ZIMBABWE CHARCOAL UTILIZATION AND MARKETING STUDY

CONSULTANCY REPORT

BY

G. ZIEROTH - IPC
R.S. MAYA - ZIDS

ON ASSIGNMENT FROM
THE WORLD BANK
WASHINGTON DC

No. 8

September 1988

Contents

Abbreviations and Acronyms

BT	Border Timbers (Anglo American)
CIF	Costs, Insurance, Freight
CAI	Current Annual Increment
EEC	European Economic Community
ESMAP	Energy Sector Management Assistance Program
FC	Forestry Commission
HPS	Hwange Power Station
LS	low sulfur
GJ	Giga Joule (1000 Mega Joule)
LP	low Phosphorus
MAI	Mean Annual Increment
MEWRD	Ministry of Energy, Water Resources and Development
MSY	Maximum Sustained Yield
MJ	Mega Joule
m^3	cubic meter (solid m^3)
kWh	kilowatt-hour; 1 kWh = 3.6 MJ
kW	kilowatt (1000 Watt)
kg	kilogram (1000 grams)
sm^3	stacked m^3 of wood
tpy	tons per year
IMR	Institute of Mining Research
WC	Wattle Company Ltd. (Lonrho)
ZPPL	Zimbabwe Pulp & Paper Ltd.
ZIDS	Zimbabwe Institute of Development Studies
ZSR	Zimbabwe Sugar Refineries Ltd.
ZR	Zimbabwe Railways
ZIMBOARD	Zimbabwe Particle Board Company Mutare
ZISCO	Zimbabwe Iron and Steel company

Conversion Factors/heating values

1 solid m^3 of pine wood:	475 kg at 15-20% moisture content (air dry)
1 solid m^3 of wattle:	800 kg at 15-20% moisture content (air dry)
1 stacked m^3 of wood:	0.65 solid m^3
1 kg air dry wood:	15 MJ
1 kg charcoal (5% moisture):	30 MJ
1 kg washed Zimbabwe Coal:	29 MJ
1 kg foundry coke:	28.5 MJ

Acknowledgement:

We are grateful to the various companies in the forestry and forestry products industry for their co-operation with us during the study and particularly for taking time to prepare and provide the data we requested. We are also thankful to Dr Taneka of the University of Zimbabwe for carrying out carbon activations; the Zimbabwe Sugar Refineries for conducting filtering trials with activated carbon, the Zimbabwe College of Forestry for hosting the charcoal production workshop held at Mutare as part of the study; Mr G. Schäfer of IPC and Ms P. Waungana of the University of Zimbabwe for their assistance in conducting wood production and marketing surveys.

1. Introduction

1.1 The Problem

1.1.1 The basic idea which led to the commissioning of the study presented here was to investigate the scope for making productive use of hitherto discarded surplus output from commercial timber plantations in Manicaland province (eastern Zimbabwe). The production and marketing of charcoal from forestry wastes was seen as an option which could perhaps supplement the national fuelwood supply and provide an economically viable substitute for fuels such as diesel oil, coal, coke and kerosene. In this context, it was the task of the study to evaluate:

a) the sustained long term availability of wood residues generated in conjunction with commercial timber production, the uses to which the residues are currently being put and the scope for expanding charcoal production beyond current levels;

b) the economics of charcoal production, taking into account both feed-stock supply costs and the cost effectiveness of current charcoal production operations;

c) the likely markets for charcoal, with emphasis on process heat generation, the curing and drying of agricultural products (tobacco, tea), carbon reduction in mineral processing industries, and cooking and space heating in institutions;

d) the overall technical and economic merits of increasing the production and utilization of charcoal in Zimbabwe.

1.1.2 The need for such an assessment had been emphasized in various earlier studies, e.g. "Rural Afforestation", which was executed by the Whitsun Foundation and the "Zimbabwe Energy Accounting Project" sponsored by the Beijer Institute, and the "Energy Pricing Study" prepared by Coopers & Lybrand. Since one of the principal medium-term objectives of the Department of Energy (DOE) is to compre-hensively investigate opportunities for developing alternative but indigenous energy resources in Zimbabwe, the DOE requested assistance from ESMAP to assess the prospects for developing waste-based charcoal production in eastern Zimbabwe. Accordingly, particular emphasis was to be given to:

a) identifying and preparing pilot demonstration projects which would help to establish the effectiveness and viability of charcoal utilization in selected settings;

b) defining investment requirements for a programme to increase charcoal consumption in the prospective markets;

c) identifying priority areas in which additional studies and/or further development efforts would help to promote the cost-effective utilization of charcoal in the prospective markets.

1.2 Scope of Activities

1.2.1 In order to assess the medium and long term availability of surplus timber within commercial plantations in Manicaland province, a survey of the production capacity of the plantations in question was carried out. The analysis included field trips and an evaluation of the productivity of various timber species under Zimbabwean growing conditions and the management schedules currently being applied by the timber producers. Using first hand information supplied by the timber producers, demand projections for timber (sawlogs, peeler logs, pulpwood, poles) were also prepared. The resulting data were used to calculate a supply and demand balance for the next five years, on the basis of which it was then possible to estimate the accessible surplus timber output - primarily thinnings from pine plantations under sawlog and peeler log regimes - and determine the charcoal production potential. The results of the feedstock assessment are presented in Chapter 2 of this report.

1.2.2 Based on the results of a sample survey which included 40 industrial, agroindustrial and institutional fuel consumers, landed prices for the most important fuels were analysed. In order to appraise the market potential for charcoal, production costs and landed costs for the fuel were calculated using data on charcoal production/distribution operations both in Zimbabwe and in other African countries. After the most promising options for charcoal utilization had been identified by comparing the landed costs of charcoal and of competing fuels, combustion trials were conducted to acquire performance data and to back up the financial analysis with empirical data on the technical feasibility of fuel substitution in specific applications. The market analysis for products based on waste wood was not restricted to charcoal as a fuel; it also included an appraisal of other options including firewood, activated carbon and wood tar. In order to assess the technical feasibility of producing activated carbon from waste based charcoal, a series of activation trials were conducted in cooperation with the Institute of Mining Research (University of Zimbabwe). The results of the market analysis and the trials are presented in Chapters 4 and 5.

1.2.3 Chapter 6 summarizes the findings of the study and identifies additional activities which will be required to lay the groundwork for cost-effective charcoal production and utilization in Zimbabwe. A pilot project is outlined which includes the establishment of a small charcoal production scheme, the monitoring of production and transport costs and further combustion trials in industries which are regarded as promising markets for charcoal. Finally, recommendations on how to expand charcoal production on a commercial basis are developed.

1.2.4 In the framework of the study a field workshop was held at the Zimbabwe College of Forestry in Mutare. The workshop included on-the-job training in the construction of improved charcoal kilns and a discussion of the draft report presented by ZIDS/IPC. The workshop was attended by representatives of the Energy Department, the Forestry Commission, the College of Forestry, The Wattle Company and ZIDS. (For a list of the participants and an overview of the workshop programme, see Annex III). The final report presented here incorporates the results of the discussions conducted during the workshop as well as the remarks and comments made by Energy Department and Forestry Commission representatives.

2. Feedstock Assessment

2.1 Supply of Plantation Wood

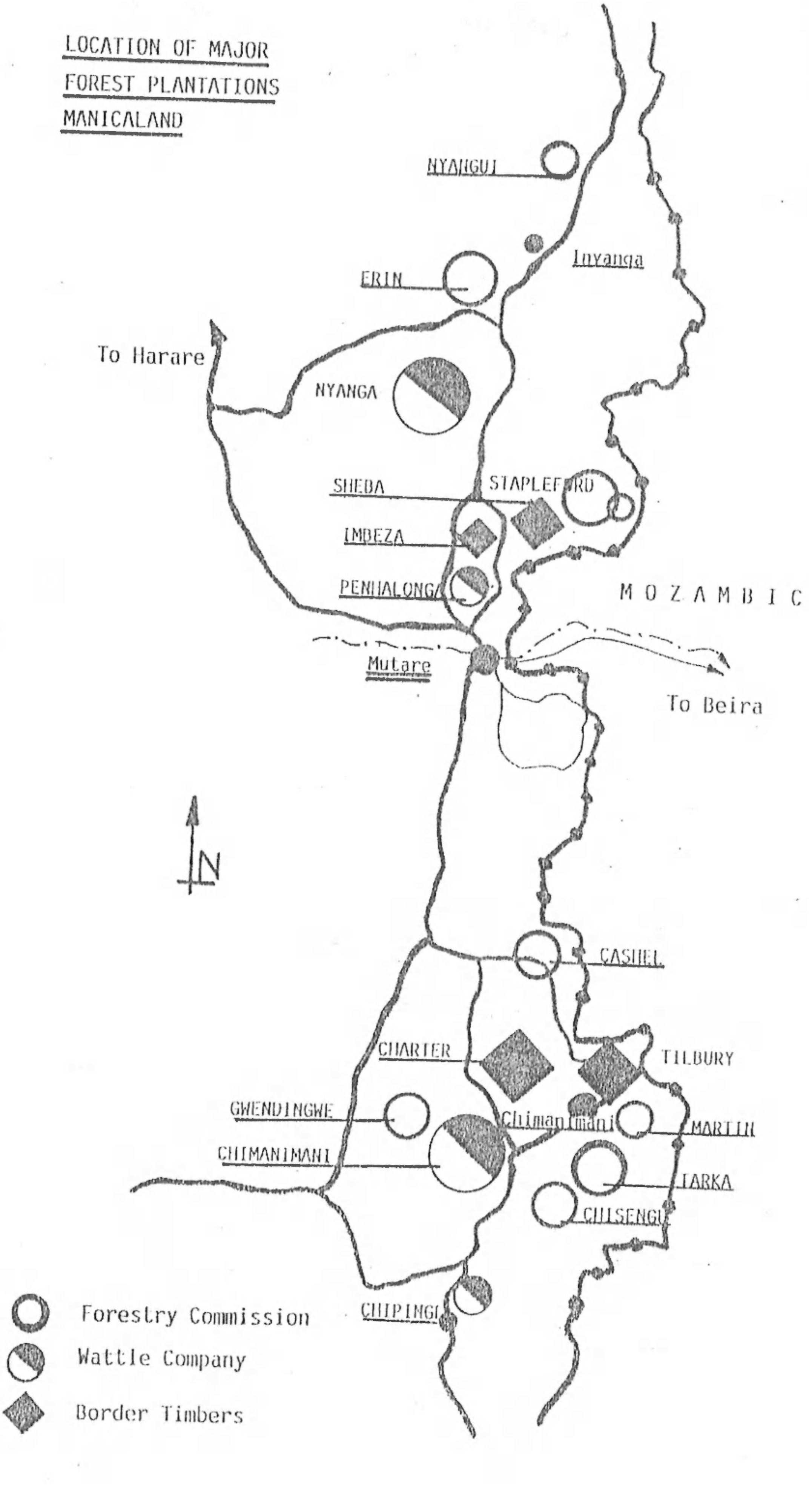
2.1.1 According to the most recent survey carried out by the Forestry Commission of Zimbabwe, the total area of commercial and industrial timber plantations was 100,522 hectares in June 1987. This area represents 0.26% of Zimbabwe's land surface. 90% of all commercial forest plantations are located in the eastern part of the country, i.e. in Manicaland province. The eastern highlands provide good to excellent growing conditions for a number of timber species: rainfall is high (between 800 and 2,000 mm per year), and the hilly terrain offers little scope for the cultivation of crops other than trees. Four major organizations are involved in forestry operations: the Forestry Commission, which is government-owned, and three private companies - namely, Border Timbers (Anglo-American); the Wattle Company (Lonrho); and Mutare Board and Paper. These four organizations own a total of 83,000 ha of planted forest which are devoted to sawlog, pole, tannin, plywood, veneer and pulpwood production (see Appendix I for details).

The following analysis focuses on the plantations of the four major producers. Small commercial operations and forest plantations outside Manicaland province will not be considered here because they are of only negligible importance as potential feedstock sources for charcoal production.

Table 2.1: Forest Plantations in Manicaland Province (ha)

Producer	Conifers	Wattle	Gum	Total
Forestry Commission	30,217	1,104	3,244	34,565
Border Timbers	23,992	0	2,909	26,901
Wattle Company	5,840	13,158	576	19,574
Mutare Board	2,719	47	30	2,796
	62,768	14,309	6,759	83,836

Source: Forestry Commission and timber companies, 1988


LOCATION OF MAJOR
FOREST PLANTATIONS
MANICALAND
NYANGUI
Inyanga
ERIN
To Harare
NYANGA
SHEBA
STAPLEFORD
IMBEZA
PENHALONGA
MOZAMBIC
Mutare
To Beira
N
CASHEL
CHARTER
TILBURY
GWENDINGWE
Chimanimani
MARTIN
CHIMANIMANI
TARKA
CHISENGU
CHIPINGE
Forestry Commission
Wattle Company
Border Timbers

The Production Capacity of the Plantations

2.1.2 The production potential of a planted forest is determined by the species, local conditions such as soil fertility and climate, the rotation period and the thinning schedule. If a forest plantation is fully utilized and properly maintained (i.e. if all necessary tending operations are carried out in accordance with management plans), the entire production potential can be mobilized and the plantation will produce its optimal output. At present, however, the majority of Zimbabwe's forest plantations are not managed in such a way that the optimal output can in fact be achieved. Although all of the organizations involved in plantation forestry have developed management plans for the individual species, the timber market in the past was not capable of absorbing the full production potential of the existing stands. Consequently, the real output of the plantations was significantly lower than their production potential. The pine plantations in particular have not been harvested according to the design rotation periods, nor have silvicultural operations (thinning) been carried out there in line with the planned schedules. The following table provides an overview of the standard schedules for Zimbabwean pine species under sawlog regimes (Table 2.2).

Table 2.2: Standard Schedules for Sawlog Regimes in Zimbabwe

	1st Th			2nd Th			3rd Th			CF		
	Age	UV	WV	Age	UV	WV	Age	UV	WV	Age	UV	WV
FC	5.0	0.0	30.0	9.0	0.0	50.0	16.0	60.0	40.0	30.0	224.0	100.0
BT	8.0	50.0	25.0	13.0	30-45	15-20	18.0	50-70	25-35	25.0	150-235	75.0
WC	8.0	20.0	5.0	12.0	52.0	8.0	16.0	120.0	10.0	25.0	195.0	15.0

UV: Utilizable Volume m^3/ha
WV: Waste Volume m^3/ha

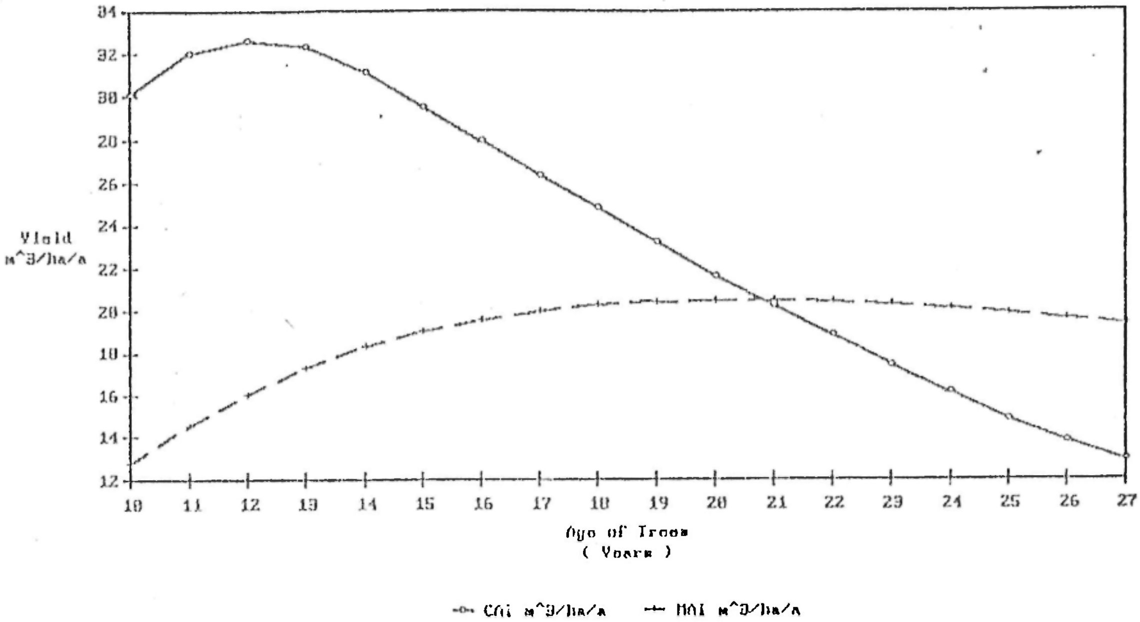
Source: Statements of timber producers

Sawlog plantations account for approximately 70 per cent of all planted stands. Mutare Board and Paper Mills maintains 2,719 hectares of pine on short rotation (14 years). These stands are devoted exclusively to pulp production, i.e. apart from pruning, no silvicultural treatment is required. For pine species under sawlog regimes, the standard schedules maintained by the timber producers result in total mean annual increment (MAI) values ranging between 17 m^3/ha (Wattle Company) and 19.0 m^3/ha (Border Timbers). These figures are consistent with pine yields achieved in other plantations in Southern Africa (e.g. p. patula, Viphya Forest, Malawi: 18 m^3/ha/a; p. patula, Usutu Forest, Swaziland: 19 m^3/ha/a).

