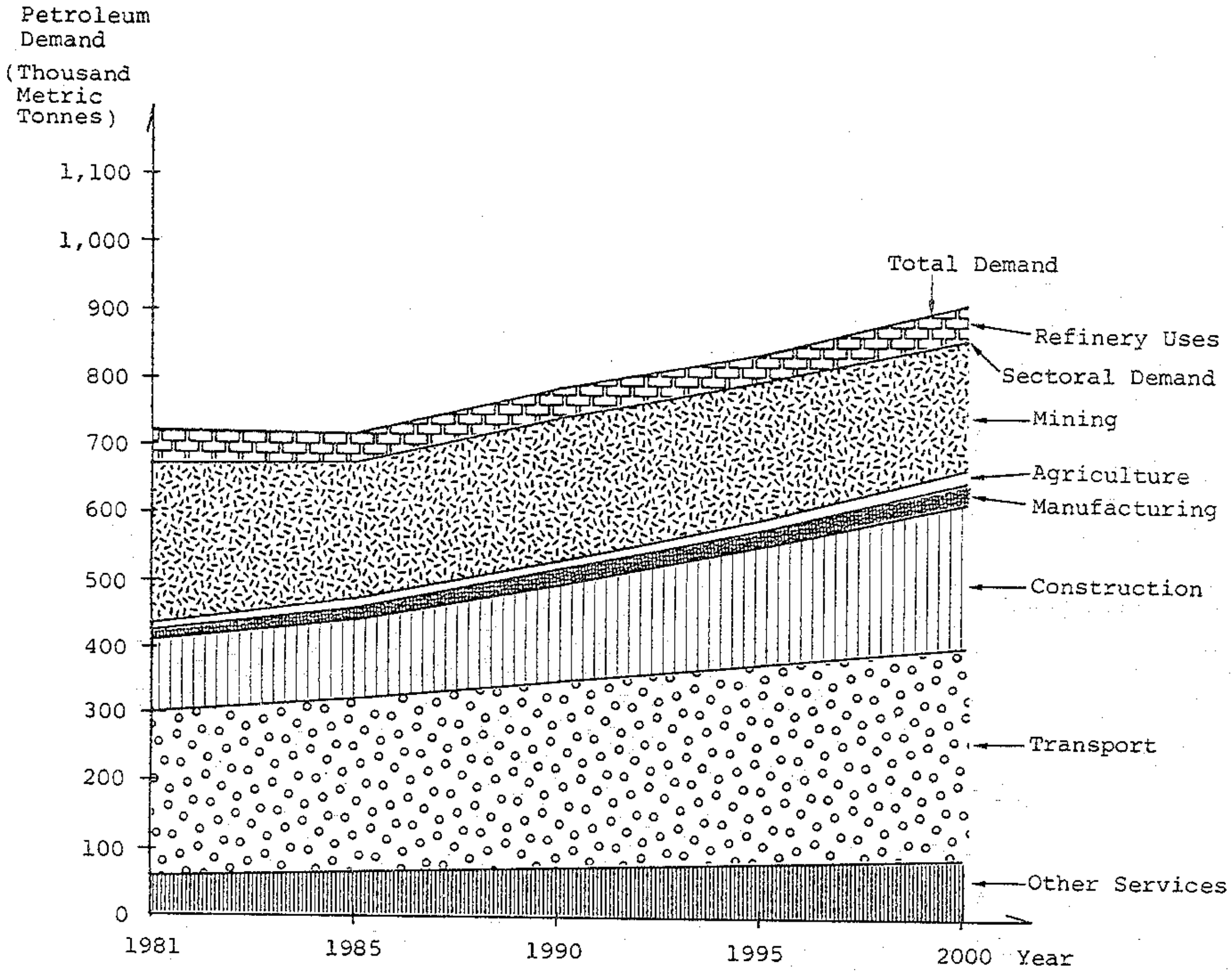


Figure 3-2-4 Demand Projections for Petroleum (Low Growth Scenario)

2) Study-2

Table 3-2-4 shows a projection for petroleum consumption. The projection is, as described in the beginning of this section, based on the existing detailed studies. Additional information from major consumers has been incorporated for some adjustments of the forecasts. The study expects that the total petroleum demand during the period of the fourth national development plan (FNDP) will remain constant.

Figure 3-2-5 illustrates petroleum consumption projections shown in Table 3-2-4.

Table 3-2-4 Petroluem Consumption Projections

Sector	1984 (1000 ton)	1984 (%)	1985 (1000 ton)	1985 (%)	Annaual Growth Rate (%)
Mining	151	26.9	151	26.9	0.0
Industry/Commerce	84	15.0	80	14.3	-0.8
Agriculture	10	1.8	14	2.5	5.8
Transport	270	48.1	270	48.1	0.0
Others/Households	46	8.2	46	8.2	0.0
Total: Domestic Use	561	100.0	561	100.0	0.0
Exports	23		23		
Total: Produced in Zambia	584		584		0.0

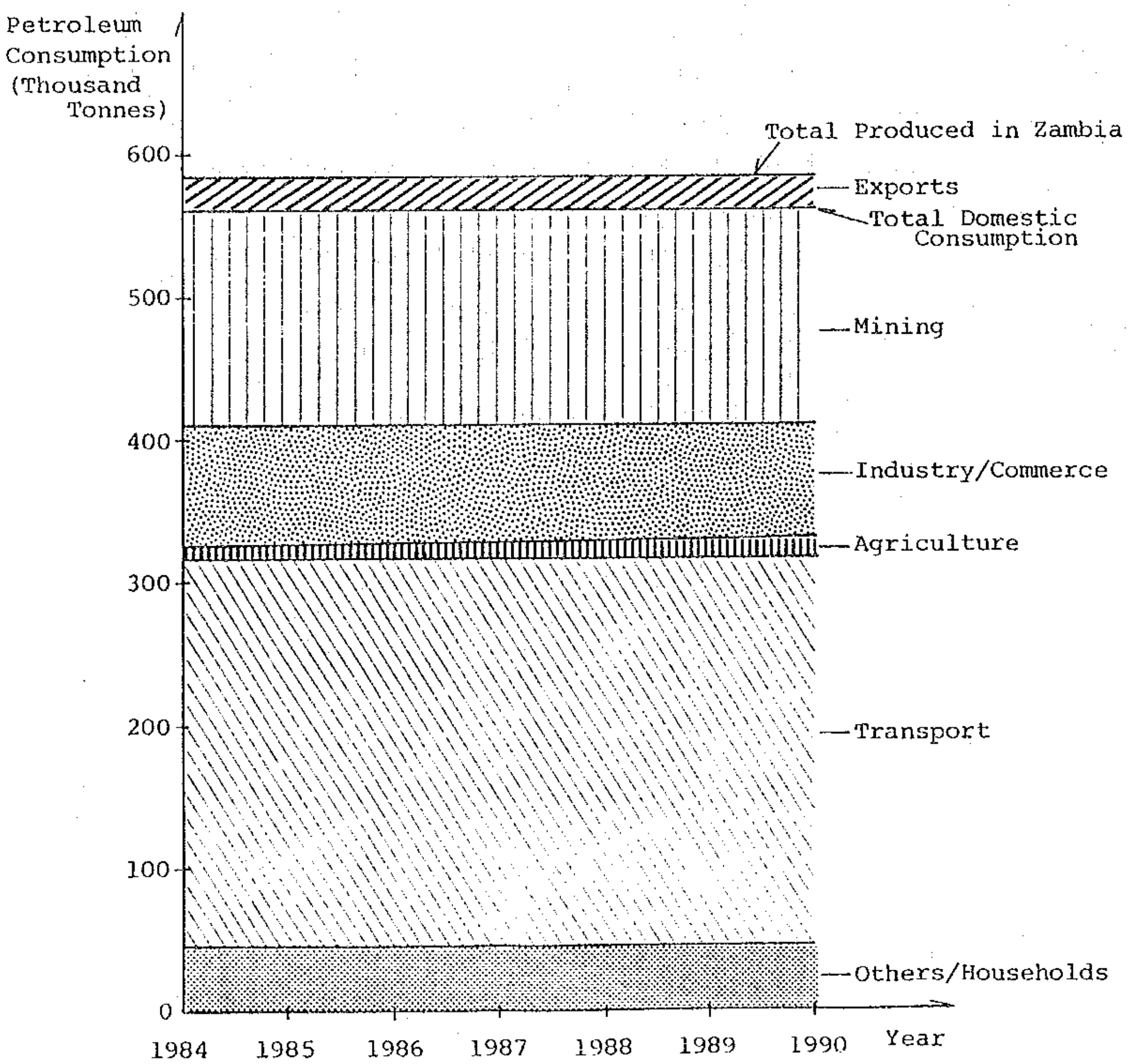


Figure 3-2-5 Petroleum Consumption Projections

(3) Coal demand projections

1) Study-1

Table 3-2-5 indicates projected coal demands which are also developed based on three economic growth scenarios; namely, the high growth scenario without fuel substitution, high growth scenario with fuel substitution and low growth scenario. The high growth scenario with fuel substitution is further divided into two sub-scenarios, one with fuel substitution by coal and the other by electricity. Both sub-scenarios assume the substitution to take place in the copper mining industry.

Table 3-2-5 Projected Coal Demand 1980-2000

(1,000 Ton)

		1980	1980	1990	2000	Growth Rate(%) 1980-1990
High Growth Scenario (No Fuel Substitution)	Mines	320	320	320	320	-
	Industries	291	410	523	852	6.0
	Total	611	730	843	1,172	3.3
High Growth Scenario (With Fuel Substitution)	Mines	320	320	600	600	6.5
				(150)	(150)	-7.3
	Industries	291	410	523	852	6.0
	Total 1/	611	730	1,123	1,452	6.3
	Total 2/	611	730	(673)	1,002	1.0
Low Growth Scenario	Mines	320	320	320	320	-
	Industries	291	320	371	499	2.5
	Total	611	640	691	819	1.2

1/ Implies coal substitutes in the mines after 1985.
2/ Implies electricity (or oxygen flash furnace) substitution in the mines after 1985.

The study also indicates possibility of the projected coal demand shown in Table 3-2-5 being affected by rehabilitation at the Maamba Collieries and the railways.

Figures 3-2-6 and 3-2-7 illustrate the projections for the high growth scenario without fuel substitution and the low growth scenario.

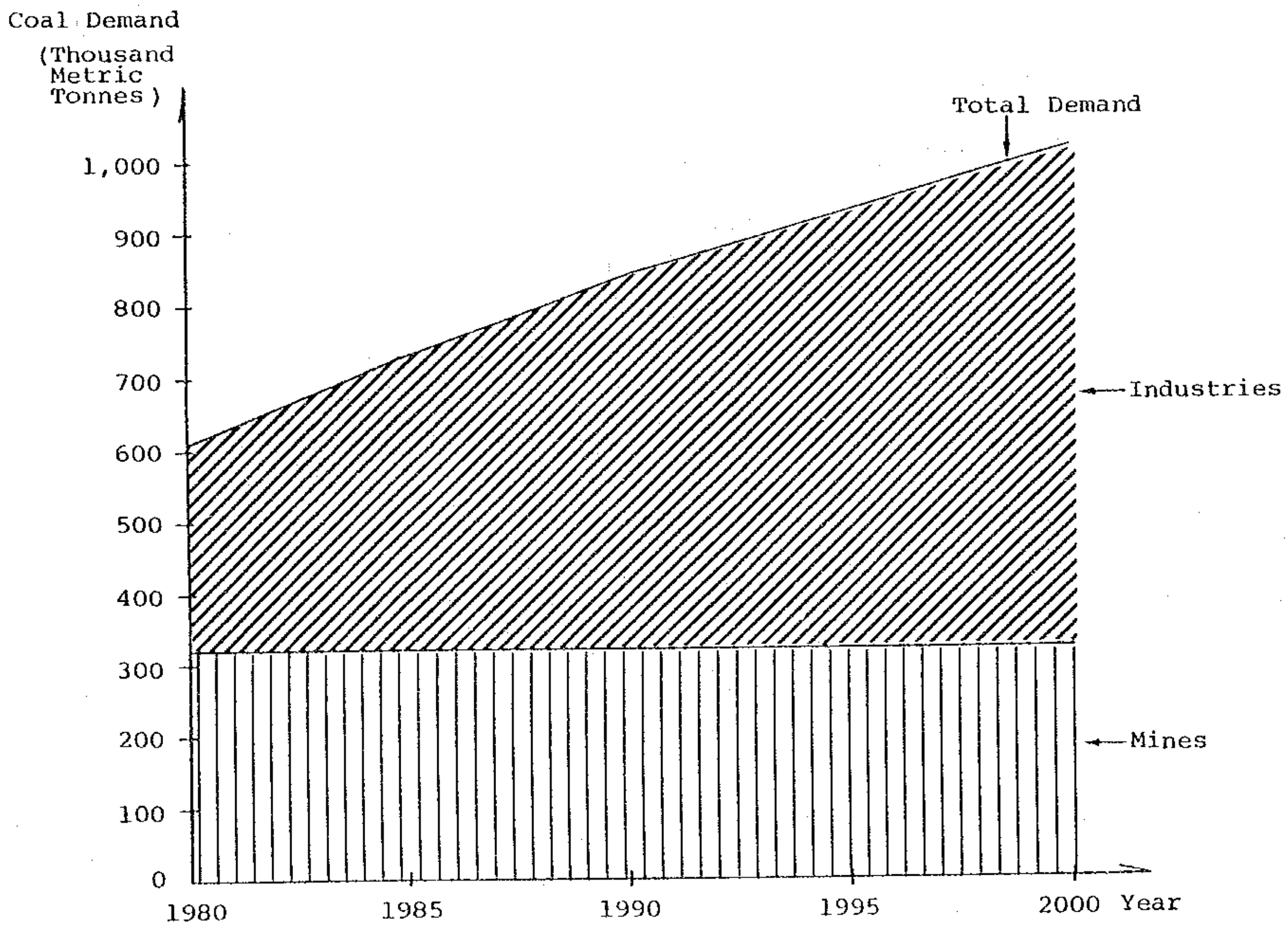


Figure 3-2-6 Projected Coal Demand
(High Growth Scenario without Fuel Substitution)

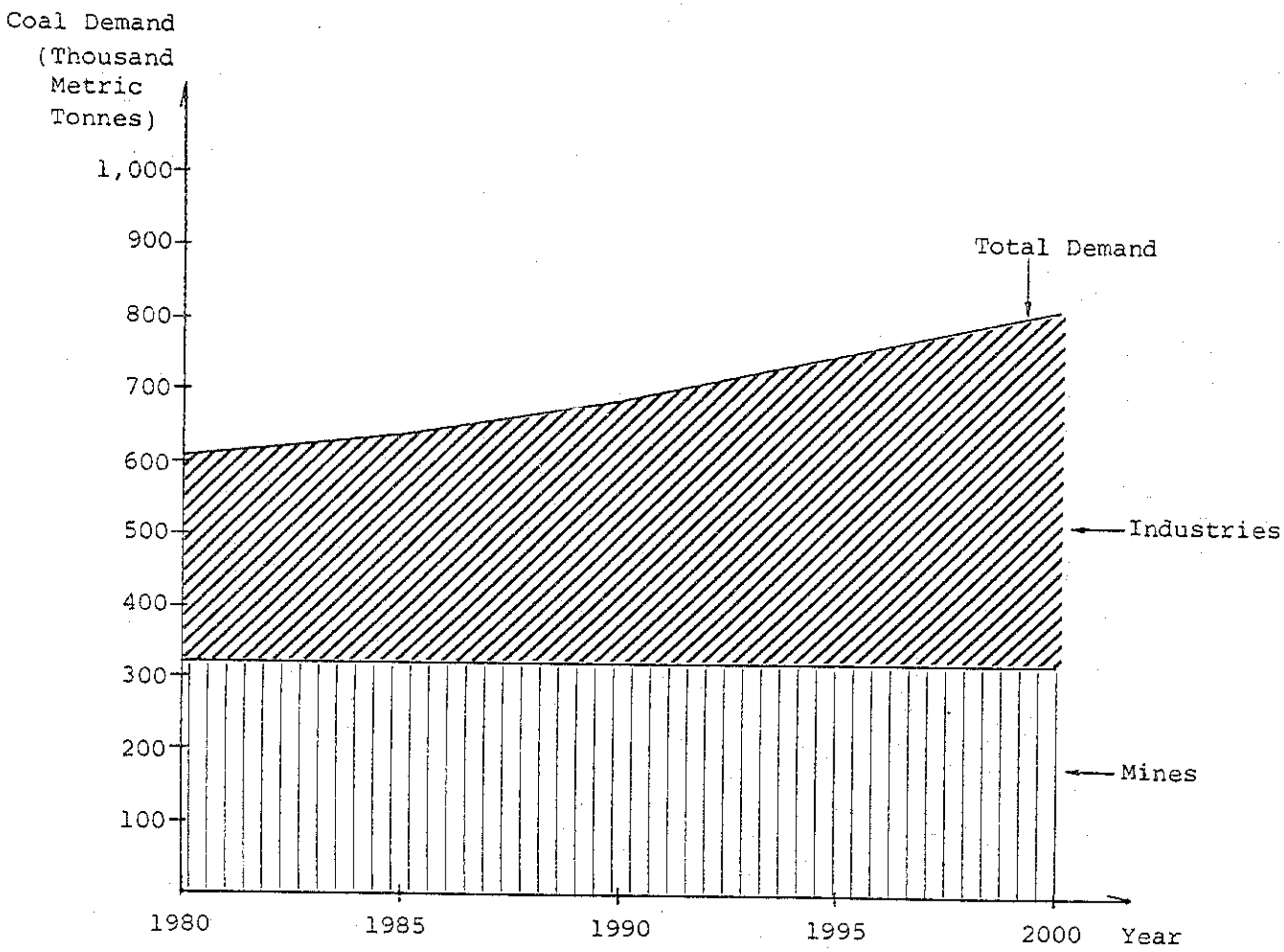


Figure 3-2-7 Projected Coal Demand (Low Growth Scenario)

2) Study-2

Table 3-2-6 shows projections for coal/coke consumption to 1990. A market study recently carried out in connection with a feasibility study for the rehabilitation of the Maamba Collieries indicates a basic coal requirement of about 700,000 tons per year for 1990.

Table 3-2-6 Coal/Coke Consumption Projections

Sector	1984 (1000 Ton)	1984 (%)	1990 (1000 Ton)	1990 (%)	Annual Growth Rate (%)
Mining	310	55.2	245	38.0	-3.8
Industry	243	43.2	390	60.6	8.2
Transport	4	0.7	4	0.6	0.0
Others	5	0.9	5	0.8	0.0
Total: Domestic Use	562	100.0	644	100.0	2.3
Exports/Imports	-96		56		
Total: Produced in Zambia	466		700		7.0

In 1984, the Maamba Colliery produced about 500,000 tons of coal but the production did not meet the demand. A rehabilitation program of the colliery is now underway intended to increase production to 700,000 tons per year in 1987/88. The study comments that when the rehabilitation is successfully carried out and production targets met, the Maamba Colliery should be able to meet the coal demand during the FNDP period.

Figure 3-2-8 illustrates coal/coke consumption projections shown in Table 3-2-6.

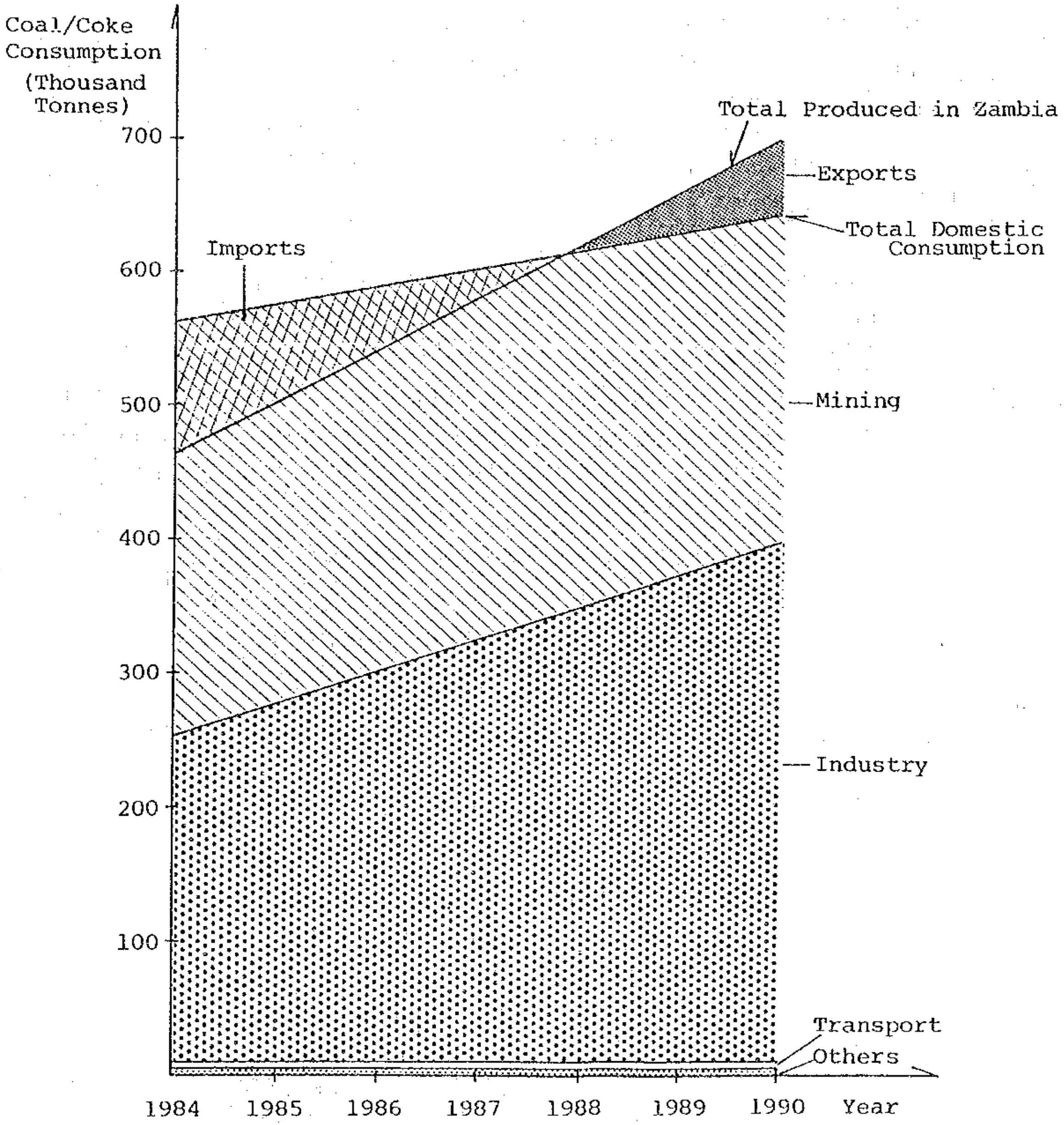


Figure 3-2-8 Coal/Coke Consumption Projections

(4) Woodfuel demand projections

As woodfuel demand projections are not included in Study-2, Study-1 and "The Status and Impact of Woodfuel in Urban Zambia" by Department of Natural Resources, hereinafter called Study-3, are briefed.

1) Study-1

Table 3-2-7 shows projected demand for woodfuels. The projection assumes the urban demand to increase by 6.7% from 1981 to 1985 and at 3.1% thereafter and other demands to grow at 1.1% until 1985 and at 3.1 thereafter. Total woodfuel demand is projected to grow to 8.7 million m^3 and 13.7 million m^3 by 1985 and 2000, respectively.

Table 3-2-7 Projected Demand for Woodfuels (1980-2000)

(Million m^3)

Sectors	1980	1985	1990	1995	2000	Average Growth Rate 1980-2000 (%)
Urban	3.8	5.3	6.2	7.2	8.4	4.0
Rural/Others	3.2	3.4	3.9	4.6	5.3	2.6
Total	7.0	8.7	10.1	11.8	13.7	3.4

Figure 3-2-9 illustrates projected demand for woodfuels shown in Table 3-2-7.

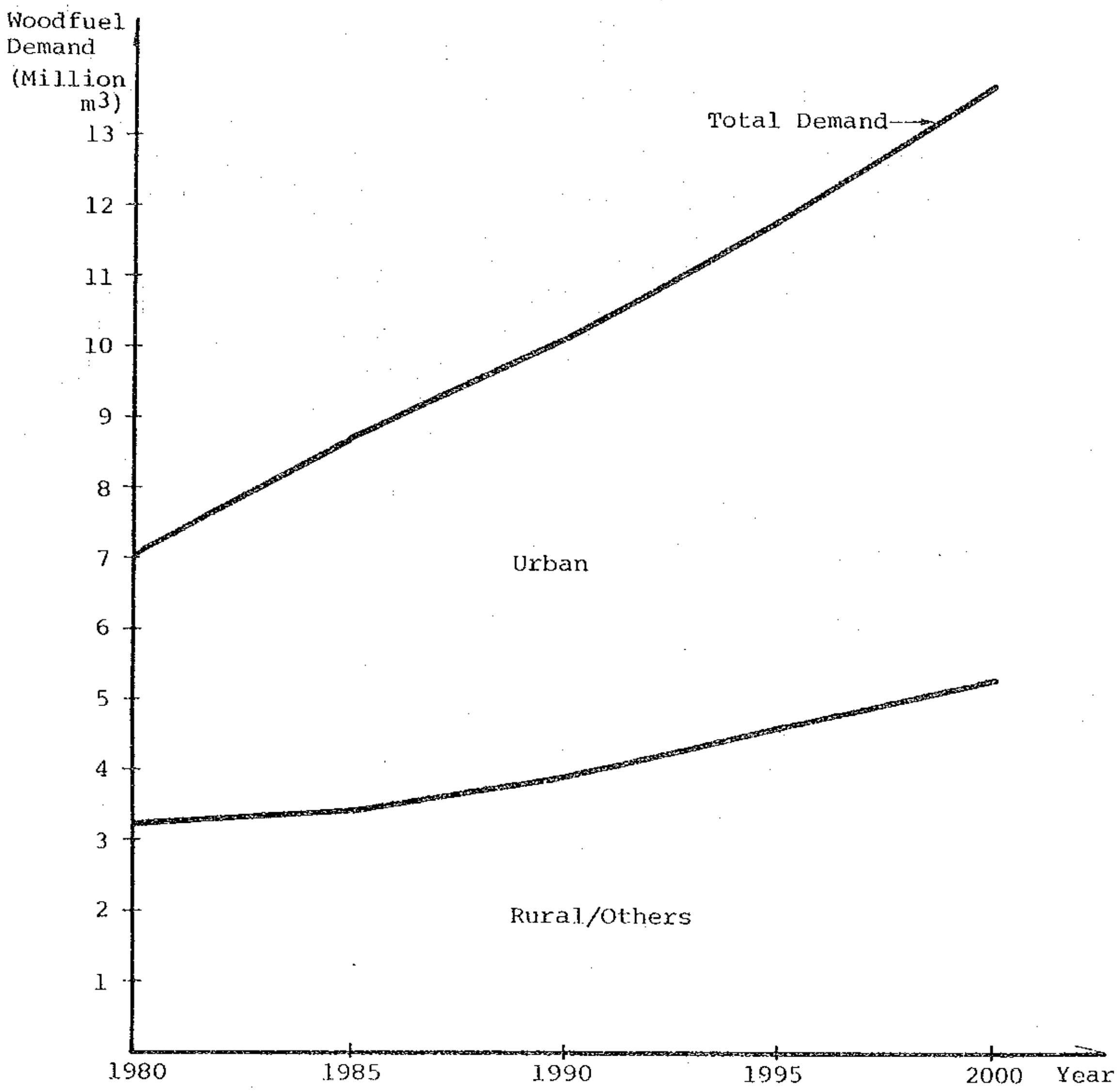


Figure 3-2-9 Projected Demand for Woodfuels (1980-2000)

2) Study-3

Woodfuel demand is forecast primarily by population and secondarily by such socio-economic factors as income, energy prices, and local energy use practices.

Table 3-2-8 shows a trend in urban population growth. The growth rate is held constant at 6.7% in calculating projected urban population size for 1983, 1990 and 2000. It was estimated that during 1983 a total of 332,868 tons of charcoal and 624,384 m3 of firewood were consumed in urban households in large towns of Central and Copperbelt regions. Of this total woodfuel consumption, Lusaka city consumed nearly 33% of the charcoal and 34% of the firewood.

Figure 3-2-10 shows current and projected increase in woodfuel consumption in large towns of Central and Copperbelt regions up to the year 2000, based on present consumption levels.

Table 3-2-8 Growth of Urban Population in Zambia and Selected Urban Areas

	Urban Area		
Year	Lusaka City	Large Towns in Central /Copperbelt Regions	All Urban
1954[1]	47,793	-	-
1947/58[1]	64,754	-	-
1963	125,346	681,994	715,020
1969	268,425	1,146,873	1,192,116
1980	576,703	1,900,276	2,440,419
1983	627,441	2,067,500	2,655,176
1990[2]	963,094	3,171,561	4,073,059
2000[2]	1,349,485	4,443,357	5,706,356

Sources of Date: GRZ Central Statistical Office (1981); Seymour (1976).

1 - African Population only

2 - Projected population based on 6.7% annual growth rate.

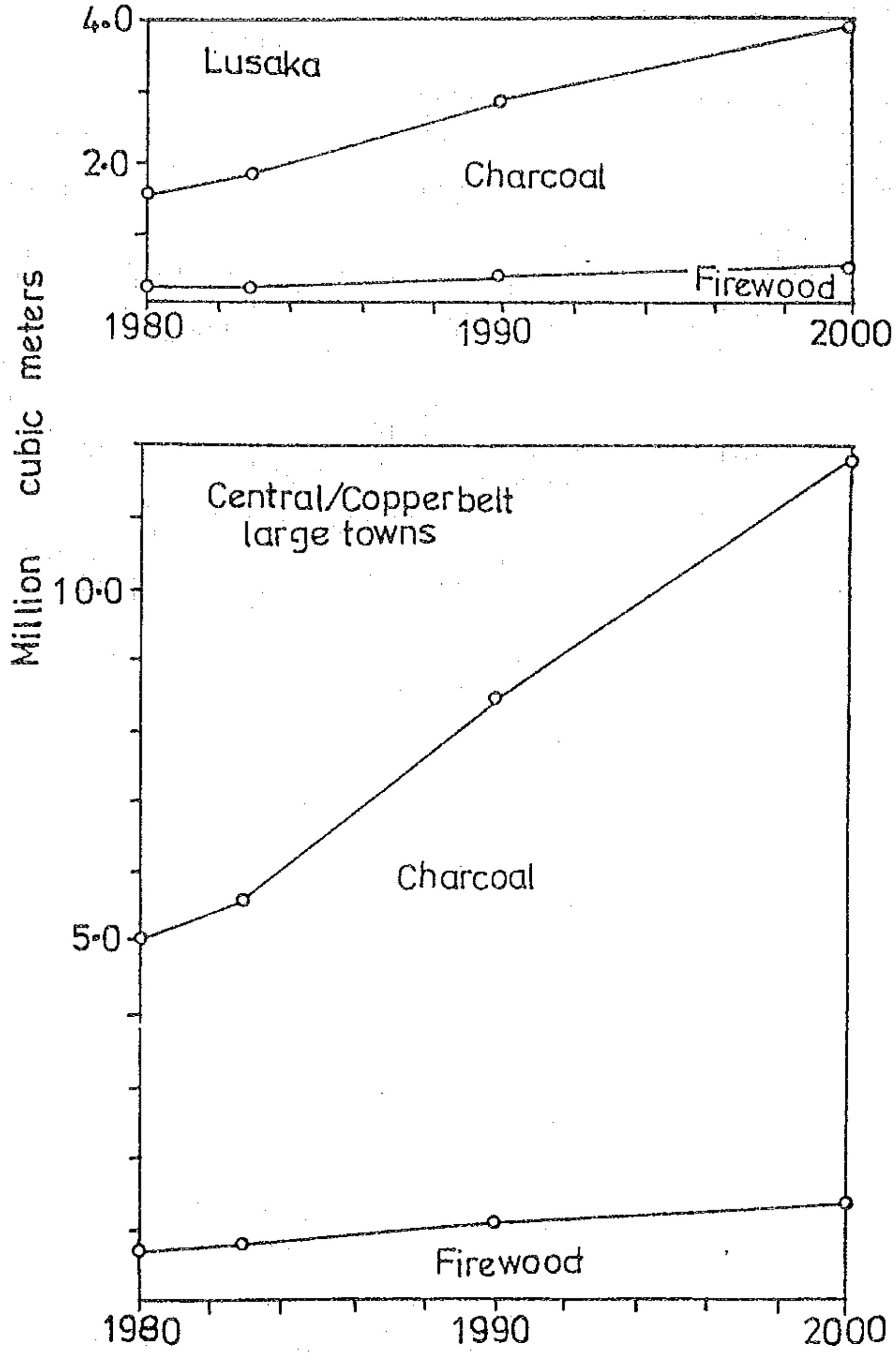


Figure 3-2-10 Woodfuel Consumption Projections in Central/Copeerbelt Large Town

(5) Summary of existing forecasts

The results of the three studies referred to are shown in Table 3-2-9 and Figure 3-2-11 in a manner to permit comparison. Study-2 does not project beyond 1990; therefore, it is extended up to 2000. These may be summarized as follows:

1) The woodfuel demand will steadily increase.