With a 10-year rotation period, a MAI of 8.6 m^3/ha is achieved on wattle plantations and MAI values for the most common eucalyptus spp. (e. grandis) range between 20 and 25 m^3/ha in Manicaland province.

2.1.3 The relationship between design production capacity and real output for a forest plantation can be explained by comparing the MAI (Mean Annual Increment) and the CAI (Current Annual Increment) values for a given timber species. Under given site conditions a particular tree species follows a definite growth pattern. Sawlog regimes for the dominant Zimbabwean pine species are normally designed in such a way that the rotation period is roughly equivalent to the rotation which yields the maximum volume output (for p. patuala, p. elliottii and p. taeda: 20-25 years). In view of the sawmilling industry's input specifications (minimum top diameter), the design rotation period could be a few years longer than the Maximum Sustained Yield period. However, the timber producers try wherever possible to harvest the trees before they become overmature. The following figure depicts the relationship between MAI and CAI for p. patula. MSY is achieved once the CAI falls to the level of the MAI. In other words, the point of intersection between the CAI and MAI curves represents the peak level which the MAI will reach. If the CAI falls below that point, the MAI itself begins to decrease gradually since less than the average increment is being added in the plantation each year.

Fig. 2.1: Marginal and Average Yield for Pinus Patula



This situation has already materialized in a number of pine stands on plantations run by the Forestry Commission and Border Timbers. In other words, the production capacity of these plantations is not being fully utilized.

2.1.4 In calculating the total average production potential of forest plantations in Manicaland, the yield figures provided by the timber growers can be used as a first approximation. Due to variations in site conditions, the calculations may involve a margin of error in the range of $\pm 10\%$. Nevertheless, using the figures in Table 2.3 one can arrive at an accurate assessment of the production potential of the existing stands. The table also indicates how much waste would be generated if all plantations were managed according to the standard schedules. In this context it should be borne in mind that wattle plantations are devoted to tannin extract production, which means that - theoretically at least - all timber could be regarded as waste. However, since the Wattle Company has developed a number of market outlets for this "by-product", only the thinnings (2nd and 3rd year) are treated as waste in its output statement. The volumes that are provided in the various producers' statements were used in calculating the production potential of pine species under sawlog regimes (see Table 2.3).

Table 2.3: **Production Potential and Waste Under Standard Management Conditions**

Organisation	Conifers			Wattle			Gum			Total	
	MAI $m^3/ha/a$	Total Vol. m^3	Total Waste m^3	MAI $m^3/ha/a$	Total Vol. m^3	Total Waste m^3	MAI $m^3/ha/a$	Total Vol. m^3	Total Waste m^3	Total Vol. m^3	T[illegible] W[illegible] m^3
Forestry Commission	17.5	528,797.0	265,909.0	8.6	9,500.0	0.0[1)]	20.0	64,900.0	16,200.0	603,197.0	291,[illegible]
Border Timbers	19.0	455,848.0	139,153.0	-	0.0	0.0	20.0	58,200.0	11,600.0	514,018.0	150,7[illegible]
Wattle Company	17.0	99,280.0	8,760.0	8.6	113,158.0	7,895.0	25.0	14,400.0	2,880.0	226,838.0	19,5[illegible]
Mutare Board & Paper Mills	22.0	59,817.0	5,981.0	-	0.0	0.0	-	0.0	0.0	59,817.0	5,9[illegible]
TOTAL		1,143,742.0	419,803.0		122,658.0	17,395.0		137,500.0	30,680.0	1,403,900.0	467,8[illegible]

1) The Forestry Commission is at present converting its wattle plantations and selling the timber as firewood

Source: Producers' statements and IPC calculations

Note that the timber producers employ different approaches in defining what they consider to be utilizable volume and waste volume. Although the Forestry Commission (FC), Border Timbers (BT) and the Wattle Company (WC) all grow the same pine species (p. patula, p. eliotti, p. taeda), the Forestry Commission classifies 50% of the overall output as waste, while Border Timbers regards 30% of its total production potential as not utilizable and the Wattle Company considers only 9% of its total volume to be waste. As a matter of fact, both Border Timbers and the Forestry Commission could sell substantial quantities of thinning wastes generated within sawlog plantations either as fuelwood or to pulp producers. In view of the specifications of the pulp mills (top diameter: 7.5-25 cm; length 2.1 m), the FC and BT could theoretically market approximately 60-70% of their thinnings. However, both the limited absorption capacity of the existing pulp mills and the management problems involved in supplying pulpwood (it must be delivered freshly cut) restrict the scope for the utilization of these wastes. The combined gross production potential of all commercial plantations in Manicaland province amounts to 1,403,000 m^3/a. If the plantations were managed and harvested according to the timber producers' existing schedules, 935,000 m^3/a could be used for sawmilling, pulp, poles, firewood, veneer, etc. Based on the present management plans, a total of 468,000 m^3/a (33%) would be regarded as waste if design rotation periods were adhered to on all plantations.

2.1.5 According to the 1987 Survey of Primary Roundwood Processing (Forestry Commission), the total volume of roundwood consumption (intake) from commercial plantations in Manicaland province was 486,078 m^3, i.e. only 52% of the production capacity of the existing stands (utilizable volume) was being exploited.

Assuming that only 67% of the felled timber went to processing plants, the amount of waste wood generated within the Manicaland plantations (thinnings, rejected clearfelllings) was 239,000 m^3 in 1987. According to information provided by the timber producers, 34,000 m^3 of such waste material was sold as firewood or used for charcoal production (Wattle Company), i.e. a total of 205,000 m^3 was either simply left in the forests or disposed of by burning. However, this situation is likely to change in the near future. Both the sawmilling and paper industries plan to expand their capacities in order to meet the growing demand for wood-based products in Zimbabwe. Although the present utilization rate of existing plantations must be regarded as low (as a consequence, production costs are high), timber growers intend to expand their production capacities within the next five years. Table 2.4 provides an overview of the planned expansion of forest plantations.

Table 2.4: Planned Expansion of Forest Plantations 1989-1995 (ha)

Producer	Conifers	Wattle	Gum	Total
Forestry Commission	9,380	-1,104 1)	1,250	9,526
Border Timbers	-	-	-	-
Wattle Company	800	300	1,500	2,600
Total	10,180	-804	2,750	12,126

1) The Forestry Commission will convert wattle into gum and pine plantations.

Source: Producers' statements (Annex I)

This expansion will increase the combined gross production potential of Manicaland plantations by approximately 220,000 m^3/a. According to information provided by the timber producers, most of the additional output will be absorbed by the pulp and paper industry.

2.2 Demand for Plantation Wood

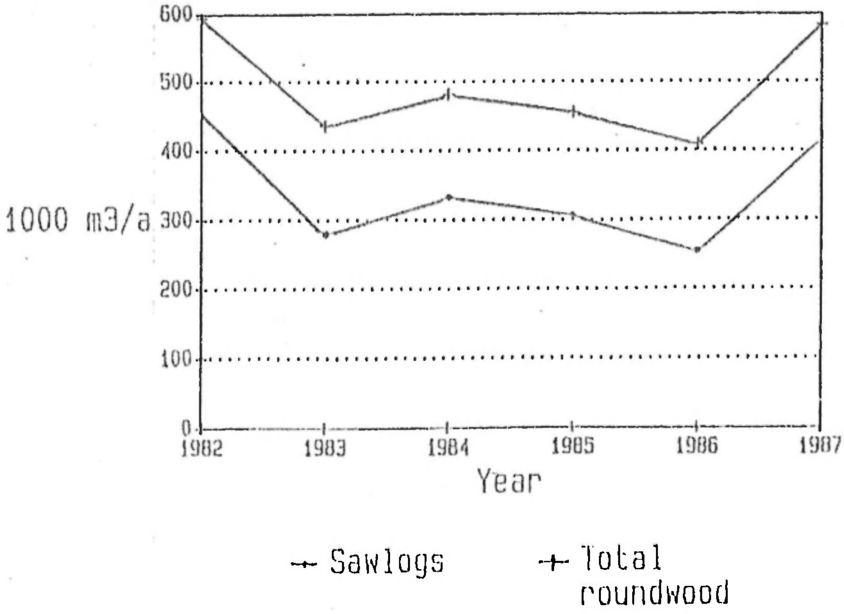
2.2.1 In order to determine the potential timber surplus which could be made available for charcoal production, the quantity of wood that would go to meet the demand for other timber products (sawlogs, pulpwood, poles, etc.) must be deducted from the production capacity of the existing plantations. Since any long-term forecast of timber demand in Zimbabwe would be highly speculative in nature, the following analysis is limited to a period of 6 years, i.e. 1987-1993. Nonetheless, it appears difficult to predict the development of the Zimbabwean timber market even for this relatively short planning period. First, there are no clear historical trends which could be analysed and used for projections of future demand (see graph). Second, some of the development plans in the pulp and paper industry which are currently under consideration may not be implemented. As regards the past development of the timber market, Table 2.5 shows the primary roundwood sales for 1982-1987. Demand for sawmilling, which absorbs the lion's share of all primary roundwood, dropped from a peak level of 453,000 m^3 in 1982 to 279,000 m^3 in 1983; it picked up during 1984-85, only to drop again in 1986, when it fell to 251,000 m^3, the lowest figure recorded over the entire 6-year period. The 1987 level (415,000 m^3) shows that demand has begun to recover, and in fact the major timber suppliers estimate that in 1988 total sawlog sales will reach 450,000 m^3, i.e. nearly the same level recorded in 1982. Pulpwood and matchwood intake remained more or less constant, while pole sales increased between 1982 and 1983, stabilizing thereafter at a level of 30,000 m^3/a.

Table 2.5: Roundwood Sales 1982-1987 (Plantation wood) in cubic metres

Year	Sawlogs	Veneer logs	Pulpwood	Poles	Matchwood	Mining Timber	Total
1982	453,329	9,442	108,594	17,873	2,688	2,120	594,046
1983	279,083	8,082	104,358	28,604	3,568	11,389	435,084
1984	333,135	8,313	100,312	29,992	2,929	6,327	481,008
1985	305,438	6,147	103,183	32,379	2,912	4,946	455,005
1986	251,487	6,390	100,440	33,183	3,751	11,876	407,127
1987	414,990	14,270	109,235	29,108	3,824	11,903	583,330

Source: Forestry Commission

Fig. 2.2: Roundwood Sales 1982-1987 (Plantation wood)



2.2.2 From an analysis of the past and present structure of the timber market in Zimbabwe it can be concluded that the future development of the supply and demand balance for forestry products will be affected

Table 2.6: **Supply and Demand Balance for Plantation Grown Timber 1987-1993 (m^3)**

Year	1987	1988	1989	1990	1991	1992	1993
FC							
Prod. Cap.	603,171	603,171	603,171	603,171	603,171	603,171	603,171
Recoverable	482,537	482,537	482,537	482,537	482,537	482,537	482,537
Demand	169,912	169,912	175,476	175,476	175,476	175,476	175,476
- Sawlogs	149,425	149,425	150,500	150,500	150,500	150,500	150,500
- Poles	6,400	6,400	14,500	14,500	14,500	14,500	14,500
- Firewood	14,087	14,087	10,476	10,476	10,476	10,476	10,476
Balance	433,259	433,259	427,695	427,695	427,695	427,695	427,695
Net Balance	312,625	312,625	307,061	307,061	307,061	307,061	307,061
BT							
Prod. Cap.	514,028	514,028	514,028	514,028	514,028	514,028	514,028
Recoverable	411,222	411,222	411,222	411,222	411,222	411,222	411,222
Demand	272,863	256,672	240,450	240,450	240,450	240,450	240,450
- Sawlogs	266,058	250,000	215,450	215,450	215,450	215,450	215,450
- Poles	6,805	6,672	25,000	25,000	25,000	25,000	25,000
- Firewood	0	0	0	0	0	0	0
Balance	241,165	257,356	273,578	273,578	273,578	273,578	273,578
Net Balance	138,359	154,550	170,772	170,772	170,772	170,772	170,772
WC							
Prod. Cap.	226,838	226,838	226,838	226,838	226,838	226,838	226,838
Recoverable	181,470	181,470	181,470	181,470	181,470	181,470	181,470
Demand	26,000	30,000	31,000	67,000	120,000	138,000	144,000
- Sawlogs	0	0	0	30,000	80,000	100,000	100,000
- Poles	6,000	6,000	6,000	7,000	8,000	8,000	8,000
- Firewood	20,000	24,000	25,000	30,000	32,000	30,000	36,000
Balance	200,838	196,838	195,838	159,838	106,838	88,838	82,838
Net Balance	155,470	151,470	150,470	114,470	61,470	43,470	37,470
MB							
Prod. Cap.	60,000	60,000	60,000	60,000	60,000	60,000	60,000
Demand	60,000	60,000	60,000	60,000	120,000	120,000	120,000
Balance	0	0	0	0	-60,000	-60,000	-60,000
HP/ZPPL							
Prod. Cap.	40,000	40,000	40,000	40,000	40,000	40,000	40,000
Demand	68,000	70,000	81,000	81,000	81,000	381,000	381,000
Balance	-28,000	-30,000	-41,000	-41,000	-41,000	-341,000	-341,000
Total Balance	578,455	588,646	587,304	551,304	438,304	120,304	114,304

primarily by the intake of the sawmilling and paper industries. At present these two market outlets take 90% (524,000 m^3) of all plantation timber produced in Zimbabwe. Our demand projections are based on forecasts provided by the timber producers and processors. The demand figures presented in Table 2.6 cover both the requirements of the timber growers' own processing plants (sawmills, etc.) and the projected levels of sales of unprocessed roundwood to external customers. Thus, for example, the demand of Zimboard, a particle board manufacturer in Mutare which currently consumes 30,000 m^3 per year, is included in the demand/sales figures for the three major timber producers. In addition to the supply and demand forecasts, Table 2.6 also shows the current production potential of the various growers.

In the gross balance of the individual companies it is assumed that 100% of the gross production capacity of the plantations can be mobilized as utilizable volume. Because this assumption may not prove valid in reality (the figures merely define the upper limit of timber supply from the existing stands), a net balance is also calculated. In this net balance, only 80% of the production potential is regarded as recoverable. As the demand for forestry products increases and exerts an upward pressure on prices, both the capacity utilization rate of the plantations and the recovery rate for felled trees (which at present average only 58% and 64%, respectively) will definitely rise as well. In view of the prevailing conditions in Zimbabwe, it appears reasonable to assume that the average utilization rate will increase to around 80% of the gross production capacity in the coming years. Three major conclusions can be drawn from the preliminary supply and demand balance given in the table:

(i) The Forestry Commission and Border Timbers will continue to underutilize the production capacity of their plantations throughout the planning period. Both organizations have made conservative projections regarding demand for timber products and the utilization of their stands.

(ii) The Wattle Company intends to reduce its surplus timber output through increased sales of pulpwood, poles and firewood. By 1993 the company estimates that the gross annual surplus will be only about 58,000 m^3. Thus, assuming a recovery rate of 80%, the supply/demand balance of the Wattle Company will presumably exhibit a surplus of only 13,000 m^3 by the end of the planning period.

(iii) If the planned expansion of production facilities in the Zimbabwean pulp and paper industry (Mutare Board and Paper, ZPPL) is implemented according to schedule, the capacity of the existing plantations would still be sufficient to meet the resulting additional demand in 1992/93. Even at a recovery rate of 80% of the production capacity, the increased demand of the paper mills could be supplied if all existing Forestry Commission and Border Timbers plantations were properly managed. With proper management, however, annual waste generation by these two producers would drop to only about 100,000 m^3.