2) The demand for electricity will increase. The present capacity (1.798 GW x 8800 h/Y x 0.7 = 11,076 Gwh/Y) will not be exceeded by demand.

3) The coal demand will gradually increase.

4) The estimated growth rates used by these studies are considerably different from the actual recorded growth rates.

Table 3-2-9 Domestic Energy Demand Projections (1984-3000)

		1984	1985	1990		1995			2000		
		(Study-2&3)	(Study-1)	(Study-1)	(Study-2&3)	(Study-1)	(Study-2&3) (Case-1)	(Case-2)	(Study-1)	(Study-2&3) (Case-1)	(Case-2)
Woodfuel	(Mill. Cubic Meter)	6.0	8.7	10.1	8.4	11.8	10.0	10.0	13.7	11.7	11.7
	(PJ)	38.6	56.0	65.0	54.1	76.0	64.4	64.4	88.2	75.3	75.3
	(%)	38.9	44.6	45.7	45.0	47.3	46.5	48.0	48.6	47.6	50.6
Electricity	(GWh)	6,294	6,373	7,375	6,965	8,315	7,842	7,577	9,375*	8,829	8,244
	(PJ)	22.7	22.9	26.6	25.1	29.9	28.2	27.3	33.8	31.8	29.7
	(%)	22.8	18.3	18.6	20.9	18.7	20.4	20.3	18.6	20.1	19.9
Petroleum	(1000 MT)	561	717	789	584	840	629	584	916	678	584
	(PJ)	23.8	30.5	33.5	24.8	35.7	26.7	24.8	38.9	28.8	24.8
	(%)	24.0	24.3	23.5	20.7	22.2	19.3	18.5	21.5	18.2	16.7
Coal/Coke	(1000 MT)	562	640	691	644	752*	758	701	819	891	762
	(PJ)	14.1	16.1	17.3	16.2	18.9	19.0	17.6	20.6	22.4	19.1
	(%)	14.2	12.8	12.2	13.5	11.8	13.7	13.1	11.3	14.1	12.8
Total	(PJ)	99.2	125.5	142.5	120.2	160.5	138.4	134.1	181.5	158.3	149.0
	(%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Note: * Figures estimated
Energy conversion factors used are:
1 GWh = 3,600 Giga Joule, or 3.6 Tera Joule,
1 Ton of the Zambian mix oil products = approx. 42.5 Giga Joule,
1 Ton of coal = approx. 25.1 Giga Joule,
1 Cubic Met of woodfuel = approx. 6.44 Giga Joule.

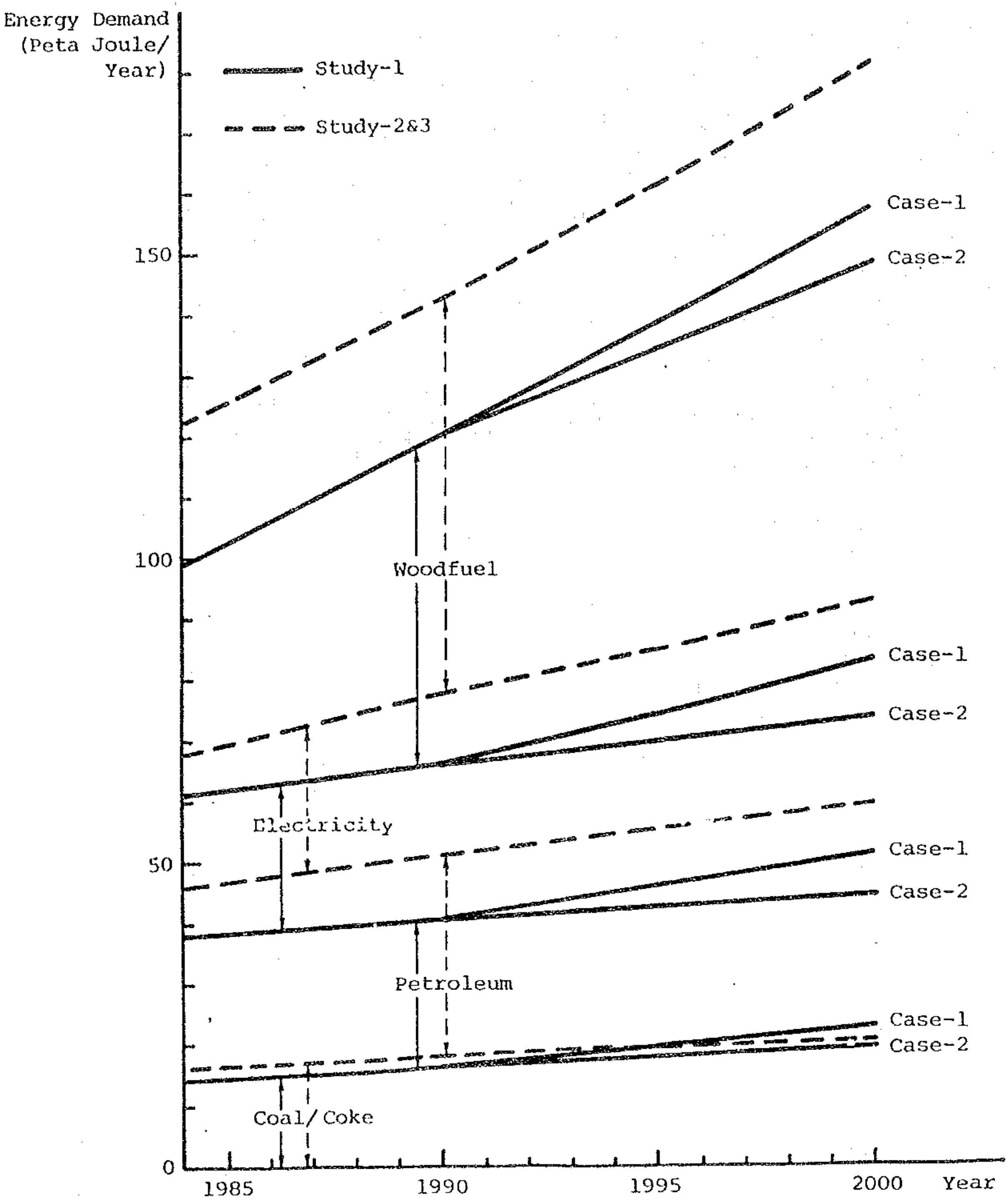


Figure 3-2-11 Domestic Energy Demand Projections(1984-2000)

Table 3-2-10 Applied Annual Energy Growth Ratesfor Two Cases by Energy Product

	Annual Energy Growth Rate (% p.a.)	Actual Annual Energy Growth Rate during 1977-1983 (% p.a.)
Electricity:		2.7
Case-1	2.4	-
Case-2	1.7	-
Petroleum:		-3.9
Case-1	1.5	-
Case-2	0.0	-
Coal/Coke:		-5.7
Case-1	3.3	-
Case-2	1.7	-

3.2.2 Forecast energy supply and demand

From the previous section 3.3.1 and the outcomes of the other parts of this feasibility study the following premises are established for forecasting energy supply and demand.

(1) Supply Premises

1) Electricity

a) There will be no major addition of hydroelectric power or thermal power capacities although small diesel-power plants will be installed for local electrification purposes.

b) The existing facilities will be well maintained.

2) Petroleum

a) Tazama pipeline will be rehabilitated but the diameter will not be increased.

b) There will be no major change in oil price.

c) No great reserve of oil or natural gas will be discovered in Zambia.

3) Coal

a) The Maamba Collieries will be rehabilitated and the original capacity of one million ton coal will be restored.

b) Production from other coal deposit will not begin before 2000.

c) The transportation bottleneck will be greatly reduced.

4) Woodfuel

a) The supply and distribution to major cities will remain basically unchanged. (Refer to Chapter 4.)

b) Charcoal supply to Lusaka will be made within a radius of 200 km.

(2) Demand premises

1) Electricity

a) As foreseen by Study-2, export to Zimbabwe will diminish.

b) A series of electricity-intensive industries to produce basic necessities like soap, paper, disinfectant for drinking water or fertilizer will be established by 1995 drawing upon cheap and abundant electricity. The total power requirement of these industries will be around 1,000 Gwh.

c) Except for the above b) the premises of Study-2 will hold.

2) Petroleum

a) There will be no great latitude for the consumers' option as now. The consumption will be limited by the physical condition of the hardware, geographical condition and the economy of the nation.

b) Effort will be made by every industry to substitute local energy for petroleum.

3) Coal

a) There will be an incremental demand of 50,000 tons to produce cement needed for infrastructure improvement by 1995. There will be substitution of 5,000 to 10,000 tons coal for diesel fuel for rail transportation by 1995.

b) Other premises of Study-2 will hold.

c) The incremental domestic demand accruing from a) b) will replace export and other demands estimated by Study 2.

4) Woodfuel

a) There will be no effective substitute for woodfuel except for coal briquettes of this project and electricity.

(3) Supply demand forecast

Based on the preceding discussions the supply and demand are forecast as follows:

1) Woodfuel would follow more or less the projection by Studies 2 & 3.

2) Electricity supply and demand will be larger than those projected by Studies 2 & 3 by about 1,000 Gwh in 1995 onward. Until 1990 the projection by Studies 2 & 3 appears right.

3) Petroleum will maintain at about the current level of 600,000 tons.

4) Coal will probably follow the projection by Studies 2 & 3.

The results of the forecast are summarized on Table 3-2-11.

Table 3-2-11 Forecast Energy Supply and Demand

		1990	1995	2000
Woodfuel	(Million Cubic Meter)	8	10	12
	(PJ)	52	64	77
	(%)	44	47	51
Electricity	(Gwh)	7,000	8,500	8,700
	(PJ)	25	31	32
	(%)	21	22	22
Petroleum	(100MT)	600	600	600
	(PH)	25	25	25
	(%)	21	18	16
Coal	(1000MT)	640	700	760
	(PJ)	16	18	19
	(%)	14	13	12
Total	(PJ)	118	138	153
	(%)	100	100	100

3.3 Energy Price Forecast

Expected future prices of electricity, petroleum products, coal, and charcoal, the leading energy sources in the Republic of Zambia, are forecast in this section. The following two methods are employed in the forecast.

1) The past trend in the price of each energy is studied and is used for forecasting the future trend with peculiar characteristic of each energy incorporated.

2) The statistical correlation between individual energy prices and the consumer's price index (C.P.I) is studied. For those correlation is found significant, the future energy price is forecast using forecast C.P.I. and recent price characteristics.

Method No. 1 is employed when the past prices are sufficiently available and the coefficient of determination (r) of the regression curve between time and price as variables is sufficiently close to 1.00. Method No. 2 is employed where Method No. 1 is not applicable. The following two assumptions were prerequisites for the application of the two methods.

1) There will be no drastic political and economic changes in Zambia or immediate surroundings.

2) The international supply and demand of crude oil is stable, without abrupt rises or plunges in price.

3.3.1 Electricity price forecast

Domestic electricity charges are set by the Zambia Electricity Supply Corporation Limited (ZESCO). Charges between September 1979 and October 1985 are shown in Table 3-3-1. This project concerns mainly household energy; therefore, this study is limited to the forecast of electric power charges for household use.

Table 3-3-1 however provides too few data to enable the trend to be analyzed. Therefore, statistical correlation between the electricity and C.P.I. was studied. The results are shown in Table 3-3-2.

Table 3-3-2 shows a very good correlation between home electricity charges and the consumer price index. A regression curve was drawn with consumer price indices from 1975 to 1984 and time (year) as variables, introducing the C.P.I. in September 1985 (526.8) as initial value. The C.P.I.'s are forecast from September 1985 to the year 2000 with some modifications made to the projected C.P.I.'s obtained from the correlation. The results are shown in Table 3-3-3.

Table 3-3-1 Electricity Tariffs in Kwacha

	9/1979	5/1983	10/1985
Domestic			
- Fixed Monthly Charge*:	3.60	4.50	7.70
- Charge per kwh :	0.0170	0.0213	0.0363
Commercial			
- Fixed Monthly Charge :	13.00	16.25	27.70
- Max. Demand Charge per KVA per month:	-	3.63	N.A.
- Charge per kwh :	0.0190	0.0238	4.05
Industrial (Max. Demand 300KVA)			
- Fixed Monthly Charge :	16.90	21.13	36.00
- Max. Demand Charge per KVA per month:	2.90	3.63	6.18
- Charge per kwh :	0.0130	0.0163	0.0278
(Max. Demand 300-2,000KVA)			
- Fixed Monthly Charge*:	325.00	406.25	690.00
- Max. Demand Charge per KVA per month:	2.60	3.25	5.53
- Charge per kwh :	0.0100	0.0125	0.0213
(Max. Demand 2,001KVA)			
- Fixed Monthly Charge per KVA per month:	3,250.00	4,062.5	6,900.0
- Max. Demand Charge per KVA per month:	2.22	2.78	4.73
- Charge per month :	0.0065	0.0082	0.0140

Note) *: Fixed Monthly Charge for Residential (Max. KVA=15.0)
Source: ZESCO

Table 3-3-2 Statistical Correlation Coefficients between Domestic Electricity Tariffs and Consumper's Price Index

	1979 Sept.	1983 May	1985 Oct.
(1) Fixed Monthly Charge (Kwacha/Month):	3.60	4.50	7.70
(2) Unit Charge (Ngwee/Kwh):	1.70	2.13	3.63
(3) Consumer's Price Index (Low Income Group)*:	181.6**	308.6	526.8**
(4) Consumer's Price Index (High Income Group)*:	169.8**	279.3	455.9**
(5) Correlation Coefficient (1) VS. (3):		0.987	
(6) Correlation Coefficient (2) VS. (3):		0.988	
(7) Correlation Coefficient (1) VS. (4):		0.984	
(8) Correlation Coefficient (2) VS. (4):		0.985	

Note : * : 1975 = 100.0
** : Average figures in 1979
***: Figures in September, 1985

Table 3-3-3 Consumer's Price Index Projection (Low Income Group)

	Actual											Projection		
Year	1975	'76	'77	'78	'79	'80	'81	'82	'83	'84	'85 Sep.	'90	'95	2000
Consumer's Price Index														
(Low Income Group)(1975 = 100.0):	100.0	118.8	142.3	165.6	181.6	202.9	231.3	260.2	311.2	374.5	526.8			
. Exponential Curve														
Fitting (r = 0.997) :											526.8	890.4	1,703.8	3,323.6
. Power Curve														
Fitting (r = 0.997) :											526.8	837.5	1,447.4	2,475.6
. Linear Regresion														
Fitting (r = 0.976) :											526.8	645.7	785.6	925.5
. Logarithmic Curve														
Fitting (r = 0.973) :											526.8	634.0	753.7	867.3

Note) r : Coefficient of Regression Curve Determination

Next, a regression curve with C.P.I. and household electricity charges as variables is drawn. It should be remembered here that the foreign currency auction system was introduced on October 11, 1985, which spurred a steep rise in price. Table 3-3-1 shows that electricity charges in October 1985 jumped by a margin unprecedented in the country's history. If this data is included in drawing the curve, the curve will be too steep to reflect the real trend. As mentioned before, this energy price forecast is made on the assumption that drastic political and economic changes will not occur in the country or its surroundings. Therefore, it is assumed that any abrupt changes comparable to those associated with the introduction of foreign currency auction system does not occur; by the same token, the October 1985 price is excluded from the regression analysis to produce a relatively gentle curve.

The results of the regression are given in Table 3-3-4. The table indicates projections derived from four regression curves based on different mathematical functions between fixed monthly charges and C.P.I.'s and between unit charges and C.P.I.'s. As the linear regression is considered to best reflect reality, the results of the linear regressions alone are shown in Figures 3-3-1 and 3-3-2.

3.3.2 Petroleum product price forecast

Zambia depends totally on imports for the supply of petroleum; therefore, Zambia's domestic petroleum product prices are linked to world crude oil prices, particularly those of OPEC. Table 3-3-8 shows gross domestic product (GDP), consumer's price index, OPEC's crude oil GSP (government selling price) average, and retail prices of petroleum products from 1978 to 1985. Good statistical correlation is found to exist between retail prices of petroleum products and OPEC GSP average (in domestic currency), DSP, and C.P.I. as shown in Table 3-3-6. The closest correlation is seen in petroleum product retail prices and the OPEC GSP average.

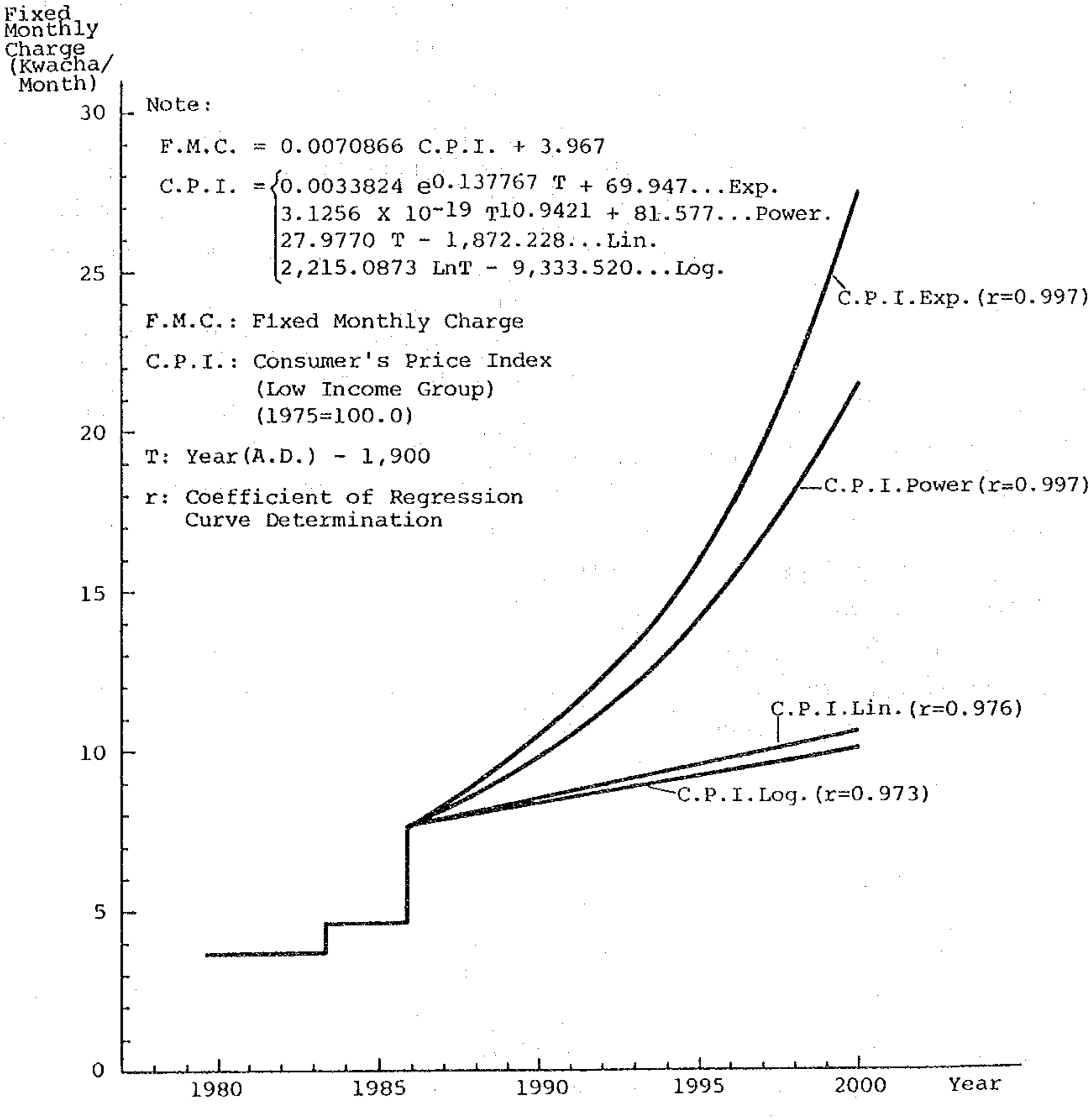


Figure 3-3-1 Domestic Electricity Tariffs Projection (Fixed Monthly Charge)

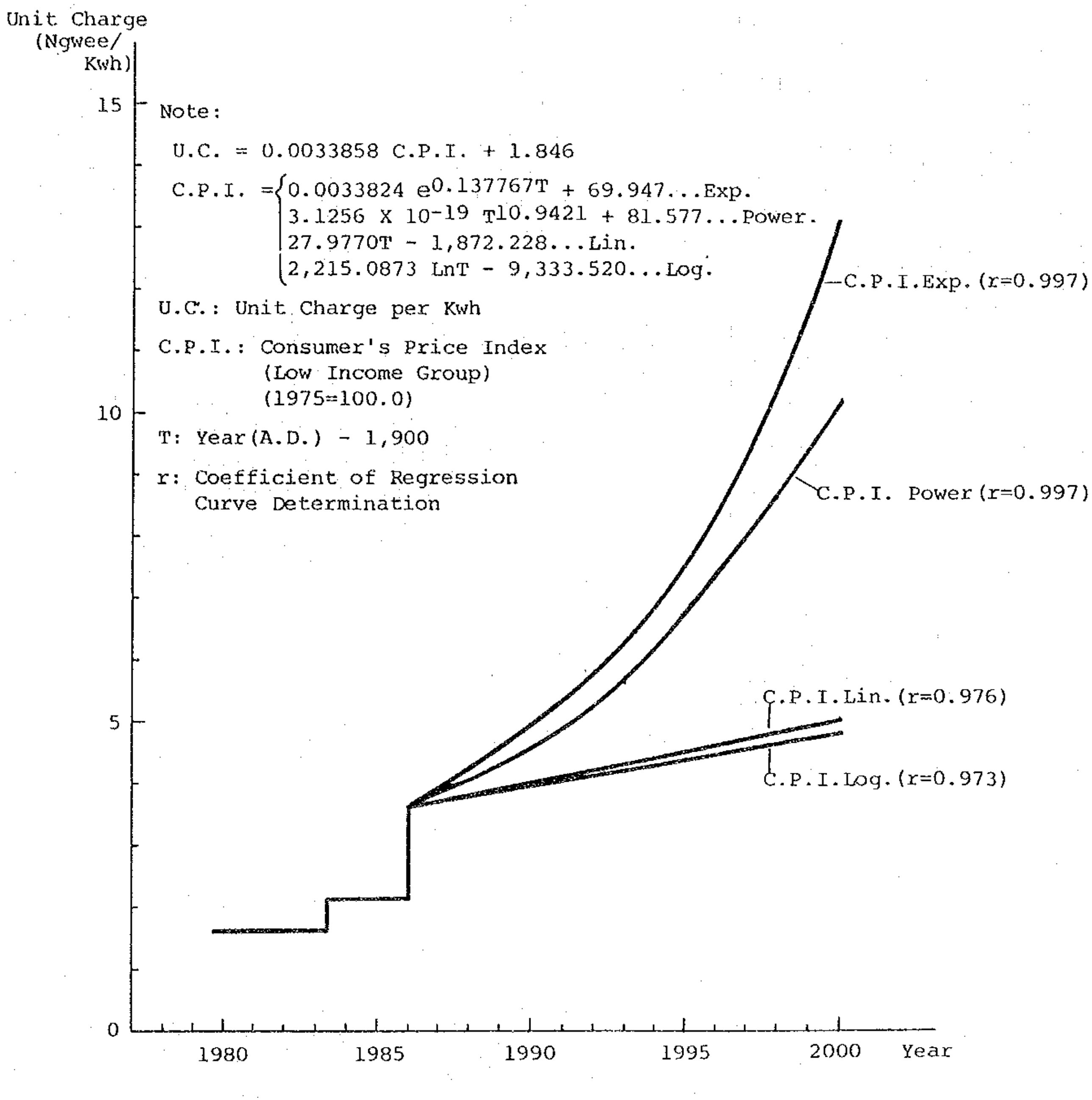


Figure 3-3-2 Domestic Electricity Tariffs Projection (Unit Charge per Kwh)

Table 3-3-4 Domestic Electricity Tariffs Projection by Consumer's Price Index (Low Income Group)

		1990				1995				2000			
	1985(Oct.)	Exp.*	Power*	Lin.*	Log.*	Exp.*	Power*	Lin.*	Log.*	Exp.*	Power*	Lin.*	Log.*
Consumer's Price Index													
(Low Income Group)(1975 = 100.0)	526.8	890.4	837.5	645.7	634.0	1,703.8	1,447.4	785.6	753.7	3,323.6	2,475.6	925.5	867.3
Fixed Monthly Charge (Kwache/Month)													
Exp. Curve	7.70	13.61	12.49	9.23	9.07	53.32	34.38	11.50	10.93	900.38	203.77	14.40	13.11
Power Curve	7.70	9.09	8.91	8.20	8.16	11.30	10.69	8.73	8.62	14.30	12.87	9.21	9.02
Lin. Regression	7.70	10.28	9.90	8.54	8.46	16.04	14.22	9.53	9.31	27.52	21.51	10.53	10.11
Log. Curve	7.70	8.59	8.49	8.05	8.01	9.69	9.42	8.38	8.31	10.83	10.33	8.66	8.55
Unit Charge (Ngwee/Kwh)													
Exp. Curve	3.63	6.48	5.94	4.37	4.29	25.86	16.58	5.46	5.19	450.58	100.35	6.86	6.24
Power Curve	3.63	4.30	4.21	3.87	3.85	5.36	5.07	4.13	4.07	6.80	6.12	4.26	4.35
Lin. Regression	3.63	4.86	4.68	4.03	3.99	7.62	6.75	4.51	4.40	13.10	10.23	4.98	4.78
Log. Curve	3.63	4.06	4.01	3.80	3.78	4.58	4.45	3.95	3.92	5.12	4.88	4.09	4.03

Note) Exp.* : Consumer's Price Index derived from Exponential Curve Fitting (See Table 3-3-3)
Power* : " Power Curve Fitting (")
Lin.* : " Linear Regression Fitting (")
Log.* : " Logarithmic Curve Fitting (")

Table 3-3-5 Gross Domestic Product, Consumer's Price Index, OPEC Oil GSP and Petroleum Products Retail Prices (1978 - 1985)

						1983				1984			1985		
	1978	1979	1980	1981	1982	Jan.29	May 4	May30	Jun.1	Jan.28	Apr.28	Oct.30	Jan.26	Oct.15	De
Gross Domestic Product (K Million)	2,250.7	2,660.4	3,063.6	3,485.4	3,595.3		4,181.2*				4,733.3*			N.A.	
(At current purchasers' value)															
Consumer's Price Index															
- Low Income Group (1975 = 100)	165.6	181.6	202.9	231.3	260.2		311.2*				372.5*		437.2	526.9(Sept.)	
- High Income Gorup (1975 = 100)	152.6	169.8	189.4	209.1	236.7		278.6*				336.8*		377.7	455.9(Sept.)	
Average OPEC GSP in US$ (US$/Barrel)	12.93	18.67	30.87	34.47	33.44		29.06*				28.48*			27.52*	
Average Exchange Rate (Kwacha/US$)	0.8008	0.7933	0.7887	0.8731	0.9308		1.2592*				1.8132*			3.1396*	
Average OPEC GSP in Kwacha (Kwacha/Litre)	6.513	9.316	15.31	18.93	19.58		23.02*				32.48*			54.35*	
Premium Gasoline (Ngwee/Litre)	51.0	79.0	84.0	100.0	103.0	106.0	98.0	97.0	97.0	105.0	130.0	130.0	141.0	282.0	28
Regular Gasoline (Ngwee/Litre)	40.0	73.0	78.0	94.0	97.0	100.0	92.0	91.0	91.0	96.5	119.0	119.0	129.0	258.0	25
Gasoil (Ngwee/Litre)	23.0	28.0	40.0	52.0	61.0	72.0	68.0	68.0	68.0	71.9	91.0	91.0	97.0	187.0	187
Kerosene (Ngwee/Litre)	11.0	17.0	19.0	36.0	41.0	51.0	51.0	51.0	51.0	51.5	69.0	69.0	72.5	152.0	152

Note) * : Figure represents the average in the corresponding year.

Table 3-3-6 Statistical Correlation Coefficients between Petroleum Products Retail Prices and, Average OPEC GSP, Gross Domestic Product, and Consumer's Price Index

Petroleum Products	Ave.OPEC GSP in Kwacha	Gross Domestic Product	Consumer's Price Index	
			Low Income	High Income
Premium Gasoline	0.987	0.983	0.989	0.987
Regular Gasoline	0.964	0.931	0.888	0.893
Gasoil	0.966	0.918	0.859	0.864
Kerosene	0.990	0.989	0.986	0.986

For this reason, the best method for predicting petroleum product prices is probably to link them with the forecast OPEC GSP average. However, forecasting GSP and Zambia's foreign exchange rate is very difficult. On the other hand, as is seen from Table 3-3-7, the petroleum product pricing structure in Zambia does not necessarily reflect the world-pricing structure. This may be attributable to the government control on the wholesale pricing of all petroleum products and pricing of gasoline, kerosene, and diesel oil at retail end.

Table 3-3-7 Comparison of International (Persian Gulf) Postings and Domestic Consumer Prices (1982)

Product	Index of Persian Gulf Posting (Kerosene = 100)	Index of Domestic Consumer Prices (Kerosene = 100)
Premium Gasoline	95	251
Regular Gasoline	91	236
Kerosene	100	100
Diesel Oil	98	149

Source: Zambia: Issues and Options in the Energy Sector Jan. 1983 Report of the Joint UNDP/World Bank Energy Sector Assessment Program

In the light of the above, Method No.1, or analysis of quantitative trends in past pricing of each petroleum product and projection of the trends to the future with some adjustment to reflect recent price levels, is used for the forecast. Table 3-3-8 shows the results of the application of this method. Figures 3-3-3 through 3-3-6 show projected values of premium gasoline, regular gasoline, gas-oil and kerosene prices based on the data in Tables 3-3-5 and 3-3-7.