2.2.3 In view of the planned expansion of pulp and paper production in Zimbabwe, it is surprising that no provision has been made in either the FC's statement or that of BT for additional timber sales to the pulp mills. Indeed, the timber sales projections of the Forestry Commission and Border Timbers do not even take into account the planned capacity expansion by Mutare Board and Paper Mills, which will probably boost annual pulpwood demand by some 60,000 m^3 by 1991. Whether the ZPPL project will in fact materialize is not, however, clear at this point. According to information provided by the chief executive of the company, the construction of the pulp and paper mill would require a total investment of Z$400 million. Given the present shortage of paper products in Zimbabwe on the one hand, and the underutilization of existing forest plantations on the other, a good case can be made for the development of additional local paper manufacturing capacities. However, the establishment of a comparatively small new paper mill might not be the least-cost approach to meeting Zimbabwe's future paper demands. While it is clearly beyond the scope of this study to evaluate the financial and economic viability of the ZPPL project, it is nonetheless a well known fact that small pulp and paper mills are often unable to take advantage of economies of scale involved in paper manufacturing, which means that, in terms of world market prices, they frequently do not prove to be internationally competitive. Moreover, Zimbabwe must define priorities as far as future investments in large scale projects are concerned. Thus, the pulp and paper mill may have to compete with other projects which are also considered to be important for the development of Zimbabwe's economy and which may appear more worthwhile from the standpoint of resource allocation.

2.3 The Potential Feedstock Supply for Charcoal Production

2.3.1 Theoretically, the size of the potential feedstock supply for charcoal production (or for any other "unconventional" utilization of plantation wood) may be determined by subtracting the current or expected timber demand of wood processing industries from the production potential of the existing plantations. At present, a supply of approximately 920,000 m^3/a would be available. Considering that approximately 80% of the production capacity is accounted for by pine stands, and that the wood of the species in question has an air-dry density of approximately 475 kg/m^3, the charcoal production potential would amount to some 98,000 tpy (based on a 30% weight-based conversion efficiency). The lion's share of the charcoal would have to be produced from surplus wood available in the Forestry Commission's plantations, which at present have the largest unexploited production potential. It is, however, very unlikely that the Forestry Commission and the other timber growers would start clearfelling their plantations merely to supply a demand for charcoal feedstock when the same trees could be left standing and sold later for the production of high value products such as sawn timber, veneer or pulp. A more realistic approach to assessing the feedstock supply potential is to assume that only the waste material which is obtained via silvicultural operations such as thinning and yielded by clearfellings could be made available for charcoaling. Silvicultural treatment is necessary to improve the quality of the remaining stands and to prevent plantations from deteriorating. But it should be noted in this context that while clearfelling always generates a certain quantity of waste, it will not necessarily yield as much waste wood per ha as is now available if the growers change their current harvesting practices and begin rejecting a smaller percentage of the cut timber.

Thinning Wastes

2.3.2 According to the management schedules of the timber growers and their estimates of the share of their thinnings that could be made available for charcoal production, the total volume of pinewood that could be obtained through thinning operations is 221,400 m^3 per annum.

Table 2.7: **Average Volume of Thinning Wastes from Pine Plantations**

Organization	Area ha	Total Volume m^3/ha/a	m^3/a	Total Waste m^3/ha/a	m^3/a
FC	30,217	6.3	190,300	4.3	129,900
BT	23,992	7.2	172,700	3.6	86,300
WC	5,840	8.6	50,200	0.9	5,200
Total	60,049		413,200		221,400

Source: Timber producers

This volume of waste will only be generated if all silvicultural operations are carried out on schedule and if all stands are harvested according to the design rotation period (BT and WC: 25 years; FC: 30 years). Although these two conditions are not now being met, all of the timber growers are currently attempting to bring their operations back in line with management schedules because timber demand is expected to rise in the coming years. Thus, over the next 2-3 years the volume of thinning wastes may be even larger than is indicated by the average figures given above. Both the Forestry Commission and Border Timbers have postponed necessary operations in the past, and a return to management schedules will entail a higher than average volume of thinning work in the near future. The quantity of waste will also increase if the producers cannot utilize or sell thinnings according to their own projections. BT, for instance, which regards approximately 40% of its 1st and 2nd thinnings as utilizable volume, currently thins the total volume of these two silvicultural operations to waste instead of selling the material as case or pulpwood. The Wattle Company only classifies a negligible quantity of its pine thinnings as waste and it sells as much of this waste material as possible to pulp mills. According to the specifications of the Zimbabwean paper mills, most of the pine thinnings are suitable for pulping. The following table summarizes these specifications.

Table 2.8: Specifications for Pulpwood

	Top diameter (cm)	Length (m)
Mutare Board	7.5-25.0	2.1
Hunyani	10.16-15.24	2.23
ZPPL	10	2.5

Source: Paper Companies

2.3.3 Thinning operations in eucalypytus and wattle stands will not be regarded as a potential source of feedstock for charcoal production. Most eucalyptus stands are not thinned at all (rotation: 10 years), and if thinning operations are carried out, the logs are usually absorbed by the pole market. In fact, at present the demand for eucalyptus poles already exceeds the supply. Wattle stands are thinned twice (from 2,400 to 1,600 stems per ha). However, these operations are carried out in the second and third years after planting, i.e. the thinnings yield only a small volume of wood per area unit. Given the small diameter and the low density of the wood at the age of two years, wattle thinnings would not provide an ideal feedstock for charcoal production. Plantations which are managed under a pulpwood regime are not thinned at all. Silvicultural treatment of pulp schemes is limited to pruning, which yields small diameter branches that are not suitable for charcoal production. Thus, at present the maximum potential feedstock supply from thinning operations is 221,400 m^3/a or 105,000 air dry tons. This equals a gross charcoal production level of 31,500 tpy.

Clearfelling

2.3.4 When timber is clearfelled, a certain percentage of waste, i.e. timber which does not meet the specifications of the sawmill, is generated - even on a well managed and properly tended plantation (e.g. a sawlog scheme). For example, on its sawlog plantations the Forestry Commission rejects all logs which do not have a top diameter of 23 cm. In addition to top diameter, specifications relating to such things as strength and density must also be met. Moreover, the level of management efficiency at a given plantation is not the only factor which determines the volume of waste generated by clearfelling operations; it is also governed by the degree of diversification of the relevant market outlets. Logs which are rejected as sawmill or veneer mill feedstock can still be used for low quality products such as wood cases or can be sold as pulpwood. At present the timber market in Zimbabwe is oversupplied, i.e. there is little incentive to recover timber which does not meet the standards of the mainline forest product that a given plantation is designed to supply. Consequently, the timber growers usually only extract easily accessible prime timber, leaving a large volume of waste on the ground.

Table 2.9: **Average Volume of Wastes from Clearfelling (Pine Sawlogs)**

Organization	Area ha	Total Volume $m^3/ha/a$	m^3/a	Waste Volume $m^3/ha/a$	m^3/a
FC	30,217	11.2	338,400	4.5	135,900
BT	23,992	11.8	283,100	2.2	52,700
WC	5,840	8.4	49,000	0.6	3,500
Total	60,049		670,500		192,100

Source: Timber producers

Under the present management schedules, pine plantations would generate 192,100 m^3 of waste per year waste when clearfelled. However, this figure merely defines a theoretical upper limit which would hardly ever be reached in practice. Indeed, the timber growers presently fell only 60% of the stands which are mature and, as a result, less waste is generated (approx. 115,000 m^3/a).

As clearfelling is stepped up to meet the increased demand for timber, the percentage of rejects (waste) will most likely decrease. Therefore, it would appear advisable to employ a more conservative estimate of the average quantity of waste generated by clearfellings in the following calculations. Accordingly, it will be assumed that the potential feedstock supply from pine (sawlog) clearfellings amounts to 100,000 m^3/a. Clearfelling wastes from gum plantations can be neglected as a potential feedstock supply source. The market for construction and fencing poles is big enough to absorb almost every log that is felled in a gum plantation. The short rotating eucalyptus stands maintained under pulp regimes also do not provide waste volumes that would be worth considering in this context.

2.3.5 The acacia mearnsii (wattle) plantations maintained by the Wattle Co. must be regarded as a special case. The mainline product of these stands is not timber but tannin, which is extracted from the bark of the trees. Consequently, all wattle trees which are felled could theoretically be viewed as a by-product or as waste material. And indeed, up until now most of the wattle stems, which grow to a diameter of approximately 15-20 cm after the 10 year rotation period, have simply been disposed of by burning following the removal of the bark. Prior to 1983 the Wattle Company discarded almost all wattle stems, with only 21,000 m^3/a (17,000 air dry tons/a) being utilized as boiler fuel in the tannin extraction factory (steam generation).

Given the MAI of wattle plantations (8.6 m^3/ha) and the total area under wattle (13,158 ha), it may be concluded that the Wattle Company burnt 92,000 m^3 of wattle stems in the field every year prior to 1983.

Starting in 1983 the Wattle Company began to develop market outlets for the wattle stems, and by 1987 it had succeeded in reducing the wastage of wattle stems to 42,000 m^3/a. In that year, 71,000 m^3 was used as firewood and pulpwood, for mining and fencing poles and for charcoal making. Taking into consideration that only 80% of the wattle stems are accessible, this means that an additional volume of only about 20,000 m^3/a would be available for use as charcoal feedstock. In other words, wattle clearfelling, which has often been regarded as the largest potential source of raw material for charcoal production, could at present only provide enough feedstock for an additional 4,800 tons of charcoal per annum. According to members of the company's management staff, this potential will most likely be further reduced in the future. The Wattle Company expects increases in pole, pulp and firewood sales which will absorb all accessible wattle clearfelling wastes by 1990. If financially attractive market outlets emerged for charcoal, the company would of course be prepared to channel more waste material into charcoal production and reduce its firewood sales. Apart from the Wattle Company, the Forestry Commission also maintains wattle stands. The Forestry Commission intends to convert its 1,104 ha of wattle into pine. Assuming that the average standing volume of the plantations is 100 m^3/ha, 110,000 m^3 of wattle stems could be made available during the next 2-3 years. However, since the feedstock source (Erin Estate) is located only 60 km from Mutare, the bulk of this timber will most probably end up on that city's firewood and pole market.

Sawmill Wastes

2.3.6 Sawmilling operations represent an additional source of waste material which could theoretically provide substantial quantities of charcoal feedstock. The Forestry Commission's sawmills, for example, recover only 42% of the total intake as sawn timber. 58% (at present, approximately 87,000 m^3) of the timber input is converted into sawdust and offcuts. Whereas offcuts are utilized as a fuel for lumber seasoning, the sawdust has to be disposed of using incinerators. The sawmills operated by Border Timbers generate approximately 43,000 m^3 of sawdust per annum, which is also simply burnt away. Although charcoal production from sawdust is technically feasible via briquetting, the unit costs associated with this option are at least twice as high as those incurred in the manufacture of lump charcoal from logs. Therefore, the sawmill wastes should not be viewed as a potential source of charcoal feedstock.

Overview of Feedstock Supply

2.3.7 The following table provides an overview of the average potential feedstock supply for charcoal production in the Manicaland forest plantations. The figures are based on production and sales statements issued by the relevant timber producers. 80% of the total waste volume is regarded as extractable.

Table 2.10: Feedstock Overview

	m^3/a	t/a[1)]	charcoal/a[2)] tpy
Pine thinnings	177,000	84,000	25,000
Pine clearfellings	80,000	38,000	11,400
Wattle clearfellings	20,000	16,000	4,800
Total	277,000	118,800	41,200

1) air dry tons at 475 kg/m^3 for pine and 800 kg/m^3 for wattle.
2) at 30% weight based conversion efficiency

A total of 41,200 tons of charcoal could be produced from hitherto wasted resources, and the bulk of the feedstock supply would be obtained from the plantations of the Forestry Commission. A breakdown by producer is given below.

Tons of charcoal per year

Forestry Commission	24,000
Border Timbers	11,700
Wattle Co. (additional)	5,500

Source: Timber producers and IPC calculations

It should be noted here that almost all of the potential feedstock supply would be generated within plantations located in the Chimanimani area, i.e. at sites located approx. 180 km from Mutare.

3. Experience to Date in the Areas of Charcoal Production and Utilization

3.1 Charcoal Production in Zimbabwe

3.1.1 Charcoal is not now - and never has been - used on any appreciable scale as a household fuel in Zimbabwe. While thousands of tons of the fuel are produced annually by small-scale traditional charcoalers in other countries in the region, charcoal making is not widespread in Zimbabwe, where production is limited to a few commercial schemes. Altogether, only three charcoal operations could be identified in Zimbabwe: the Wattle Company, Mutare; the Forestry Commission, which has also produced wattle charcoal on a trial basis; and a private company in Kwekwe which uses indigenous trees (clearing wastes) for charcoaling.

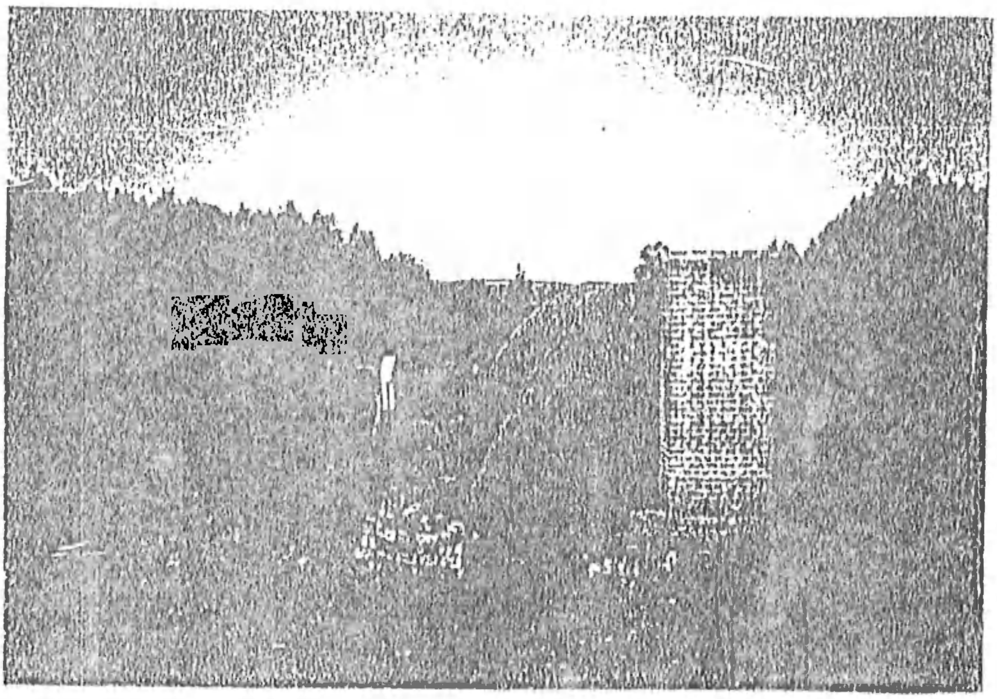
The Wattle Company

3.1.2 The Wattle Company, which is a subsidiary of the Lonrho Group, started to produce charcoal from wattle clearfelling wastes in 1983. The debarked acacia logs had previously been disposed of by burning, and the idea of using them in this way originally came from Kenya, where a sister company (Wattle Company, Eldoret) had long been utilizing the same material to produce charcoal. Wattle stems provide a good feedstock for carbonization. They have a more or less uniform diameter (15-25 cm) and length (3.5-4.00 m), and the bark - which normally impedes the carbonization process - has already been stripped off. Moreover, given the relatively high density of the acacia wood, an acceptable charcoal quality can be achieved even though the trees are comparatively young (8-9 years) when felled. At 20-25% moisture content the stems exhibit a density of 800 kg/m^3.

3.1.3 The Wattle Company employs a kiln technology which was also adopted from the Kenyan sister company. All in all, 14 so-called tunnel type kilns are in operation in the Chimanimani area. The kilns are constructed of locally produced fire bricks and clay soil mortar. Each kiln has a geometric capacity of 115 m^3. At a stacked/solid ratio of 0.65 for wattle stems, the kilns can accomodate a charge of approximately 75 m^3 (60 tons at 25% moisture content wet basis). The kilns are loaded and unloaded at the front end through a steel door. Owing to their large volume, the carbonization cycle takes at least 2 weeks from ignition to unloading. Although the carbonization phase itself is terminated within 4-5 days after ignition, a comparatively long cooling period is required. Not only must the hot charcoal cool down to a temperature level which is low enough to permit unloading; the 9 inch thick walls of the kiln also exhibit a sizeable heat retention capacity which extends the cooling process. Company management staff reported that even after more than 10 days' cooling, charcoal loads ignited spontaneously when kilns were opened. Such fires invariably led to heavy charcoal losses.

3.1.4 The design of the tunnel kilns is based on the downdraught principle. After loading has been completed and the door has been shut and sealed, the wood charge is ignited through two holes in the top of the kiln. The operator now controls the process by means of two systems. The flow of primary air through the charge is regulated by a vent at the front end of the kiln. Once it enters this vent, the air is distributed via a longitudinal channel underneath the wood charge. The channel extends to a chimney at the rear end of the kiln. A secondary control is achieved via a line of holes along the base of the kiln.

Through these holes additional air is supplied during the first phase of carbonization. The holes are kept open until the carbonization process extends to the bottom of the charge. As soon as the operator sees charcoal through the bottom holes, they are closed using fire bricks and clay soil mortar. When the carbonization process has been completed throughout the charge, all vents have to be sealed properly and cooling can start.