Table 3-3-8 Petroleum Products Retail Prices Projection

	1985 Dec.	1990	1995	2000
. Premium Gasoline (Ngwee/Litre)				
- Exponential Curve Fitting (r=0.880)	282.0	350.0	482.6	699.3
- Power Curve Fitting (r=0.891)	282.0	320.9	370.6	421.6
- Linear Regression Fitting (r=0.874)	282.0	318.0	362.5	407.1
- Logarithmic Curve Fitting (r=0.872)	282.0	304.8	327.3	345.8
. Regular Gasoline (Ngwee/Litre)				
- Exponential Curve Fitting (r=0.859)	258.0	331.5	481.1	739.4
- Power Curve Fitting (r=0.879)	258.0	300.1	355.9	413.8
- Linear Regression Fitting (r=0.877)	258.0	292.8	335.9	379.0
- Logarithmic Curve Fitting (r=0.883)	258.0	280.2	302.2	320.2
. Gasoil (Ngwee/Litre)				
- Exponential Curve Fitting (r=0.976)	187.0	316.3	695.5	1,666.4
- Power Curve Fitting (r=0.983)	187.0	252.3	356.9	488.8
- Linear Regression Fitting (r=0.968)	187.0	226.2	274.8	323.4
- Logarithmic Curve Fitting (r=0.960)	187.0	211.7	236.1	256.1
. Kerosene (Ngwee/Litre)				
- Exponential Curve Fitting (r=0.975)	152.0	318.6	972.5	3,260.4
- Power Curve Fitting (r=0.983)	152.0	229.6	375.7	588.3
- Linear Regression Fitting (r=0.971)	152.0	186.1	228.2	270.4
- Logarithmic Curve Fitting (r=0.961)	152.0	173.4	194.5	211.8

Note) r: Coefficient of Regression Curve Determination

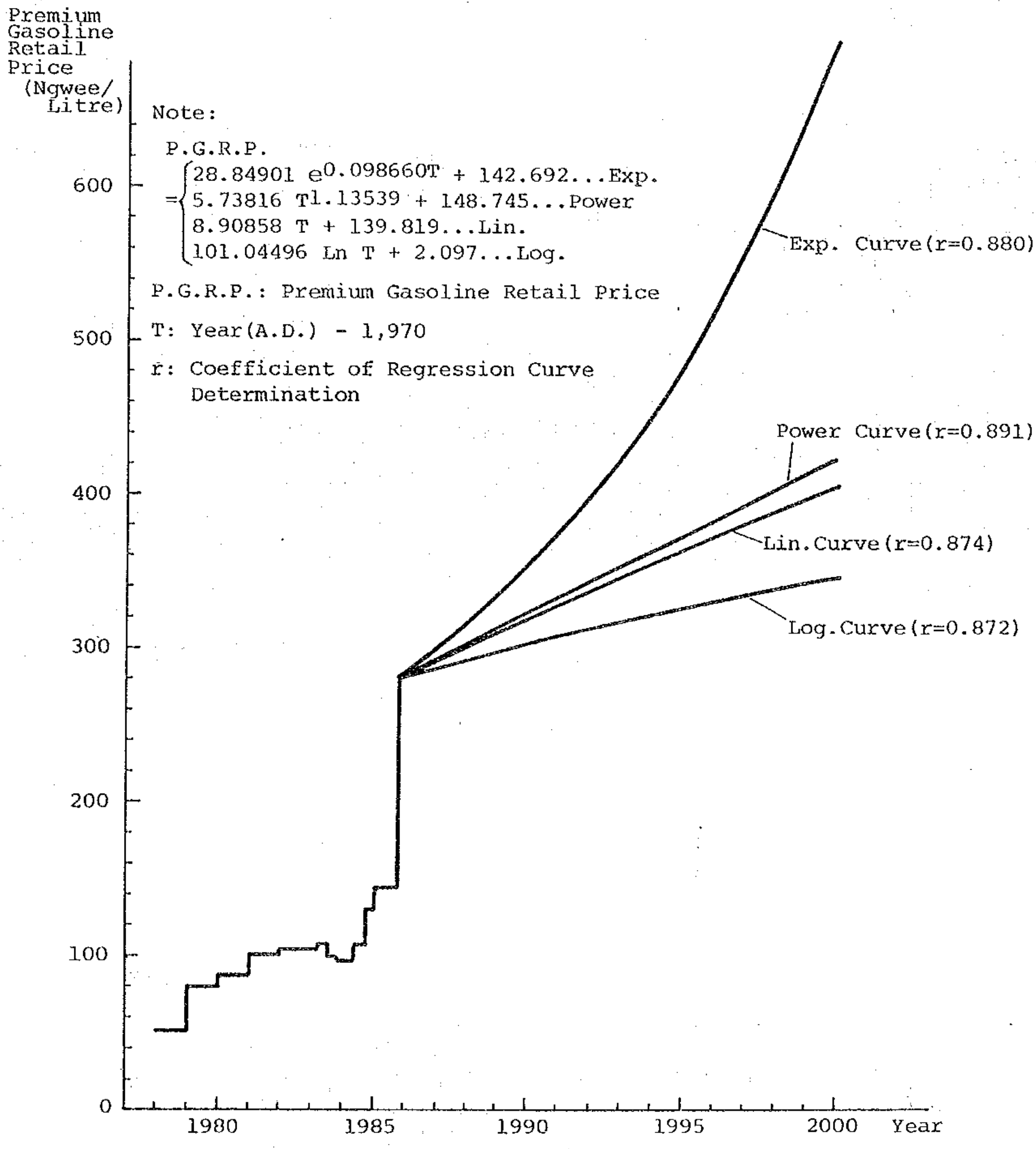


Figure 3-3-3 Premium Gasoline Retail Price Projection

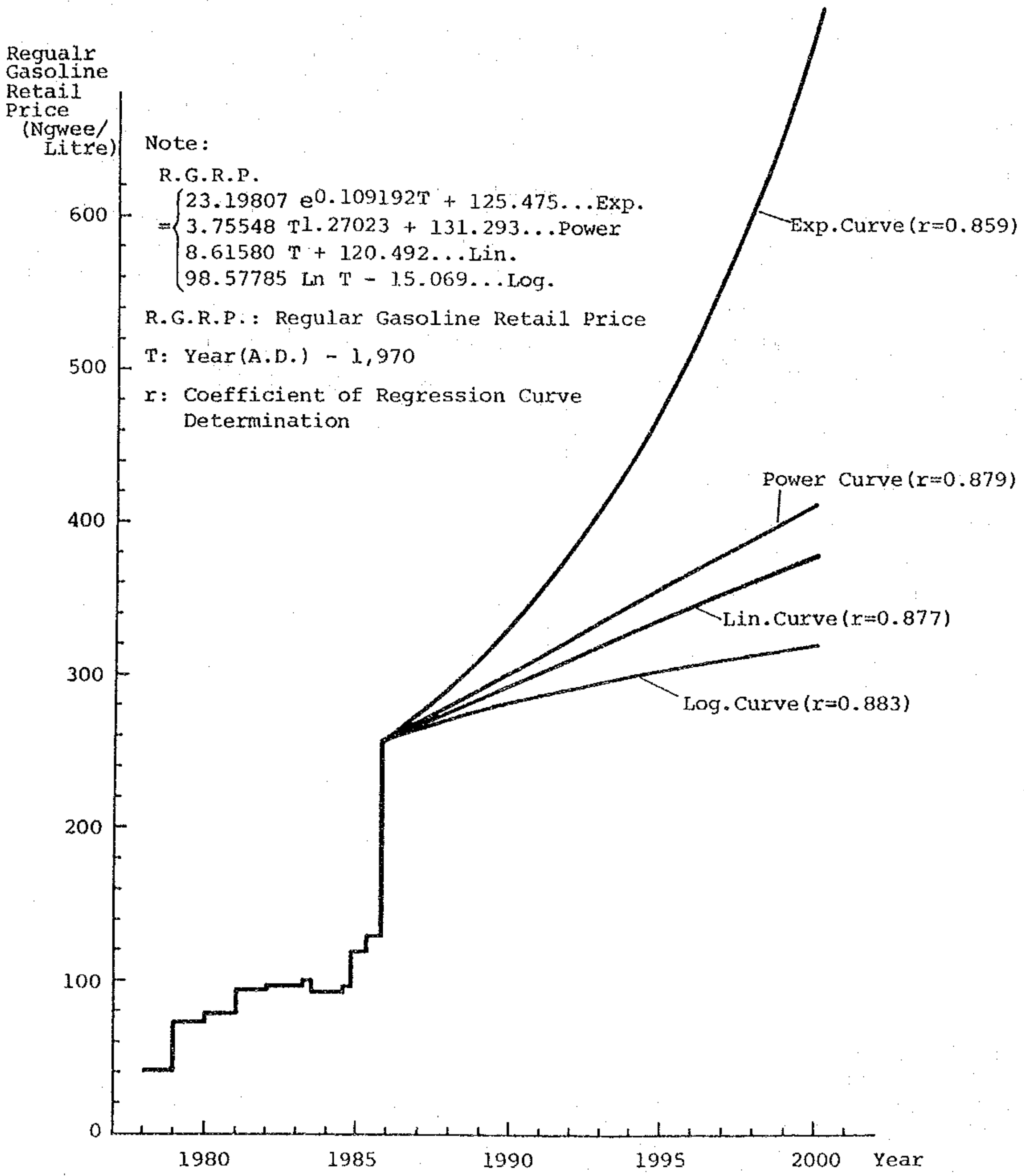


Figure 3-3-4 Regular Gasoline Retail Price Projection

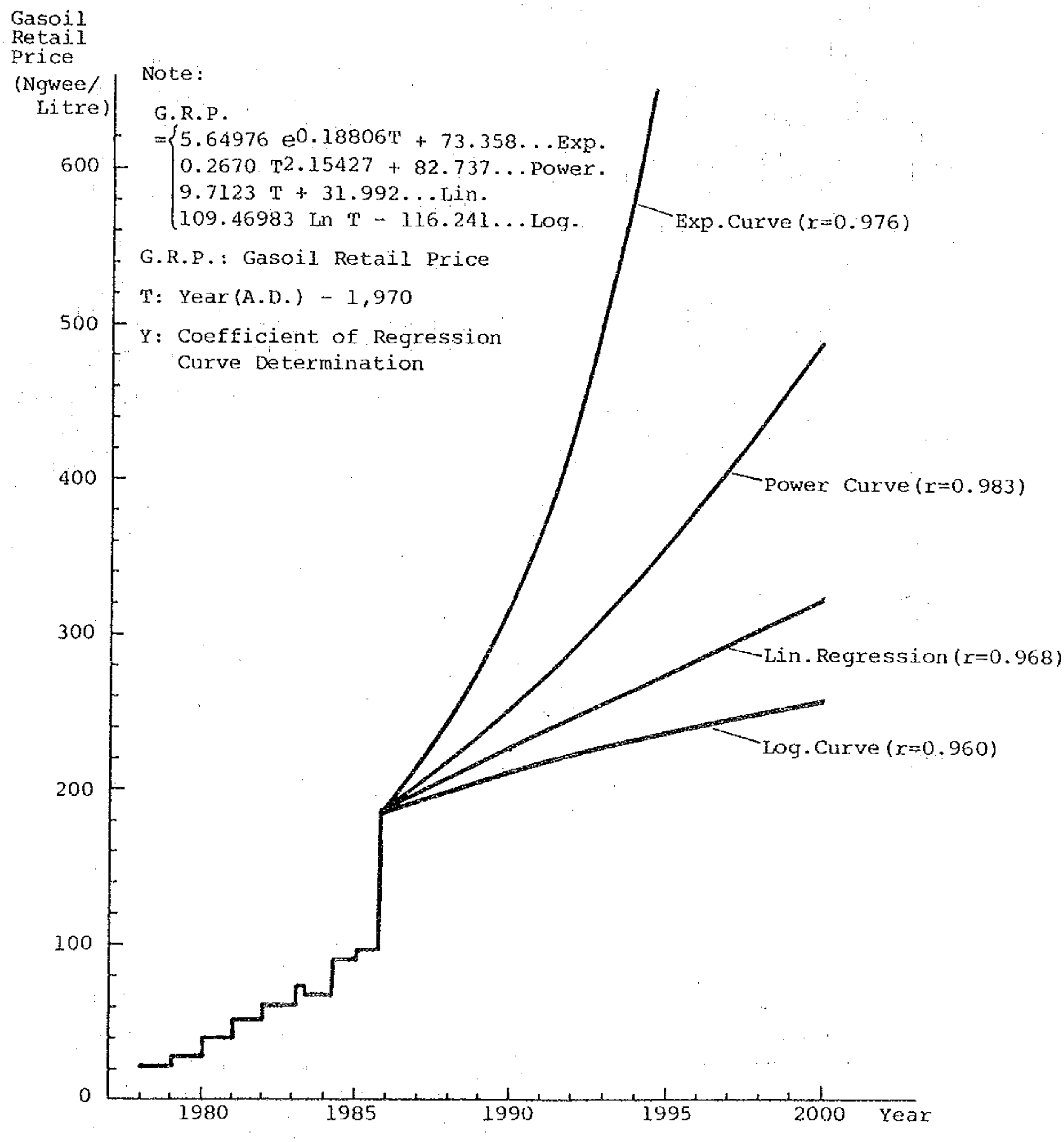


Figure 3-3-5 Gasoil Retail Price Projection

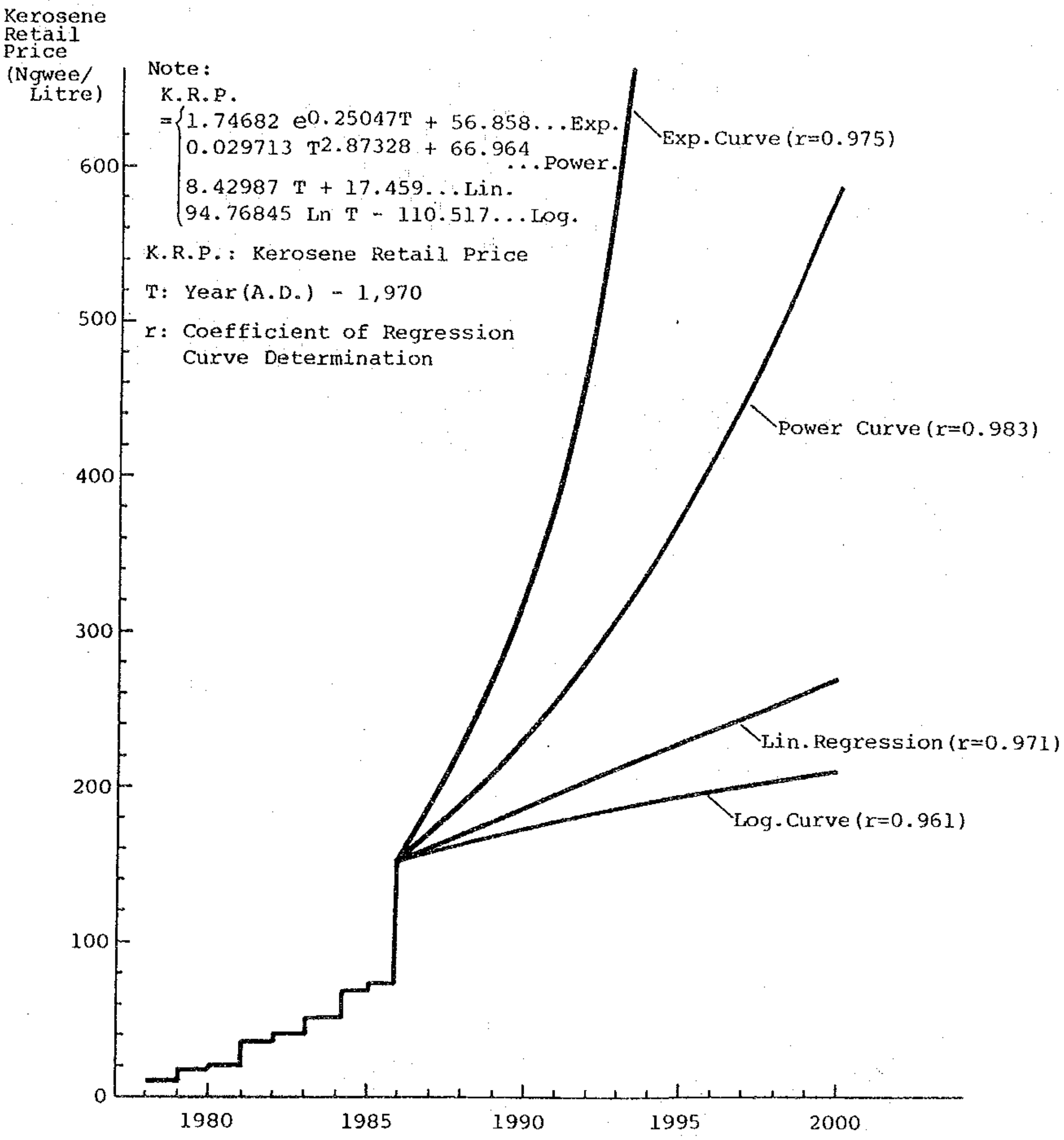


Figure 3-3-6 Kerosene Retail Price Projection

3.3.3 Coal price forecast

Coal is one of nation's major domestic energy resources and is being mined at the Maamba Collieries. Coal prices ex-Maamba Collieries are controlled by the government and, as is evident from Table 3-3-9, do not reflect production costs. For this reason, coal prices (at Maamba) are forecast by means of analysis of quantitative trends in the past and their projection to the future with adjustments to reflect latest prices. Tables 3-3-10 and 3-3-11 show average prices of Maamba coal from 1978 to 1985 and projected prices to the year 2000.

Table 3-3-9 ZAMBIA: COST OF PRODUCTION (1980-1982)

(Kwacha per ton - 1K = US$ 1.12)

Year	1980/81	1981-82 1/
Production ('000 tonnes)	575,495	255,390
Cost/tonne		
Mining	K 10.08	K 11.93
Washing	2.89	3.58
Ropeway & Dispatch	4.54	4.47
Infrastructure 2/	6.53	9.18
Depreciation	5.88	9.41
Interest	0.77	1.98
Working Capital	1.00	1.18
Total/ton	K 31.69	K 41.73
Sale Price/ton	K 32.64	K 32.10 3/

1/ Provisional for six months, April to September 1981.
2/ Infrastructure includes Stores, Purchase, Administration, Township, Welfare, Medical, School, etc.
3/ This price is less than the recommended price of K 36.80 per ton which was to have been implemented in October 1981.

Original Source: Maamba Colliery
Source: Zambia: Issues and Options in the Energy Sector Jan. 1983
Report of the Joint UNDP/World Bank Energy Sector Assessment Program

Figure 3-3-7 also indicates the projected price of Maamba coal based on data in Tables 3-3-10 and 3-3-11.

Table 3-3-10 Average Prices of Maamba Coal (in Kwacha per ton)

Yaer	Maamba Coal Price
1977/78	19.55
1978/79	26.85
1979/80	26.76
1980/81	32.19
1981/82	35.33
1982/83	37.86
1983/84	46.96
1984	60.09
1985	82.25

Source: Fourth National Development Plan Energy
(10th February, 1986)

Table 3-3-11 Maamba Coal Price Projection (in Kwacha per ton)

Regression Curve	1985 (Actual)	1990	1995	2000
Exponential (r=0.979)	82.55	146.93	277.39	540.58
Power (r=0.966)	82.55	139.42	241.45	418.11
Linear (r=0.954)	82.55	107.30	132.34	157.39
Logarithmic (r=0.951)	82.55	105.22	126.94	147.55

Note) r: Coefficient of Regression Curve Determination

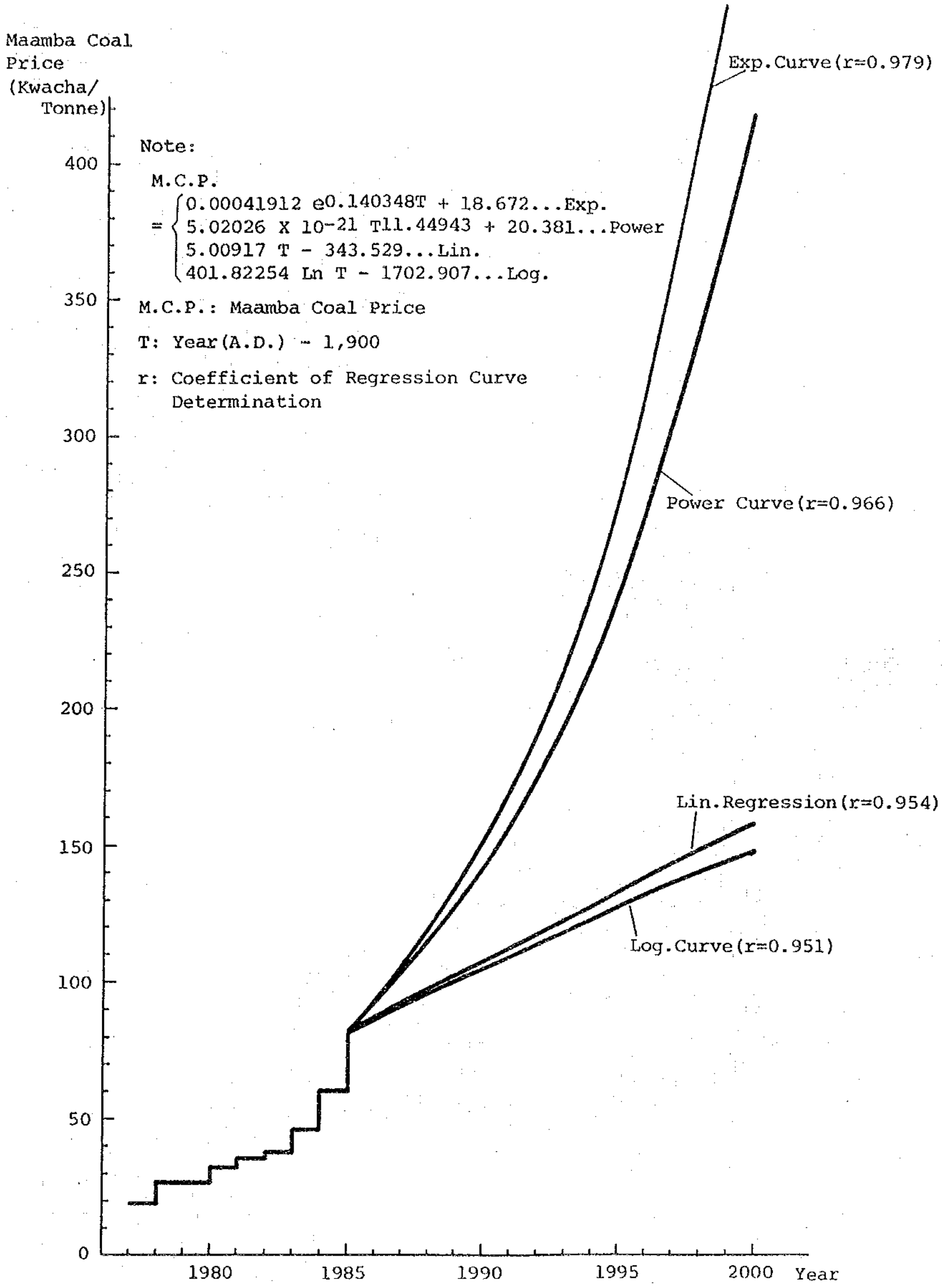


Figure 3-3-7 Maamba Coal Price Projection

3.3.4 Wood fuel prices

As previously described, wood fuel is a vital source of energy for household use. More than 80% of all households use charcoal or firewood to meet their energy needs. Since this project concerns the production of coal briquettes to replace wood fuel as a household energy source, this feasibility study places particular emphasis upon the study of wood fuel. Firewood is used by more than 90% of the households in rural areas and charcoal by more than 80% in urban areas. In view of future briquette prices and distribution channels, it is essential that the trends in charcoal prices in urban areas, particularly in the city of Lusaka, be analyzed.

Table 3-3-12 gives charcoal retail prices in the urban area of Lusaka from 1978 to 1986 together with consumer price index. Consumer price indices are shown because data for retail charcoal prices are scarce before 1983 and there is a very steep rise in prices after 1984; therefore, Method No. 2 mentioned at the introduction of this section is considered better and chosen. In other words, retail charcoal prices are forecast in relation to consumer's price index.

Table 3-3-12 Consumer's Price Index and Lusaka Urban Charcoal Retail Price in Kwacha per 35-40 kg Bag (1978-1986)

	1978	1983(Jul.)	1984(Oct.)	1985(Jan.)	1985(Jun.)	1985(Dec.)	1986(Mar.)
Consumer's Price Index							
- Low Income Group (1975=100.0)	165.6	317.9	383.3	437.2	487.5	N.A.	N.A.
- High Income Group (1975=100.0)	152.6	283.6	350.5	377.7	424.9	N.A.	N.A.
Charcoal Retail Price	2.50-3.00	4.00-4.50	5.00-6.00	6.50-7.00	7.00-8.00	10.00*	12.00*
in Lusaka Urban	2.75*	4.25*	5.50*	6.75*	7.50*		

Note) *: Figure indicate the averages.

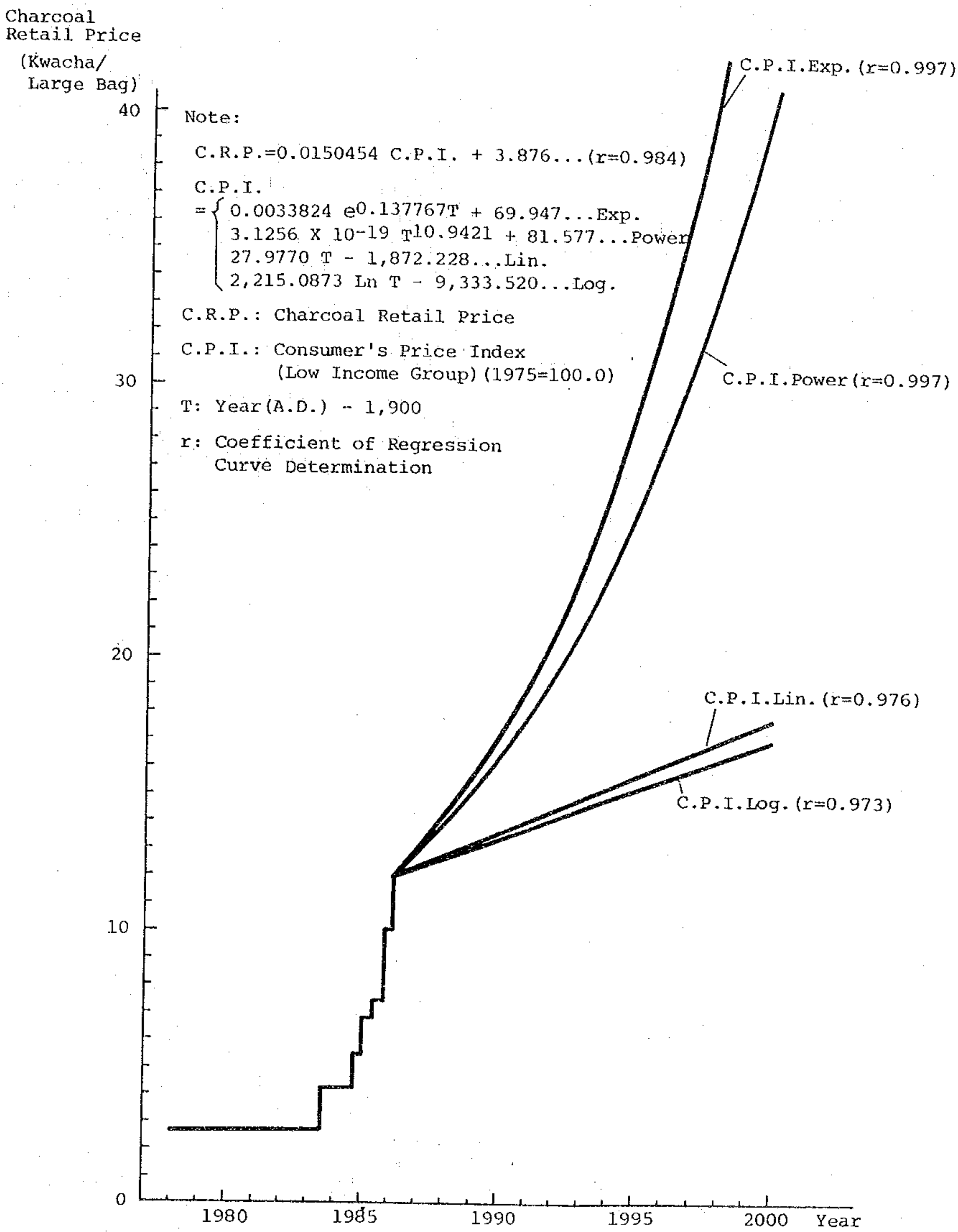


Figure 3-3-8 Lusaka Urban Charcoal Retail Price Projection

Table 3-3-14 Lusaka Urban Charcoal Retail Price Projection Consumer's Price Index (Low Income Group)

	1986 (Mar.)				1990				1995				2000			
	Exp.*	Power*	Lin.*	Log.*	Exp.*	Power*	Lin.*	Log.*	Exp.*	Power*	Lin.*	Log.*	Exp.*	Power*	Lin.*	Log.
Consumer's Price Index																
(Low Income Group)(1975=100.0)	557.36	554.24	539.95	557.36	890.41	837.5	645.7	634.0	1,703.8	1,447.4	785.6	753.7	3,323.6	2,475.6	925.5	867.
Charcoal Retail Price																
- Exponential Curve (r=0.997)	12.00	12.00	12.00	12.00	30.31	26.04	15.66	15.22	382.80	169.37	22.86	20.9	69,287.11	4,544.39	34.15	28.
- Power Curve (r=0.982)	12.00	12.00	12.00	12.00	16.37	15.72	13.41	13.26	26.58	23.45	15.24	14.8	45.94	35.97	17.05	16.
- Linear Regression (r=0.984)	12.00	12.00	12.00	12.00	17.01	16.26	13.59	13.43	29.25	25.44	15.70	15.2	53.62	40.91	17.80	16.9
- Logarithmic Curve (r=0.948)	12.00	12.00	12.00	12.00	13.99	13.75	12.76	13.99	16.74	16.07	13.59	13.4	19.56	18.34	14.28	14.0

Note) Exp.* Consumer's Price Index derived from Exponential Curve Fitting (See Table 3-3-3)
Power* " Power Curve Fitting (")
Lin.* " Linear Regression Fitting (")
Log.* " Logarithmic Curve Fitting (")

Firewood is used mostly in rural areas. This project considers Lusaka as the principal market; in this regard, retail firewood prices from 1979 to 1986 are shown in Table 3-3-15.

Table 3-3-15 Lusaka Urban Firewood Retail Price in Kwacha per Cubic Metre

Year	1979	1980	1981	1982	1983	1984	1985	1986
Firewood Retail Price	4.25	5.60	7.50	8.75	10.00	11.65	12.50	13.50

Source: Provincial Forest Office

Firewood is ordinarily sold in small lots or by single bough, roughly 10 cm. in diameter and 1 meter long; therefore, the price is difficult to quantify or to compare with other fuel forms. For this reason, the data in the above table should be taken as approximation. The government, with the Forest Department in charge, collects fee from woodcutters, the amounts being as shown in Table 3-3-16, and uses the proceeds for conservation of the forests. However, as mentioned in Section 3.1.4 on Wood fuels, the number of licensed woodcutters actually paying such charges is presumably small.

Method No. 1 is applied to forecast firewood prices because sufficient past data, though not very exact, are available and the effect of the auction system on firewood prices may be considered minimal.

Table 3-3-7 shows projected firewood prices to the year 2000, based on data in Table 3-3-17.

Figure 3-3-9 also plots the forecast firewood price.

Table 3-3-16 Woodfuel Government Fee (Harvested Under Licence)

Description	Unit	Unit Charge (Kwacha)
Stacked firewood	Cubic metre	0.12
Firewood (1m X 1m X 3m)	Cord	0.35
Firewood (headload)	5 headloads	0.12
Charcoal	Standard grain measure	0.09

Source: Ministry of Lands and Natural Resources

Table 3-3-17 Lusaka Urban Firewood Retail Price Projection

(Kwacha per Cubic Meter)

Regression Curve	1986 (Actual)	1990	1995	2000
Exponential (r=0.978)	13.50	30.66	79.05	197.00
Power (r=0.980)	13.50	28.93	67.23	145.59
Linear (r=0.997)	13.50	19.12	26.15	33.18
Logarithmic (r=0.998)	13.50	18.74	24.97	30.88

Note) r: Coefficient of Regression Curve Determination

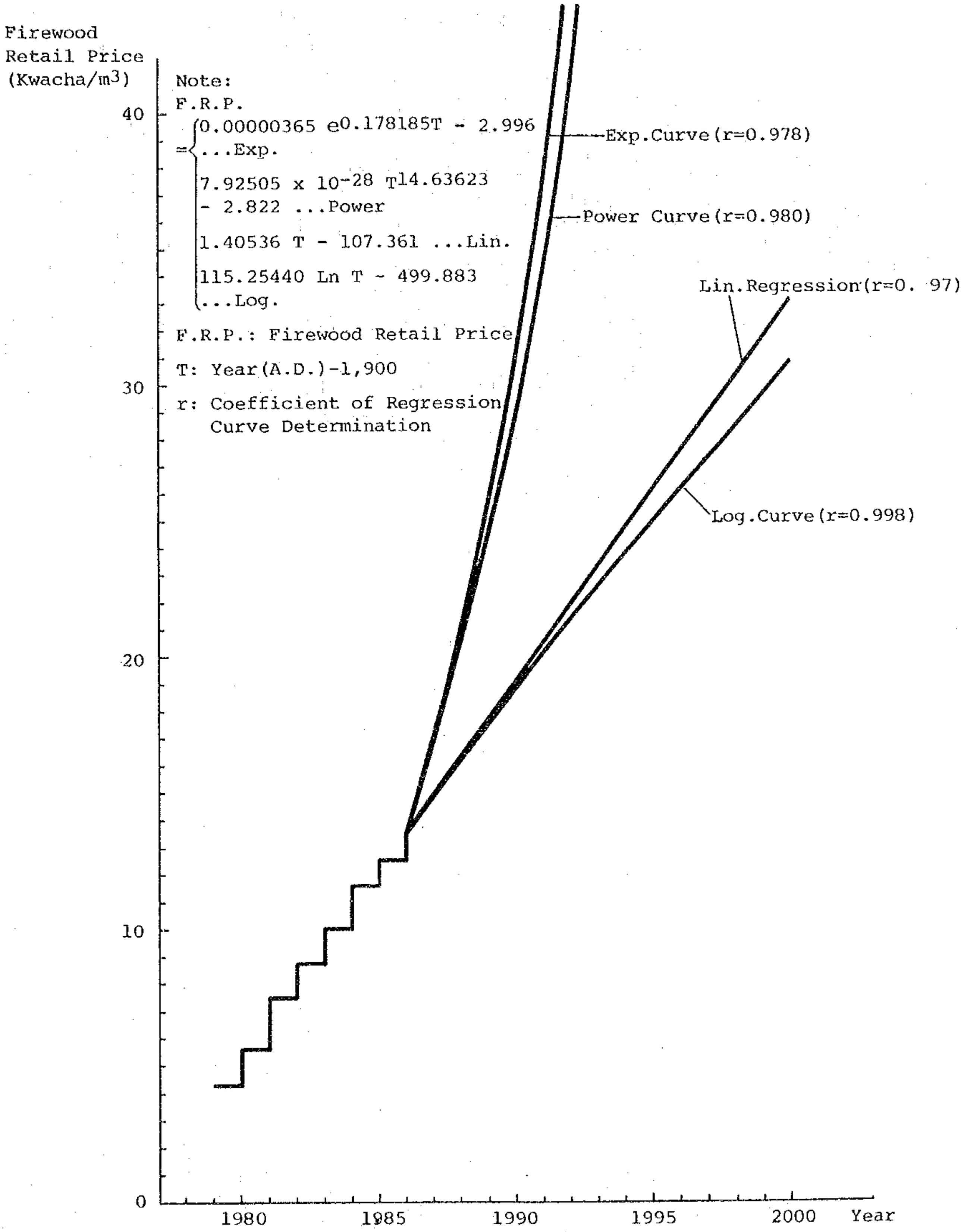


Figure 3-3-9 Lusaka Urban Firewood Retail Price Projection

4. MARKET AND SUPPLY DEMAND

Ideally, the coal briquettes and clay stoves of this project should be distributed throughout Zambia. However, in order to be realistic the major market is decided on Lusaka where sales promotion will be most effective from every practical standpoint. This chapter studies characteristics of the middle- and low-income classes, the intended beneficiaries of this project, in the use of household fuels, and sizes up the briquette and clay stove markets and their viable prices, and finally appraises the possible marketing approachs for the sale of these products.

4.1 Household Fuels and their Characteristics in Consumption

At present, coal briquette market does not exist in Zambia. The first question is which fuel the coal briquettes are to replace. The answer to this question lies in the analysis of the household fuels used by the low- and middle-income strata, particularly the types of fuels and their shares and how they are used.

4.1.1 Household fuels and consumption pattern

Generally speaking, the types of fuel to use depends largely on the income level of the household. Table 4-1-1 and Figure 4-1-1 show fuel consumption per capita in Lusaka broken down in four residential classes. Households are first divided into electricity users and non-users. The former is subdivided into high-cost residences and medium- to low-cost residences; and the latter into medium- to low-cost and low-cost residences.

The follwoing may be noted from the table and figure:

1) The share of charcoal is highest in the medium- and low-cost residences, with 55.0% to 69.1%.

2) Charcoal is used even among the high-cost residences where electricity use is highest, at nearly 20%.

3) The ratio of electicity use is high only among the high-cost residences, at 76.7%.

4) The use of firewood increases as residential class goes down.

5) Kerosene is used mostly for lighting, particularly in the groups in which electricity is not available.

As is evident from Nos. 1 and 2 above, charcoal is the most important form of fuel among low- and medium-cost residences in Lusaka. Table 4-1-2 and Figure 4-1-2 indicate the average monthly expenditure on household fuel in urban Central and Copperbelt areas during the June-July period in 1983, from which the following summary may be drawn.

Table 4-1-1 Annual Per Capita Household Fuel Consumption in Lusaka

Fuel Type		With Electricity: High Cost	With Electricity: Medium/ Low Cost	Without Electricity: Medium/ Low Cost	Without Electricity: Low Cost
Electricity	(Kwh)	2,223	794		
	(10^3 Kcal)	1,912	683		
	(%)	76.7	35.4		
Kerosene	(liter)	2.50	6.42	12.20	13.30
	(10^3 Kcal)	22	57	109	118
	(%)	0.9	3.0	5.5	4.9
Charcoal	(kg)	61.3	151.9	194.4	213.7
	(10^3 Kcal)	429	1,063	1,361	1,496
	(%)	17.2	55.0	69.1	62.6
Firewood	(m^3)	0.084	0.084	0.324	0.504
	(10^3 Kcal)	129	129	499	776
	(%)	5.2	6.7	25.3	32.5
Total	(10^3 Kcal)	2,492	1,932	1,969	2,390
	(%)	100.0	100.1*	99.9*	100.0

Note: Energy conversion factors used are:
Electricity: 1 Kwh = 860 Kcal
Kerosene: 1 Liter = 8,900 Kcal
Charcoal: 1 Kg = 7,000 Kcal
Firewood: 1 m^3 = 1,540 x 10^3 Kcal

* These figures do not necessarily sum up to 100.0 due to rounding.

Source: The Status and Impact of Woodfuel in Zambia (Department of Natural Resources)

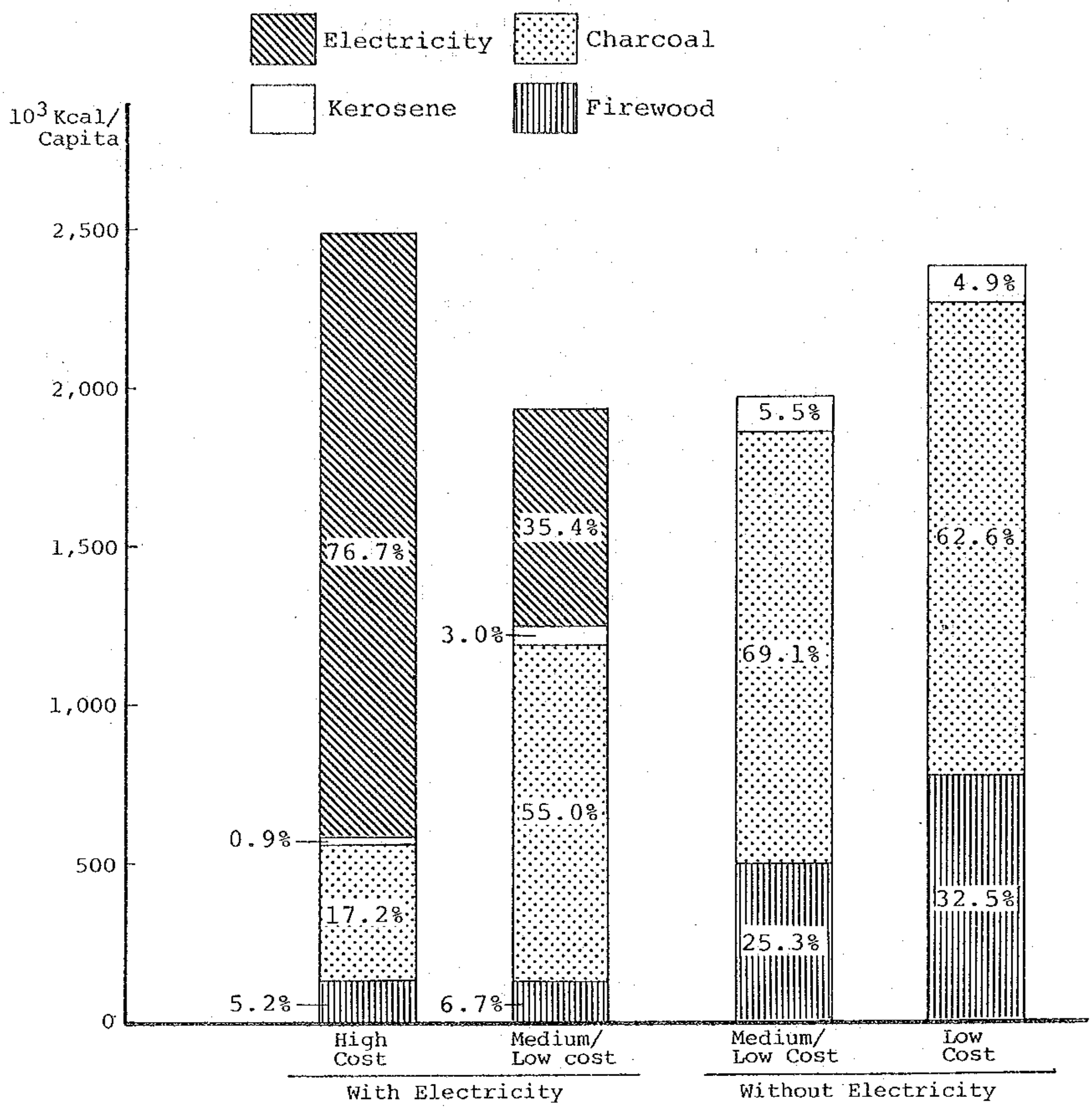


Figure 4-1-1 Annual per capita Household Fuel Consumption in Lusaka

Table 4-1-2 Average Monthly Expenditure on Household Energy Sources in Large Towns of Central and Copperbelt Regions in June/July 1983

(Kwacha/Household)

Energy Type		With Electricityty		Without Electricity	
		High Cost	Medium/ Low Cost	Medium/ Low Cost	Low Cost
Electricity		30.93	12.61		
	(%)	(73.5)	(46.2)		
Kerosene		0.59	1.46	4.15	2.99
	(%)	(1.4)	(5.4)	(19.3)	(17.0)
Charcoal		9.77	12.28	15.05	11.54
	(%)	(23.2)	(45.0)	(70.2)	(65.5)
Firewood		0.35	0.55	1.78	2.55
	(%)	(0.8)	(2.0)	(8.3)	(14.5)
Candles		0.46	0.37	0.47	0.55
	(%)	(1.1)	(1.4)	(2.2)	(3.1)
Total		42.10	27.27	21.45	17.63
	(%)	(100.0)	(100.0)	(100.0)	(100.0)*

Note: * Figure is not always 100.0 due to rounding.

Source: The Status and Impact of Woodfuel in Urban Zambia (Department of Natural Resources)

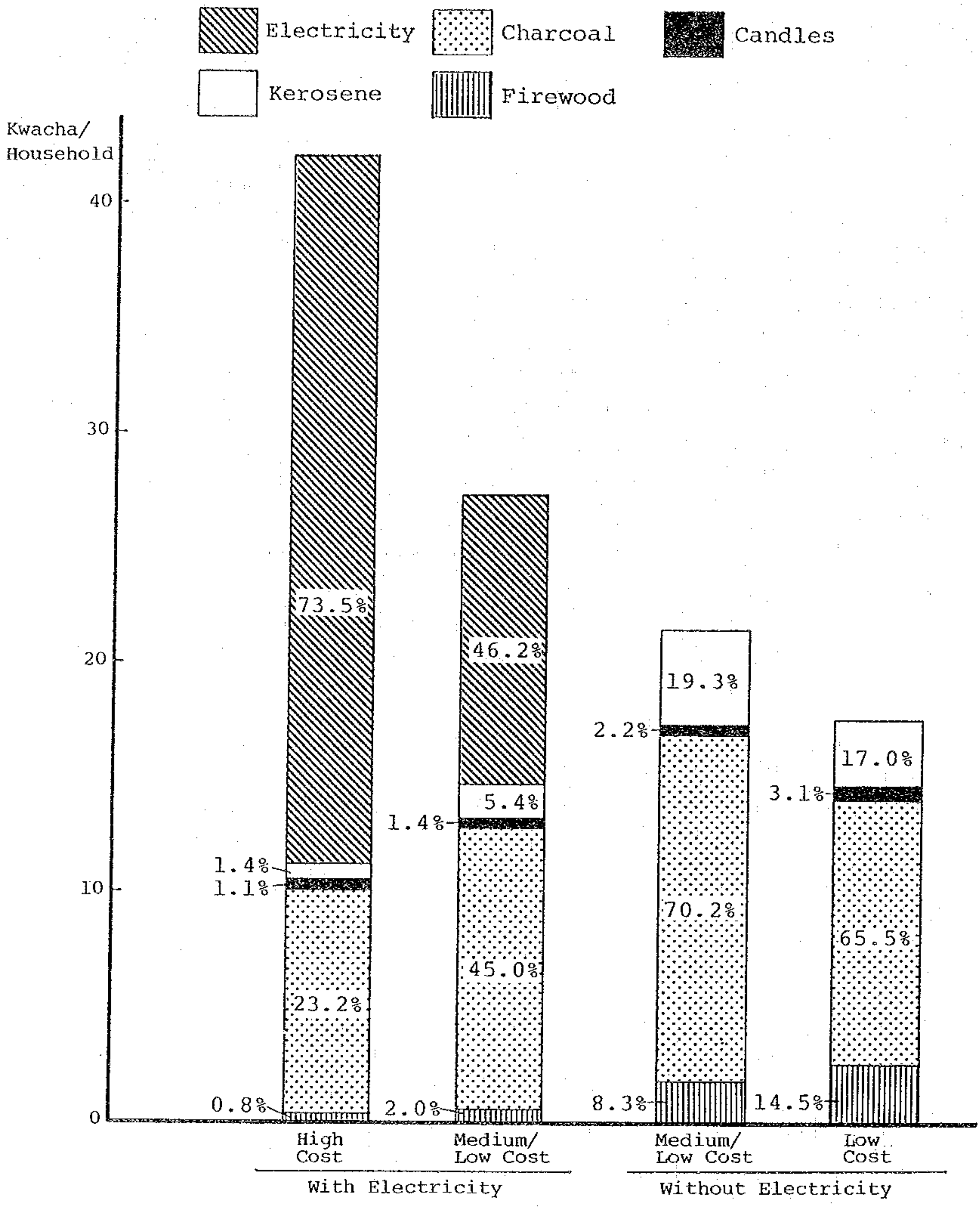


Figure 4-1-2 Average Monthly Expenditure on Household Energy Sources in Large Towns of Central and Copperbelt Regions in June/July 1983

1) The expenditure in charcoal is highest among non-electricity users, amounting to 65.5% to 70.2%.

2) Among electriciy users, electricity accounts for 46.2 to 73.5%, the highest among all fuels.

3) The share of expenditure in kerosene among non-electricity users is markedly high compared with the share of kerosene use indicated in Table 4-1-1, reflecting the high price of the product.

4) The expenditure in charcoal and that in electricity among medium- and low-cost electricity users are roughly equal at 45.0% and 46.2%, respectively.

These combine to show that charcoal is a vital household energy for medium- and low-cost groups from the standpoint of household economy.

Table 4-1-3 shows the degree of prevalence of four types of fuel in urban Lusaka in terms of percentage of households using each fuel on total households. This table also demonstrates the extremely high rate of charcoal use.

Table 4-1-3 Average Percentage of Urban Household Using Each of The Four Energy Sources

Energy Source	Percent of User Households
Firewood	32.6
Charcoal	84.7
Candles	21.0
Kerosene	72.9

Source: The Status and Impact of Woodfuel in Urban Zambia (Department of Natural Resources)

Charcoal certainly ranks very high in the number of households burning it and also in the cost borne by households. Against such a background promotion of the use of coal briquettes and clay stoves of this project would contribute greatly to more efficient use of household fuels in Lusaka by replacement of charcoal by coal briquettes and traditional mbaulas by clay stoves.

4.1.2 Lifestyle and cooking style

The coal briquettes and clay stoves of this project should naturally be compatible with the cooking and heating habits and lifestyles of the lower income groups. Hence, this section studies their lifestyle and cooking style, particularly in Lusaka.

(1) Lifestyle

The lifestyle of households in Lusaka varies largely depending upon the level of income. The lifestyle of people differs distinctively according to the residential area; namely, townships or compounds to which people belong. Residential areas may be divided roughly into those planned and managed by the City Council and those which are not. The former could be further classified into four kinds; high-cost areas, medium-cost areas, and low-cost areas all complete with site, housing and facilities, and residential areas only with site and main utility services. Those not managed by the City Council are shanty compounds and squatter areas in which people illegally build shanties in unplanned areas.

Residents of the high- and medium-cost areas are employees of a limited number of large industries, civil servants, and owners of small garages, retail stores or the like. They belong to high or middle income group and are mostly supplied with electricity by ZESCO, Zambia Electricity Supply Corporation, and enjoy modern lifestyles. They constitute only 20% or so of the entire population of Lusaka. They use electricity and kerosene, and LPG but very seldom, for cooking and heating, the latter required from June to August only.

In contrast, many in the lower-income groups live in small houses made of bricks, sun-dried bricks, or wood only as high as 2 meters. These people make up 80% of the Lusaka population. They use charcoal and firewood for cooking and heating, oil and candles for lighting. As may be noted from Figure 4-1-1, they tend to choose firewood in preference to charcoal as the income level comes down.

Table 4-1-4 exhibits the sources of supply to households in Lusaka of wood fuel, charcoal and firewood.

Table 4-1-4 Percentage of Householders that Purchased Woodfuel from Municipal Markets and Private Selling Points

	Charcoal Purchases			Firewood Purchases		
	Sample Size	Municipal Market	Private Selling Points	Sample Size	Municipal Market	Private Selling Points
Lusaka	314	54.1%	45.9%	26	15.4%	84.6%

Source: The Status and Impact of Woodfuel in Urban Zambia (Department of Natural Resources)

They purchase charcoal from the city open markets and charcoal vendors in the residential areas in a ratio of about one to one.

(2) Cooking Style

Generally, the high-income households use electricity and oil, while others use charcoal and firewood for cooking; the former on electric or oil stoves in kitchens typical of industrialized countries, the latter on mbaulas. To avoid smoking the rooms, cooking is done frequently outdoors. During the winter, however, they sometimes use fire indoors with doors and windows closed. There have been cases of death believed to be caused by carbon monoxide poisoning.

The average size of households in Luska is five persons according to the 1980 population and household census. The average cooking pan and pot are about 20 to 30 cm across, large enough to cook one meal for a family of five or so. With electric or oil stoves, cooking is easy and quick in the case of wealthier classes. However, cooking takes time with charcoal or firewood with all the tediousness of starting, maintaining and controlling fire.

The staple food of the Zambians, regardless of income level, is "nshima," corn, or maize, meal cooked and kneaded with water to a paste normally eaten mixed with side dishes.

Cooking nshima requires a rapid heating or a high input of calory. Thermally inefficient mbaulas, less than 20%, are in daily use in low and middle income households with associated waste of energy and time.

4.2 Coal Briquette Market

The discussion on household fuels developed in the preceding section naturally leads to the conclusion that the coal briquettes should replace charcoal. This section therefore first examines the trends in charcoal demand in the city of Lusaka and proceeds to forecast the size of the coal briquettes market and their right prices.

4.2.1 Charcoal supply in Lusaka

(1) Charcoal demand in Lusaka

In Lusaka, people buy charcoal in bag, maize bag for example, or without any package by a volume filling a small pail. Bags are large, medium, or small, which when filled weigh roughly 40, 32, and 16 kilograms, respectively. People come to shops usually with their own bags; otherwise, they have to pay for the bag. Since charcoal is cheaper in bags, most people buy it in bag.

Table 4-2-1 and 4-2-2 give estimated charcoal demand based respectively on the approximate number of households and on the population of Lusaka in 1985. The estimated demand is 5,795 thousand bags or 148,357 tons. The average charcoal weight per bag is therefore 25.6 kilograms.

Table 4-2-1 1985 Estimated Household Charcoal Demand in Lusaka by Projected Households

	Share in Total Households*(%)	No. of Households** (1000 Households)	Charcoal Consump.Rate*** (Bags/Year/ Household)	Charcoal Demand (1000 Bags/Year)
Projected Households:	100.00	182.80		
With Electricity				
-High Cost Group:	19.13	34.97	2.00	839.27
-Medium/Low Cost Group:	22.26	40.69	2.90	1,416.06
Without Electricity				
-Medium/Low Cost Group:	40.18	73.45	2.86	2,520.77
-Low Cost Group:	18.43	33.69	2.52	1,018.79
Estimated Charcoal Demand:				5,794.89

Source: * Prices & Incomes Commission
** 1980 Population and Housing Census of Zambia
*** The Status and Impact of Woodfuel in Urban Zambia

Table 4-2-2 1985 Estimated Household Charcoal Demand in Lusaka by Projected Population

	Share in Total Population*(%)	Projected Population**	Charcoal Consump.Rate*** (Kgs/Year/Capita)	Charcoal Demand (Ton/Year)
Projected Households:	100.00	909,976		
With Electricity				
-High Cost Group:	19.13	174,078	61.30	10,671
-Medium/Low Cost Group:	22.26	202,561	151.90	30,769
Without Electricity				
-Medium/Low Cost Group:	40.18	365,628	194.40	71,078
-Low Cost Group:	18.43	167,709	213.70	35,839
Estimated Charcoal Demand:				148,357

Source: * Prices & Incomes Commission
** 1980 Population and Housing Census of Zambia
*** The Status and Impact of Woodfuel in Urban Zambia

Table 4-2-3 shows the commercial charcoal demand in Lusaka's open markets. Those figures given in the table are the findings by surveyors who actually visited these markets. Summing up their numbers amounts to 154,000 bags--or 4,000 tons a year, assuming the average bag weight to be 25.6 kilograms. Combining both household and commercial demands, the total volume is estimated to be 152,000 tons.

(2) Charcoal supply in Lusaka

Charcoal is sold in Lusaka at shops in the open market or by charcoal vendors in the townships or compounds. There is no monopolistic huge sales organization; therefore, a large scale discount sale is not done.

Table 4-2-4 and 2-4-5 indicate the supplies for open markets and townships, respectively, estimated from data and information collected through direct survey efforts by the hired students. Their numbers for the open markets and townships sum up to 5,258 thousand bags, or 135,000 tons, and 15,174 thousand bags, or 388,000 tons, respectively -- or a total of 20,432 thousand bags, or 523,000 tons. The supplies thus estimated for the open markets and townships are 25.7% and 74.3%, respectively; the latter oddly too large in the light of Table 4-1-4.

Similarly, the total supply, 523,000 tons, is 3.4 times the estimated demand of 154,000 tons and is evidently too large to be realistic. In addition, the number of households in Lusaka by the students' survey adds up to about 624,000, or 3.4 times the accepted household number of 182,000 shown in Table 4-2-1, and is evidently wide of the mark. It would therefore be a right judgement to regard the survey as having tended to exaggerate numbers at the points of data collection and, therefore, accept the previously mentioned 152,000 tons.

Table 4-2-3A Estimated Commercial Charcoal Demand in Lusaka Markets
(Continued on Table 4-2-3B)

Name of Markets	Nshima Shops				Roast Maize Shops			
	No. of Shops (Shops)	Daily Consump. Rate (Bags/Day/Shop)	Ave. Selling Days (Days/Year)	Total Ann. Consump. (Bags/Year)	No. of Shops (Shops)	Daily Consump. Rate (Bags/Day/Shop)	Ave. Selling Days (Days/Year)	Total Ann. Consump. (Bags/Year)
1.Arrakan Barracks	2	0.250	240	120	0	0.000	0	0
2.Chachacha Road	77	0.500	365	14,053	0	0.000	0	0
3.Chainda	0	0.000	0	0	7	0.500	365	1,278
4.Chaisa	9	0.250	360	810	4	0.200	240	192
5.Chawama	8	0.500	360	1,440	16	0.250	240	960
6.Chelston	5	0.500	365	913	8	0.500	365	1,460
7.Chibolya(Soweto)	195	0.500	310	30,225	4	0.500	240	480
8.Chifundo	12	0.500	360	2,160	12	0.143	240	412
9.Chilenje	7	0.250	365	639	2	0.500	365	365
10.Chilulu	3	0.333	300	300	8	0.500	300	1,200
11.Chingwere	0	0.000	0	0	0	0.000	0	0
12.Chipata	11	0.333	300	1,099	12	0.071	200	170
13.Chitukuko	10	0.500	365	1,825	15	0.500	365	2,738
14.Chunga	0	0.000	0	0	0	0.000	0	0
15.Garden	3	0.333	300	300	6	0.333	200	400
16.John Howard	1	0.333	300	100	11	0.143	240	378
17.Kabwata	12	0.333	360	1,439	3	0.333	240	240
18.Kalingalinga	3	0.333	300	300	2	0.143	200	57
19.Kanyama(New)	5	0.100	360	180	7	0.167	240	281
20.Kaunda Square	2	0.250	365	183	11	0.071	210	164
21.Kulima Tower	1	0.500	240	120	0	0.000	0	0
22.Libala	5	0.250	365	456	1	0.500	365	183
23.Lilanda	14	0.500	360	2,520	17	0.125	210	446
24.Longacres	0	0.000	0	0	6	0.500	240	720
25.Lubuma(Kamwala)	38	0.250	340	3,230	10	0.400	240	960
26.Malipole	1	0.500	300	150	1	0.083	200	17
27.Mandevu	10	0.500	360	1,800	16	0.143	240	549
28.Matero	8	0.500	360	1,440	6	0.500	240	720
29.Mutambe	2	0.143	365	104	0	0.000	0	0
30.Mutendere	5	0.143	360	257	8	0.500	240	960
31.Mwaziona	11	0.500	365	2,008	11	0.250	365	1,004
32.Ngombe	4	0.143	300	172	0	0.000	0	0
33.Northmead	3	0.333	300	300	6	0.071	200	85
34.Nyerere	0	0.000	0	0	0	0.000	0	0
35.Olympia Park	7	0.250	365	639	1	0.500	365	183
Total	474	-	-	69,278	211	-	-	16,599

Table 4-2-3B Estimated Commercial Charcoal Demand in Lusaka Markets
(Continued from Table 4-2-3A)

Name of Markets	Roast Beef Shops: No. of Shops (Shops)	Roast Beef Shops: Daily Consump. Rate (Bags/Day/Shop)	Roast Beef Shops: Ave. Selling Days (Days/Year)	Roast Beef Shops: Total Ann. Consump. (Bags/Year)	Fritter Shops: No. of Shops (Shops)	Fritter Shops: Daily Consump. Rate (Bags/Day/Shop)	Fritter Shops: Ave. Selling Days (Days/Year)	Fritter Shops: Total Ann. Consump. (Bags/Year)	Grand Total Ann. Consumption (Bags/Year)
1.Arrakan Barracks	1	0.250	240	60	5	0.250	365	456	636
2.Chachacha Road	77	0.250	365	7,026	0	0.000	0	0	21,079
3.Chainda	7	0.500	365	1,278	4	0.250	300	300	2,855
4.Chaisa	0	0.000	0	0	10	0.200	360	720	1,722
5.Chawama	0	0.000	0	0	21	0.250	360	1,890	4,290
6.Chelston	1	0.250	365	91	0	0.000	0	0	2,464
7.Chibolya(Soweto)	185	0.500	365	33,763	7	0.250	360	630	65,098
8.Chifundo	0	0.000	0	0	5	0.250	360	450	3,022
9.Chilenje	0	0.000	0	0	25	0.250	365	2,281	3,285
10.Chilulu	0	0.000	0	0	8	0.500	200	800	2,300
11.Chingwere	0	0.000	0	0	3	0.100	360	108	108
12.Chipata	0	0.000	0	0	6	0.067	200	80	1,350
13.Chitukuko	0	0.000	0	0	5	0.250	365	456	5,019
14.Chunga	0	0.000	0	0	7	0.100	300	210	210
15.Garden	0	0.000	0	0	20	0.250	300	1,500	2,199
16.John Howard	0	0.000	0	0	8	0.200	365	584	1,061
17.Kabwata	0	0.000	0	0	5	0.250	365	456	2,135
18.Kalingalinga	0	0.000	0	0	9	0.143	300	386	743
19.Kanyama(New)	0	0.000	0	0	12	0.250	360	1,080	1,541
20.Kaunda Square	0	0.000	0	0	0	0.000	0	0	347
21.Kulima Tower	0	0.000	0	0	0	0.000	0	0	120
22.Libala	0	0.000	0	0	25	0.250	365	2,281	2,920
23.Lilanda	0	0.000	0	0	8	0.143	300	343	3,309
24.Longacres	0	0.000	0	0	2	0.250	300	150	870
25.Lubuma(Kamwala)	0	0.000	0	0	12	0.500	365	2,190	6,380
26.Malipole	0	0.000	0	0	5	0.143	300	215	381
27.Mandevu	0	0.000	0	0	7	0.143	360	360	2,709
28.Matero	0	0.000	0	0	8	0.250	360	720	2,880
29.Mutambe	0	0.000	0	0	4	0.143	365	209	313
30.Mutendere	0	0.000	0	0	10	0.333	360	1,199	2,416
31.Mwaziona	0	0.000	0	0	6	0.250	365	548	3,559
32.Ngombe	0	0.000	0	0	5	0.071	300	107	278
33.Northmead	0	0.000	0	0	5	0.100	300	150	535
34.Nyerere	0	0.000	0	0	0	0.000	0	0	0
35.Olympia Park	0	0.000	0	0	1	0.071	365	26	847
Total	271	-	-	42,218	258	-	-	20,885	148,981

Table 4-2-4 Estimated Charcoal Supply in Lusaka Markets

Name of Markets	No.of Shops (Shops)	Daily Sales Vol. (Bags/Day/Shop)	Ave.Selling Days (Days/Year)	Ann.Sales Vol. (1,000 Bags/Year)
1.Arrakan Barracks	4	3.33	360	4.80
2.Chachacha Road	0	0.00	0	0.00
3.Chainda	2	3.33	360	2.40
4.Chaisa	10	350.00	360	1,260.00
5.Chawama	6	201.50	360	435.24
6.Chelston	7	16.00	365	40.88
7.Chibolya(Soweto)	9	13.50	360	43.74
8.Chifundo	2	45.00	360	32.40
9.Chilenje	5	35.00	360	63.00
10.Chilulu	4	80.00	300	96.00
11.Chingwere	1	62.00	360	22.32
12.Chipata	13	152.00	300	592.80
13.Chitukuko	10	350.00	365	1,277.50
14.Chunga	0	0.00	0	0.00
15.Garden	4	92.50	360	133.20
16.John Howard	6	6.00	365	13.14
17.Kabwata	5	12.50	360	22.50
18.Kalingalinga	6	11.50	300	20.70
19.Kanyama(New)	1	10.50	360	3.78
20.Kaunda Square	10	80.00	300	240.00
21.Kulima Tower	0	0.00	0	0.00
22.Libala	3	155.00	365	169.73
23.Lilanda	3	201.50	300	181.35
24.Longacres	0	0.00	0	0.00
25.Lubuma(Kamwala)	14	11.00	365	56.21
26.Malipole	4	26.00	300	31.20
27.Mandevu	8	3.33	360	9.59
28.Matero	5	176.50	360	317.70
29.Mutambe	6	32.50	365	71.18
30.Mutendere	17	8.00	360	48.96
31.Mwaziona	0	0.00	0	0.00
32.Ngombe	1	25.50	300	7.65
33.Northmead	1	201.50	300	60.45
34.Nyerere	0	0.00	0	0.00
35.Olympia Park	0	0.00	0	0.00
Total	167	-	-	5,258.40

(Source : JICA)

Table 4-2-5 Estimated Household Charcoal Supply in Lusaka Townships

Name of Townships	Ward Number	Townships Areas	No.of Households	No. of Shops (Shops)	Daily Sales Vol. (Bags/Day/Shop)	Ave.Selling Days (Days/Year)	Ann.Sales Vol. (1,000 Bags/Year)
1.Chunga	15 & 31	Site & Service	12,000	10	57.50	365	209.88
2.George	15 & 17	Site & Service	20,000	45	115.00	365	1,888.88
3.Lilanda(Kapvepve)	15	Medium/Low Cost	14,000	17	90.00	365	558.45
4.Chingvere	14	Council Control	13,000	12	115.00	365	503.70
5.Matero East(Mchinga)	14	Medium/Low Cost	12,000	11	60.00	365	240.90
6.Emmasdale	10	Site & Service	15,000	12	62.50	365	273.75
7.Mulobela	16	High Cost	11,000	2	103.50	365	75.56
8.Namnunga	16	High Cost	11,000	0	0.00	0	0.00
9.Chinika	16	Site & Service	900	1	40.00	360	14.40
10.Mutambe	12	Council Control	11,000	10	60.00	365	219.00
11.Marrapodi	11	Site & Service	20,000	40	120.00	365	1,752.00
12.Mandevu	12	Site & Service	15,000	25	115.00	365	1,049.38
13.Chaisa	13	Site & Service	16,000	45	62.50	365	1,026.56
14.Chipata(Mpulungu)	11	Site & Service	19,000	10	95.00	365	346.75
15.Garden	9	Site & Service	13,000	20	90.00	365	657.00
16.Roma	7	High Cost	2,000	18	60.00	365	394.20
17.N'Gombe	7	Site & Service	4,894	9	85.00	0	0.00
18.Kalundu	8	High Cost	5,000	0	0.00	0	0.00
19.Chivata Mabve	8	High Cost	1,000	0	0.00	0	0.00
20.Chikonkoto	8 & 10	High Cost	9,000	0	0.00	0	0.00
21.Luneta	10	High Cost	10,000	0	0.00	0	0.00
22.Chudleigh	6	Site & Service	3,000	0	0.00	0	0.00
23.Mvambula	6	High Cost	6,000	0	0.00	0	0.00
24.Kaunda Square	6	S. & S./C. C. H.	16,000	15	60.00	365	328.50
25.Chamba Valley	6	Peri-Urban	2,000	0	0.00	0	0.00
26.Kamanga	6	Site & Service	15,000	9	65.00	365	213.53
27.Chelston	5	Council Control	11,000	8	55.00	365	160.60
28.Chakunkula(Chainda)	1	Medium/Low Cost	7,400	8	55.00	365	160.60
29.Avondale	1	Council Control	9,000	5	35.00	365	63.88
30.Mutendere	2	Site & Service	30,000	25	115.00	365	1,049.38
31.Helen Kaunda	2 & 4	Council Control	11,000	5	40.00	365	73.00
32.Kalingalinga	4	Site & Service	12,000	9	60.00	365	197.10
33.Shikosuve	4	High Cost	7,000	0	0.00	0	0.00
34.Bimbe	4	High Cost	6,000	0	0.00	0	0.00
35.Kabulonga	3	High Cost	8,000	0	0.00	0	0.00
36.Ibex Hill	3	High Cost	7,000	0	0.00	0	0.00
37.Tukunka	3	High Cost	10,000	0	0.00	0	0.00
38.Bauleni	3	Site & Service	11,000	5	105.00	365	191.63
40.Ridgeway	30	High Cost	6,000	0	0.00	0	0.00
41.Woodlands	30	High Cost	7,000	0	0.00	0	0.00
42.Chilenje	29	Medium/Low Cost	25,000	12	60.00	365	262.80
43.Chilenje South	29	Medium/Low Cost	9,000	10	60.00	365	219.00
44.Libala	28	Medium/Low Cost	10,000	6	42.50	365	93.08
45.Kabvata	27	Medium/Low Cost	13,000	10	60.00	365	219.00
46.Kamvala	25	Medium/Low Cost	9,000	7	55.00	365	140.53
47.Maluba	26	High Cost	7,000	0	0.00	0	0.00
48.Kapila	26 & 4	High Cost	7,000	0	0.00	0	0.00
49.Chibolya	19	Site & Service	8,000	8	65.00	365	189.80
50.John Lange	19	Site & Service	10,000	9	60.00	365	197.10
51.Misisi	19 & 22	Site & Service	12,000	10	65.00	365	237.25
52.John Hovard	23	Site & Service	15,000	20	120.00	365	876.00
53.Chavama	23	Site & Service	19,000	15	90.00	365	492.75
54.Jack	22	Site & Service	12,000	10	65.00	365	237.25
55.Ngverere	9	Site & Service	4,000	1	8.50	365	3.10
56.Kanyama	20	Site & Service	10,000	7	65.00	365	166.08
57.Cathedral Hill	4,25,26,27 & 30	High Cost	9,000	0	0.00	0	0.00
58.Kalikiliki	?	Site & Service	6,507	4	35.00	365	51.10
59.Kabanana	11	Peri-Urban	14,000	7	55.00	365	140.53
60.Mvenbezi(Ward)	31	Peri-Urban	5,000	0	0.00	0	0.00
Total	-	-	623,701	512	-	-	15,173.95

Note: 'C.C.H.' and 'S. & S.' represent 'Council Control Houses' and 'Site and Service', respectively.
'Ward Number' corresponds to the following ward: No.1-Chainda, No.2-Mutendere, No.3-Kabulonga, No.4-Kalingalinga, No.5-Chakunkula,A, No.6-Munali, No.7-Roma, No.8-Mulungushi, No.9-Ngverere, No.10-Silvizuya, No.11-Mpulungu, No.12-Justin Kabve, No.13-Chaisa, No.14-Mchinga, No.15-Kapvepve, No.16-Matero, No.17-Lima, No .18-Chisegalumbve, No.19-Chibolya, No.20-KANYAMA, No.21-Munkolo, No.22-Nkoloma, No.23-Chavama, No.24-Lilayi, No.25-Kamvala, No.26-Independence, No.27-Shivang'andu, No.28-Libala, No.29-Chilenje, No.30-Lubva, No.31-Mvembezi

4.2.2 Briquette market size in Lusaka

As described earlier in this chapter, there is no coal briquette market in Zambia and therefore the supply of briquettes of this project would create a new market which is expected to grow gradually as an alternative to charcoal. However, the growth of this market depends on the following factors:

1) The economic advantages of briquettes and clay stoves over charcoal and mbaulas

2) Preferential treatment by the Zambian government to the sale and purchase of coal briquettes and clay stoves

3) Sales promotion efforts to coal briquettes and clay stoves

4) Distribution method applied to coal briquettes and clay stoves

5) Possibility of supply of coal briquettes and clay stoves.