3.1.5 The tunnel kilns are neither easy nor cheap to build. Construction of the arch requires the use of a template around which the bricks must be laid. Although the template facilitates the building of the arch, the services of skilled masons are nonetheless needed in order to construct a kiln which exhibits satisfactory structural strength. Due to the large volume of the kiln, the structure is subject to a comparatively high level of thermal stress during operation. Improperly executed masonry work will therefore result in cracks and leaks. The Wattle Company reported construction costs of Z$ 6,000 per unit in 1983. In 1988 the construction costs would be in the neighbourhood of Z$ 15,000 (130 Z$/$m^3$).

3.1.6 The Wattle Company's 14 tunnel kilns represent a total production capacity of 4,200 tpy (annual output per unit: 300 t at 25% weight based conversion efficiency, 15 tons per cycle and 20 cycles per year). At present only 20% of this production capacity is being utilized. Although various attempts have been made to sell more wattle charcoal both in Zimbabwe and on the export market, the Wattle Company has never managed to market more than 800-1,000 tpy. Consequently, unit production costs are comparatively high for the wattle charcoal. The company reports the following cost structure:

Table 3.1: **Ex Kiln Production Costs of Wattle Charcoal**

	Z$/ton of charcoal
Feedstock extraction	24
Internal transport	14
Kiln operation	24
Bagging	39
Overheads, administration	26
Total	127

Source: Wattle Company

The total ex kiln production costs of Z$127 per metric ton compare with average production costs of approx. Z$60 in other African countries (excluding feedstock costs). In addition to the low capacity utilization rate of the Wattle Company's charcoal schemes, three other factors boost production costs above the average levels reported in other countries:

- labour costs are well above the level of other countries (minimum wage for workers in forest operations: approx. 140 Z$/month);
- internal transport costs for the feedstock (tractor-trailers are utilized) are high owing to the large size of the catchment areas which supply the individual production centres;
- packaging materials (hessian bags) are not recycled and the packaging costs account for more than 30% of the total ex kiln costs.

Obviously, there is scope for cost reductions. Smaller kilns and a more decentralized approach to charcoal production would reduce internal transport costs. Increasing the weight based conversion efficiency from its current level of 25% to 30%, making full use of the existing production capacity and lowering the packaging costs by recycling the bags could reduce the ex kiln production costs even further.

Forestry Commission

3.1.7 The Forestry Commission operated two Mark V steel kilns from 1983 until 1984, using wattle trees as feedstock. They were obtained when an FC wattle plantation was converted to pine. The charcoal was produced in the Inyanga area and the output of the small operation was sold to hotels and lodges in the vicinity of the production site. In 1984, when the steel kilns were due for replacement, the Forestry Commission decided to discontinue charcoal production. Two major reasons for this decision are cited by the FC: First, the market potential for barbecue charcoal was very small; and second, the sale of wattle stems as firewood was found to be financially more attractive than charcoal production.

Pretorius Ltd.

3.1.8 Pretorius Ltd., located in Kwekwe, is a small private company which performs land clearing work on a contract basis for farmers, agricultural estates, irrigation schemes and ranches in the Kwekwe/Gweru area. In 1986 the company started operating 4 mobile steel kilns to produce charcoal from clearing wastes. In theory, the Mopane hardwoods provide an ideal feedstock for the production of a high quality charcoal. However, due to the nature of the operation (not enough time to season the wood properly, no experienced charcoal burners, utilization of relatively inefficient steel kilns), the quality of the product has always been rather low. Zimalloys, which had considered using the Pretorius charcoal as a feedstock for their ferrosilicon 75 production, tested the fuel and found significant variations in the fixed carbon and volatile contents. According to information provided by

Pretorius Ltd., the current charcoal output is 20 tons per month. Ex kiln production costs are 110 Z$/ton, 80% of which is accounted for by labour costs. The company's management does not see much scope for raising output beyond the current level. Given the remote location of its clearing sites (relatively low share of economically accessible wastes) and the overall scale of its operations, the feedstock supply will remain quite limited in size. Thus, for Pretorius Ltd. charcoal production will continue to be a small scale operation supplying barbeque charcoal to the local community in the Kwekwe/Gweru area.

3.2 Charcoal Utilization

3.2.1 At present charcoal utilization in Zimbabwe is limited to two market segments. The lion's share of the Wattle Company's output is absorbed by industrial consumers. Only a small portion is supplied to the so-called barbecue market. The following table summarizes the 1987 charcoal sales of the Wattle Company.

Table 3.2: Charcoal Sales Wattle Co. 1987

	tons	price Z$/ton
Leyland Mutare	450	209
Bikita Mine	320	420
Barbecue Charcoal	100	800
Total	870	

Source: Wattle Company and charcoal consumers

3.2.2 Leyland Mutare, a car and truck assembly plant, began using charcoal in 1983. The charcoal is combusted in a Cochrane gasifier which provides the heat for the factory's paint shop drying chambers. The gasifier, which was commissioned in 1976, replaced a diesel oil fired paint shop drying system that had been in use up until then. Prior to 1983 Leyland fuelled the unit with coke. As soon as charcoal became available from the Wattle Company, Leyland switched to the new fuel because the operation and maintenance of the system had proved difficult owing to the high ash content and abrasive properties of the coke. Although the gasifier was originally designed for coke operation, substituting charcoal did not cause any technical problems. On the contrary: the improvements that had been expected to result from the fuel switch (less ash, cleaner gas, lower maintenance costs) were in fact achieved.

3.2.3 The gas is produced in an updraught generator. It rises from the fuel bed through a hot gas main to a cyclone where solid particles are removed. From the cyclone the gas is drawn into a water cooler scrubber in which its temperature is reduced and more dust particles are removed. After cooling, the gas enters a filter column where the remaining solid particles and condensable volatiles are removed. A booster fan then moves the gas into the main gas pipe which distributes it to the various burners that are located on top of the paint drying chambers. The rated output of the Leyland gasifier is 5 GJ/hour. In a nine-hour shift the unit consumes 2.5 tons of charcoal. Assuming an average net heating value of 28 GJ/ton of charcoal, the overall efficiency of the system is 64%.

3.2.4 In 1985 Leyland Mutare monitored the operating costs of the gasifier unit. The following breakdown was provided by the company:

Table 3.3: Operating Costs of Charcoal Fuelled Gasifier (1985)

	Z$ in 1985
Fuel (charcoal)	105,000
Electricity	5,000
Labour	12,000
Maintenance	4,000
Total	126,000

Source: Leyland

Although it was felt that a diesel oil fired system would be cheaper (150,000 litres at 0.6 Z$1 per litre would have been required to provide the same drying services), the company decided to retain the gasifier unit and continue operating it on charcoal because both the gas generator and the fuel were local products.

3.2.5 Bikita Minerals, a lithium mining and processing company, also operates a 5 GJ/hour Cochrane gasifier which is fuelled with charcoal supplied by the Wattle Company. The gas is used to fire a Johnson rotary dryer in which the moisture content of the lithium ore is driven off prior to further processing. Although the ore drying process requires a hot gas stream (approx. 1,000°C), the raw gas is not injected directly into the rotary dryer. In order to ensure that the high value lithium ore is not contaminated with impurities from the fuel, the gas is first cooled and washed before it is supplied to the rotary dryer. The Bikita charcoal gasifier is an example of an application where the specific fuel properties of charcoal (low level of impurities) are required. The company is prepared to pay a considerable premium (landed costs of charcoal: Z$420/ton) for the fuel because coke, although cheaper, would not provide a gas which is clean enough for its purposes.

3.2.6 Private middle and upper class households purchase their barbecue charcoal from petrol stations. A retailing company purchases the charcoal in bulk from the Wattle Company, puts it into 5 kg paper bags and distributes it through the network of filling stations. Sales are limited to approximately 60-70 tons per year (retail price: Z$3.80 per bag). Some hotels and restaurants also use barbecue charcoal for roasting meat. They normally purchase the fuel directly from the Wattle Company's depots. Altogether, the restaurant market absorbs 30-40 tons per year.

4. The Market Potential for Charcoal

4.1 The Fuel Market in Zimbabwe

4.1.1 The structure of energy consumption in Zimbabwe reflects the relative importance of industry and commercial agriculture in the country's economy (taken together, these two sectors accounted for 44.9% of GDP in 1984). A well developed power system and local coal production are geared primarily to meeting the energy needs of the large commercial consumers in the various industries. Although current per capita energy consumption (approximately 30 GJ/cap/a) is high by African standards, 80% of the population still relies on traditional woodfuels, which account for approx. 58% of the country's primary energy consumption (6.46 million air dry tons in 1984).

Table 4.1: **Fuel Consumption and Electric Power Use by Sector**

Sector	Liquid Fuels	Coal Coke	Electricity	Commercial Wood	Fuelwood
Households	5.1	-	13.6	91.7	93.2
Agriculture	10.4	18.3	7.3	-	6.6
Industry	4.4	58.9	65.6	3.8	-
Transport	76.8	15.7	-	-	-
Construction	3.3	-	0.6	4.5	-
Others	-	7.1	12.9	-	0.2
Total	100	100	100	100	100

Source: Beijer/ZEAP 1984

Table 4.1 shows the sectoral breakdown of energy consumption in Zimbabwe as calculated by the Beijer/ZEAP Project for 1983. Although the individual percentage shares may have changed slightly over the past five years, the above data still provide a valid picture of the structure of the country's energy supply/demand balance. As far as supply is concerned, coal products accounted for the second largest primary energy input (20%) followed by liquid fuels and electricity (both 11%). In 1987/88, coal production at the Hwange Colliery was up significantly, with sales rising to a record level of 4.5 million tons, which represented a 35% increase over the 1986/87 tonnage. The recent growth in coal production was mainly attributable to the increase in consumption by the Hwange Power Station, which fired 2.2 million tons in 1987/88 as compared with 1.2 million in 1986/87.

4.1.2 By and large, the structure of commercial energy consumption is determined by the market prices for the various options. However, prices for commercial fuels and electricity are controlled by the government and reflect its intention to provide incentives for the utilization of local resources. This policy has resulted in the use of coal products on a massive scale in the industrial and agroindustrial sectors, where coal products (technical feasibility of coal firing assumed) normally provide the least cost option for consumers. Table 4.2 below summarizes the current fuel prices in Zimbabwe.

Table 4.2: **Current Energy Prices in Zimbabwe**

Fuel	Z$/Unit
Coal	32/ton washed peas free on rail
Diesel/Paraffin	0.6/l ex pump
Electricity	0.0715/kWh household tariff
Firewood	70/ton ex depot Harare

Supply Costs for Coal

4.1.3 In order to assess the fuel market situation in major demand centres, transport costs for coal (from Thompson Junction to the specific individual consumers) must be taken into account. Since only large scale consumers deal directly with the Hwange Coal Mining Company, delivered coal prices for smaller consumers include not only transport costs, but also handling and administration charges as well as profit and overheads of coal merchants who supply the fuel to the individual consumer. In the framework of this study, a sample survey was carried out among 40 enterprises and organizations that use various types of fuel. The results of this survey indicate that, for a given user, landed fuel prices will vary in accordance with his scale of consumption and location. The following table (4.3) summarizes the figures for eleven selected consumers. This group includes large scale industrial consumers in the country's urban centres as well as small and medium size consumers in both remote locations and areas that are close to the urban centres. The lowest landed price for coal products was paid by Clay Products, Bulawayo. The company fired 22, 000 tons of the fuel in its refractory kilns and paid Z$36 per ton of unwashed coal. Circle Cement, Harare, and Zimalloys, Gweru, had to pay Z$46 and Z$42.45 per ton, respectively, due to longer transport distances. Supply prices for washed coal ranged from Z$50.69 per ton (Olivine Industries, Harare) to Z$232 per ton (Bondolfi Teachers College, Masvingo area). The latter is a very small consumer (22 tons per year) located in a remote place and, as a result, its coal supply costs are significantly higher than those incurred by the majority of the country's smaller consumers. For most small and medium size consumers who are supplied by road transport from a coal depot or railway station, landed prices can be assumed to range between 100 and 150 Z$ per ton. The Katiyo Tea and Coffee Estate in the vicinity of Mutare is such a consumer. In 1987 it used 750 tons of coal at a landed price of Z$125 per ton.

4.1.4 Coal consumers in the Mutare area are of particular interest here because they represent a market which is located close to the feedstock resources for charcoal production. Large scale consumers such as Mutare Board and Paper (coal consumption in 1987: 12,580 tons) can obtain coal at comparatively low landed prices if they are connected to the railway system. In 1987 the company had to pay an average of Z$55.47 per ton of washed pea size coal, which includes the FOR price Thompson Junction (Z$32/ton), rail transport (21.92 Z$/ton according to the Railway Tariff Book) and a commission of Z$1.55 per ton for the Wattle Company, which acts as a coal merchant for consumers in Manicaland province. Smaller users who must obtain their supplies from the Wattle Company's coal depot have to pay Z$72 per ton of washed coal plus transport to their factory or estate. For short and medium range road transport in the Mutare area, prices of 0.2 Z$ per ton and kilometre can be assumed, i.e. a consumer who is located within a radius of 100 km from Mutare would pay a landed price of approximately 92 Z$ per ton

Table 4.3: Landed Prices for Fuels 1987

Consumer	Location	Dry Coal		Washed Coal		Local Coke		Imported Coke		Diesel	Fuel	Firewood		Electricity	
		tons	Z$/ton	tons	Z$/ton	tons	Z$/ton	tons	Z$/ton	tons	Z$/ton	tons	Z$/ton	MWh	Z$/MWh
Olivine Indust. Chemica's	Harare	0	0	21,600	50.69	0	0	0	0	310	500	0	0	582	83
Circle Cement Cement	Harare	41,146	46	0	0	0	0	0	0	0	0	0	0	50,311	26
Willards Food Process	Harare	0	0	1,200	70.5	1,500	164.65	0	0	0	0	0	0	320	50
Clay Products Ceramic	Bulawayo	22,000	36	0	0	0	0	0	0	0	0	0		0	0
ZIMASCO Metall Process	Kwekwe	0	0	40,000	92	0	0	60,000	224	400	500	0	0	700,000	30
ZIMALLOYS Mineral Process	Gweru	7,904	42.45	0	0	41,035	145.94	11,057	241.19	110	500	20	18	480,000	7
Mutare Board Paper	Mutare	0	0	12,580	55.47	0	0	0	0	0	0	0	0	0	0
Gorubi Farm Tobacco	Mutare	0	0	0	0	0	0	0	0	0	0	600	5	0	0
Katiyo Estate Tea, Coffee	Mutare	0	0	759	125.23	0	0	0	0	0	0	0	0	0	0
Morgenster Hosp. Instititional	Masvingo	2	62	102	67.2	0	0	0	0	0	0	0	0	0	0
Bondolfi Coll. Institutional	Masvingo	0	0	22	232	0	0	0	0	0	0	0	0	0	0

tons: annual consuption
Z$/ton: Average landed price in 1987

Source: Sample Survey ZIDS/IPC/P88

of coal. In 1987 the Wattle Company sold 20,000 tons to industrial and 5,000 tons to agro-industrial consumers. The average commission price was Z$58/t for these customers. In addition, the company sold 12,500 tons ex depot.

Firewood

4.1.5 Whereas coal prices can be calculated for almost any location in the country, the situation is different for firewood. The majority of the rural population considers firewood to be a free good, i.e. the fuel is collected from indigenous forests in the vicinity of the users' dwellings. (For 1984, rural fuelwood consumption was estimated at 6.04 million air dry tons, or 93% of total fuelwood consumption). For most rural households, the only "supply costs" involved in obtaining firewood are the expenditures of time and effort required to cut and collect it. On average, a rural family must spend 8 working hours per week to meet its firewood needs (Energy Pricing Study, Ministry of Energy, Water Resources and Development). In recent years, however, commercialization of fuelwood in rural areas has been observed. The ongoing process of deforestation has led to severe local shortages of firewood, and as the distance to the nearest fuelwood collection area increases, fuel procurement consumes an ever larger share of a family's labour budget. Eventually the expenditure of time and effort becomes excessive and they are forced to begin purchasing firewood.

Especially during the rainy season, when the entire labour budget of rural households must be allocated to agricultural activities, wood is supplied by local traders. While accurate price data are not currently available, recent reports from various parts of Zimbabwe indicate that rural consumers are now paying between 5 and 20 Z$ per ton of air dry firewood. Smallholder farmers who collect wattle stems or pine thinnings on the plantations of the Wattle Company or Border Timbers in Manicaland province have to pay Z$10 per ton of firewood ex forest road. Medium size commercial farms that grow their own fuelwood for tobacco or tea drying estimate production costs at 5-10 Z$ per stacked m^3 (14-28 Z$/air dry ton). These figures are more or less consistent with the financial fuelwood production costs calculated by Coopers & Lybrand in the Energy Pricing Study (15-23 Z$/air dry ton).