These could boil down to a question of how to arouse in Lusaka motivation to sell or buy coal briquettes and clay stoves. The above five factors emcompass clay stoves because clay stoves should go along with coal briquettes if coal briquettes are to be accepted by people.

Table 4-2-6 and Figure 4-2-1 project household charcoal demand in Lusaka based on population forecast. Table 4-2-7 and Figure 4-2-2 estimate coal briquette demand in Lusaka. These estimates are based on assumed penetration rates of briquette into the charcoal market. The projection of coal briquettes market uses 7,000 kcal/kg and 5,200 kcal/kg as heating values of charcoal and coal briquettes. The charcoal the study team purchased at a Lusaka open market has a heating value of 6,738.9 kcal/kg but this study uses the standard value of 7,000 kcal/kg.

Table 4-2-6 Projected Household Charcoal Demand in Lusaka by Projected Population

	Share in Total Households*(%)	Charcoal Consump. rate** (Kgs/Year/Capita)	1985 Projected Population***	1985 Charcoal Demand (Tons/Year)	1990 Projected Population***	1990 Charcoal Demand (Tons/Year)	1995 Projected Population***	1995 Charcoal Demand (Tons/Year)	2000 Projected Population***	2000 Charcoal Demand (Tons/Year)
Projected Population:	100.00	-	909,976	-	1,211,573	-	1,607,537	-	2,123,658	-
With Electricity										
- High Cost Group:	19.13	61.30	174,078	10,671	231,774	14,208	307,522	18,851	406,256	24,903
- Medium/Low Cost Group:	22.26	151.90	202,561	30,769	269,696	40,967	357,838	54,356	472,726	71,807
Without Electricity										
- Medium/Low Cost Group	40.18	194.40	365,628	71,078	486,810	94,636	645,908	125,565	853,286	165,879
- Low Cost Group:	18.43	213.70	167,709	35,839	223,293	47,718	296,269	63,313	391,390	83,640
Projected Charcoal Demand:	-	-	-	148,357	-	197,528	-	262,084	-	346,229

Source: * Prices & Incomes Commission
** The Status and Impact of Woodfuel in Urban Zambia
*** 1980 Population and Housing Census of Zambia

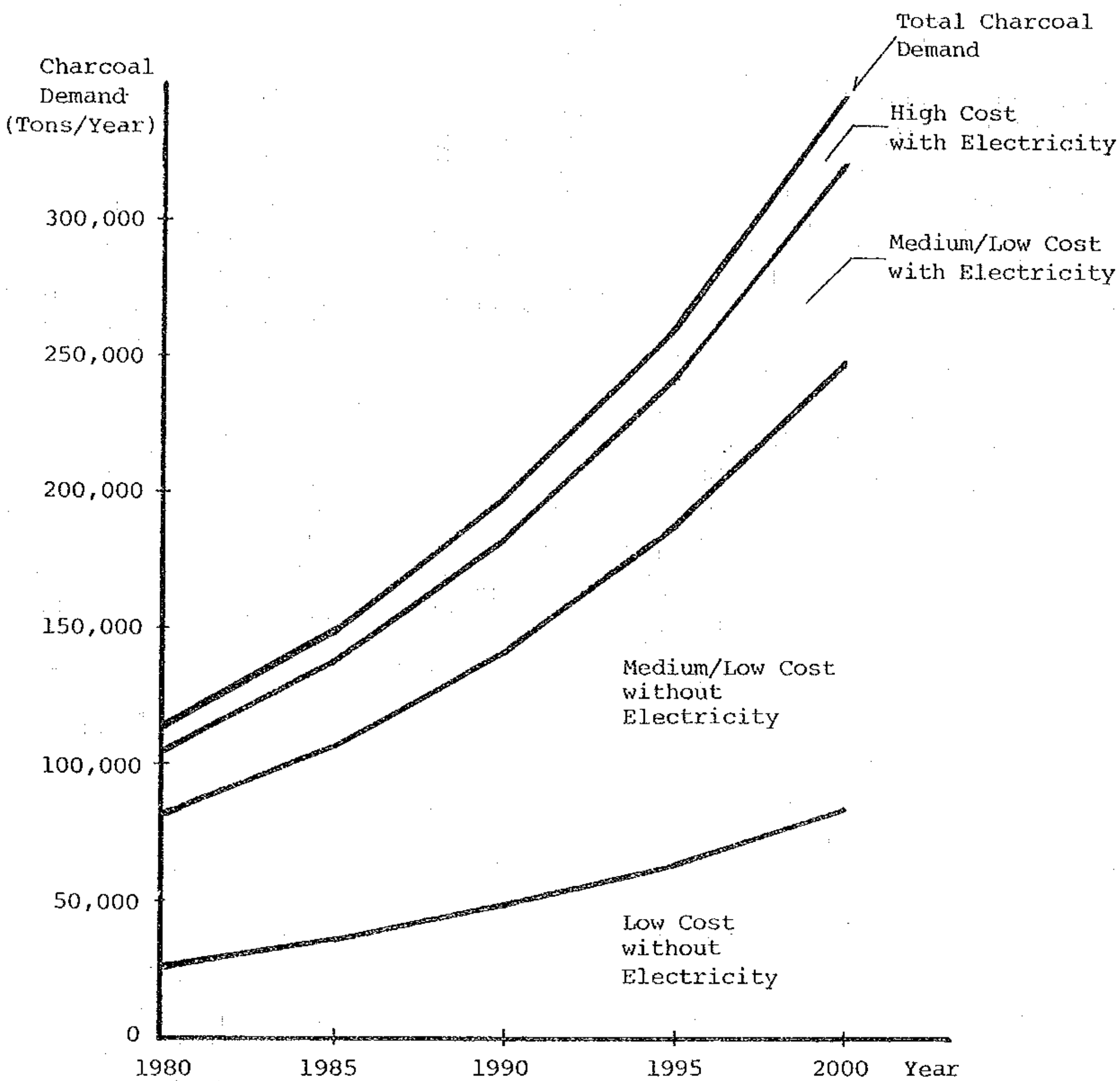


Figure 4-2-1 Projected Household Charcoal Demand in Lusaka by Projected Population

Table 4-2-7 Projected Coal Briquettes Demand in Lusaka by Market Penetration of Household Charcoal Market

	1985	1990	1995	2000
Projected Population*:	909,976	1,211,573	1,607,537	2,123,658
Projected Charcoal Demand** (Ton/Year):	148,357	197,528	262,084	346,229
Heating Value (Thousand Million Kcal):	1,038.50	1,382.70	1,834.59	2,423.61
Projected Coal Briquettes Demand (Ton/Year):				
Market Penetration Rate				
1% Case	1,997	2,657	3,528	4,661
2% Case	3,994	5,318	7,056	9,322
3% Case	5,991	7,977	10,584	13,982
4% Case	7,988	10,636	14,112	18,643
5% Case	9,986	13,295	17,640	23,304

Source: * 1980 Population and Housing Census of Zambia
** Table 4-2-6

Note: Heating values of charcoal and briquettes are assumed to be 7,000 Kca./kg and 5,200 Kcal/kg, respectively.

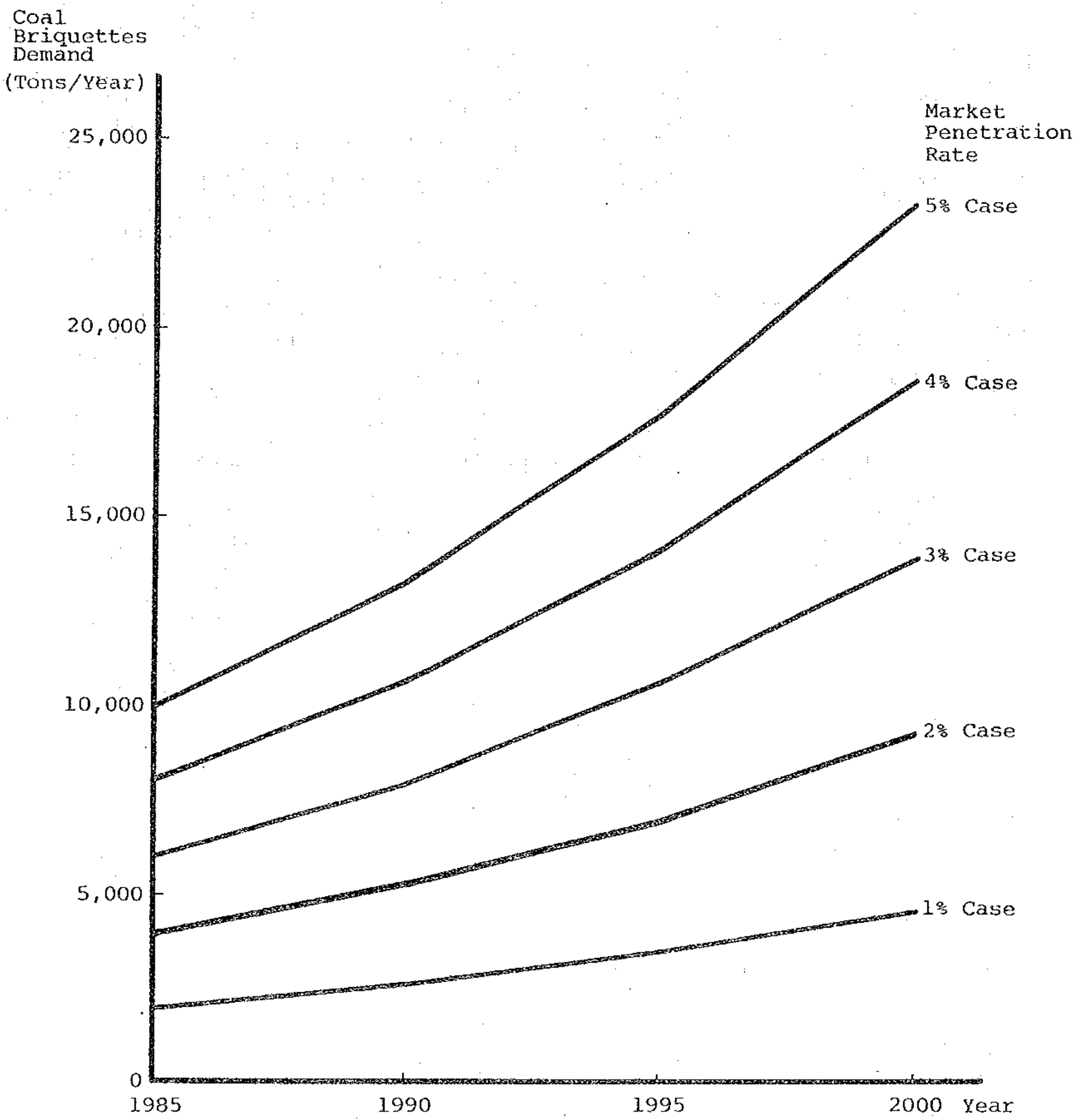


Figure 4-2-2 Projected Coal Briquettes Demand in Lusaka by Market Penetration of Household Charcoal Market

To backup the estimates on coal briquettes market size from demand standpoint, the market size is analyzed from supply standpoint. As seen in Table 4-2-4, there are presently 35 open markets in Lusaka, of which 28 open markets have a total of 167 charcoal shops. These shops are supervised by the City Council, each paying 75 ngwees per day to the council.

Assuming that, with the approval of the Council, briquettes are sold by 10% of these shops at a rate of 10 bags, or 256 kilograms, per day, the sale is calculated to be 1,700 tons per annum as:

25.6 kg. of charcoal/bag x 10 bags per day/shop x 16 shops x 300 days/year x 7,000 kcal/charcoal kg = 8.60 x 10^9 kcal/year
8.60 x 10^9 kcal/year - 5,200 kcal/briquette kg. - 1,000 Briquette kg/briquette ton = 1,700 briquette tons/year

These calculations cover the open markets only and are considerably conservative. When combined with briquette sales in townships or compounds the total sale would be twice this number, or 3,400 tons briquettes per year, as indicated by Table 4-1-4 that half the charcoal is sold at townships or compounds. At present, the 1% or 2% cases in Table 4-2-7 and Figure 4-2-2 may be taken as a reasonable estimate of the market size.

4.2.3 Coal briquette prices in Lusaka

(1) Charcoal pricing structure

Coal briquettes are an alternative fuel to charcoal; for this reason, the prices of charcoal and coal briquettes must be linked. Table 4-2-8 shows the charcoal pricing structure in Lusaka.

The comparison of 1978 and March 1986 prices in the table shows that the growth rate of the producer price of charcoal is not relatively high. This is reflected in the growth of share of each price factor. While the profit share of the charcoal vendor rose 29.0 points, the share of charcoal producer price depreciated 25.0 points. On the other hand, transportation fees rose 280.0 points in price and 42.5 points in share. Whether or not this was caused by the increase in transportation distances resulting from destruction of the nearer forests is studied below. Tables 4-2-9 and 4-2-10 show the charcoal suppliers to traders in the Lusaka open markets and townships, transportation distances from the suppliers to Lusaka, and charcoal producer prices. These two tables show that the charcoal retail price does not depend on transportation distance. This is also vindicated by the following calculation.

Table 4-2-8 Structure of Charcoal Pirce in Lusaka

(Kwacha/Bag)

	1978		1986 (Mar.)		Growth Rate of	Growth Rate of
	Price	(%)	Price	(%)	Price(%)	Share(%)
Producer Price	2.50	55.6	5.00	41.7	100.0	-25.0
Transportation Fee	1.00	22.2	3.80*	31.7	280.0	42.5
Forest Department Fee	0.10	2.2	0.10	0.8	0.0	-63.6
Trader Profit	0.90	20.0	3.10	25.8	244.4	29.0
Empty Bag Price	0.50	-	3.00	-	500.0	-
Total Price Inputs	5.00	-	15.00	-	200.0	-
Retail Price (Less Empty Bag)	4.50	100.0	12.00	100.0	166.7	-

* Hired truck fee plus cost

Table 4-2-9 Charcoal Buying Place for Charcoal sellers in Lusaka Markets

Name of Markets	Charcoal Buying Place	Average Distance from Lusaka (Km)	Ave.Buying Price (Kwacha/Bag)	Ave.Sales Price (Kwacha/Bag)
1.Arrakan Barracks	N.A.	N.A.	N.A.	N.A.
2.Chachacha Road	N.A.	N.A.	N.A.	N.A.
3.Chainda	N.A.	N.A.	N.A.	N.A.
4.Chaisa	Mumbwa/Chongwe	130/60	5.00	N.A.
5.Chawama	Kapiri Mposhi	180	N.A.	12.00
6.Chelston	Chongwe	60	5.00	12.00
7.Chibolya(Soweto)	Kabwe/Mumbwe	120/130	4.50	11.00
8.Chifundo	N.A.	N.A.	5.00	11.00
9.Chilenje	Mumbwa/Katuba	130/70	5.00	12.00
10.Chilulu	Kasisi	60	5.00	12.00
11.Chingwere	Kaphoor/Kapiri Mposhi	180	5.00	12.00
12.Chipata	Chongwe/Kapiri Mposhi/Mumbwa	60/180/130	4.50	12.00
13.Chitukuko	Kapiri Mposhi	180	5.00	12.00
14.Chunga	Mumbwa	130	N.A.	12.00
15.Garden	Mumbwa	130	4.50	11.00
16.John Howard	Mumbwa	130	4.00	11.00
17.Kabwata	Congwe/Kasisi	60	5.00	12.00
18.Kalingalinga	Chongwe	60	4.50	12.00
19.Kanyama(New)	Kapiri Mposhi/Mumbwa	180/130	N.A.	10.00
20.Kaunda Square	Kasisi/Chongwe/Chisamba	60	5.00	12.00
21.Kulima Tower	N.A.	N.A.	N.A.	N.A.
22.Libala	Chongwe	60	5.00	12.00
23.Lilanda	Mumbwa	130	5.00	12.00
24.Longacres	N.A.	N.A.	N.A.	N.A.
25.Lubuma(Kamwala)	Chongwe/Kapiri Mposhi/Mumbwa	60/180/130	5.00	12.00
26.Malipole	Kapiri Mposhi	180	5.00	12.00
27.Mandevu	Pamaa Pang	N.A.	5.00	12.00
28.Matero	Kapiri Mposhi/Chongwe	180/60	5.00	12.00
29.Mutambe	Chongwe	60	5.00	12.00
30.Mutendere	Chongwe/Mumbwa	60/130	1.50	10.00
31.Mwaziona	N.A.	N.A.	N.A.	N.A.
32.Ngombe	Kasisi	60	5.00	12.00
33.Northmead	Kasisi/Mungule	60	5.00	13.00
34.Nyerere	N.A.	N.A.	N.A.	12.00
35.Olympia Park	N.A.	N.A.	N.A.	N.A.

Talbe 4-2-10 Charcoal Buying Place for Charcoal sellers in Lusaka Townships

Name of Townships	Charcoal Buying Place	Ave.Distance From Lusaka(Km)	Ave.Buying Price (Kwacha/Bag)	Ave. Sales Price (Kwacha/Bag)
1.Chunga	Kapiri Mposhi	180	5.00	12.00
2.George	Chongwe	60	5.00	12.00
3.Lilanda(Kapwepwe)	Mumbwa	130	5.00	12.00
4.Chingwere	Mumbwa	130	5.00	12.00
5.Matero East(Mchinga)	Mumbwa	130	5.00	12.00
6.Emmasdale	Chongwe	60	5.00	12.00
7.Mulobela	Chinyunyu/Kabile	N.A.	5.00	12.00
8.Namnunga	N.A.	N.A.	N.A.	N.A.
9.Chinika	Mumbwa	130	4.00	10.00
10.Mutambe	Kapiri Mposhi	180	5.00	12.00
11.Marrapodi	Kabwe	120	5.00	12.00
12.Mandevu	Kabwe	120	5.00	12.00
13.Chaisa	Kapiri Mposhi	180	5.00	12.00
14.Chipata(Mpulungu)	Kapiri Mposhi	180	5.00	12.00
15.Garden	Mumbwa	130	5.00	12.00
16.Roma	N.A.	N.A.	N.A.	N.A.
17.N'Gombe	Chongwe	60	5.00	12.00
18.Kalundu	N.A.	N.A.	N.A.	N.A.
19.Chivala Mabwe	N.A.	N.A.	N.A.	N.A.
20.Chikonkoto	N.A.	N.A.	N.A.	N.A.
21.Luneta	N.A.	N.A.	N.A.	N.A.
22.Chudleigh	N.A.	N.A.	N.A.	N.A.
23.Mwambula	N.A.	N.A.	N.A.	N.A.
24.Kaunda Square	Chongwe	60	5.00	12.00
25.Chamba Valley	N.A.	N.A.	N.A.	N.A.
26.Kamanga	Chongwe	60	5.00	12.00
27.Chelston	Chongwe	60	5.00	12.00
28.Chakunkula(Chainda)	N.A.	N.A.	N.A.	N.A.
29.Avondale	Chongwe	60	5.00	12.00
30.Mutendere	Chongwe	60	5.00	10.00
31.Helen Kaunda	Kasisi	60	5.00	10.00
32.Kalingalinga	Kasisi/Chongwe	60	5.00	10.00
33.Shikosuwe	N.A.	N.A.	N.A.	N.A.
34.Bimbe	N.A.	N.A.	N.A.	N.A.
35.Kabulonga	N.A.	N.A.	N.A.	N.A.
36.Ibex Hill	N.A.	N.A.	N.A.	N.A.
37.Tukunka	N.A.	N.A.	N.A.	N.A.
38.Bauleni	Chongwe	60	5.00	12.00
40.Ridgeway	N.A.	N.A.	N.A.	N.A.
41.Woodlands	N.A.	N.A.	N.A.	N.A.
42.Chilenje	Katuba	70	4.00	10.00
43.Chilenje South	Katuba	70	4.00	10.00
44.Libala	Mumbwa	130	4.00	10.00
45.Kabwata	Mumbwa	130	4.00	10.00
46.Kamwala	Kasisi	60	4.00	10.00
47.Maluba	N.A.	N.A.	N.A.	N.A.
48.Kaila	N.A.	N.A.	N.A.	N.A.
49.Chibolya	Mumbwa	130	4.00	10.00
50.John Lange	Kasisi	60	5.00	10.00
51.Misisi	Mumbwa	130	4.00	10.00
52.John Howard	Mumbwa	130	4.00	10.00
53.Chawama	Chongwe	60	4.00	10.00
54.Jack	Chongwe	60	5.00	10.00
55.Ngwerere	Kabwe	120	5.00	12.00
56.Knyama	Mumbwa	130	4.00	10.00
57.Cathedral Hill	N.A.	N.A.	N.A.	N.A.
58.Kalikiliki	Chongwe	60	4.00	12.00
59.Kabanana	Chongwe	60	5.00	12.00
60.Mwenbezi(Ward)	N.A.	N.A.	N.A.	N.A.

Transportation by a 5-ton truck over 100 kms:
Fuel cost per bag of charcoal=100 km ÷ 5 km/light oil liter/truck x 1.88 kwacha/light oil liter ÷ 170 bags/truck = 0.22 kwacha/bag

This calculation indicates that even if the distance increases to 200 kilometers, the fuel cost per bag of charcoal is only 0.44 kwacha which has a negligible influence on the final charcoal retail price.

(2) Briquette price forecast

As discussed above, charcoal prices in Lusaka are not necessarily dependent on the producer prices nor on transportation costs. Therefore it is more reasonable to predict future charcoal prices by analyzing trends in charcoal retail prices. The predictions made based on this thinking are shown in Figure 3-3-8. This approach would be invalid if wood as raw material for charcoal is not sufficiently available. The total forest area in Central and Lusaka Provinces is 9.9 million hectare according to the Forest Vegetation of Zambia Wood Consumption Study Technical Notes No.2: The Forest Area January 1986; Forest Department. The annual depletion of forest is calculated to be 13,000 hectares using charcoal demand of 150,000 tons, equivalent to the demand of Lusaka, and forest area requirement of 11.4 ton charcoal per hectore, of which the source is The Status and Impact of Woodfuel in Urban Zambia; Department of Natural Resources. The simple calculation yields 750 years for depletion. The intention behind this calculation should not be misinterpreted as thinking light of forest destruction but for the purpose of assessing the impact on transportation cost only.

The prices of coal briquette must be lower than that of charcoal in energy value from the consumer's standpoint. In addition, from the trader's standpoint, they naturally expect more profits by taking up coal briquettes, a new commodity. Therefore coal briquettes should be priced at retail and ex-factory respectively lower than charcoal at retail and wholesale at Lusaka, which is producer price plus transportation cost plus retail tax. Table 4-2-11 and Figure 4-2-3 show the projected coal briquette retail price based on projected charcoal retail price in urban Lusaka, shown in Table 3-3-14 and Figure 3-3-8 in Chapter 3. The projections are based on the assumption that the correlation between the consumer's price index and the coal briquette retail price is sufficiently significant on the primary regression curve. The forecast coal briquettes price are calculated from the projected charcoal retail prices using thermal value ratio of the two. The coal briquette prices thus calculated must be accepted as the highest possible prices. Coal briquettes retail prices are forecast on Figure 4-2-3 using four different regression curves of projected consumer's price index. Of these the exponential regression (r=0.997) would be most appropriate as are the cases in general of consumer's price forecasts.

Table 4-2-11 Coal Briquettes Retail Price Forecast based on Projected Charcoal Retail Price

	1986(Mar.)				1990				1995				2000			
	Exp.*	Power*	Lin.*	Log.*	Exp.*	Power*	Lin.*	Log.*	Exp.*	Power*	Lin.*	Log.*	Exp.*	Power*	Lin.*	Log.*
Projected Charcoal Retail Price (Kvacha/Bag) :	12.00	12.00	12.00	12.00	17.01	16.26	13.59	13.34	29.25	25.44	15.70	15.23	53.62	40.91	17.80	16.94
Projected Charcoal Retail Price (Kvacha/Ton) :	375.00	375.00	375.00	375.00	531.56	508.13	424.69	416.88	914.06	795.00	490.63	475.94	1,675.63	1,278.44	556.25	529.38
Projected Coal Briquettes Retail Price (Kvacha/Ton) :	278.57	278.57	278.57	278.57	394.88	377.46	315.48	309.68	679.02	590.57	364.46	353.55	1,244.75	949.70	413.21	393.25

Note) Exp.* : Consumer's Price Index derived from Exponential Curve Fitting (see Table 3-3-3)
Power*: Consumer's Price Index derived from Power Curve Fitting (See Table 3-3-3)
Lin.* : Consumer's Price Index derived from Linear Regression Fitting (See Table 3-3-3)
Log.* : Consumer's Price Index derived from Logarithmic Curve Fitting (See Table 3-3-3)
Projected Charcoal Retail Price is shown in Table 3-3-14 and Figure 3-3-8, respectively.
Heating Values of Charcoal and Coal Briquettes are assumed to be 7,000 Kcal/Kg and 5,200 Kcal/Kg, respectively.

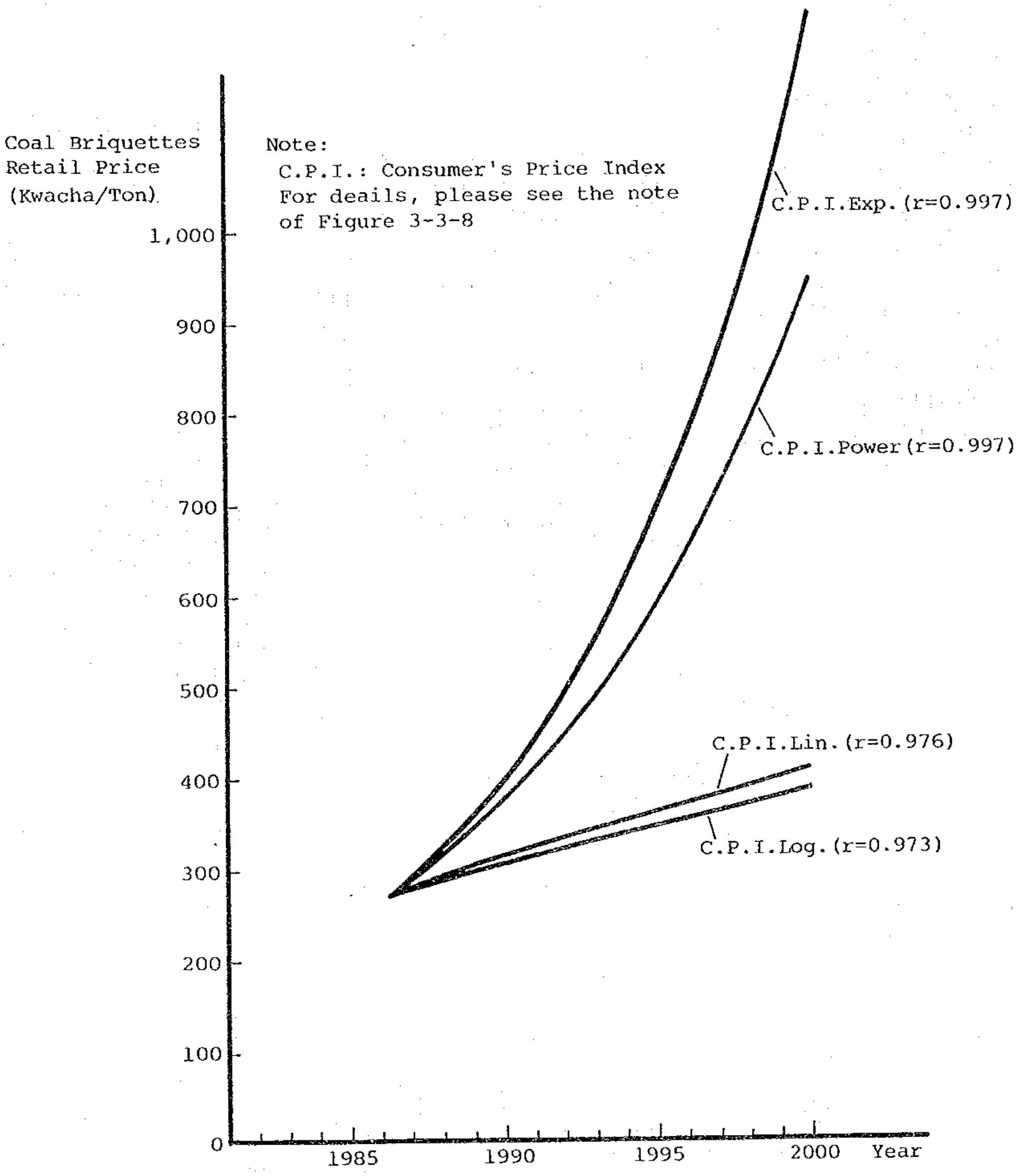


Figure 4-2-3 Coal Briquettes Retail Price Forecast based on Projected Charcoal Retail Price

4.3 Clay Stove Market

As described earlier in 4.1.2 (2) in reference to traditional cooking styles, electric stoves, kerosene stoves, mbaulas, and firewood tripods are presently in use for household cooking. The clay stoves of this project are by far the more efficient to burn charcoal than mbaulas now used with charcoal, although the clay stoves are intended primarily for use with coal briquettes. It is therefore necessary to consider possible substitution for the mbaulas to burn charcoal when assessing the clay stove market. This section examines the supply and demand of mbaulas in Lusaka first and then proceeds to the market size and price of the clay stoves.

4.3.1. Supply and demand for mbaulas in Lusaka

(1) Mbaula demand in Lusaka

Virtually all households in Lusaka use mbaulas to burn charcoal. The size of the mbaulas varies with the size of the househods; the average mbaula for an average Zambian family of five is 20 to 30 cm in diameter, and approximately 20 cm deep.

Table 4-3-1 estimates mbaula demand in Lusaka from the projected number of households in 1985.

Average annual consumption of mbaulas per household is determined by the number of mbaulas owned per household and the frequency of use which is, in turn, closely linked to the life of the mbaula. As is seen from the table, the consumption rises as the income level falls. Moreover, it also shows that the total demand for mbaulas in the city is approximately 85,000 per year--or roughly 0.47 per household on average. Table 4-3-2 indicates the mbaula demand for commercial use at the Lusaka open markets. The figures are based on data collected through local surveys. It shows that the demand for commercial pruposes is estimated to be 2,000 units. Therefore, the total demand in Lusaka, combining both household and commercial uses, is in the neighborhood of 87,000 units.