4.1.6 Urban firewood supply is almost completely commercialized. Of the estimated total firewood consumption of urban households in 1984 (420,000 air dry tons), nearly 100% was supplied by wood traders. Prices can vary considerably according to location, the quantity purchased and the season. The Wattle Company sells bulk firewood at prices of Z$30 per ton ex Mutare and Z$70 per ton ex Harare depot. Consumers purchasing small quantities from urban wood traders (5-10 kg) may pay up to Z$120 per ton (Z$8/GJ).

Table 4.4 compares fuelwood production/supply costs and selling prices for bulk and standard retail quantities at various locations.

Table 4.4: Current Firewood Costs/Prices

	Z$/ton	Z$/GJ[1)]
Wattle/pine ex forest road	10	0.67
Rural wood traders	5-20	0.33-1.33
On farm production	14-28	0.93-1.87
Bulk firewood ex depot Mutare	30	2.0
Bulk firewood ex depot Harare	70	4.67
Urban wood traders bulk	60-80	4.0-5.33
Urban wood traders retail	80-120	5.33-8.0
Financial costs fuelwood plantation	15-23	1.0-1.53

1) at 15 GJ per air dry ton

Source: ZIDS/ZEAP

4.2 Charcoal Production and Supply Costs

4.2.1 The ex kiln production costs of charcoal produced by the Wattle Company in the Chimanimani area are currently Z$127 per ton. This figure includes feedstock extraction, internal transport, kiln operation, bagging and overheads. Although the Wattle Company considers the value of the feedstock to be zero, production costs are comparatively high. In the following, charcoal production and supply costs are calculated on the basis of empirical data derived from charcoal production schemes implemented in other African settings which operated in a more competitive environment than that now found in Zimbabwe.

Feedstock Valuation

4.2.2 The supply sources for charcoal feedstock, i.e. the Manicaland forest plantations, are not designed to produce fuelwood. The plantations were established and are being maintained in order to supply sawlogs, peeler logs, tannin extract, poles and pulpwood. Therefore, charcoal production would utilize only (a) waste material generated by silvicultural tending operations and (b) rejects, i.e. felled timber which does not meet the standards for the mainline end products. In other words, the production costs of the various mainline products do not affect the economic value of the material which would be used as charcoal feedstock. In view of the fact that most of the material in question is currently being discarded, one could theoretically set the feedstock supply costs equal to the costs incurred in recovering the raw material from the site where it is generated. However, opportunity costs may be involved even if the material is not currently being put to productive use. These costs are determined by the profit which would accrue from an alternative use of the feedstock in comparison to the returns which can be expected from charcoal production. From the timber growers' point of view, opportunity costs are at present involved only in the case of waste material generated in the Inyanga plantations (±60 km from Mutare). They sell this material as poles, firewood or pulpwood and the revenue from these sales exceeds the revenue that they would obtain by selling the waste wood as charcoal feedstock. We shall therefore concentrate on the Chimanimani plantations, where the bulk of the unutilized timber in Manicaland province is generated. Opportunity costs will have to be taken into account if this raw material is found to have a positive net back value at a potential market outlet, and it is assumed that for the next 3-5 years, the only alternative commercial use for the wastes will be as firewood. After that, the picture may change owing to the increased demand for pulpwood.

4.2.3 At present firewood commands a bulk price of Z$30 per ton in Mutare and Z$70 in Harare (ex depot). Assuming that only the Harare market would have the capacity to absorb a significant additional volume of wood, the net back value of waste wood from the Chimanimani plantations when sold as firewood works out as follows:

Table 4.5: **Net Back Value of Waste Wood**

	Wattle Z$/ton	Pine Z$/ton
Extraction, cutting[1)]	15.00	19.30
Transport to Mutare[1)] rail terminal	25.50	25.00
Terminal costs	6.00	6.00
Railage to Harare[2)]	12.00	17.45
Depot handling, distribution	5.00	5.00
Total	63.50	72.75
Current market price	70.00	70.00
Net back value	6.50	-2.75

1) according to information provided by the Wattle Company and the Forestry Commission.
2) at 28 tons per goods wagon for wattle and 19.3 tons for pine

Source: IPC calculations/ZR

Due to the higher bulk density of wattle and its lower extraction costs (clearfelling), only wattle stems exhibit a positive net back value on the Harare firewood market. In other words, opportunity costs arise for wattle only; pine wastes can be regarded as having an economic value of zero. If the same calculations are undertaken for wastes generated in the Inyanga plantations (transport costs to Mutare rail terminal: 10-15 Z$/ton), both types of wastes from this source are shown to have a positive net back value as firewood in the Harare market (wattle: Z$16.5/ton and pine: Z$7.25/ton).

Production Costs for Charcoal

4.2.4 The figures used in the following calculation of production costs are based on information provided by the timber growers in Manicaland province and on empirical data derived from charcoal production schemes in Malawi (Malawi Charcoal Project) and Kenya (Muka Mukuu Charcoal Scheme), both of which were operated under the supervision of IPC personnel. Based on the practical experience acquired in these projects, it can be concluded that small to medium size brick kilns - in particular, the Half Orange and Beehive designs - will also prove to be the least cost technology under the conditions to be found in the Manicaland plantations. As has already been pointed out, it would indeed be possible to bring charcoal production costs down from the overly high levels reported by the Wattle Company. There are three essential points here: First, internal transport distances must be kept short; second, optimal use must be made of the comparatively expensive labour force; and third, a high level of energy conversion efficiency must be maintained in the carbonization process (because of the comparatively high costs of the feedstock landed kiln site). These criteria can best be met if charcoal is produced in batteries of 6-12 Half Orange kilns operating in individual catchment areas comprising 100-200 ha of forest plantation land. If such production centres have been properly sited, the internal transport distance can be reduced to an average of 3.5-4.5 km.

4.2.5 The cost of feedstock extraction and preparation (collection of logs and branches, cutting them into sections 1.5-2.0 metres long and hauling them to the nearest forest road) can be assumed to average Z$6 per ton for wattle and Z$9 per ton for pine. The figure for pine is higher because of the wood's lower density and because thinnings are more difficult to extract than clearfellings. In its wood processing operations the Forestry Commission reports internal timber transport costs of 4.25 Z$ per m^3 of pinewood, and it can be assumed that the average distance involved is around 25 km (from felling site to sawmill). At a transport distance of less than 5 km the figure should be approx. Z$1.8 per m^3 or Z$3.80 per air dry ton (at an average air dry density of 475 kg/m^3). The Wattle Company currently reports internal transport costs of Z$3 per ton of wattle for its charcoal production scheme. Due to the large capacity of the kilns being used, the average transport distance is approximately 10 km. At an average distance of 4.5 km, costs should drop to roughly Z$ 2.5 per ton. Thus, feedstock costs landed kiln site work out at Z$8.5/air dry ton for wattle and Z$12.80/air dry ton for pine. Construction costs for a Half Orange kiln work out at Z$620 per unit. The relevant cost assumptions are summarized below in Table 4.6.

Table 4.6: **Construction Costs of Half Orange Kiln (15m³ capacity)**

	Z$
Material (2,500 fire bricks, 1m³ clay soil)	400
Labour (20 working days)	220
Tools, miscellaneous	100
Total	620

One kiln has a production capacity of 100 tpy of charcoal using pine and 160 tpy when charged with wattle. At an interest rate of 12% and a lifetime of 5 years, capital costs are 172 Z$ per annum, or Z$1.70 per ton of pine charcoal output and Z$1.10 per ton of wattle charcoal. In order to cover the cost of other necessary facilities and infrastructure development work at charcoal production sites (e.g. construction of storge sheds, water tanks and access roads), Z$1.0 must be added to the per-ton capital costs accounted for by the kiln. Kiln operation requires a manpower input of 2.0 man days per ton of wattle charcoal and 2.4 man days per ton of pine charcoal. At an average wage of Z$160 per month for unskilled labour, specific labour costs work out at Z$17.6 for wattle and Z$19.20 for pine charcoal (based on 20 working days per month). Packaging costs, currently Z$39 per ton of charcoal within the Wattle Company's production scheme, could be reduced to Z$27.50/t through recycling (costs of Z$2.5 per standard bag, 33 bags per ton and 2 recyclings). Table 4.7 summarizes the overall charcoal production costs for the two timber species in question.

Table 4.7: Summary of Charcoal Production Costs in Z$ per Ton of Charcoal at 30% Weight Based Conversion Efficiency

	Wattle	Pine
Feedstock Extraction	20.0	30.0
Feedstock transport	8.3	12.7
Kiln operation	19.7	21.9
Bagging	27.5	27.5
Opportunity costs	6.50	0
Total	82.0	92.1

Note that the above production cost figures make no allowance for overheads or profit. At least Z$15 per ton of charcoal would be required to cover administrative and management costs and to allow for a profit of approximately Z$5 per ton, giving minimum ex kiln costs of Z$97/t for wattle charcoal and Z$107/t for pine.

Supply Costs at Market Outlets

4.2.6 The closest market outlet for charcoal produced in the Chimanimani area is Mutare (180 km). Because the Wattle Company uses its own trucks to transport its charcoal output from the Chimanimani production sites to Mutare, the freight rate is a comparatively low Z$25 per ton (implied specific transport costs: Z$0.14 per ton and km). External, private transporters would charge up to Z$0.25/t/km for the same service (Z$45 per ton). Thus, it can be assumed that supply costs delivered Mutare would range between Z$122 and Z$142 per ton for wattle and between Z$132 and Z$152 per ton for pine charcoal. According to the Railway Tariff Book, railage for charcoal from Mutare to Harare would be Z$0.057/t/km. Including terminal handling costs of Z$3 per ton, overall rail transport costs for the 273 km trip to Harare would be 18.8 Z$ per ton, which means that the minimum supply costs free Harare terminal would be Z$140.8/t for wattle and Z$150.8/t for pine charcoal. These supply cost levels would apply only to customers with private rail sidings at their plants. If charcoal had to be transported by truck from the Harare rail terminal to a consumer within the town area, an average surcharge of approximately Z$5-10 per ton would have to be added. Distribution from a depot would add another Z$10 per ton. Table 4.8 compares the minimum supply costs for bagged charcoal free rail terminal in Zimbabwe's major industrial centres.

Table 4.8: **Minimum Supply Costs for Charcoal**1)

Market outlet	Rail distance (km)	Railage costs Z$/ton	Wattle Z$/ton	Pine Z$/ton
Harare	280	15.90	140.9	150.9
Kwekwe	510	24.69	149.7	159.9
Gweru	580	26.88	151.9	161.9
Bulawayo	760	32.47	157.5	167.5

1) Local Goods Tariff 11 plus 20%, minimum 15 tons per goods wagon. Supply costs include Z$3 per ton for terminal handling.

As can be seen from the above figures, railage costs are relatively low compared to the road transport costs involved in supplying the charcoal to the Mutare railway terminal. Distribution costs of Z$15-20/ton must be added to the above supply costs if it is assumed that consumers will be purchasing the fuel through a retail network.

4.3 Potential Market Outlets for Charcoal

4.3.1 As it is a homogeneous, high grade fuel, charcoal could theoretically be used by a broad spectrum of consumers ranging from private households and institutional kitchens to small, medium and large scale industrial operations. And indeed, experience in other countries has clearly established the technical feasibility of charcoal utilization in industrial steam generation, cement production, steel processing, lime burning, tobacco curing and tea drying. Most of these commercial applications are found in Zimbabwe as well. In the following, the market potential for charcoal in the household, industrial and agroindustrial sectors will be examined.

Charcoal as a Domestic Fuel

4.3.2 Charcoal is the major fuel for low and middle income households in a number of African countries, including Zimbabwe's neighbours. Average consumption figures are usually in the range of 400-600 kg per person per year. The fuel is used in simple metal stoves of various designs whose efficiency is approximately 20%. More efficient, improved stoves, which are now being marketed in a number of countries where real charcoal prices have been steadily increasing, exhibit an efficiency of 30-35%. As compared to an open wood fire or a simple traditional wood stove (10-15% efficiency), the use of charcoal - whether in a simple metal stove or in one of the improved stoves - results in a higher end use efficiency. If the energy losses that occur during the carbonization process are taken into account, the total energy efficiency of charcoal use works out at a maximum of 18% (assuming a conversion efficiency of 60% in the carbonization process and 30% efficiency in end use). However, there are other advantages involved in the utilization of charcoal as a domestic fuel. It is easy to handle, burns without smoke and is easy to store and transport. However, in most countries charcoal is not produced from the output of managed plantations or indigenous forests where wood extraction is strictly controlled. Traditional charcoal makers do not pay for the wood which they cut, nor are there any effective means of preventing the indiscriminate felling of trees for charcoal production. As a result, the traditional charcoal "industry" has been an important factor in the destruction of large forest areas in a number of places, and thus it would probably be unwise to promote the utilization of this fuel in the household sector in Zimbabwe. Once charcoal had been introduced on a large scale, the supply from waste wood generated in forest plantations might not be sufficient to meet what would surely be a steadily increasing demand. As a consequence, the uncontrolled cutting of indigenous forest wood for charcoal production could become a problem in Zimbabwe as well. Moreover, the promotion of charcoal as a household fuel might prove to be a step in the wrong direction from the standpoint of the government, which for some years now has been pursuing a policy of encouraging residential consumers to switch from firewood to coal and electricity. And, in fact, coal has already started to penetrate the urban household fuel market, albeit slowly. According to the Hwange Colliery, current coal sales to private households are in the range of 30,000 tpy. Another 40,000 tpy is sold to institutions and organizations which purchase coal in bulk and provide it to their employees for use as a domestic fuel. Although a number of constraints still limit the use of coal as an urban household fuel (comparatively expensive flued appliance required; coal is regarded as a dirty and sometimes dangerous fuel to use), it would appear worthwhile for the government to continue promoting the fuel. A low cost improved stove which has been designed by the Hwange Colliery (Z$74 per unit) may facilitate the introduction of coal as a household fuel. It must also be borne in mind here that although the appliance required for charcoal use would be less expensive than a coal stove, fuel costs for charcoal would be higher; indeed, for the average family, outlays for charcoal would be approximately double what they would have to pay to meet their energy needs with coal. Therefore, the household and institutional markets should not be viewed as a potential outlet for plantation charcoal.

4.3.3 If the goal is to supply the low income population of Harare with an environmentally safe fuel, it would make more sense to simply ship wastes from the Manicaland plantations to the high density areas of the city for use as firewood. Pinewood could be supplied at Z$ 72.75 per ton (excluding overheads and profit), and wattle could be landed at 63.50 Z$/ton. Although these supply costs would not allow for high profits, the introduction of wastes from the plantations could help to conserve indigenous forest stocks, which are currently being cut down illegally to supply the Harare market with fuelwood. Given the prevailing retail wood price of approx. Z$ 100 per ton, pine and wattle wastes could compete against hardwood, provided of course that they met with consumer acceptance. In any case, if plantation wastes were supplied as an alternative to hardwood, the Government would be able to more effectively enforce the ban on the sale of indigenous wood in the city area. It must be noted, however, that it is difficult to measure the economic value of wood wastes used as firewood in the Harare area. First, there is no land available in the vicinity of the city on which large scale fuelwood production could be initiated. Thus, the value of wastes from Manicaland plantations cannot be assessed in terms of the costs of fuelwood supply from peri-urban plantations. Second, a precise method for calculating the economic value of indigenous forest resources. I.e., there is only a general consensus that indigenous forests should be conserved for ecological reasons. Thus, the only approach which would not be completely conjectural in nature would be to compute the value of the wood on the basis of the long run average supply costs of what may be regarded as the closest substitute for forestry wastes - namely, plantation grown fuelwood produced in areas which are suitable for plantation forestry, i.e. the eastern highlands. With this method, however, one will obviously arrive at higher supply costs as compared to waste material because the overall supply costs of plantation fuelwood include direct production costs of approx. Z$ 20 per ton at the stump in addition to logging, transport and distribution costs.

4.3.4 One could, of course argue that it would inadvisable to promote the use of waste wood as a household fuel in Harare for several reasons. For one thing, it would be a comparatively expensive fuel for low income households (as indigenous hardwood is at present). The following table compares overall cooking energy costs for an average household in a high density area which is assumed to use either 5 kg of firewood per day or an equivalent amount of useful energy provided by one of the currently available alternatives. Assuming a net heating value of 15 MJ/kg for air dry firewood and an end use efficiency of 15% for wood use (without improved stove), the net cooking energy requirements of such a family would be 4,106 MJ/a (useful energy). At current retail prices for the various fuels and appliances in question, coal turns out to be the cheapest option. Regardless of whether it is combusted in the low cost brick-and-plate-stove or the all metal "Master Cooker", coal is cheaper than wood, which is only the third best option even when burnt in an improved stove. It should be noted here that the figures presented in the table on electricity use are somewhat misleading. In particular, the load limited tariff (Z$ 19.55 per month for 7.5 Amps) is much more attractive in practice than it would appear to be here. Indeed, if we assume that the energy requirements of our standard household double, total costs for power would remain constant, whereas costs for solid or liquid fuels would nearly double, thus making electricity a much more competitive option at higher energy demand levels. In addition, grid connection has significant advantages with respect to non-cooking energy supply: households can install electric lighting and operate radios, refrigerators and other appliances. Although both coal and electricity are attractive options not only financially but also in terms of their impact on consumers' overall standard of living, it cannot be assumed that urban households will switch to them immediately. It will take time to complete this move up the "energy ladder", and during the transition period there will still be a substantial demand for fuelwood. If this demand is not supplied from environmentally sound sources, the indiscriminate cutting of indigenous forest wood will continue.

Table 4.9: Comparison of Annual Household (Cooking) Energy Costs at Current Retail Fuel Prices

Fuel/appliance	Costs Appliance Z$/Unit	Lifetime years	Capital[1] Costs Z$/a	Heating Value MJ/kg	Efficiency %	Quantity required kg	Unit costs Z$/kg	Fuel costs Z$/a	Total annual energy costs Z$/a
Firewood/ no stove	0	-	0	15	15	1,825	0.10	182.5	182.5
Firewood/ improved stove	20	5	5.5	15	25	1,095	0.10	109.5	115.0
Charcoal[1]/ improved stove	20	5	5.5	30	30	456	0.28	127.7	133.2
Coal[2]/low cost stove	74	5	20.5	30	30	456	0.11	51.2	71.7
Coal/all metal stove	375	10	66.4	30	35	390	0.11	43.0	109.4
Paraffin[3]/ wick burner	14	2	8.3	43	40	238	0.74	176.3	184.6
Power metered[4]/ one plate	100	10	17.7	3.6/kWh	70	1,630 kWh	0.0715 per kWh	210.7	228.4
Power load limited/ one plate	100	10	17.7	3.6/kWh	70	1,630 kWh	19.55 per month	230.6	248.3

1) current charcoal retail price ex Wattle Co. depot (283 Z$ per ton)
2) at 10.8 Z$ per 90-kg bag for washed cobbles
3) at 0.6 per litre (0.74 Z$ per kg)
4) at ZESA tariffs effective 1st of October 1988, fixed charge for meter Z$ 7.85 per month and Z$ 19.55 per month for 7.5 A load limited

Agroindustrial Consumers

4.3.5 The most important agroindustrial fuel user is the flue cured tobacco industry. In 1986/87 Zimbabwe's total production of flue cured tobacco was 114,300 tons. According to the Tobacco Research Board of Zimbabwe, approximately 80% of the crop was cured with coal, which means that consumption by the industry as a whole was around 228,000 tpy (implied average specific fuel consumption: 2.5 kg/kg). The equipment used for tobacco curing ranges from highly efficient tunnel dryers and multiple circulation barns to conventional barns which are either fired via automatic underfeed stokers or simply hand stoked. Firewood is used primarily by smallholder tobacco growers and by commercial estates located in remote areas. The latter find that fuelwood (eucalyptus species) produced on their own plantations is the least cost fuel option for their drying operations, given the high transport costs that would be involved in the use of coal. Theoretically, charcoal could substitute for both coal and firewood in the curing equipment that is currently used. There is, however, little likelihood that charcoal would prove to be financially competitive. The commercial tobacco estates in Manicaland province currently pay Z$100-130 per landed ton of coal. Even an estate in the immediate vicinity of Mutare would have to pay a minimum of Z$140 per ton of charcoal. Estates which produce their own fuelwood report fuel supply costs (financial) in the range of Z$14-28 per air dry ton of wood (at 15 MJ/kg). Although these farms do not normally make allowance for opportunity costs (revenue that would accrue from the cultivation of other crops on the land that is currently used to grow fuelwood) when calculating their energy supply costs, it would be hard to convince them to switch to an external fuel supply option. In any case, given the costs involved in charcoal supply, they would consider coal to be the closest substitute for the firewood they currently use. Smallholder tobacco growers who are located in the vicinity of the charcoal source (Odzi area, approximately 200 km from Chimanimani) are the only other potential target group among the country's agroindustrial producers. For these smallholders, coal supply costs (consumption limited to only 5-10 tons year) tend to be high because of the small quantities involved and the remote location of their farms. However, charcoal supply would be expensive for the same reasons, and if the fuel had to be trucked in from Mutare, landed charcoal costs would significantly exceed the landed cost of coal for these consumers. Not even the Chimanimani area can be regarded as a potential charcoal market. Generally speaking, the closer a given consumer is located to the sources of wood, the more sense it will make for him to use firewood rather than charcoal.

With given unit costs for transport and given resource costs for firewood and charcoal, a break-even transport distance can be determined. The break-even transport distance is the distance at which the landed costs for a ton of charcoal are equal to the landed costs of the amount of firewood which contains the same energy as a ton of charcoal. The break-even transport distance is determined using the following formula:

$$D = \frac{R_c - R_w \cdot a}{(a \cdot U_w) - U_c} = 456 \text{ km for pine, } 360 \text{ km for wattle}$$

where

R_w = resource costs of wood (Z\$19.3/t for pine and Z\$21.5/t for wattle)

R_c = resource costs of charcoal (Z\$107/t for pine and Z\$97/t for wattle)

U_w = specific transport costs for wood (Z\$0.2/t/km)

U_c = specific transport costs for charcoal (Z\$0.25/t/km)

a = heating value correction factor (2)

(charcoal: 30 MJ/kg; firewood: 15 MJ/kg)

Thus, straight firewood consumption would be the cheaper alternative for any user located within a road transport distance of 360 km from the timber plantations. Assuming that charcoal can be used at a higher efficiency level as compared to firewood (heating value correction factor 3), the break even transport distance is still 93 km for wattle charcoal. In other words, a given agroindustrial or agricultural consumer who is located near Chimanimani must compare supply costs for coal (from Mutare) and supply costs for firewood from the Chimanimani plantations in order to determine which of these two fuels is the least cost option in his specific case.

In 1987 the Wattle Co. began selling firewood to tobacco estates in the Mutare area which had not been able to obtain an adequate supply of coal owing to shortages in rail transport capacity between Harare and Manicaland province. Railway capacity constraints continue to be a problem, and so far the company has sold approx. 1,500 tons of wattle stems to these agro-industrial consumers at a price of Z$ 30/t ex Mutare depot.

Industrial Coal Consumers

4.3.6 Coal consumption for steam generation in Zimbabwe is currently in the range of 350,000 tpy. Some 2,000 boilers are operated throughout the country, and the majority are standard three pass flame tube units equipped with chaingrate stokers (steam capacity: 2-6 tons per hour). There are also a small number of large water tube boilers (20 tons of steam per hour) and a few fixed grate, hand stoked flame tube boilers, the majority of which are operated on agricultural estates. Most of the standard boilers were supplied by NEI Cochrane, the leading boiler manufacturer in Zimbabwe. All of these boilers could theoretically be converted to charcoal firing, and the use of fuel blends (up to 50% charcoal) would clearly be feasible. Indeed, combustion trials performed in Malawi showed that no modifications or retrofits of plant equipment are necessary when charcoal/coal blends are used. However, charcoal would not be a competitive boiler fuel in Zimbabwe for obvious reasons. Even in Mutare, coal would be cheaper by far than charcoal. Mutare Board and Paper, for example, which operates 4 three ton per hour steam boilers (NEI Cochrane three pass flame tube units), currently pays only Z$55.47 per ton of washed pea size coal. Thus even if minimum supply costs for charcoal (Z$122/ton) are assumed, it would not make economic sense for the company to switch to charcoal, as charcoal use would be more than twice as expensive as coal firing.

In the early 1970s approximately 20 fuel oil fired boilers were installed at various industrial and agroindustrial facilities in Zimbabwe, and all of them are currently being run on diesel oil owing to the unavailability of heavy fuel oil (refinery in Mutare not operational). It would be technically feasible to convert these units to charcoal firing using NEI Cochrane gasifiers. However, such a retrofit would involve the same level of investment costs as the installation of a new standard coal boiler, and thus it cannot be regarded as a financially viable option. The same is true of Zimbabwe's brick makers and other manufacturers of ceramic products - i.e. at present no applications can be identified in this sector where charcoal would be able to compete against coal.

Coke Consumers

4.3.7 At present two companies in Zimbabwe produce coke: the Hwange Colliery and ZISCO. Almost all of ZISCO's output (approx. 430,000 tpy) is consumed in the company's own blast furnaces (iron ore reduction). The Hwange Colliery produces coke for export (Zambia, Zaire), for Zimbabwean ferrochrome producers, and for general use in other industries. In 1987/88 the Hwange Colliery produced a total of 81,000 tons of coke. The two major ferrochrome companies - ZIMASCO and ZIMALLOYS - use different smelting and reduction processes to produce end products which exhibit differing levels of sensitivity to the phosphorous and sulphur content of the coal and coke in the charge. ZIMASCO's main product is high carbon ferrochrome. ZIMASCO is currently meeting all of its coke requirements with imports from the RSA (60,000 tons in 1987) because the manufacture of high carbon ferrochrome requires a coke that is low in both phosphorous and sulphur, and the Hwange Colliery can supply only low phosphorous coke. The low carbon ferrochrome produced by ZIMALLOYS can tolerate a higher sulphur content and, as a result, it could theoretically meet all of its requirements with domestic coke. Indeed, of ZIMALLOYS' total coke consumption of 52,000 tons in 1987, 41,000 tons was supplied by the Hwange Colliery. And if the colliery had not been in the process of refurbishing its coke ovens, it could also have supplied the remaining 11,000 tons, which had to be imported from the RSA.

Table 4.10: **Specifications for Coke**

	P %	S %
Wankie Standard	0.03	1.2
Wankie Low P	0.015	1.1
Imported Coke	0.02	0.7

Source: Ferrochrome companies

4.3.8 The ferrochrome production process is comparatively simple: Oxide chrome ores are heated in the presence of carbon to a temperature at which the carbon supplied from coke and coal combines with the oxygen contained in the ore. Carbon monoxide and carbon gas are released, leaving a mixture of metal and mineral constituents (reducing process). In order to reduce viscosity and ensure that the molten mass will flow, either quartz or felsite is added as a flux. The standard blend fed into a ZIMASCO furnace would normally be:

Raw Material	tons per charge
Chrome ore	33.12
Coke	3.8
Coal	3.5
Felsite	1.8
Zimalloys Slag	3.0

The Zimalloys slag is added as a diluent which helps to control the sulphur content. The above mixture can be expected to yield an output of 13.5 tons of alloy. The raw materials are mixed and continuously fed into the top of the furnace. Three electrodes feed a constant electric current into the mixture, resulting in high temperatures which are conducive to the reducing process. The furnace is discharged from the bottom where a tap is opened approximately every 90 minutes. Molten metal and slag flow out from the furnace into chill moulds where the metal settles to the bottom and the lighter slag rises, forming a cap over the alloy. After 8 hours of cooling in the mould the alloy is removed, cooled further and finally broken, crushed and sorted. The quality of the final product is entirely dependent on the properties of the input materials. Five major constituents determine the grade of the alloy. The following table shows the specifications of the most common grades.

Table 4.11: Specifications of Chrome Alloys (%)

Constituent	Grade 6	Grade 7	Grade 8
Cr	66-69	66-69	63-66
Si	2.0	3.0	6.0
C	6.0	7.0	6.5
P	0.03	0.03	0.03
S	0.06	0.07	0.05

Source: ZIMASCO

As far as the level of P and S is concerned, charcoal could easily meet the standards required by the ferrochrome producers. However, in the reduction processes employed by the Zimbabwean companies, not only the chemical properties of the fuel are important. In order to ensure that the proper conditions are maintained during the reduction process, the fuel must also exhibit mechanical strength, i.e. it must not crush or exhibit a high friability when fed into the furnace with the raw materials. Therefore, pine and wattle charcoal, which are both comparatively friable, cannot be regarded as an ideal fuel for the ferrochrome process, even though they would be a financially attractive option. At present ZIMASCO imports low P, low S coke from the RSA for Z$224 per ton. Charcoal from Chimanimani could be supplied at Z$160-170/ton, and thus if it were used to substitute for imported coke, the company could save up to Z$64/t in fuel costs. Use of a 50% blend of charcoal and imported coke would result in financial savings for ZIMASCO in the range of Z$2 million per year, with annual foreign exchange expenditures dropping by approximately Z$6 million. In view of the potential savings that would accrue from such a partial fuel switch, there would seem to be a clear incentive for ZIMASCO to undertake a series of reducing trials at its plant using a 50% blend to assess the technical feasibility of charcoal/coke firing. The ZIMASCO management has expressed an interest in conducting reducing trials using various grades of charcoal as soon as the requisite production capacity is available. At present, world market prices and demand for ferro-alloys are so high that the plant is running at 100% capacity and no furnace capacity can be made available for experiments. Moreover, in view of the comparatively high risk involved in full scale production trials (every furnace charge which had to be scrapped because the product was of inferior quality would represent a loss of approx. Z$ 35,000), the company management would prefer to have some lab scale testing done before production trials are carried out. The lab trials could be performed in cooperation with the Institute of Mining Research (IMR), which has the equipment required for this kind of testing (electric arc furnaces).

4.3.9 Zimalloys Gweru intends to establish a new production line of special export grade ferrosilicon 75, and the company management is considering the utilization of charcoal as a reducing agent because the coke qualities that are currently available would not meet the requirements of the production process for this high grade alloy. At present Zimalloys only produces low grade ferrosilicon 75 for local consumption (ZISCO). Wankie coke is used as a reductant for this alloy, and, as a result, it has a rather high aluminium content (approx. 2%). The value of this product is not high enough (approx. Z$ 600 per ton) to make exportation feasible. Given Zimbabwe's remote location, transport alone would add approx. Z$ 350 per ton to the product's cost before it even reached the world market. Low aluminium FeSi 75, however, would command a price of approx. Z$ 1,200 per ton on the international market and is therefore seen as a much more attractive export option. There are two supply options for an appropriate reductant: charcoal from indigenous hardwood feedstock generated as a by-product of land clearing operations and pine and wattle charcoal from forestry wastes. Although the Kwekwe company (Pretorius Ltd.) that is involved in land clearing operations produces charcoal from mopane wood which exhibits a higher mechanical strength than either wattle or pine charcoal, Zimalloys has ruled out the first alternative. For one thing, the company's production potential is limited to approx. 20 - 30 tons a month, a quantity which would not be sufficient to meet Zimalloys' requirements. Furthermore, the inconsistent quality of the Kwekwe company's charcoal output (wide variations in fixed carbon content) makes it unsuitable for use in the production of export grade FeSi 75. Accordingly, Zimalloys has also expressed interest in the wattle/pine option and plans to conduct reducing trials using plantation charcoal in November 1988. However, the company's management expects the friability of the charcoal to cause problems. If too large a quantity of fines is fed into the furnace, the load may lose its permeability, resulting in the formation of carbides, which reduce the quality of the product. But if charcoal use proves to be technically feasible, the production of ferrosilicon 75 would absorb approximately 2,500 tpy.

Gasifiers

4.3.10 In terms of its market potential, the most promising application for plantation charcoal is the utilization of the fuel in gasifiers, where it would substitute for coke.

As far as technical feasibility is concerned, there is no doubt that charcoal is an ideal fuel for the Cochrane gasifiers. Two charcoal fired units have been in use in Zimbabwe since 1983 (Leyland and Bikita Minerals) and the operating experience to date demonstrates conclusively that the substitution of charcoal for coke considerably reduces operating and maintenance costs. The gasifier manufacturer estimates the lifetime of a charcoal fired gasifier at 15 years, compared with only 10 years for a coke fired unit. In particular, the abrasive properties of coke cause heavy mechanical wear and tear on all parts of the plant which come in contact with the fuel. Condensates and the gas itself are less corrosive if the gasifiers are fired with charcoal. However, in view of the charcoal prices currently charged by the Wattle Company, the operators of such equipment have little incentive to switch from coke to charcoal: the landed price in Harare is 283 Z$/ton, whereas coke peas are supplied for Z$131/ton.

In the following table, which compares overall operating costs for Cochrane gasifiers when fired with both coke and charcoal, three cases are distinguished. Case I represents the current situation in Harare. The units are fired with coke peas supplied by the gasifier manufacturer at Z$131 per ton. (Cochrane organizes the fuel supply for its customers and provides a graded fuel which meets the specifications of the gasifiers.) In Case II it is assumed that the units are fuelled with wattle charcoal, which currently sells for Z$283/ton delivered Harare (Wattle Company).