Table 4-3-1 1985 Estimated Mbaulas Demand in Lusaka by Projected Households

	Share in total Households*(%)	No. of Households** (1000 Households)	Mbaulas Consump. Rate*** (Pieces/ Year/Households)	Mbaulas Demand (1000 Pieces /year)
Projected Households:	100.00	182.80	-	-
With Electricity				
-High Cost Group:	19.13	34.97	0.250	8.74
-Medium/Low Cost Group:	22.26	40.69	0.333	13.55
Without Electricity				
-Medium/Low Cost Group:	40.18	73.45	0.400	29.38
-Low Cost Group:	18.43	33.69	1.000	33.69
Estimated Mbaulas Demand:	-	-	-	85.36

Source: * Prices & Incomes Commission
** 1980 Population and Housing Census of Zambia
*** National Council for Scientific Research

Table 4-3-2A Estimated Commercial Mbaulas Demand in Lusaka Markets
(Continued on Table 4-3-2B)

Name of Markets	Nshima Shops			Roast Maize Shops		
	No. of Shops (Shops)	Ann. Consump. Rate (Pieces/Year/Shop)	Total Ann. Consump. (Pieces/Year)	No. of Shops (Shops)	Ann. Consump. Rate (Pieces/Year/Shop)	Total Ann. Consump. (Pieces/Year)
1.Arrakan Barracks	2	3.00	6	0	0.00	0
2.Chachacha Road	77	3.00	231	0	0.00	0
3.Chainda	0	0.00	0	7	0.00	0
4.Chaisa	9	2.00	18	4	1.00	4
5.Chawama	8	4.00	32	16	1.00	16
6.Chelston	5	2.00	10	8	3.00	24
7.Chibolya(Soweto)	195	3.00	585	4	1.00	4
8.Chifundo	12	3.00	36	12	1.00	12
9.Chilenje	7	3.00	21	2	2.00	4
10.Chilulu	3	2.00	6	8	1.00	8
11.Chingwere	0	0.00	0	0	0.00	0
12.Chipata	11	3.00	33	12	1.00	12
13.Chitukuko	10	2.00	20	15	2.00	30
14.Chunga	0	0.00	0	0	0.00	0
15.Garden	3	2.00	6	6	1.00	6
16.John Howard	1	1.00	1	11	1.00	11
17.Kabwata	12	4.00	48	3	1.00	3
18.Kalingalinga	3	3.00	9	2	1.00	2
19.Kanyama(New)	5	1.00	5	7	1.00	7
20.Kaunda Square	2	2.00	4	11	1.00	11
21.Kulima Tower	1	2.00	2	0	0.00	0
22.Libala	5	3.00	15	1	2.00	2
23.Lilanda	14	3.00	42	17	1.00	17
24.Longacres	0	0.00	0	6	1.00	6
25.Lubuma(Kamwala)	38	3.00	114	10	1.00	10
26.Malipole	1	2.00	2	1	1.00	1
27.Mandevu	10	2.00	20	16	1.00	16
28.Matero	8	3.00	24	6	1.00	6
29.Mutambe	2	3.00	6	0	0.00	0
30.Mutendere	5	1.00	5	8	1.00	8
31.Mwaziona	11	3.00	33	11	1.00	11
32.Ngombe	4	2.00	8	0	0.00	0
33.Northmead	3	3.00	9	6	1.00	6
34.Nyerere	0	0.00	0	0	0.00	0
35.Olympia Park	7	2.00	14	1	2.00	2
Total	474	-	1,365	211	-	239

Table 4-3-2B Estimated Commercial Mbaulas Demand in Lusaka Markets
(Continued from Table 4-3-2A)

Name of Markets	Roast Beef Shops: No. of Shops (Shops)	Roast Beef Shops: Ann. Consump. Rate (Pieces/Year/Shop)	Roast Beef Shops: Total Ann. Consump. (Pieces/Year)	Fritter Shops: No. of Shops (Shops)	Fritter Shops: Ann. Consump. Rate (Pieces/Year/Shop)	Fritter Shops: Total Ann. Consump. (Pieces/Year)	Grand Total Ann. Consumption (Pieces/Year)
1.Arrakan Barracks	1	1.00	1	5	2.00	10	17
2.Chachacha Road	77	1.00	77	0	0.00	0	308
3.Chainda	7	1.00	7	4	1.00	4	11
4.Chaisa	0	0.00	0	10	1.00	10	32
5.Chavama	0	0.00	0	21	1.00	21	69
6.Chelston	1	1.00	1	0	0.00	0	35
7.Chibolya(Soveto)	185	1.00	185	7	1.00	7	781
8.Chifundo	0	0.00	0	5	1.00	5	53
9.Chilenje	0	0.00	0	25	1.00	25	50
10.Chilulu	0	0.00	0	8	1.00	8	22
11.Chingvere	0	0.00	0	3	1.00	3	3
12.Chipata	0	0.00	0	6	1.00	6	51
13.Chitukuko	0	0.00	0	5	1.00	5	55
14.Chunga	0	0.00	0	7	1.00	7	7
15.Garden	0	0.00	0	20	1.00	20	32
16.John Hovard	0	0.00	0	8	1.00	8	20
17.Kabvata	0	0.00	0	5	1.00	5	56
18.Kalingalinga	0	0.00	0	9	1.00	9	20
19.Kanyama(Nev)	0	0.00	0	12	1.00	12	24
20.Kaunda Square	0	0.00	0	0	0.00	0	15
21.Kulima Tover	0	0.00	0	0	0.00	0	2
22.Libala	0	0.00	0	25	1.00	25	42
23.Lilanda	0	0.00	0	8	1.00	8	67
24.Longacres	0	0.00	0	2	0.00	0	6
25.Lubuma(Kamvala)	0	0.00	0	12	1.00	12	136
26.Malipole	0	0.00	0	5	1.00	5	8
27.Mandevu	0	0.00	0	7	1.00	7	43
28.Matero	0	0.00	0	8	1.00	8	38
29.Mutambe	0	0.00	0	4	1.00	4	10
30.Mutendere	0	0.00	0	10	2.00	20	33
31.Mwaziona	0	0.00	0	6	1.00	6	50
32.Ngombe	0	0.00	0	5	1.00	5	13
33.Northmead	0	0.00	0	5	1.00	5	20
34.Nyerere	0	0.00	0	0	0.00	0	0
35.Olympia Park	0	0.00	0	1	1.00	1	17
Total	271	-	271	258	-	271	2,146

(2) Mbaula supply in Lusaka

As in the case with charcoal sales, mbaulas are sold at hardware retail shops at open markets or by vendors in townships and other residential areas. These mbaulas are produced there by these same vendors, who take metal plates from old drums, car bodies or washing machines and forge them into mbaulas. One metal drum ordinarily produces five to six mbaulas. As far as the field survey by the feasibility study could confirm, there is no instance of mass marketing, say in supermarkets.

4.3.2 Market size of clay stoves in Lusaka

Like coal briquettes, clay stove market does not exists in Zambia today. Hence, the market for this product must be created along with that of coal briquettes. This market will grow gradually as substitution for mbaulas takes place. The pace of growth depends largely on those factors discussed in the preceding section which determine the rate of substitution for charcoal by coal briquettes. However, attention should be paid to the fact that clay stoves can also be used for burning charcoal fuel, which implies that the market size of the clay stoves needs not necessarily be linked with that of coal briquettes.

In a fashion similar to the estimation of the market size of coal briquettes, the size of the clay stove market may be expressed in terms of rate of penetration of clay stoves into the mbaula market. Table 4-3-3 and Figure 4-3-1 exhibit the projected mbaula demand based on the estimated number of households in Lusaka. Table 4-3-4 and Figure 4-3-2 show projections of mbaula demands togeter with forecast clay stove demands with the rate of penetration of clay stoves into the mbaula market as parameter, the same approach employed for estimating the coal briquettes demand.

Thus far, the clay stove market has been studied from the standpoint of demand. The market size is also analyzed from supply standpoint. Mbaula are sold at hardware shops in the open markets and charcoal and hardware vendors in the townships and compounds. If the target is limited to the open market charcoal shops and 10%, or 16 out of 167 shops sell one clay stove per day, the total supply will amount to 7,800 units per year as:

clay stove sale by open market charcoal retailers 1.0 unit per day per store x 16 stores x 300 days per year
= 4,800 units per year, and

clay stove sales by open market hardware retailers 1.0 unit per day per store x 10 stores x 300 days per year
= 3,000 units per year

As the calculation covers only the open markets, the figures are considerably underestimated. If the sale by vendors in the townships are added, supply of at least 15,000 units would be possible. For this reason, the 9% or 18% case in Table 4-3-4 and Figure 4-3-2 would be the reasonable projected market size for clay stoves.

4.3.3 Clay stove prices in Lusaka

As repeatedly mentioned, the clay stoves may be considered a replacement for the mbaulas and for this reason, the prices of clay stoves must be studied in relation to the prices of the mbaulas. The size of mbaulas sold in Lusaka ranges from 15 to 50 cm in ciameter. The price varies by size. According to cooking style sruveys and direct interviews conducted as part of this feasibility study, the size of mbaulas most frequently used by medium- and low-income groups, the target groups for which the clay stoves are intended, is from 20 to 30 cm across. For this reason, the clay stoves of this project are sized so that they could replace the mbaulas of this range. Their retail prices in Lusaka varies by shops but is between 10 and 15 kwachas.

Table 4-3-3 Projected Mbaulas Demand in Lusaka by Projected Households

	Share in Total Households*(%)	Mbaulas Consump. Rate*** (Pieces/Year/Household)	1985		1990		1995		2000	
			No. of Households (1,000 Households)	Mbaulas Demand (1,000 Pieces/Year)	No. of Households (1,000 Households)	Mbaulas Demand (1,000 Pieces/Year)	No. of Households (1,000 Households)	Mbaulas Demand (1,000 Pieces/Year)	No. of Households (1,000 Households)	Mbaulas Demand (1,000 Pieces/Year)
Projected Households**:	100.00	-	182.80	-	242.70	-	321.80	-	411.40	-
With Electricity										
- High Cost Group:	19.13	0.250	34.97	8.74	46.43	11.61	61.56	15.39	78.70	19.68
- Medium/Low Cost Group:	22.26	0.333	40.69	13.55	54.03	17.99	71.63	23.85	91.58	30.50
Without Electricity										
- Medium/Low Cost Group:	40.18	0.400	73.45	29.38	97.52	39.01	129.30	51.72	165.30	66.12
- Low Cost Group:	18.43	1.000	33.69	33.69	44.73	44.73	59.31	59.31	75.82	75.82
Projected Mbaulas Demand:	-	-	-	85.36	-	113.33	-	150.27	-	192.11

Source: * Prices & Incomes Commission
** 1980 Population and Housing Census of Zambia
*** National Council for Scientific Research

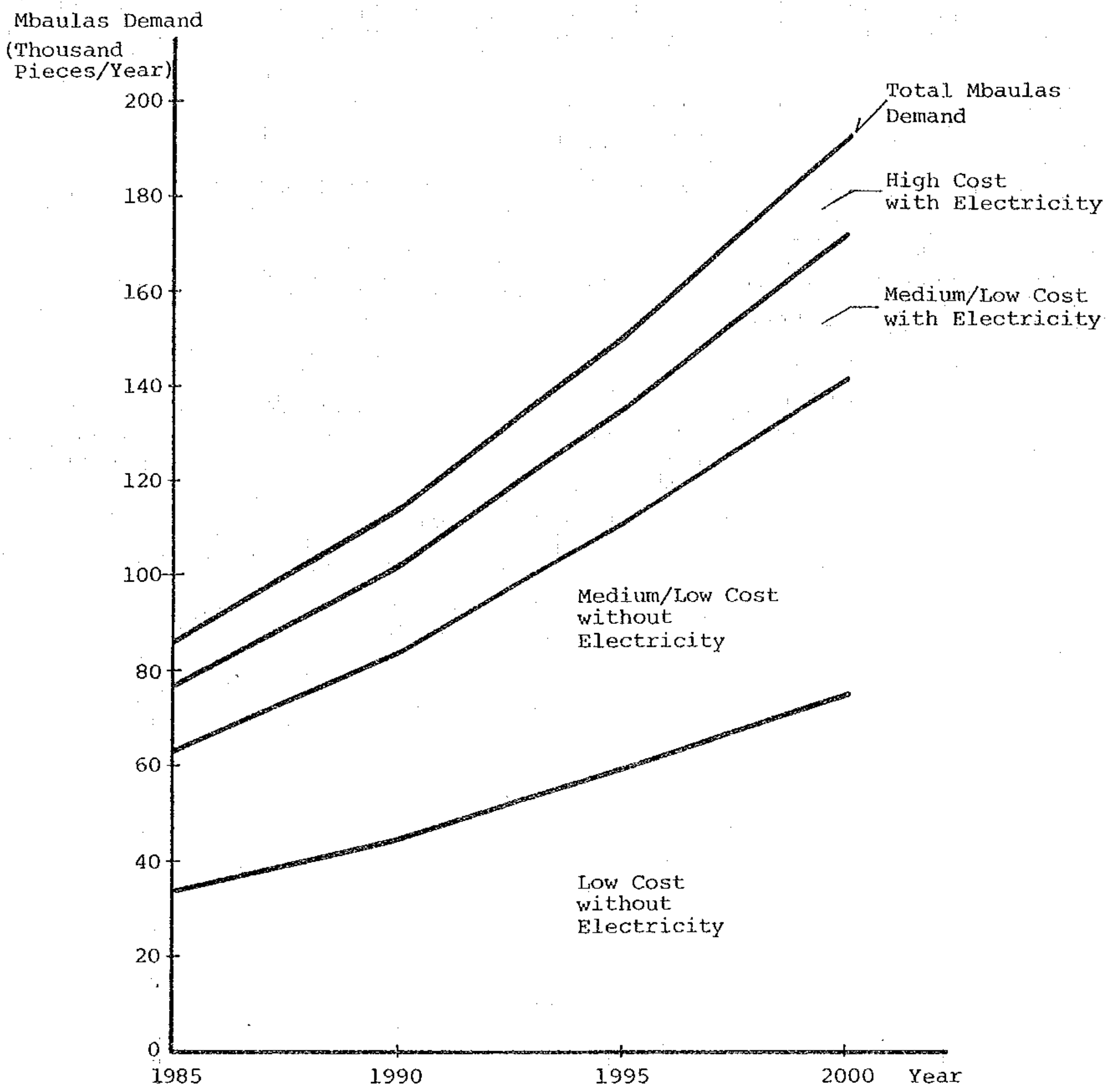


Figure 4-3-1 Projected Mbaulas Demand in Lusaka by Projected Households

Table 4-3-4 Projected Clay Stoves Demand in Lusaka by Market Penetration of Mbaulas Market

	1985	1990	1995	2000
Projected Households* (1000 Households/Year):	182.80	242.70	321.80	411.40
Projected Mbaulas Demand** (1000 Pieces/Year):	85.36	113.33	150.27	192.11
Projected Clay Stoves Demand (Pieces/Year): Market Penetration Rate				
5% Case	4,268	5,667	7,514	9,606
6% Case	5,122	6,800	9,016	11,527
7% Case	5,975	7,933	10,519	13,448
8% Case	6,829	9,066	12,022	15,369
9% Case	7,682	10,200	13,524	17,290
10% Case	8,536	11,333	15,027	19,211
11% Case	9,390	12,466	16,530	21,132
12% Case	10,243	13,600	18,032	23,053
13% Case	11,097	14,733	19,535	24,974
14% Case	11,950	15,866	21,038	26,895
15% Case	12,804	17,000	22,541	28,817
16% Case	13,658	18,133	24,043	30,738
17% Case	14,511	19,266	25,546	32,659
18% Case	15,365	20,399	27,049	34,580
19% Case	16,218	21,533	28,551	36,501
20% Case	17,072	22,666	30,054	38,422

Source: * 1980 Population and Housing of Zambia
** Table 4-3-3

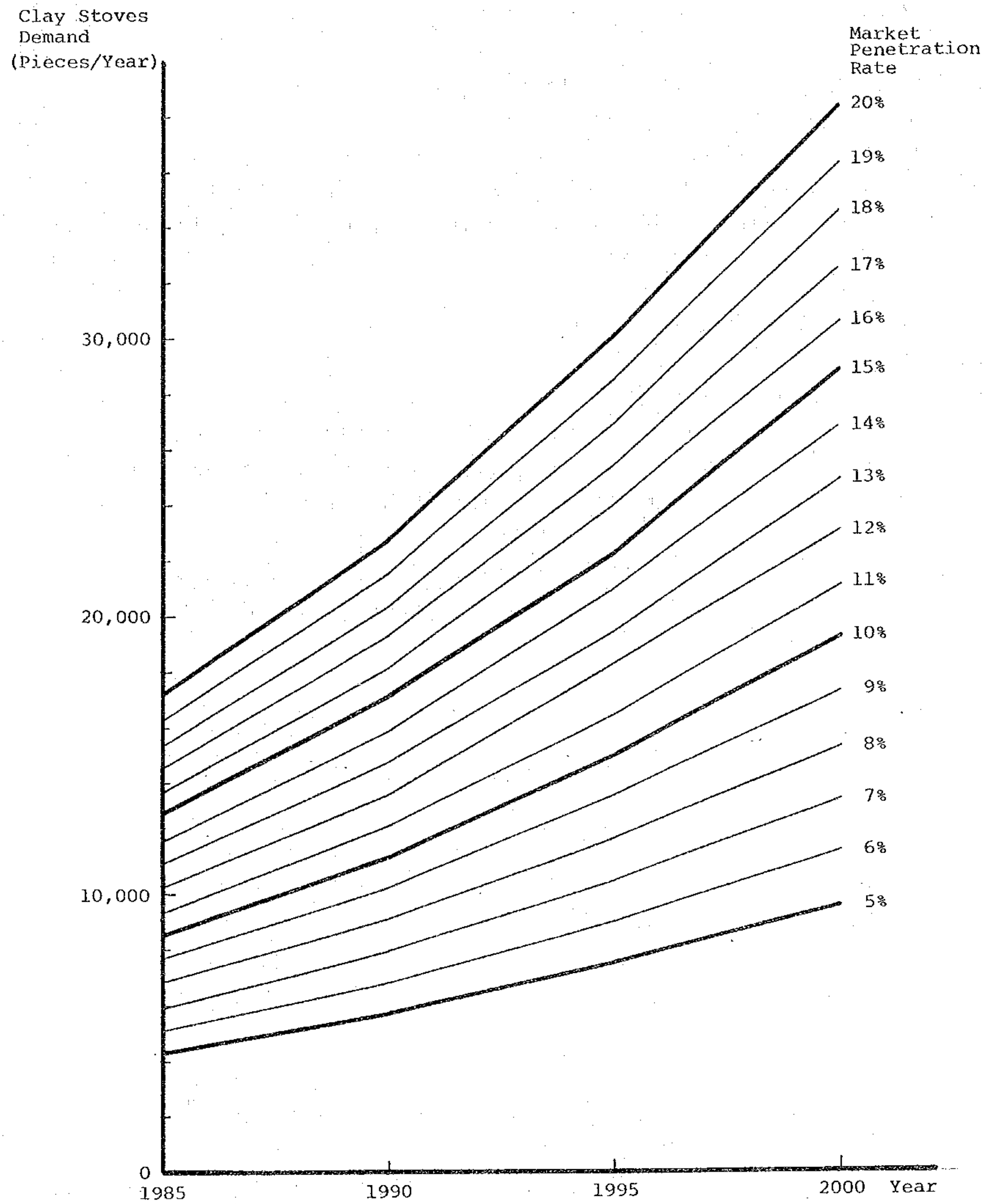


Figure 4-3-2 Projected Clay Stoves Demand in Lusaka by Market Penetration of Mbaulas Market

4.4 Marketing

The coal briquettes and clay stoves of this project will form an entirely new market in Zambia as they are new commodities not introduced before. Accordingly, effective strategy must be devised for the development of this new market and promotion of sales. This section considers distribution channels, public relation approaches and sales promotion for coal briquettes and clay stoves.

4.4.1 Distribution channels

Coal briquettes will use chiefly the existing charcoal distribution channels. Clay stoves would substitute for mbaulas. Mbaulas are produced at the places of sales; therefore, there is no such a thing as distribution channel. For the sale of clay stoves, it would be most practical to use hardware stores which sell mbaulas or, as in the case of Japan, charcoal shops. Distribution channels for charcoal and other prospective channels are studied with a basic strategy that clay stoves will be placed on the same distribution channels as those for coal briquettes.

(1) Charcoal distribution channel

A charcoal burners' association has been reportedly established in Kitwe under the name of Kitwe Professional Charcoal Burners Association. There is no such an organization in Lusaka. Charcoal used in Lusaka is generally distributed through three channels; the first channel being charcoal shops in open markets; the second through charcoal vendors in townships or compounds; the third direct sales from producers to consumers on the street. The first and second channels occasionally include such intermediaries as charcoal wholesalers and brokers or charcoal transporters. However, most charcoal shops buy charcoal directly from producers, transport it by their own trucks and sell at their shops.

Figure 4-4-1 illustrates Zambia's charcoal distribution channels. These channels, except those for copper refining charcoal, apply to Lusaka. The market section in the figure is applicable to sales of coal briquettes and clay stoves. Sales of briquettes and stoves would be through the charcoal shops. The charcoal shops have direct and intimate contacts with consumers; therefore, this method should be very effective to sell coal briquettes and clay stoves as substitutes for charcoal and mbaulas.

(2) Utilization of other distribution channels

It is considered possible and effective as well to sell coal briquettes and clay stoves through distributors or companies having particular distribution channels in addition to using the aforementioned charcoal distribution channels.

The following organizations and companies are promising:

(a) National Import and Export Corporation Limited (NIEC)

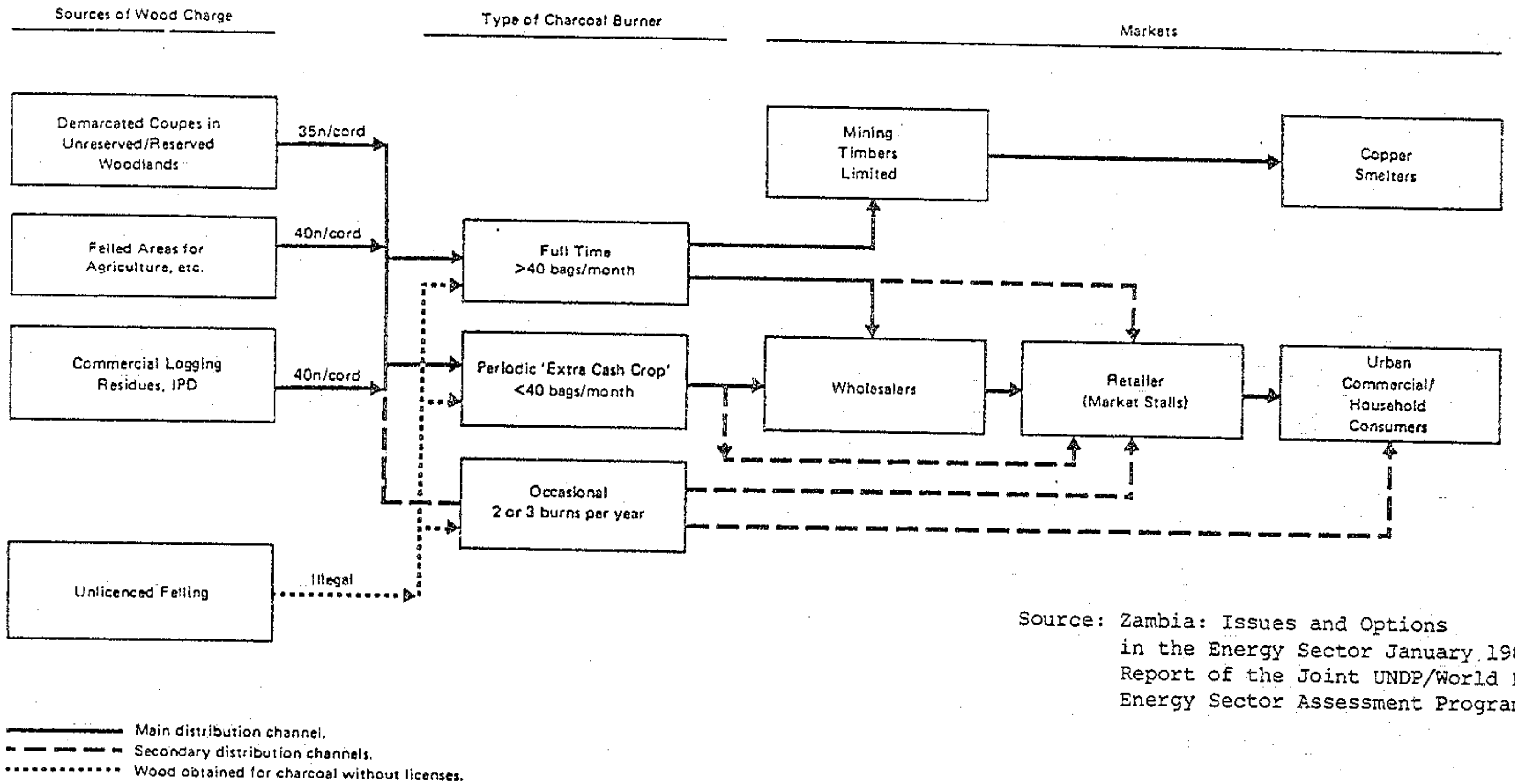
This is Zambia's largest distribution company and has the following affiliated firms.

1) Wholesale Sector

*Zambia National Wholesale and Marketing Company Limited (ZNWNC)

2) Retail Sector

* Consumer Buying Corporation of Zambia Limited (ZCBC)
* NIEC Stores Limited
* Mwaiseni Stores Limited



Source: Zambia: Issues and Options
in the Energy Sector January 1983
Report of the Joint UNDP/World Bank
Energy Sector Assessment Program

Figure 4-4-1 Charcoal Production/Marketing Channels in Zambia

3) Pharmaceutical Sector

* National Drug Company Limted

4) Agricultural Sector

* Zambia Horticultural Products Limited (Zamhort)

5) Purchasing

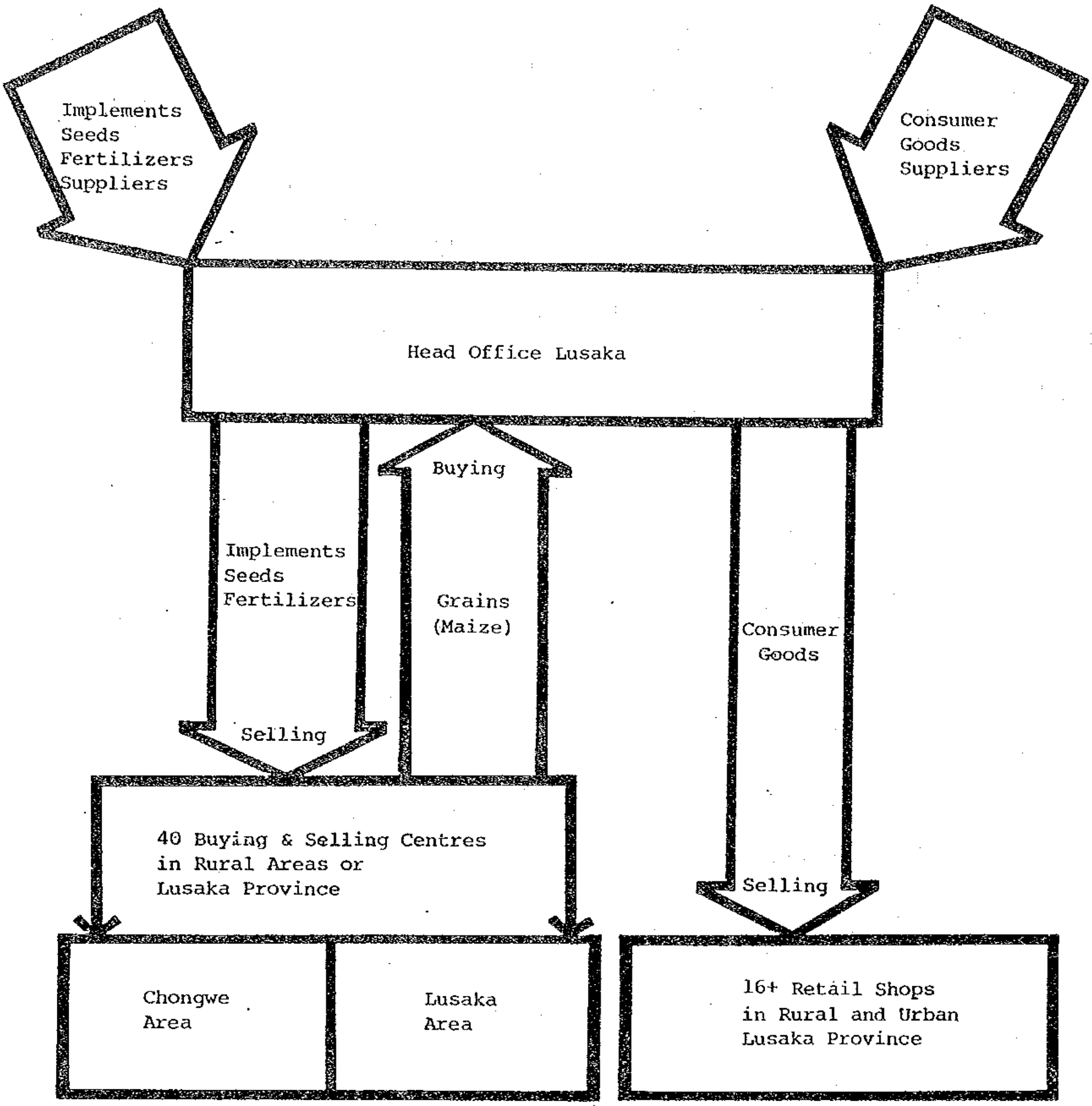
* NIEC Overseas Service (Zambia) Limited

(b) Lusaka Province Co-operative Union Limited

This is an agricultural cooperative established in 1980 with a view to promoting contribution to the advancement of local communities by participating in economic and social development activities. The cooperative union has 27 branches called primary cooperative societies, about 2,000 members and 40 operation centers, or depots. The union deals in mostly agricultural produces but is now planning to diversify their operation. Figure 4-4-2 shows the union's distribution channels.

(c) Midlands Farmers Co-operative Societies Limited.

This is also an agricultural cooperative and has branches and members throughout the country. At the interview during the field survey, the study team was advised that if the sales territory is not limited to Lusaka, the co-operative could sell 1,000 tons of coal briquettes and 4,000 units of stoves. While NIEC's customers tend to be high-income earners, the above (b) and (c) cover a fairly broad range of customers including those belonging to the low and middle-income brackets.



Source: Lusaka Province Co-operative Union Ltd.

Figure 4-4-2 Lusaka Province Cooperative Union Marketing Channels

As a basic strategy, how to handle the delivery of the products from the pilot plants should be decided. The following cases are possible.

Case 1: A wholesle firm will take delivery of all products and wholesales to retailors.

Case 2: Distributors will come directly to the pilot plants to take delivery of products.

The wholesale firm in Case 1 could either be a subsidiary of NCSR or a completely unrelated firm. Case 1 apparently has an advantage that sales targeting, marketing and sales development become easier. However, the retail price would be higher due to the presence of the wholesaler. What is more, NCSR would lose direct contact with the market. Case 2, on the other hand, could reduce the sales costs but would involve NCSR in tedious daily routines of delivery, marketing plan, daily marketing operation, etc. However, NCSR could get hold of the market need. Shown in Table 4-4-1 are six marketing routes for coal briquettes and clay stoves, conceivable for Cases 1 and 2 of which Case 2-3 would best meet the purpose of this project.

Table 4-4-1 Optional Marketing Channels for Coal briquettes and Clay Stoves

	Wholesale Company	Charcoal Marketing Channels*	New Marketing Channels**
Case 1-1	o	o	x
Case 1-2	o	x	o
Case 1-3	o	o	o
Case 2-1	x	o	x
Case 2-2	x	x	o
Case 2-3	x	o	o

o Applicable
x Not applicable
* See Figure 4-4-1
** See Figure 4-4-2

4.4.2 Public relations methods

Coal briquettes and clay stoves are not known in Zambia among consumers. It is therefore necessary at first to effectively draw attention of the consumers in Lusaka to the availability and the advantages of the coal briquettes and clay stoves.

There are a number of mass media in Lusaka, including broadcasting stations, newspaper and magazine publishers. However, as the potential buyers of coal briquettes and clay stoves are mainly low and middle-income households, use of these media should be avoided if it means an additional cost in marketing. Use of these media could be useful to draw the consumers' attention to coal briquettes and clay stoves but would not carry convincing enough messages about their merits directly to the consumers. With these points in mind, methods for effective promotion to housewives, the actual consumers of these products, are studied in the following paragraphs.

(1) Grass-roots approach

Lusaka City has more than 60 townships/compounds, each of which has a women's society. The townships/compounds are divided into wards, a ward into branches, and a branch into sections. Twenty-five houses form one section; 10 sections form one branch and 16 branches form one ward. Each section, branch or ward has its own elected chairman and chairwoman. The chairmen and chairwomen hold regular meetings.

It would be very effective to promote coal briquettes and clay stoves through the channels of these women's societies. Through actual demonstrations their leaders should be educated on the advantages of coal briquettes and clay stoves. Then, the demonstration should be expanded to include women's associations at the branch or section levels.

(2) Top-down approach

Zambia's political system is based on single-party democracy by the United National Independence Party (UNIP) which is very influential. If the Women's League of the party could be convinced of the advantages of coal briquettes and clay stoves and actively participate in the PR activities, the effect would be very pervasive. Cooperation could also be solicited from the Department of Community Development, a subordinate body of the Ministry of Labor and Social Services as part of its household economy program. These approaches should be very effective according to the interviews with the Business and Economic Study Department of University of Zambia.

(3) Other approaches

If sales are through distributors or a wholesale firm cited in 4.4.1 (2), their marketing specialists could develop effective PR systems.

4.4.3 Sales

Coal briquettes and clay stoves distribution channels that could be utilized are explained in 4.4.1. This section suggests actual sales steps and types of packing.

(1) Sales steps

The market for coal briquettes and clay stoves must be newly developed on a step-by-step basis. The conditions surrounding sales promotion of coal briquettes are explained in 4.2.2. The promotion would be surer if it follows the following steps.