Table 4.12: **Comparison of Overall Gasifier Operating Costs**

Case	Size GJ/h	Capital Inv. Z$	Annuity Z$/a	Maint. Z$/a	Labour Z$/a	Fuel Z$/a	Power Z$/a	Total Z$/a
I	5	618,000	123,138	8,000	12,000	81,875	5,000	230,013
	10	1,000,000	199,252	10,400	15,600	163,750	6,500	395,502
II	5	618,000	123,138	4,000	12,000	176,875	5,000	321,013
	10	1,000,000	199,252	5,200	15,600	353,750	6,500	580,302
III	5	618,000	105,689	4,000	12,000	93,750	5,000	220,439
	10	1,000,000	171,017	5,200	15,600	187,500	6,500	385,817

In Case III it is also assumed that charcoal is used, but fuel supply costs are set at a minimum level of Z$150 per ton. Due to the longer lifetime of the charcoal fired unit (15 years as against 10 when fired with coke), capital costs are reduced significantly. As maintenance costs are also lower, total costs for the charcoal fired unit turn out to be slightly below the overall cost level for coke firing. Note that in this calculation minimum supply costs for charcoal are assumed. If landed charcoal costs at the gasifier are Z$160/ton or higher, coke proves to be the cheaper alternative. However, when assessing the economics of a fuel switch, the operator of a gasifier unit will consider not only the gross cost per unit of energy; annual equipment downtime, which is reduced by changing from coke to charcoal, also influences the overall cost level.

<u>Charcoal Export</u>

4.3.11 The volume of charcoal traded on global markets has increased steadily over the past decade, and the lion's share of world charcoal exports is absorbed by Western Europe - in particular, the UK, France, Germany, Denmark, Belgium, Holland and Norway - and the Arab countries. In 1987 the EEC countries imported approx. 200,000 tons of charcoal from various sources, most of which was supplied to the barbecue market. CIF values at European ports of entry currently range from 360 to 420 US$ per ton. Although sizable quantities of charcoal are still produced in EEC countries, imports now account for a substantial - and steadily increasing - share of all charcoal sales in the Community. Indeed, given the high feedstock and labour costs in Central and Northern Europe, even African and Latin American charcoal is often competitive on EEC markets. Supply sources for the European charcoal importing countries mentioned above include Portugal and Spain (60%), the Eastern Bloc countries (15%), South Africa (7%), and various South American countries (5%). Importers in Europe expect an increasing import volume from overseas sources even though high transport costs reduce profit margins for producers in Africa and South America.

However, in order to successfully market their charcoal in European countries, producers must not only be able to supply the commodity at competitive prices; even more important, they must also be able to meet high product quality standards. Standard specifications for barbecue charcoal have been introduced in France, Germany and the UK which cover, among other things, fixed carbon content (minimum: 80-85%), moisture content (maximum: 5-7%) and screening analysis (75-80% of all lumps must measure more than 20 mm). Charcoal supplied to European markets must also be packed in 3 ply paper bags which must display the weight and a label as well as safety instructions.

Normally, the packaging material is supplied by the European distributor (importer); only large scale producers use their own material and labels. Shipments also have to be made in standard containers (20 or 40 feet). Receiving importers insist on good quality, the maintenance of delivery schedules and the reliable provision of specified contract volumes.

Supply contracts below 2,000 tons per year are usually not acceptable because they result in excessively high administrative costs for the importer. Established, dependable suppliers are able to charge higher prices than "newcomers". Thus, if an overseas charcoal producer wishes to enter the EEC market, he must first of all convince an importer that he is reliable and capable of meeting the required specifications, and, second, he must make price concessions, i.e. he must quote lower CIF prices than his more established competitors.

4.3.12 In this market, the prospects for charcoal produced from wattle and pine wastes in Zimbabwe would be gloomy indeed. First, the quality of such charcoal would be inferior to that of the dense hardwood charcoal which is preferred for both barbecue use and industrial applications (bulk density of top grade hardwood charcoal: 350 kg/m^3; bulk density of wattle and pine charcoal: 200-240 kg/m^3). Second, transport costs (railage to Beira + maritime transport to European markets) would be so high that, in terms of CIF prices, Zimbabwean charcoal could not at present compete with imports from other non-EEC sources.

The following table summarizes the CIF costs for Zimbabwean charcoal under present conditions.

Table 4.13: CIF Value of Zimbabwean Charcoal at a European Port

	Z$/ton	US$/ton
Ex kiln	90	48
Transport Mutare	25	13
Packaging[1)] (5 kg bags)	160	86
Container transport[2)] to Beira	90	48
Shipment to Europe[3)]	462	250
TOTAL	827	445

1) at 0.8 Z$ per 5 kg bag
2) rate quoted by transport firms to the Wattle Company
3) quotation obtained from transport companies

It is obvious that charcoal exportation cannot be regarded as a financially viable option at present. The landed CIF costs alone (445 US$/ton) are higher than the current average market price for charcoal imports in EEC countries. Thus, even if a Zimbabwean producer were actually willing to charge no more than the above landed CIF price, which makes no allowance for either overheads or profits, his charcoal would still not be competitive on the world market - as the Wattle Co. was forced to conclude when it attempted to export charcoal in 1985/86.

5. Market Potential for Other Wood Based Products

5.1 Activated Carbon

5.1.1 Activated carbon is an industrial feedstock which is used in a number of production processes. Although it can be produced using both charcoal and mineral coal as a raw material, the lion's share of the activated carbon currently traded on the world market is made from charcoal. Two basic production processes can be distinguished: steam activation and chemical activation. In view of the large number of applications in which activated carbon is used, the substance is produced in a wide range of grades, each of which is designed to meet the requirements of a specific process. At present, Zimbabwe imports approx. 1,300 tons of activated carbon and related products (animal black) every year. In 1987 the average border prices for such commodities were in the range of Z$ 1,300 per ton, i.e. activated carbon can be regarded as a high value product.

Table 5.1: Activated Carbon Imports 1985 - 1987

Year	Tons	Value ('000 Z$)
1985	840	773
1986	1,276	1,503
1987 (Jan. - Oct.)	1,023	1,302

Source: CSO, Code 598920

5.1.2 Most of the activated carbon which is currently imported by Zimbabwean firms is used either in gold extraction or in food processing. The former application requires a product which exhibits a high mechanical strength and a high degree of activation. The ideal activated carbon for gold extraction (cyanide heap leaching process) is obtained from coconut shells which are first carbonized into charcoal and then steam activated. Although activated carbon which meets the requirements of the cyanide gold extraction process could also be produced from ordinary wood charcoal (i.e. from waste wood generated in the Manicaland plantations), it would only make sense to initiate the manufacture of wood based carbon if the coconut based product were no longer available. However, in view of the fact that a supply agreement was recently concluded between the Zimbabwean gold mining companies and Mozambican suppliers of coconut charcoal (coconut charcoal will be manufactured in the coastal region of Mozambique and supplied to Zimbabwe through the Beira Corridor), the market prospects for a wood based coconut carbon substitute are gloomy. The Zimbabwean gold mining companies have clearly stated that they will not switch to any other product as long as coconut carbon is readily available and can be supplied at an acceptable price.

5.1.3 Zimbabwean food processing companies also use activated carbon, although in smaller quantities than the gold industry. Willards Food, the country's largest food processing firm, currently imports approx. 600 kg per annum. The product is used to decolourize and deodorize wines, liquid pectin and fruit juices. Three different grades are involved - namely, CA1, B1 and C1e. The bulk of the activated carbon used in food processing is imported CA1 grade material supplied by NORIT, a Dutch firm.

CA1 is a wood based phosphoric acid activated carbon made specifically for wine decolourization. Through the application 75-200 grams of CA1 per hectolitre of wine, colour components which originate from plant pigments (tannin, carotenoids, chlorophyll and anthocyanidins) are eliminated via absorption. The other two grades of activated carbon are used in conventional filters where fruit juices and liquid pectin are deodorized and decolourized. Although Zimbabwean food processing companies would surely utilize a locally produced - and less expensive - substitute for the imported activated carbon if it were available, the quantities involved in these types of applications are currently too small to justify the development of a manufacturing capability. For example, an output of 1,000-2,000 tons per year is regarded as the minimum economic size for conventional steam activation plants. In other words, an activation plant would not be a financially viable undertaking unless sizable export markets were developed. However, the local demand for activated carbon may increase considerably in the near future. Willards plans to establish a new production line of hydrolysed vegetable proteins (HVPs). Substantial quantities of activated carbon will be required for the manufacture of these products, which must be thoroughly decolourized before they are spray dried.

5.1.4 Zimbabwe Sugar Refineries (ZSR) Ltd., which has production facilities in both Harare and Bulawayo, has already investigated the scope for employing activated carbon as a substitute for bone char, which is currently used as a filtering agent at both refineries. In particular, the production of liquid sugar - which ZSR would like to begin manufacturing and which is used mainly in the production of soft drinks - requires a degree of purification which can not be achieved using bone char. The accessible internal surface of the material, which determines the quality of the filtering agent, is comparativey small (see Table 5.2 for specifications), and thus it does not remove a sufficient quantity of impurities from the sugar. There are two options for producing a liquid sugar of the required quality: ion exchange and activated carbon. The former process is capital intensive, relatively sophisticated in nature, and it involves significant economies of scale. The use of activated carbon offers a higher degree of flexibility, capital investment would be comparativey small, and all required plant components could be manufactured by Zimbabwean engineering firms. Thus, ZSR regards activated carbon as the most promising option for the decolourization of liquid sugar.

Table 5.2: Specifications of Bone Char

Test	Char: New	Char: Good Stock	Char: Average Stock
1. Total surface OT/water at equilibrium (moles/g. char)	275	210	150
2. Readily accessible surface OT/water, ½ h. rate (moles/g. char)	240	160	120
3. Carbon surface CTAB/water at equilibrium (moles/g. char)	225	150	110
4. Readily accessible carbon surface CTAB/water, 3 h. rate (moles/g. char)	140	90	60
5. Carbon content C as CO_2 by oxidation at 620°C (%)	7-9	7-9	7-9
6. Carbon dispersity Test 4/Test 5, (moles CTAB/g. carbon)	2500	1700	1400
7. Hydroxyapatite activity DH test, elutable Ca^{++} (mN) (20 g./100 ml. distilled water, 1h.)	<2	2	3
8. pH of aqueous extract (on same samples as Test 7)	8.5-9.0	8.5-9.0	8.5-9.0
9. Lye Test Sulphide extracted in NaOH	0	0	0
10. Sulphate content SO_4 expressed as $CaSO_4$ % char	0.1	0.5-1.0	>1.0
11. Carbonate content CO_3 expressed as $CaCO_3$ % char	7-9	4-5	4-5
12. Liquor decolorization test % colour removal, Ca^{++} and liquor pH (20-30 g./100 ml. liquor at 75°C for 4 h.)	Comparative test		

Various samples of the material have already been lab tested by ZSR, and only one grade of imported wood based activated carbon yielded satisfactory results. ZSR has indicated that it will not consider initiating the production of highly decolourized liquid sugar unless an adequate supply of locally produced activated carbon is available which meets its specific requirements. According to ZSR's management, the firm's total annual demand would be in the range of 150-200 tons. However, even if annual activated carbon consumption in Zimbabwe were to increase by this amount, the resulting overall demand for wood based activated carbon would still be too small to justify the development of a full scale domestic production facility.

Activation Trials

5.1.5 In order to assess the technical feasibility of manufacturing activated carbon from waste based charcoal, a series of activation trials using wattle charcoal was carried out in the framework of this study. In cooperation with the Institute of Mining Research (University of Zimbabwe), a total of 60 samples were prepared using a small scale steam activation unit constructed by a member of the institute's research staff. A number of different batches of charcoal covering a range of four different lump sizes (± 5 mm, ± 4 mm, ± 2.5 mm, ± 1 mm) were activated, and each was processed at 3 different temperature levels (800, 900 and 1000°C). In order to produce the full range of 60 samples, each batch was run through the activation plant between one and five times. The samples were given to ZSR and Willards for lab testing. First tests performed by ZSR yielded promissing results: The batch which has been activated at 800°C removed 68% colour from the liquid sugar. This value lies very close to the 75% colour remoral which is the goal of ZSR for liquid sugar. The 75% value can most probably improved by further optimization. ZSR management has decided to pursue the issue and perform further trials in Cooperation with IMR.

5.2 Creosote, Wood Tar

5.2.1 The carbonization of one ton of dry wood yields approx. 200 kg of condensable gases. If low tech kilns are employed, these gases are simply released into the atmosphere. With more advanced kiln and retort processes, however, the condensable gases can be recovered in the form of a liquid by-product which contains acetic acid, methanol, phenolic compounds, aromatic hydrocarbons, paraffin, pitch and various fatty acids.[1] Although condensable compounds can be employed as a feedstock for a number of chemical processes and products, the easiest way to make productive use of the condensates is to utilize them to make creosote, a preservative agent for wood poles. At present, Zimbabwe's creosote demand (approx. 2,000 tons per year) is met by imports from the RSA, where the product is obtained as a by-product of coal liquefaction in the SASSOL plants. The landed costs are Z$ 750 per ton, and thus Zimbabwe's total annual import bill for creosote amounts to approx. 1.5 million Z$. Assuming that one of the secondary objectives of charcoal production was to make the country completely self-sufficient in cresote using carbonization by-products, then a charcoal production capacity of 15,000 tons per year would be required, with all condensable gases being recovered and processed into wood tar/creosote. However, this would involve a high level of capital investment (retort technology) and would necessitate the utilization of a centralized charcoal production concept, which would in turn significantly increase unit production costs for the fuel (high feedstock transport costs).

5.2.2 There is a much less expensive - and thus much more attractive - option for manufacturing a substitute for imported creosote, i.e. the utilization of the coal tar which is currently produced in the Hwange Colliery's coke ovens. 33 kg of coal tar are generated per ton of coal fed into the ovens. Tar extraction takes place in three stages: First, the off-gases are cooled by spraying them with a weak ammoniacal liquor. In a second step the gases are conveyed to a set of condensers where the lion's share of the tar is removed. The remaining tar is extracted in

---

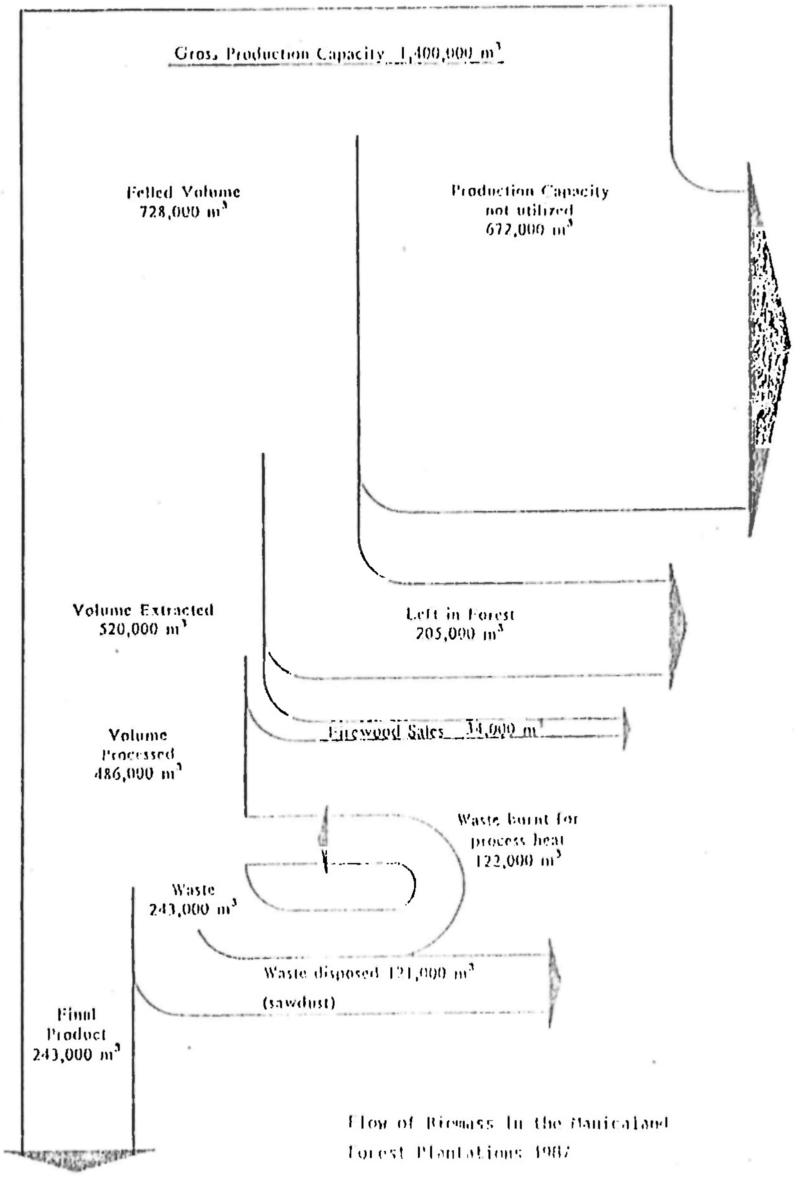
1) Non-condensable volatiles such as CO, CH_4 and C_2H_4 can also be recovered, but such gases are normally utilized for process heat generation.

electrostatic precipitators. This process yielded a total of 3,951 tons of tar in 1987/88, of which only 2,500 tons could be sold as road tar or coal tar fuel (TP 7 and TP 12). The balance had to be disposed of due to the lack of market outlets. Although an old plant which would produce a coal based pole preservation creosote is in place at the Hwange Colliery, the production of this commodity does not appear to be attractive enough to justify refurbishing the plant. Indeed, in terms of overall costs, it would be 40-50% cheaper to make creosote from coal tar (which is currently being sold at the extraordinarily low price of Z$ 47.00 per ton) than it would be to manufacture it from carbonization by-products. Thus, since it is clear that wood based creosote production would not be an economically viable option, future investigations in this area should focus on the utilization of coal tar - a by-product which is already being generated in substantial quantities in Zimbabwe.