Step 1: At open markets maximum exposure of coal briquettes and clay stoves to general consumers could be expected. Therefore the sales should be through selected charcoal and hardware shops in the open markets. In that case, the Zambian government should guarantee sales profits equal to or higher than those from charcoal or mbaulas by means of preferential measures so that sales may be promoted.

Step 2: As Step 1 shows effects sales should be expanded to the channels of distributors and charcoal and hardware vendors in the townships and compounds.

The targets for the sales are 300 to 400 kg of coal briquettes, equivalent to 10 bags of charcoal, and one clay stove per shop per day on average.

(2) Types of packing

In Zambia, charcoal is transported in grain bags including maize bags. As mbaulas are made at the hardware shops and usually not transported. Mbaulas are not fragile and presumably not packaged even if they are transported. For coal briquettes, use of beautifully-printed paper or vinyl bags is a normal practice in Japan. However, in consideration of the established practice of recycling charcoal bags and an unavoidable rise in sales price due to the use of one-way paper or vinyl bags it may be better to use the same bags as those for charcoal. It would suffice to just to bind two clay stoves with code for transportation.

4.5 Related Laws and Regulations

Laws and regulations which concern the sale of charcoal and mbaulas would also apply to the sales of coal briquettes and clay stoves.

4.5.1 Laws and regulations

(1) Charcoal

1) Laws and regulations relating to charcoal are shown in the Appendix concerning the Forest Department.

2) Lusaka Urban District Council: Shops operating at Lusaka open markets shall pay 75 ngwee per shop per day to Lusaka Urban District Council.

(2) Mbaula

Only 4.5.1 (2) relates to the sales of mbaula. The existing laws would not prevent charcoal and clay stoves from being marketed on the channels studied in this chapter.

5. RAW MATERIAL FOR COAL BRIQUETTES

5.1 Raw Materials in Perspective

5.1.1 Quality and uses

The coal briquette is a solid fuel which are commercially manufactured from various carbon sources and very handy to burn. Ordinarily, smokeless coal briquettes are burnt in residential areas for household and commercial purposes. The smokeless coal briquettes need very simple burning apparatus. The smoking coal briquettes, in contrast, adversely affect the living conditions by smoke, dust and sulfur dioxide they produce upon burning. When burnt in a large quantity, the effect on the environment is very serious even with a chimney to assist combustion and safe disposal of emissions. The burning equipment is destined to be complex and costly.

The smokeless coal briquettes can be produced in various grades and qualities depending upon the selection of raw materials and production processes. In order that the briquettes may be accepted by consumers in competition with charcoal, the coal briquettes should basically satisfy the following requirements:

1) The coal briquettes must be virtually smokeless and odorless.

2) The coal briquettes must be easy to start fire.

3) The coal briquettes must burn at an acceptable combustion rate.

4) Residual carbon left after combustion must be a minimal.

5) The coal briquettes must be rigid enough to endure transportation and normal handlings for use.

6) The coal briquettes must have an appropriate ash content and are not fragile while burning.

7) The coal briquettes should have a calorific value of around 5,000 kcal/kg.

To be competitive with charcoal, the coal briquettes must meet the above quality requirements while manufactured and marketed under competitive conditions using the raw materials available. However, in view of the raw materials available and the production processes conceivable for this project, and also how the coal briquettes will be consumed, it would not entirely adequate to aim at achieving the quality quite equal to that of charcoal. What is important is to give the consumers the same degree of satisfaction as they have with charcoal. The following considerations would be important to achieve this objective:

1) Because the Maamba coal slurry produces smoke upon combustion and has relatively low combustibility, it is necessary to employ fluidized carbonization to remove smoke and sulfur and at the same time improve the combustibility.

2) Ignitability and burning rate should be independently controlled.

3) Charcoal has advantages in high ignitability and high burning rate. But charcoal is difficult to extinguish once it is burnt, which is not necessarily advantageous in practice. The coal briquettes are somewhat inferior with respect to ignitability; nevertheless, its burning rate or intensity is controlable, although this depends upon the performance of the stove. Consumers' acceptance should be pursued through appropriate quality design of the briquettes and development of adequate stoves together with utilization best suited to coal briquettes.

5.1.2 Zambian raw materials

Coal briquettes are quite flexible in the selection of raw materials. Zambia has coal, bagasse, charcoal, and farm wastes as carbon resources, molasses as binder and slaked lime as sulfur fixer. These could be utilized economically and effectively.

Also the product quality could be designed with a wide range of flexibility as previously mentioned to accommodate the economy as well as consumer's needs.

5.2 Maamba Coal

The Maamba Collieries Ltd. is located some 350 km south of Lusaka. The mine has a proven reserve of 150 million tons of which the minable reserve is 35 million tons. The average production for the past five years is 520 thousand tons. On completion of the renovation of the mine currently under way the capacity is expected to become one million tons of coal per year. An estimated amount of about 300 thousand tons of waste coal fine, or coal slurry, is laid waste in the settling ponds of the washing process of the mine.

The Maamba coal is non-caking bituminous coal which, when powdered, exhibits a weak tendency for agglomeration. The coal slightly expands when it is rapidly heated. Upon heating at temperatures between 450°C and 550°C, the coal produces tar and a small amount of gas and becomes char. The ignition temperature of the Maamba coal depends on the method used for measurement; the oxidation reaction begins when the temperature reaches between 270°C and 300°C and combustion could start depending on conditions.

The burning rate is relatively slow; however, this would not be a problem if appropriate burners or stoves are used.

The past production record of the Maamba Collieries is shown in Table 5-2-1.

Table 5-2-1 Coal Production Record

Year	Production (1,000 ton)
1980	571
1981	539
1982	543
1983	509
1984	449
Average	522

The production of coal slurry from the coal washing process in future is estimated at 4% of the annual coal output. The slurry will consists principally of particles smaller than 0.5 mm. The slurry production will then be 22 thousand tons if the coal production is maintained at the past level, or 40 thousand tons at the maximum coal output and 30 thousand tons at 700,000 tons coal production.

Table 5-2-2 shows representative proximate analyses of the coal, reject and waste slurry produced in the washing process. Figure 5-2-1 shows relation between ash and heating value. The raw coal from the mine goes through crushing, classification, jigging, and finally washing to be separated into refined coal, reject and waste slurry. The raw coal as mined has rather high contents of ash and sulfur. The coal is washed to upgrade the quality to satisfy a certain quality standard, which naturally results in concentration of ash and sulfur in the reject and slurry. This makes it necessary to pay a particular consideration to the quality of the slurry when its effective utilization is planned. While the refined coal contains 16 to 18% ash, the ash content of the fresh slurry ranges wider from 20.2 to 34.2%. While the total sulfur and total calorific value of the refined coal are 1.0±0.5% and 6,500±200 kcal/kg, respectively; these are from 2.5 to 7% and 5,600±600 kcal/kg, respectively for the fresh slurry. The slurry has a good calorific value but its sulfur content is very high and the particles are very fine. On completion of the renovation, however, the quality of the slurry would change.

Table 5-2-2 Proximate Analysis of Coal

		Raw Coal	Washed Coal	Reject	Slurry
Moisture	%	1±0.2	1.0±0.5	1±2	1.2±0.2 (-0.5mm)
Ash	%	25±2	17.0±1.0	50±15	27.2±7
Volatile Matter	%	17±2	19±1	15±2	17.0±1
Fixed Carbon	%	56±2	65±2	40±10	54.7±5
Total Sulfur	%	2.5±0.5	1±0.5	6±4	2.5 to 7
Calorific Value	Kcal/kg	5600±250	6500±200	4000±1000	5600±600

(NCSR)

Ash fusion temp 1400-1450°C

Note that about 62% of the total S is the combustible pyritic S as FeS_2.

The sulfur range in the slurries is from 2.5 to 7%, the average 3.2%.

During the field survey, samples were taken from the old pond to the depth of 2 meters from the surface. The analysis of these samples indicates rather low sulfur contents. The sulfur content of the slurry lying deeper has not been tested. When utilizing the deeper slurry the possibility of encountering higher sulfur content should be taken into account.

Table 5-2-3 shows results of an ultimate analysis; the distribution among carbon, hydrogen and oxygen is normal.

Table 5-2-2 gives the results of analysis by NCSR of the samples taken as produced. The coal slurry to be used as raw material for coal briquettes has been weathered and desulfurized in the ponds the detail of which will be explained later.

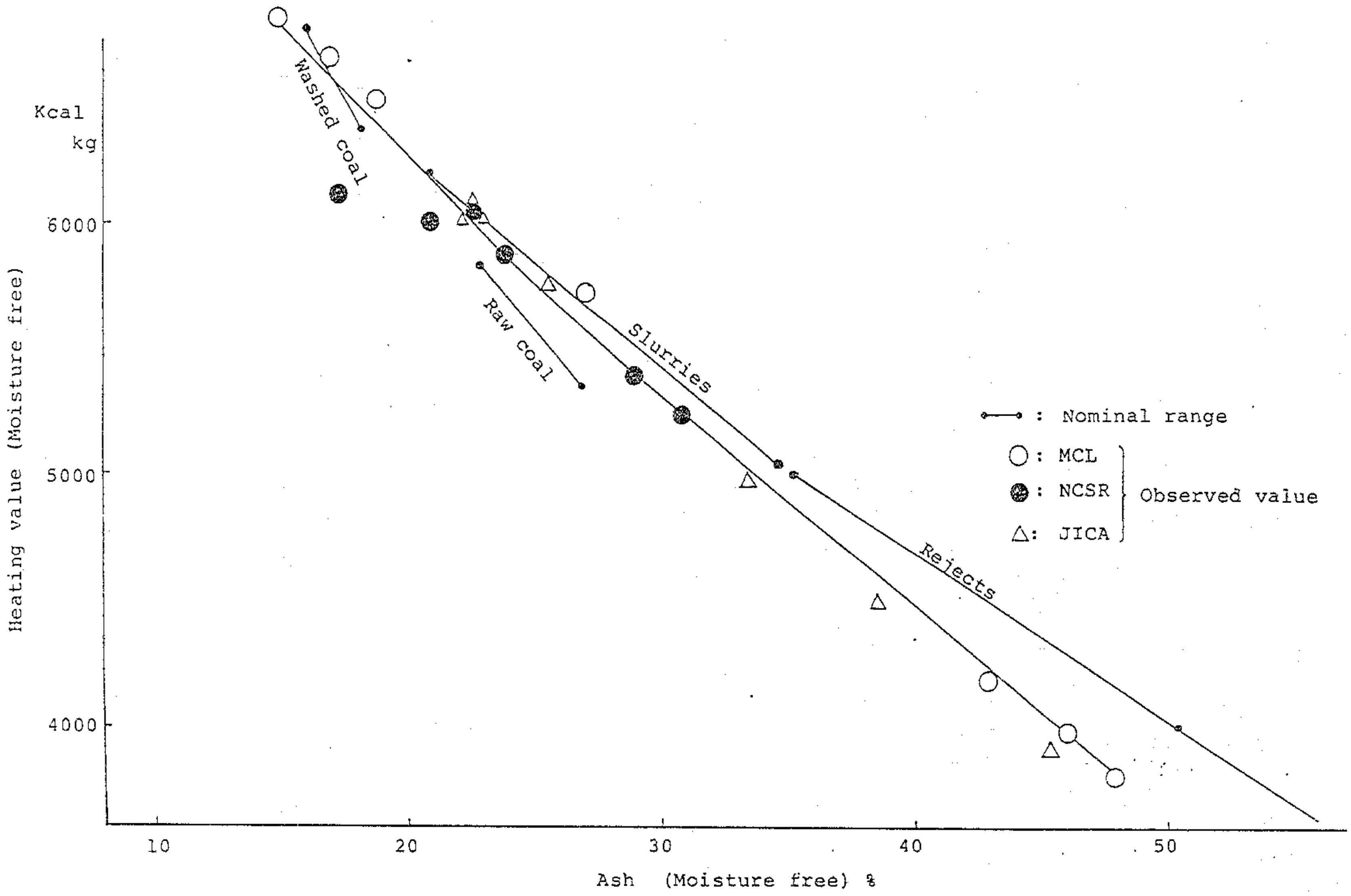


Figure 5-2-1 Relation between Heating value and Ash content

Tabel 5-2-3 Ultimate Analysis of Washed Coal

	C	H	O	N	S(Comb)	Ash	Moisture
Coal	63.2	4.1	5.9	1.8	1.4	13.6	10.0
D.M.F.	84.8	5.5	7.3	2.4			

(NCZ)

Table 5-2-4 compares results of proximate analyses of various samples by different institutes. Heating values both on M.A.F. and M.M.F. are shown as indication of the evaluation of calorific value of coal. M.A.F. and M.M.F. stand for Moisture and Ash Free Base and Moisture and Mineral Free Base, respectively. It may be understood from the table that M.M.F. should be used for the evaluation of the Maamba coal and char. The total calorific value of the coal material appears to be somewhat low compared with that estimated from the rank of coalification evaluated from the ultimate analysis values and moisture content. However, char retains much of the calorie of the original coal after carbonization since calorie that is lost as a result of the removal of tar, methane or other hydrocarbons is not large. In this regard, this coal is suited for the production of char by carbonization, because the content of volatile matter is low and; therefore, the yield of char is high.

Comparing fresh coal and weathered coal slurry in Table 5-2-4, the loss of M.M.F. base heating value by coal slurry is rather low at 100 to 150 kcal/kg. This is one of the advantages this coal slurry has when utilization of the slurry is planned.

The new slurry pond is swampy; any attempt to use the slurry in this pond by this project is not realistic. In the future the slurry in the new pond should be considered as raw material. As far as this pilot plant project is concerned, the older pond has enough coal slurry to feed the pilot plant for the entire period of the project life.

Table 5-2-4 Proximate Analysis of Coal and Slurries

	Inherent Moisture %	Ash %	Volatile Matter %	Fixed Carbon %	Total Sulfur %	Heating Value KCAL/kg	Heating Value M.A.F.	Heating Value M.M.F.	
1 Seam A	1.12	18.56	17.97	62,35	1.14	6,408	7,978	8,164	Washed
2 Seam B	1.09	14.85	18.65	65.41	1.24	6,750	8,030	8,181	Coal
3 Combined	1.10	16.70	18.31	63.89	1.19	6,579	8,004	8,173	(MCL)
4 Rejected+40mm	0.75	45.76	15.43	38.06	2.99	3,942	7,369	8,058	Rejected
5 " -40+10mm	0.69	47.52	15.41	36.38	5.93	3,774	7,287	8,170	Coal
6 " -10+0.5mm	0.75	42.64	16.23	40.38	9.13	4,134	7,302	8,198	(MCL)
7 Slurries	1.11	26.79	17.29	54.81	3.55	5,660	7,850	8,217	-0.5mm
8 "		20.89			0.77	5,983	7,659	7,851	NCSR
9 "		28.58			1.44	5,331	7,570	7,874	
10 "		22.21			1.27	5,969	7,773	7,972	
11 "		23.67			1.19	5,831	7,740	7,979	
12 "		30.56			1.44	5,168	7,551	7,882	
13 "		17.24			0.78	6,034	7,389	7,529	
14 G-mix	2.30	22.30	18.96	56.44	1.40	5,922	7,854	8,112	
15 F-0.1mm under	2.30	23.06	19.44	55.20	1.37	5.881	7.879	8.152	JICA
16 Slurries	2.10	21.95	19,39	56.56		5,968	7,858	(8,045)	
17 0.1mm under	1.80	44.61	19.24	34,35	5.12	3,827	6,901	7,896	
18 0.1mm under	2.27	37.59	18.68	41.46	3.20	4,388	7,296	7,813	
19 A-2m	2.31	22.64	17.78	57.27	1.07	5,891	7,849	8,080	
20 A-mix.	2.28	22.39	18.95	56.38	1.29	5,895	7,326	8,059	
21 B-mix.	2.51	22.14	19.93	54.42	1.00	5,863	7,781	8,000	
22 C-mix.	1.75	33.06	19.90	45.29	2.43	4,899	7,515	7,926	
23 D-mix.	2.24	25.10	19.44	53.22	1.44	5,657	7,786	8,056	
Average								8,017	

M.A.F.: Moisture and Ash free base
M.M.F.: Moisture Mineral free base (Mineral Matter estimated = 1.08A + 0.55 Scomb.)

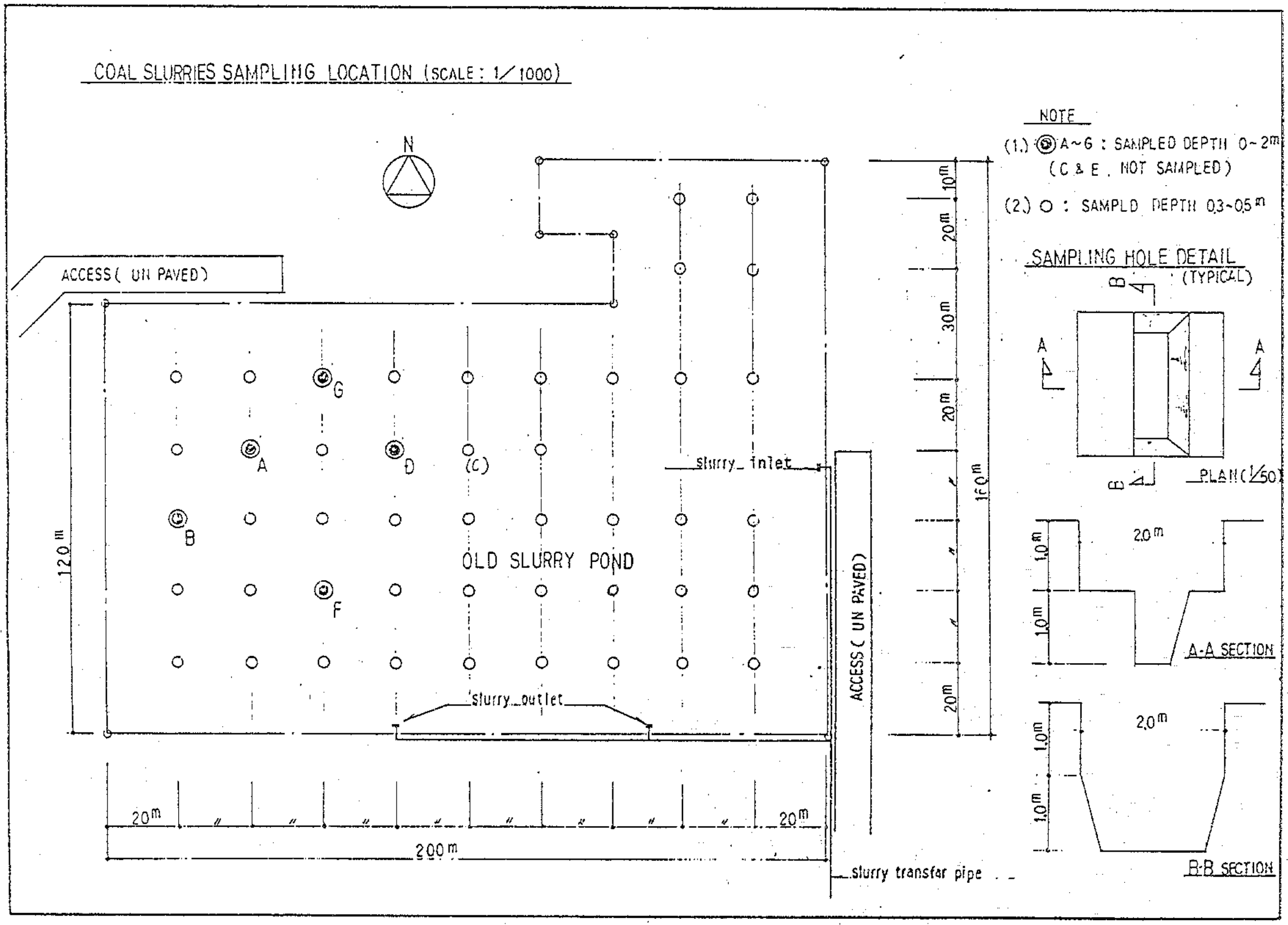
5.2.1 Waste coal slurry ponds

Since the new pond is currently in use and swampy, not suited for collection of raw material slurry, the study is concentrated on the older pond. Only a few samples were taken from the new pond.

5.2.2 Waste slurry deposit volume

Figure 5-2-2 is a rough sketch of the older slurry pond. The pond is 200 meters in east-west direction, and 120 meters in north-south direction, with a depth of about 4 to 5 meters. The effective dimensions taken to be 180m x 90m x 4m, the amount of the slurry is calculated to be 65,000m^3, or 58,000 tons. The older pond is well drained. The surface is dry but the slurry are too soft to sustain a heavy equipment for digging. The slurry were therefore manually dug and samples were collected using hand shovels. Six points (A, B, C, D, F and G) were selected for this operation, and the layer conditions were observed to a depth of 2 meters as indicated on Figure 5-2-2. At Point C clay was found mixed with the slurry which meant that pretreatment is necessary and was judged as undesirable as the feed. Therefore, samples for analytical purposes only were taken. At Point B near the overflow outlet, the slurry consists of black, clayish and plastic fine particles.

The conditions at Points A, D, F and G were observed and found similar, being of the quality suitable as raw material for the production of coal briquettes to the depth of at least 2m at which depth digging was discontinued for the reason of safety; however, the deeper layers may be considered to be in the similar condition. The amount of coal slurry confirmed to be suitable as raw material is calculated to be 12,000 tons. Samples amounting to 0.5 tons on dry base were taken at these points.



COAL SLURRIES SAMPLING LOCATION (SCALE : 1/1000)
N
ACCESS (UN PAVED)
NOTE
(1.) ◎ A~G : SAMPLED DEPTH 0~2m
(C & E . NOT SAMPLED)
(2.) ○ : SAMPLD DEPTH 0.3~0.5m
SAMPLING HOLE DETAIL
(TYPICAL)
PLAN (1/50)
A-A SECTION
B-B SECTION
2.0m
1.0m
G
A
D
(C)
B
F
OLD SLURRY POND
slurry_inlet
slurry_outlet
ACCESS (UN PAVED)
slurry transfer pipe
120m
200m
160m
20m
30m
10m

5.2.3 Properties of coal slurry

Tables 5-2-5 and 5-2-6 show particle size distribution and moisture content, and proximate analysis of the coal slurry samples, respectively. The samples taken at Points A, D, F and G show similar results for size distribution and proximate analysis. The samples A-mix and D-mix contain particles larger than 100 mesh or 0.15 mm of 74% and 76.4%, respectively, and the ash content of the proximate analysis of 22.39% and 25.10%, respectively. In contrast, the sample C-mix taken closer to the inlet contains particles larger than 100 mesh of 81.4% and ash of 33.06%, respectively; the sample C-mix contains a greater proportion of coarser particles and more ash, or particles of greater sedimentation velocity; the total sulfur is higher at 2.43%.

Sample B-mix taken downstream of points A, D, F and G contains 50% of 100 mesh, meaning that the sample B-mix consists of finer particles. However, its total sulfur content is 1.00% and ash content is 22.14%, similar to the values of sample A-mix. Figure 5-2-3 is a graphical presentation of the relation between these tests and sampling locations. The ash content should desirably be less than about 25% for making smokeless briquettes by means of carbonization; the samples taken downstream of Point D satisfies this requirement. Likewise, the sulfur content should be low from the viewpoint of odor during combustion of coal briquettes. Coal slurry containing 0.6 to 0.9% of combustible sulfur can be stably obtained in the ash content range of less than 25%; the ratio of combustible sulfur to total sulfur is based on the NCSR data. The sulfur remaining in the briquettes can be virtually removed by absorption by slaked lime mixed in the briquettes.

The sulfur contained in coal consists of organic sulfur bound to coal structure and inorganic sulfur, existing in the forms of sulfides and sulfates. Sulfur can also be classified into combustible sulfur and incombustible sulfur. The coal slurry is a waste from the coal washing process and is naturally concentrated with ash and sulfur and instable with respect to composition. Fortunately, the older pond is found to be functioning as sulfur and ash remover.

Table 5-2-5 Sieve Analysis of Slurries

Mesh	mm	A-Bottom %	A-mix. %	B-mix. %	C-mix. %	D-mix. %	F-mix. %	G-mix. %
10	1.65	0.9	3.2	0.4	4.0	5.5	3.0	7.3
20	0.84	5.2	10.5	2.8	11.0	11.2		
30	0.59	19.8	18.5	6.0	19.9	19.0	22.9	25.8
40	0.42	16.5	11.2	6.0	13.0	11.0		
50	0.30	18.5	9.9	7.1	11.8	10.2		
60	0.25	11.8	8.1	10.7	8.9	7.8	29.8	23.5
100	0.15	13.6	12.6	16.9	12.8	11.7	17.6	11.6
-100		12.7	25.0	46.2	17.9	20.9	26.7	31.8
Loss		1.0	1.0	3.9	0.7	2.7		
Total		100.0	100.0	100.0	100.0	100.0	100.0	100.0
Moisture %		10.8	16.1	21.6	12.1	14.3	13.4	16.0
Bulk density			0.7-0.8					
			0.9(wet)					

Table 5-2-6 Proximate Analysis of Slurries

	A-Bottom	A-mix.	B-mix.	C-mix.	D-mix.	F-mix.	G-mix.
Inherent moisture	2.31%	2.28	2.51	1.75	2.24	2.50	2.30
ash	22.64	22.39	22.14	33.06	25.10	25.10	22.30
Volatile matter	17.78	18.95	19.93	19.93	19.44	19.90	18.96
Fixed carbon	57.27	56.38	54.42	45.25	53.22	52.50	56.44
Heating value	5,891	5,894	5,863	4,899	5,657	5,704	5,922
Total sulfur	1.07	1.29	1.00	2.43	1.44	1.47	1.40

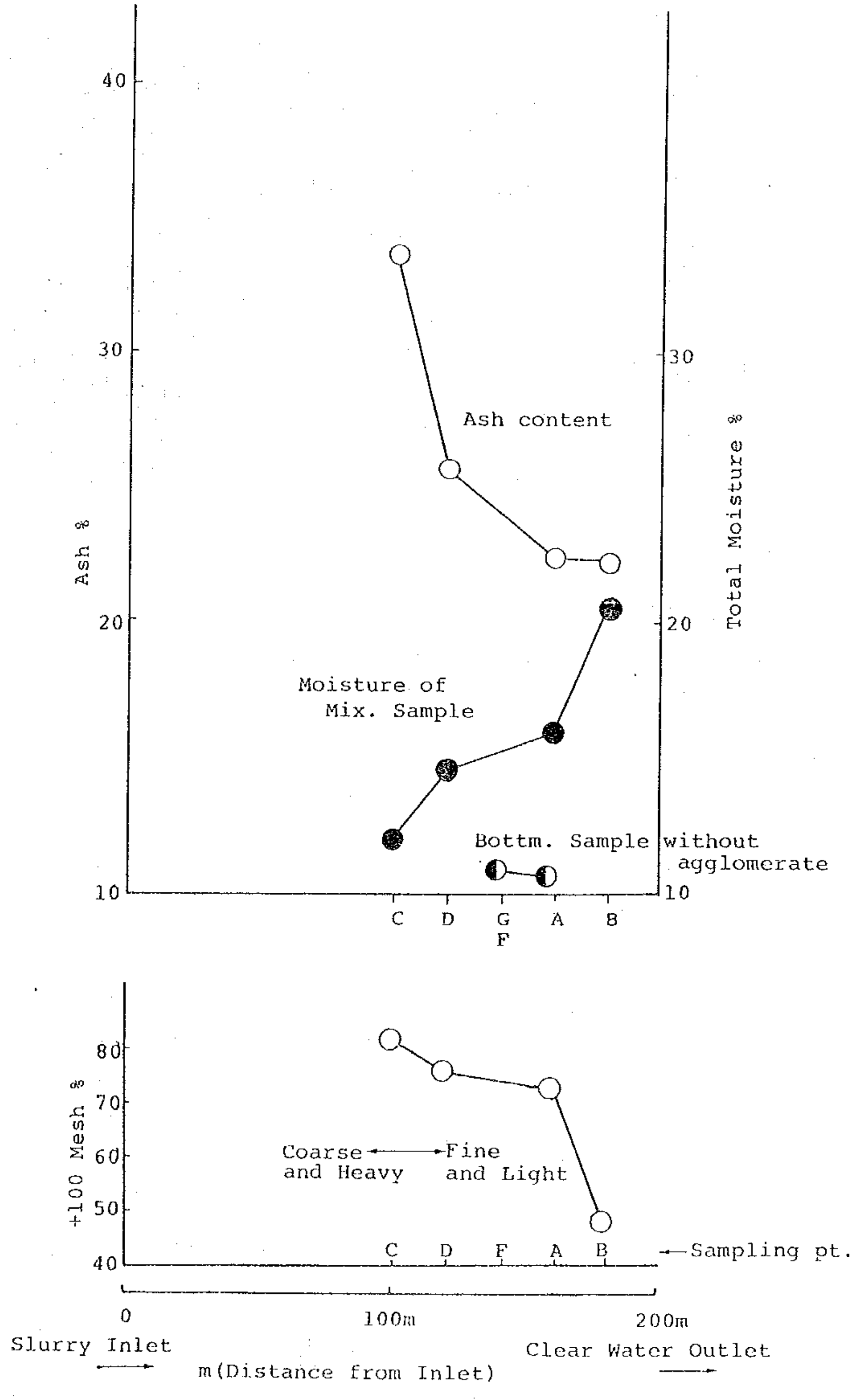


Figure 5-2-3 Sieve Analysis and Moisture by Sampling points

Figure 5-2-4 compares the coal slurry samples taken from the pond, fresh slurry, raw coal and washed coal in their relations between ash content and total sulfur content.

While the total sulfur content of the fresh slurry is 2.5 to 7%, the total sulfur is reduced to one third or 0.7 to 2.5% in the weathered slurry on the same ash content range. On Figure 5-2-4 the slurry samples containing 33.6 and 44.6% ash are 0.1mm or smaller coarse coal which remained after removing lumps. The ash content of the lumps, even consisting of dust coal of the same nature, ranges from 22 to 25%, and its sulfur content is lower than 1.5%.

The sulfur which is removed as a result of weathering exist mainly in the form of pyrite, or iron pyrite, for which the following chemical reaction is considered to occur:

$$FeS_2 + O_2 = FeS + SO_2 \qquad -\Delta H_{18} = 50\ Kcal$$
$$FeS + 2O_2 = FeSO_4 \qquad -\Delta H_{18} = 200\ Kcal$$

$$FeSO_4 + 2H_2O = Fe(OH)_2 + H_2SO_4$$

Note: 1. There are some reports maintaining the first reaction occurs only above 500°C.

$FeSO_4$ is soluble in water and acidic. Therefore, at the initial stage of weathering, water flowing out of the slurry pond is acidic. With lapse of time, however, water containing $FeSO_4$ has been almost discharged. At the sampled points of the older pond where ash content as well as residual iron sulfide(FeS) is low, the hydrogen ion concentration is neutral.

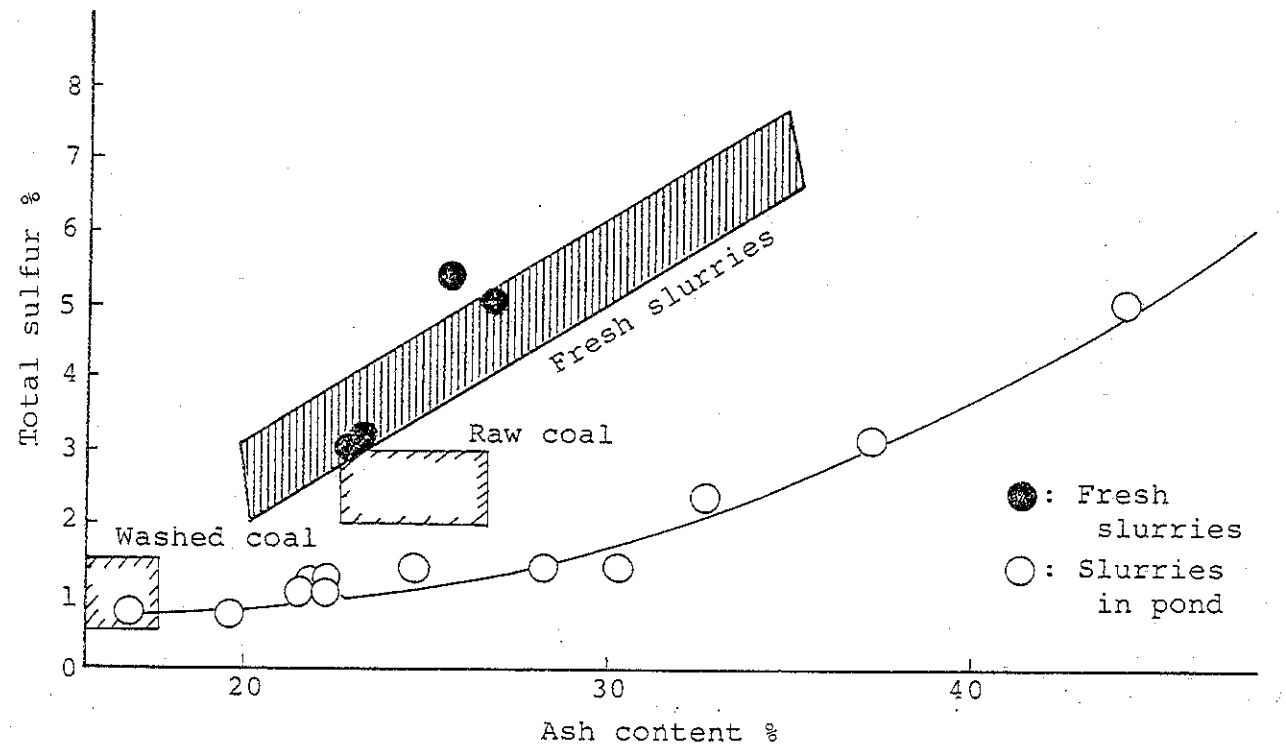


Figure 5-2-4 Relation between Ash content and Total sulfur

5.2.4 Selection and collection of coal slurry

As a result of the study on the formation of the slurry deposit and its quality, it has been found that only by proper selection of slurry collection location, more specifically downstream of Point D, the slurry of the quality that would meet requirements for sulfur, ash, particle size distribution and water content could be collected.

5.2.5 Safety considerations for handling of slurry

The safety measures to prevent hazards or damages as enumerated below should be considered when excavating the slurry pond:

1) Collapse of the pit that could happen when the pit is dried up or during rainfall

2) Oxygen deficiency in the excavated pit

3) Collapse of the equipment

4) Corrosion of the equipment

5) Fire accident due to dried dust coal

6) Pneumoconiosis, or black lung, due to inhalation of dust coal

When the samples were collected during the field survey, the slurry quite fortunately contained an proper moisture to permit digging of nearly vertical pits. However, such a good condition cannot always be expected. This is further confirmed by the experiments on the samples which tend to be fluidized when too much water is contained, but to flow like sand when surface water is lost. In particular, utmost care must be taken to ensure the safe placement of equipment during excavation. The conditions of the slurry bed could change each time it rains and with time after the rainfall. Use of heavy equipment should be avoided.

5.2.6 Price of coal slurry

As per discussions with NCSR and the Maamba Collieries, it is understood that the price of the coal slurry as feed is zero for this project.

5.3 Bagasse

5.3.1 Production of bagasse

The Nakambala Sugar Estate is located between Kafue River and a railroad passing Mazabuka Station about 130 km south of Lusaka on the way to the Maamba Collieries. The estate has its own siding rail. The estate has a plating area of 9,900 hectares. Nearby are also other cane farms totaling 2,100 hectares.

The Estate produces 150 thousand tons of crude sugar per year, processes 1,300 thousand tons of sugar canes, and produces 400 thousand tons of bagasse. The bagasse contains 50% of moisture at the outlet of the sugar mill. Of this amount of bagasse, 350 thousand tons are burned in the boiler to produce steam required for the operation of the mill, leaving about 50 thousand of excess bagasse. The excess bagasse is piled in the open. The residual sugar contained in the bagasse is leached by rain water; and when the bagasse has been piled for a long time it becomes humus by the effect of biochemical decomposition. The piled excess bagasse, therefore, is not uniform in quality.

On dry basis, 25 thousand tons of excess bagasse is available. The wet packing density is 160 to 190 kg/m^3 containing 50% moisture; the bulk density is 40kg/m^3. Table 5-3-1 shows the result of a sieve analysis of the bagasse. Table 5-3-2 shows a proximate analysis of the bagasse and that of a sawdust as reference.

Table 5-3-1 Sieve Analysis of Bagasse

mm	%
Longer fibrous materials	38.8
1.8	31.9
0.59	22.9
0.25	4.9
0.1	1.5
0.1	0.0
Total	100.0

Max. long piece (Unit mm)	Length:	120
	Width:	10 to 15
	Thickness:	6

Table 5-3-2 Proximate Analysis of Bagasse and Sawdust

	Bagasse	Sawdust
Inherent moisture	5.7%	-
Ash	2.4	0.4%
Volatile matter	80.5	83.6
Fixed carbon	11.4	16.0
Heating value	3770.0	4700.0
Total sulfur	0.06	0.0

Sugar cane is grown during the rainy season which lasts from November to March and harvested during the dry season lasting from April to October. The production of bagasse is also limited to the dry season.

5.3.2 Bagasse as raw material

This project plans to transport the bagasse to the pilot plant in Lusaka, carbonize it and blend it into coal briquettes to improve the burning quality, or ignitability and combustibility of the coal briquettes. The bagasse therefore is desirably dry. However even during the rainy season if care is exercised to select not drenched portion of the bagasse from the pile, it can be used as a feed. Presently, 50,000 tons are excess. There is at present no definite plan to utilize this excess except for this project; this excess can be counted on as feed.

5.3.3 Properties of bagasse

Table 5-3-1 shows the result of a screen analysis of the bagasse. Being composed of long fibrous materials of the cane, the bagasse is difficult to grind or crush. Table 5-3-2 gives the result of proximate analyses of bagasse, and sawdust for comparison. Table 5-3-3 shows the results of an ultimate analysis in comparison with those of sawdust, cellulose and wood. The bagasse contains more ash and less fixed carbon compared with sawdust. The bagasse has a bulk density of 0.04 to 0.11 Kg/l, and is difficult to compact because of it being of fibrous nature.

Table 5-3-3 Ultimate Analysis of Bagasse and Other Vegetable Materials

		Bagasse	Sawdust	Cellulose	Wood
Carbon	%	47.3	51.0	44.4	49.7
Hydrogen	%	5.4	6.1	6.2	6.1
Oxygen	%	41.7	42.1	49.4	44.1
Nitrogen	%	0.4	0.1	-	0.1
Sulfur	% combustible	0.00	0.0	-	-
Ash	%	5.2	0.4	-	-
			100.0		

5.3.4 Possibility of using uncarbonized bagasse

The raw, or uncarbonized bagasse, burns with smokes; therefore, the raw bagasse cannot be blended in coal briquettes. In addition, the raw bagasse has tough fibrous tissues too difficult and inefficient to chip or crush. Further, the raw bagasse contains long rigid fibers of 50 to 100 mm long which make the raw bagasse difficult to be mixed with the slurry to be shaped into briquettes. When carbonized, the raw bagasse emits disagreeable odor similar to that emitted by the carbonization of lignite. In view of the above, it is not practical to attempt to use the raw bagasse. After all, this feasibility study has established that it is much more desirable to carbonize the coal slurry and bagasse before briquetting than briquette them first and carbonize later; accordingly, there is no point to plan to blend the raw bagasse.

5.3.5 Price

This project intends to use the excess bagasse after the Nakambala Sugar Estate has used it as home fuel. Besides, there is no plan to manufacture paper, pulp, animal feed from bagasse on a large scale. Accordingly, the price may be set as zero.

5.4 Molasses

Molasses are obtained as a byproduct in the production process of crude sugar. Of 45,000 to 50,000 tons of molasses produced yearly, 40,000 to 50,000 tons are exported. These molasses are supplied to neighboring markets as animal feed with or without mixed urea, or otherwise as fermentation raw material for alcohol or yeast production. The Sugar Estate has one 4,500 ton tank and two 6,000 ton tanks.

Molasses can be shipped in tank wagon, tank lorry or 45-gallon drum.

Molasses is a brown liquid containing 2.5 to 3% sugar and it ferments generating bubbles if left to stand long enough. The price is 40k per ton.

5.5 Slaked Lime

Limestone of good quality occurs in Lusaka area. Crush Stone Sales, Ltd. operating in Lusaka produces and sells high-purity snow-white slaked lime. Their capacity is 30 tons per day. The price of slaked lime is 440k per ton.

5.6 Carbonaceous Fly Ash from Gasifier

Nitorogen Chemicals of Zambia in Kafue gasifies the Maamba coal by the Koppers-Tötzek gasifier to produce fertilizers and explosives such as ammonium nitrate. Their carbonaceous fly ash produced from this gasifying plant was investigated during the field survey and was found unsuitable as raw material for coal briquettes. The carbonaceous fly ash contains only 25% carbon which is sooty dust carbon produced as a residue of gasification of coal fines. The material is in the form of a suspension in water at the plant and in a mixture with pyrite cinder in the sedimentation basin.

6. TRANSPORTATION

6.1 Infrastructure for Transportation of Coal Briquettes and Clay Stoves

6.1.1 Railroads

Zambia's railroad system is run by two organizations, the Zambia Railways (ZR) with a length of 1,260 km and the Tanzania -Zambia Railway Authority (TAZARA) covering a distance of 1,860 km. Table 6-1-1 is a compilation of data giving an outline of the present conditions of ZR.

The cars owned by ZR are as broken down in Table 6-1-2. The organization, however, is faced with many problems at present; ageing locomotives and freight cars, shortage of spare parts for maintenance and repairs, and lack of diesel fuel, among others. In order to deal with these problems, a program is being initiated under the name of "Plan for Revitalization of Zambia Railways Considering the Present Economic Climate, 1984-1994."

The network of railroads is as given in Figure 6-1-1. Coal is mined at Maamba and moved to Masuku by a ropeway system (see 6.1.3) before being loaded to freight cars to be transported to the Copper Belt. The distance between Lusaka and Masuku is 321 km.

Table 6-1-1 Rolling Stocks, Passenger Traffic and Goods Traffic Carried by Zambia Railways (1974-82)

Year	Rolling stock			Passenger		Goods traffic	
	Locomotive	Passenger coach	Goods wagon	Passengers carried (thousand)	man. km (million)	Tons carried (thousand)	Ton. km (million)
1974	117	91	1,934	1,213	316	6,658	1,106
1975	94	89	1,944	1,136	270	6,402	1,397
1976	93	89	1,632	1,053	251	5,259	1,294
1977	92	91	2,229	1,243	296	4,783	1,110
1978	91	91	2,809	1,560	371	4,798	1,220
1979	93	92	2,402	1,570	372	4,800	1,245
1980	86	86	6,796	1,683	374	4,380	1,209
1981	84	88	6,768	1,853	371	4,324	1,409
1982	84	88	6,768	1,807	434	4,934	1,403

Source: Central Statistical Office

Table 6-1-2 Cars Owned by ZR

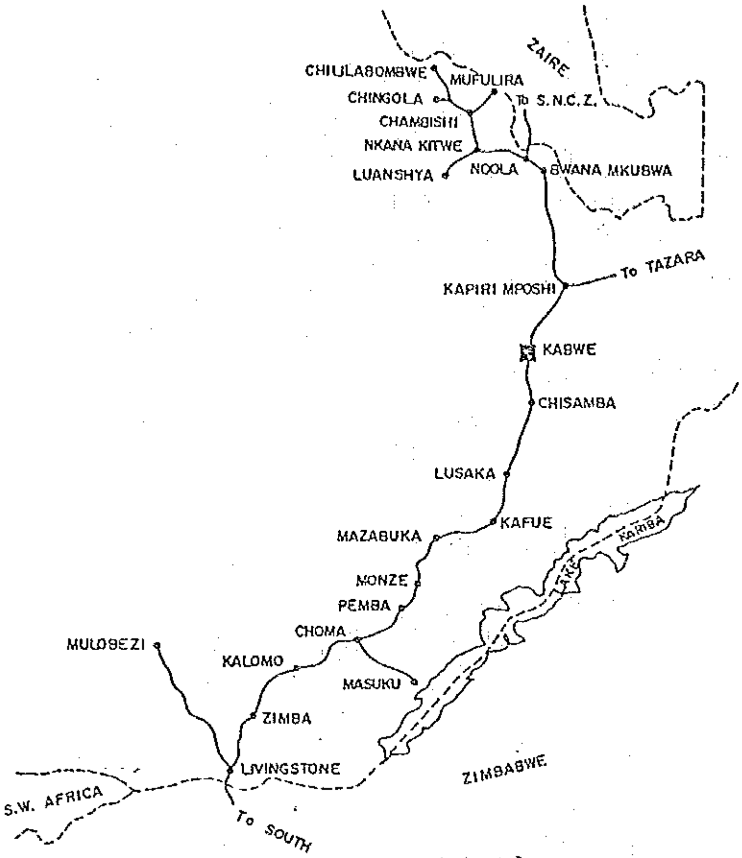
Cars in possession	Number of cars		Remarks
Locomotive	For trunk line:	68	Diesel electirc
	For standby :	16	locomotive
Freight wagon		6,768	About 1,300 are out of service
Passenger coach	Regular	88	
	Rail car	17	

According to "Railway Tariff Book (ZR, 1982)," freight is carried for K24.7 per ton up to 100 km. Long-distance rates apply over 100 km, K49.4 for 300 km and K68.1 for 500 km, for example.

6.1.2 Roads

The nation's road network covers a distance of about 37,000 km; paved roads, however, account for only 15% of the total. Figure 6-1-2 illustrates the road network and Table 6-1-3 shows its divisions and type, i.e., classification as to paved and not paved. Although principal trunk roads are paved, most roads with the exception of those in Lusaka and other big cities have only two lanes. Roads are designated by the letters T, M, and D and numbers that follow the letters. The roads that pertain to the present report are as given below; all of them are paved and maintained in good condition.

Lusaka-Kafue T2
Kafue-Batoka .... Tl
Batoka-Maamba D775



Source) Africa Research Bulletin (London) 1980.

Figure 6-1-1 Railroad Network

Table 6-1-3 Road Classification and Pavement

Type of roads	Type of surface	Roads Dept.	By Cities municipalities	By Rural Local Authority	By Other non-Govt.	Total
Inter Territorial Main	Class I, Bitumen	2,831	63	-	-	2,894
	Class II, Gravel	-				-
	Class III, Gravel	64				64
	Unclassified	172				172
	Subtotal	3,067	63	-	-	3,130
Territorial Main	Class I, Bitumen	1,974	17			1,991
	Class II, Gravel	1,228				1,228
	Class IIi, Gravel	612				612
	Unclassified	216				216
	Subtotal	4,030	17			4,047
District	Class I, Bitumen	698				698
	Class II, Gravel	1,193				1,193
	Class III, Gravel	5,612				5,612
	Unclassified	6,072		10,186		16,258
	Subtotal	13,575		10,186		23,761
Rural	Unclassified			5,714		5,714
Branches	Unclassified			8	432	440
Others	Unclassified				164	164
Total			80	15,908	596	37,256

Source: Ministry of Works and Supply

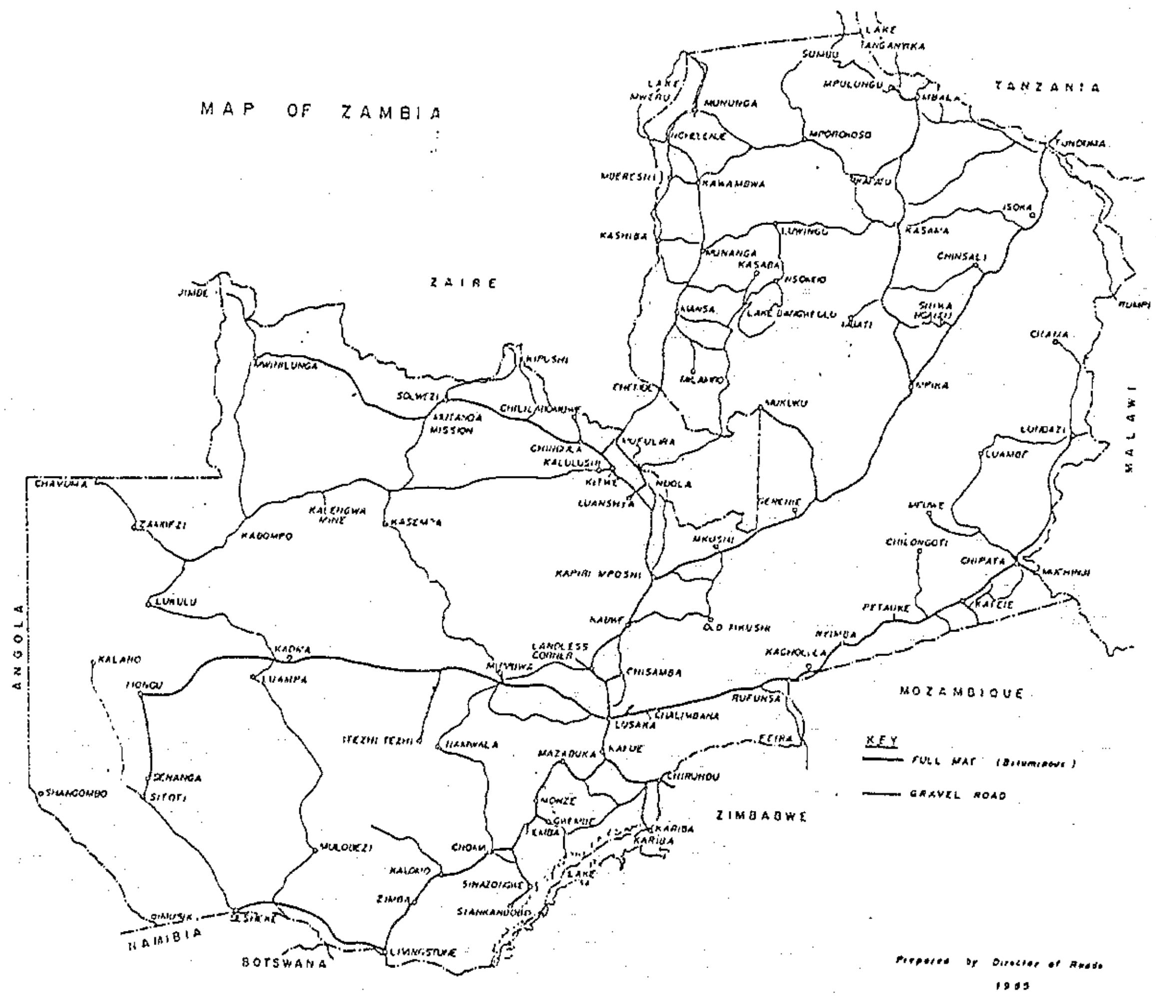


Figure 6-1-2 Road Network

The maintenance of road concern the following four works: (1) weed control (2) maintenance of signs and markings, (3) maintenance of pavement, and (4) drainage. For the purpose of maintenance of the road, the nation is divided into 127 zones. The maintenance is conducted on a zone basis and those that relate to the present report are also divided into six blocks as shown in Figure 6-1-3.

The method of repairing principal paved roads differs between the rainy season and the dry season. During the rainy season, a mixture of cement and soil is put into holes, while during the rainy season an asphalt mixture is spread in 3 cm to 5 cm layers.

Table 6-1-4 shows automobile ownership and volume of traffic. About 110,000 automobiles are used nationwide, of which 60% are passenger cars or the like. As to the volume of traffic, an average of 650 vehicles per day, of which 25% were large vehicles, used TI in fiscal 1984.

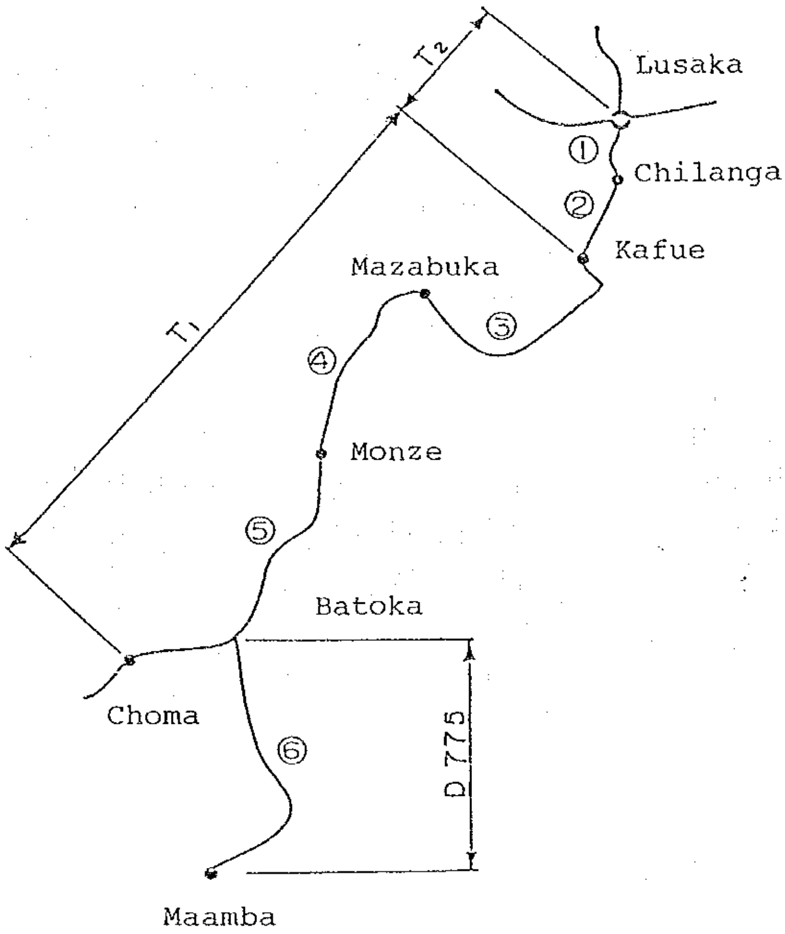


Figure 6-1-3 Road Maintenance Block

Table 6-1-4 Number of Registered Private Vehicles: 1970-82
(As of 31 December of Each Year)

Year	Total	Cars, station wagons	Vans, vanettes	Trucks	Buses	Construction vehicles	Tractors	Motor-cycles	Trailers
1970	99,508	58,508	16,253	10,740	668	220	2,759	6,331	4,330
1971	107,612	61,579	18,118	18,118	690	258	3,393	6,939	4,969
1972	117,828	65,794	20,705	12,725	769	382	3,910	8,233	5,310
1973	128,763	72,140	23,502	13,375	780	472	4,469	8,446	5,519
1974	142,224	81,899	25,071	14,415	814	568	4,669	8,969	5,819
1975	150,843	85,994	27,077	15,712	855	659	5,010	9,417	6,110
1976	144,374	83,203	25,097	14,645	1,002	634	5,032	9,057	5,604
1977	134,826	79,761	22,831	12,966	837	483	4,994	7,760	5,194
1978	125,264	76,440	19,344	12,035	690	401	4,755	7,059	4,540
1979	117,278	71,615	17,454	12,157	734	320	4,641	5,984	4,373
1980	113,849	68,709	17,590	12,377	916	227	4,632	5,229	4,169
1981	111,516	67,506	17,169	12,745	1,030	189	4,283	4,734	3,860
1982	112,972	68,032	18,545	12,681	1,064	175	4,260	4,819	3,396

Source: Ministry of Works and Supply

6.1.3 Ropeway system

This ropeway system is used to carry coal from Maamba Collieries Ltd. to Masuku Station of ZR.

```
MCL--Belt------1HP--Ropeway--1HP--Belt------2HP--Z.R.
     Conveyor   |            |    Conveyor
                |            |
                |<---11.7km-->|
```

Note: HP stands for hopper

(Outline of System)

1.	Travel time	: 58 min (11.7 km)
2.	Container capacity	: 1.5 t
3.	Containers in operation	: 200 containers
	Containers in operation (max.)	: 284 containers
4.	Max. transport capacity	: 272 t/h
5.	Others	: 18 km unpaved maintenance road is provided.

Figure 6-1-4 Ropeway System Outline

6.2 Transportation System for Coal Briquettes and Stove Raw Materials

6.2.1 Definition of transportation system

The word "transportation" means moving of goods from one place to another by means of various vehicles or railroads without changing the nature or shape of the goods. Broadly interpreted, the word transportation refers to a series of operations; loading and unloading, transhipment, movement, collection, and distribution. The present report uses the word in such a broad meaning.

6.2.2 Coal briquettes

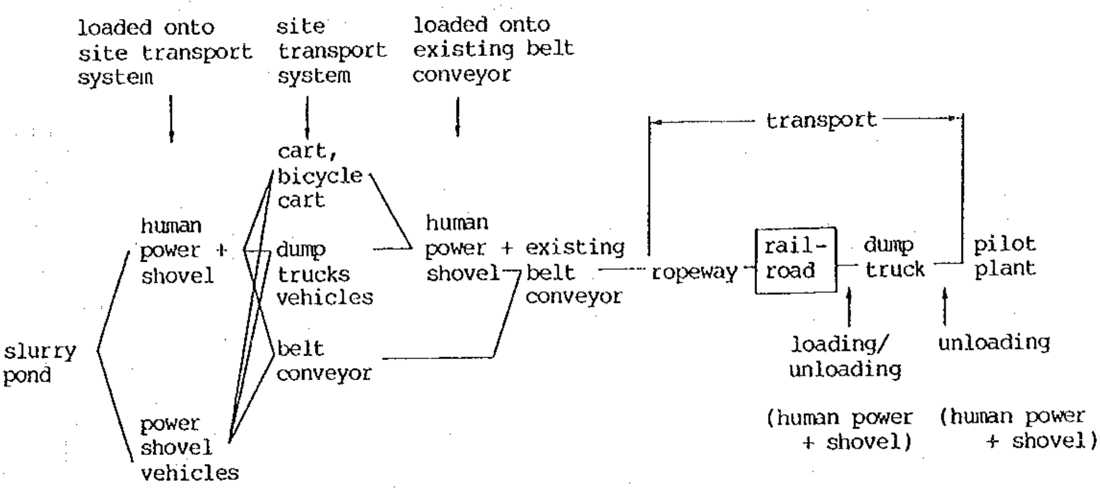
The following four materials have been selected as raw material for coal briquettes.

(1) Coal slurry
(2) Molasses
(3) Bagasse
(4) Slaked lime

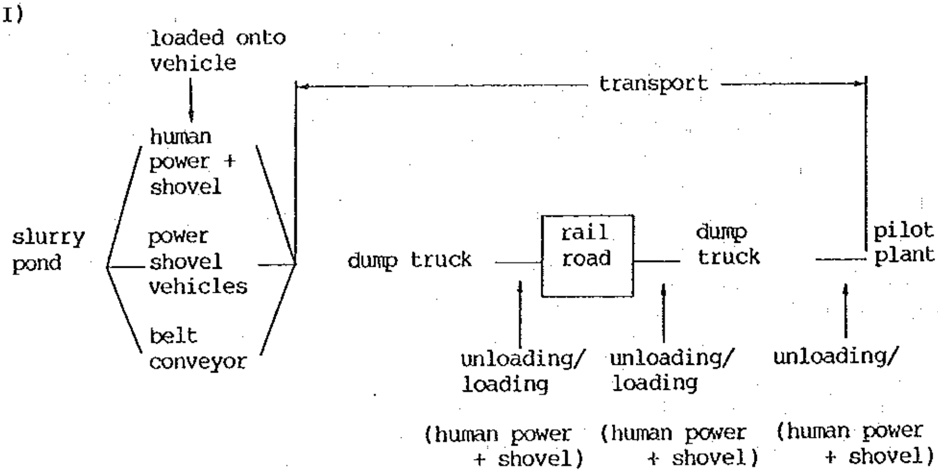
(1) Coal slurry

Coal slurries are left as waste in the slurry ponds in the Maamba Coal Site. For transportation of this material from the site to the pilot plant, the following alternative systems are conceivable.

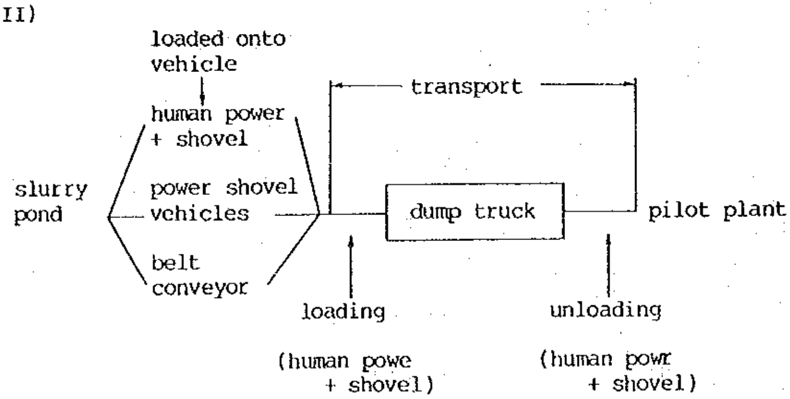
(I)


loaded onto site transport system
site transport system
loaded onto existing belt conveyor
transport
cart, bicycle cart
human power + shovel
dump trucks vehicles
human power + shovel
existing belt conveyor
ropeway
rail-road
dump truck
pilot plant
slurry pond
belt conveyor
loading/ unloading
unloading
power shovel vehicles
(human power + shovel)
(human power + shovel)

(II)


loaded onto vehicle
transport
human power + shovel
slurry pond
power shovel vehicles
dump truck
rail road
dump truck
pilot plant
belt conveyor
unloading/ loading
unloading/ loading
unloading/
(human power + shovel)
(human power + shovel)
(human power + shovel)

(III)


loaded onto vehicle
transport
human power + shovel
slurry pond
power shovel vehicles
dump truck
pilot plant
belt conveyor
loading
unloading
(human powe + shovel)
(human powr + shovel)

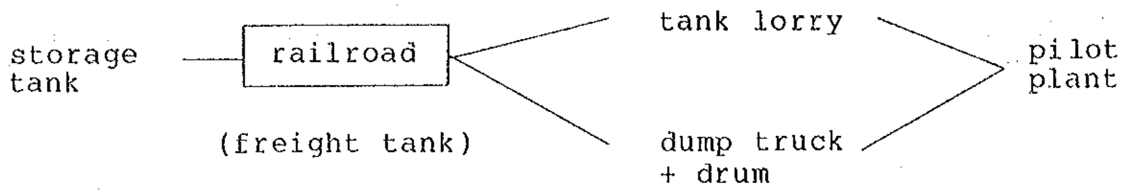
Each of these three systems, 1), 2), and 3), may be summarized as follows:

		Distance (km)
1) MCL to Masuku	Ropeway	12
Masuku to Lusaka	Rail	321
Lusaka to Plant Site	Road	2
2) MCL to Batoka	Road	88
Batoka to Lusaka	Rail	226
Lusaka to Plant Site	Road	2
3) MCL to Plant Site	Road	352

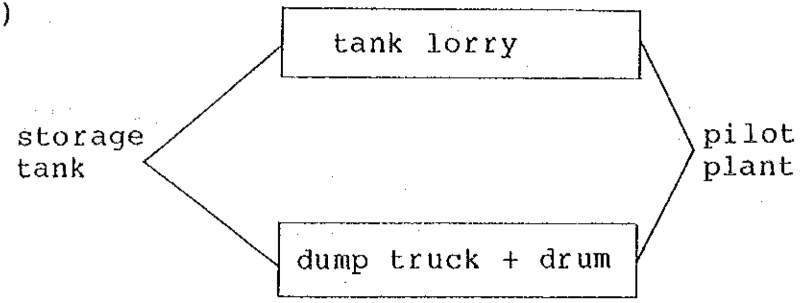
(2) Molasses

Molasses is a liquid and needs to be transported in special containers by road or by railroad. Molasses is loaded onto tank cars at the railroad lead-in line inside the Nakambala Sugar Estate and exported to the neighboring countries. Similarly, molasses may be transported by railroad and may be assumed as such in this feasibility study as an alternative. Accordingly, the transportation system has alternatives shown below.

(I)



(II)



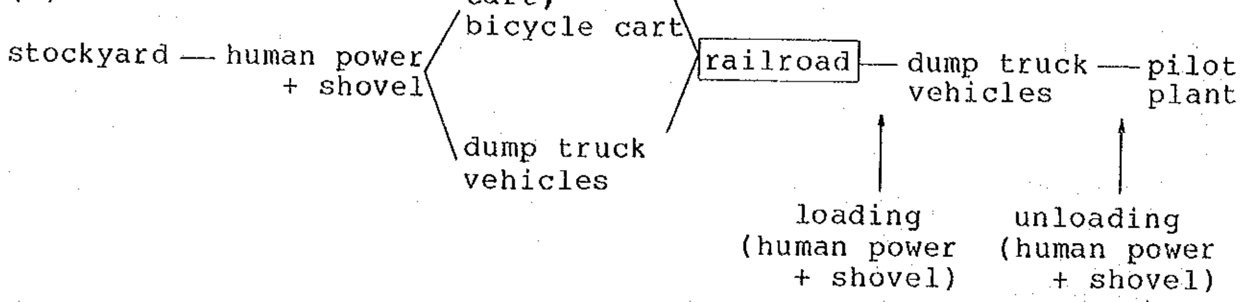
Each of these two systems, 1) and 2), may be summarized as follows:

		Distance (km)
1) Nakambala to Lusaka	Rail	96
Lusaka to Plant Site	Road	2
2) Nakambala to Plant Site	Road	132

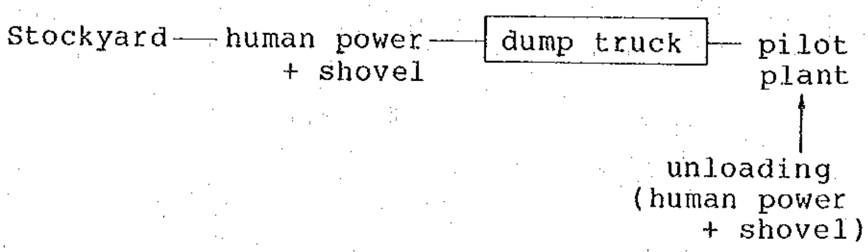
(3) Bagasse

Bagasse is piled up in the outdoor space of the Estate. It is used as fuel for the Estate's plants and as fertilizer in this area. Presently, bagasse is not used for any other purposes and, therefore, not transported for any appreciable distance. However, use of railroads as well as road is possible and the following system may be conceivable.

(I)



(II)



Each of these two systems, 1) and 2), may be summarized as follows:

		Distance (km)
1) Nakambala to Lusaka	Rail	96
Lusaka to Plant Site	Road	2
2) Nakambala to Plant Site	Road	132