6. Conclusions and Recommendations

6.1 Major Findings and Conclusions

6.1.1 The timber plantations in eastern Zimbabwe have a total area of 84,000 ha and a gross production potential of 1,400,000 solid m^3 of wood per annum. If these plantations were managed and harvested according to the timber producers' existing schedules, 935,000 m^3/a could be made available for sawmilling as well as pulp, pole, veneer and firewood production. In 1987 only 728,000 m^3 of roundwood was felled (52% of the gross production potential). Of this quantity, 486,000 m^3 went to processing plants, 34,000 m^3 was sold as firewood, and 205,000 m^3 was either left in the forest or disposed of by burning (see chart). Assuming that the timber industry in Zimbabwe makes better use of the existing production capacity of the plantations in the coming years and increases its output in accordance with the expected rise in demand for wood products, 277,000 m^3 or 118,000 air dry tons of waste material (thinnings, rejected clearfellings) will be generated per year. This represents a charcoal production potential of 41,200 tpy. The plantations of the Forestry Commission exhibit the largest waste recovery potential (24,000 tons of charcoal per year). The private timber companies could produce 11,700 t/a (Border Timbers) and 5,500 t/a (Wattle Company).



Flow of Biomass in the Manicaland Forest Plantations 1987

6.1.2 At present the utilization of forestry wastes is limited to firewood sales from the Inyanga Plantations, northern Manicaland (34,000 m³), charcoal production in the Chimanimani area (5,000 m³) and the use of sawmilling wastes and wattle stems as boiler fuel in timber processing plants (121,000 m³). The scope for charcoal utilization is currently restricted by two factors. First, both the production costs and the selling price of the charcoal supplied by the Wattle Company - the country's only major producer - are extremely high. At an ex depot price of Z$ 286 per metric ton, the charcoal cannot compete in the solid fuel market, which is dominated by comparatively cheap coal and coal products. Consequently, charcoal is currently used by only two industrial consumers (Leyland Mutare and Bikita Minerals), both of whom are willing to pay a premium for its specific fuel properties (low ash, low level of impurities, less abrasive than coke). A small share of the Wattle Co.'s output is marketed in 5-kg paper bags as barbecue fuel. Attempts by the company to develop export markets for wattle charcoal have failed due to the fuel's high FOB prices and its poor quality.

6.1.3 However, forestry wastes - at present a largely untapped biomass resource - could be utilized on a significantly larger scale. First, there is the option of substituting timber wastes for domestic firewood which is now being extracted from indigenous forests. In the Harare market a ton of firewood currently sells for Z$ 100 (retail price). At landed costs (depot) of Z$ 63.50 for wattle and Z$ 72.75 for pine wastes, the profit margin for the traditional wood traders would not be extremely attractive, but it would nonetheless be high enough to justify the promotion of this option. A fuel switch from indigenous hardwood to timber wastes would also contribute to the conservation of Zimbabwe's natural forest cover, a major objective of the Forestry Commission's policy. Second, charcoal could substitute for high grade coke (low sulphur, low phosphorous), which is used in Zimbabwe's ferrochrome industry. At present the ferrochrome producers import approx. 60,000 tons of coke per year from the RSA (CIF value: Z$ 224 per ton). Assuming that efficient production and transport systems were utilized, charcoal made from forestry wastes in Chimanimani could be landed in Gweru for 160 - 170 Z$/ton, thus providing a competitive alternative to imported coke. There are, however, certain technical problems which must be solved if charcoal is used as a substitute for coke in ferroalloy production. Due to its comparatively high friability, care must be taken when charging the electric arc furnaces with charcoal. If too large a quantity of fines is generated during handling and loading, there may be a decline in the quality of the end product. It should be noted here that the technical feasibility of producing various ferro-alloys using charcoal as a reductant has already been established. However, a series of laboratory and production trials would have to be carried out prior to the introduction of charcoal in this market segment. Since both ZIMALLOYS and ZIMASCO have expressed an interest in participating in such trials, this area should be prioritized in further project activities.

6.1.4 The substitution of charcoal for coke in gasifier applications would create a third market outlet for waste based fuel. Assuming that the existing potential for cost reductions in the production and transport of waste based charcoal can be exploited, and that the fuel can be landed for, say, Z$ 150/t in Harare, then the overall operating costs for Cochrane single stage gasifiers would be lower with charcoal than with coke, which is what the units are currently fired with. In other words, if a landed price of Z$ 150 per ton can be achieved in Harare, the switch to charcoal would make economic sense even though fuel costs would go up: the resulting increase in gasifier lifetime and decrease in maintenance costs would more than offset the rise in fuel outlays. Last but not least, a certain amount of charcoal could be used for the production of activated carbon. At present, all activated carbon, which is employed as a decolourizing and deodorizing agent in the food processing industry, has to be imported. All of the companies in Zimbabwe which use the commodity have expressed an interest in substituting locally manufactured carbon for the imported product.

6.1.5 The utilization of charcoal as a substitute for local coal cannot be regarded as a financially viable option. Landed coal prices are so low that additional efforts in this area would not be justified. The promotion of charcoal as a household fuel would also be inadvisable. Retail prices would be too high for households in high-density urban and rural areas. However, the supply of unprocessed wastes from the Manicaland plantations for use as firewood could be increased. (The Wattle Company is currently shipping a modest volume of firewood from its Inyanga plantations to Harare.) At landed costs in the range of Z$ 70 per ton, firewood from the Chimanimani area could compete in the Harare market with indigenous hardwood, which currently sells there for approx. Z$ 100 per ton. Over the next few years, the supply of forestry wastes from the eastern plantations could provide an environmentally safe substitute for firewood which is illegally extracted from natural forests. However, it would clearly be an interim solution rather than a long term strategic option. Over the long run, the pressure on the natural forests - which at present provide the resource base for household woodfuels in Zimbabwe - can only be reduced if the utilization of coal or smokeless coke is promoted on a large scale in the residential sector. A separate proposal for the combined production of smokeless coke and liquid fuels is presented in Annex 4 at the end of this report.

6.2 The Pilot Project

6.2.1 The results of the present study make it clear that the Government of Zimbabwe should continue to promote the increased utilization of forestry wastes. Both the production of charcoal and the marketing of unprocessed wastes for use as firewood are potentially viable strategies from both a financial and an economic standpoint. Consequently, it is recommended that a pilot project be implemented. Given the fact that ample quantities of raw materials are already available, and since there is no doubt as to the basic feasibility of selling wood and charcoal in existing segments of the Zimbabwean solid fuel market, it should not be necessary to launch a large scale, i.e. expensive, promotion programme in order to provide the impetus for commercial exploitation of these valuable but at present largely untapped biomass resources. In the course of executing the field research required for this study, the Consultants had numerous opportunities to talk with representatives of relevant private sector entities, and they expressed a clear interest in expanding their involvement in semi-industrial charcoal production on a larger scale and supplying a high grade fuel to specific segments of the industrial market. Nonetheless, it would appear both worthwhile and necessary to provide technical support to the relevant firms and institutions - in particular, the Forestry Commission, which is Zimbabwe's largest producer of waste and surplus wood - in the framework of a pilot project. The pilot activities described in the following sections were discussed with representatives of both the Energy Department and the Forestry Commission - and approved by them - in the course of the Consultants' field investigations. Both institutions emphasized that they would be interested in participating in such a project and continuing the practical work which was initiated in the framework of this study.

Objectives of the Pilot Project

6.2.2 The overall objective of the proposed pilot project is to create the prerequisites for the commercial utilization of waste wood from the Manicaland forest plantations. This will require the provision of technical assistance to the relevant organizations and their personnel will have to be given training in the utilization of efficient semi-industrial charcoal production techniques. In addition, empirical data on the production, transport, marketing and utilization of wood and charcoal by households and industrial users should be collected and analysed with a view to demonstrating the financial viability of fuel production from forestry wastes. In particular with respect to the utilization of charcoal as a substitute for imported coke in the manufacture of ferroalloys, a series of individual activities in the area of applied reserach will be required. One of the pilot project's other broad objectives will be to support - and provide advisory assistance to - the Zimbabwean Ministry of Energy, Water Resources and Development in the area of biomass resource management. This will be particularly important in terms of long-term policy development since the utilization of surplus biomass from the forestry plantations in Manicaland plantations will, in the Consultants' view, be a case in point: it will demonstrate how, with the help of a comprehensive analysis of the raw material supply situation and of the potential market for the various products in question, resources which are either not being exploited at all or not being exploited efficiently can be used to help stabilize the country's fuel markets. In future, the basic approach and design concept employed in the proposed pilot project could be used in programmes aimed at increasing the productive utilization of other raw materials, above all agro-industrial wastes.

Scope of Activities

6.2.3 The proposed pilot project should consist of four main components. They can presumably be implemented in a period of 6-8 months. The project executing agency should be the Energy Department; the individual measures will have to be carried out in close cooperation with the Forestry Commission, the Insitute for Mining Research (University of Zimbabwe) and relevant private sector entities. The Energy Department should focus on the overall coordination of the different individual measures, the collection and evaluation of the data yielded by the pilot project as well as the monitoring and supervision of the various specialized activities in the areas of fuel utilization and marketing. The Forestry Commission would be responsible above all for the implementation of the pilot charcoal production programme and the fuelwood extraction trials.

Fuelwood Extraction and Marketing

6.2.4 In view of the current market prices for firewood in Harare, it would clearly be feasible to substitute plantation wastes for illegally cut wood from natural forests. In the framework of the pilot project, unprocessed waste wood should be test marketed as a household fuel. This marketing trial would involve:

- Extraction and transport to Harare of pine wastes from the Chimanimani area including a detailed documentation of the costs incurred (altogether, at least 100 tons of wood should be test marketed);

- Supply of wood to traders operating in the high density areas of Harare for sale to retail customers and, in addition, the implementation of marketing trials by the project to assess both profit margins and the response of the end users;

- Identification of individual channels within the distribution network of the firewood trade which could handle retailing on a long term basis if the results of the trial are positive;

- Analysis of the response by the end users to the introduction of a fuel which, in its combustion properties, differs from the indigenous hardwood which has traditionally been used by urban household consumers.

The marketing trial for unprocessed waste wood will would conclude with an evaluation of the financial viability of this option, an estimate of the size of the potential retail market and an assessment of the acceptance level for the fuel among the consumers. If the results of these investigations are positive, a plan should be developed for commercializing the extraction and marketing of plantation wastes for use as firewood on the basis of licensing contracts. The Forestry Commission would grant the rights of utilization of forestry wastes from certain precisely defined areas to licensees. If the marketing trial should show that, when all supply and distribution costs are taken into account, a positive net back value is achieved, this amount - even though it may be quite small - should be collected from the licensees as a stumpage fee.

Pilot Charcoal Production

6.2.5 A pilot charcoal scheme should be established in a Forestry Commission plantation in the Chimanimani area. The camp should be utilized to provide technical training to local personnel and for the production of the charcoal which will be required for the industrial trials. The capacity of the pilot scheme should be approx. 1,000 tons per annum so that about 300-400 tons can be produced in the framework of the pilot project. The pilot scheme should focus on the utilization of pine wastes since they would be the most important feedstock supply source for expanded charcoal production operations in the future. As in the case of the marketing trial for firewood that was described above, all production, transport and distribution costs should be documented. The plantation management staff of the Forestry Commission should be responsible for carrying out the pilot production activities. During the pilot phase, however, the scope for transferring responsibility for the expansion of production to private licensees should be assessed. In addition to furnishing technical training to local personnel in charcoal making techniques, this pilot scheme would compete directly with the Wattle Co. i.e. the provision of an additional supply of charcoal - possibly at lower prices - could have a stimulative effect on the Zimbabwean charcoal market.

Reduction Trials

6.2.6 The ferroalloy industry represents the largest potential market for charcoal. In close cooperation with ZIMASCO (high carbon ferrochrome) and ZIMALLOYS (low Al ferrosilicon 75), both laboratory and production trials should be conducted using charcoal as a reductant. Initially, laboratory tests will have to be carried out in cooperation with the IMR in order to help answer certain basic questions with respect to friability, homogeneity of the reductant, permeability of the furnace charge, and losses through spontaneous combustion during furnace loading and charcoal handling. This lab testing phase will have to be implemented in close consultation with the potential consumers so that realistic test parameters can be defined which accurately reflect the specific demands and characteristics of practical applications. Following the completion of the lab tests, production-scale reduction trials should be conducted for both high carbon ferrochrome and low Al FeSi 75. Approx. 250 tons of pine and wattle charcoal will have to be made available for these trials, which should also involve a comparison of these two types of charcoal in order to document any possible differences in their suitability for use in reduction processes. Both the lab and the production trials should include the utilization of coke/charcoal blends (partial substitution). The reduction trials will conclude with a technical and financial evaluation of this option. Assuming that the results of this evaluation are positive, planning work for a subsequent expansion of the charcoal production capacity will have to be based on a precise estimate of the size of the potential market in the ferroalloy industry, and such an estimate would also have be prepared in the framework of the pilot project.

Follow Up Gasification and Activation Trials

6.2.7 Although the firewood and ferroalloy options must be given priority in terms of lab/production testing and trial marketing, the activities which were initiated in the framework of this study with respect to the utilization of charcoal in gasifiers and in the production of activated carbon should be continued. It is unclear whether an adequate supply of wattle charcoal could be guaranteed in the future (alternative utilization of wattle waste material as construction poles), and thus it would seem advisable to conduct a combustion trial with pine charcoal. This trial could be carried out either at Leyland Mutare or at the plant of the gasifier manufacturer, NEI Cochrane Engineering Ltd. With respect to marketing, the project should consult with the manufacturer in order to determine whether gasifier operators could be convinced to substitute charcoal for coke, assuming supply costs were lower than the Wattle Co.'s current charcoal prices. As regards activated carbon production, additional trials should be conducted in order to a) make available a larger quantity of the commodity for use in tests by potential users, and b) improve the quality of the activated carbon, which so far has not been satisfactory. Both the production of additional carbon for testing by users and the utilization trials themselves should be carried out in cooperation with the IMR. It will also be necessary to coordinate all measures with the two largest potential users (ZSR and Willards Food). Activities in this area will conclude with the preparation of precise estimates of the size of the potential market for locally manufactured activated carbon and an assessment of the financial viability of local production. Recommendations regarding the design and operation (annual output, process parameters) of a production plant for steam activated charcoal should also be presented.

Costs of the Pilot Project

6.2.8 Assuming a total implementation period of 8 months, the estimated costs of the pilot project work out at US$ 200,000. In the following, a detailed breakdown is provided:

		Z$
1.	Marketing Trial Firewood	
	- wood extraction and preparation	3,000
	- transport	2,500
	- storage in Harare	2,500
	Total	8,000
2.	Pilot Charcoal Production	
	- Construction of 15 kilns, storage facilities, water tanks	24,000
	- wood extraction and internal transport	6,000
	- labour force - charcoal camp	3,000
	- packaging material (bags)	15,000
	- charcoal transport road/rail	25,000
	- charcoal storage	3,000
	Total	76,000
3.	Reduction Trials	
	- Manpower IMR (technician and helper: 6 man months, scientist: 2 man months)	30,000
	- hardware and necessary material (electronic equipment, ores, chemicals)	25,000
	- lab testing, use of IMR facilities	5,000
	Total	60,000
4.	Gasification and Activation	
	- production of 300 kg of activated carbon	3,000
	- lab testing including chemicals, etc.	4,000
	- production trials - sugar, HVPs	3,000
	Total	10,000

5. Technical Assistance

- international consultant (charcoal and biomass expert): 6 man months	150,000
- local consultants (economist)	30,000
- travel expenses and allowances for staff of Zimbabwean executing agencies	10,000
- miscellaneous expenses and price contingencies	20,000
Total	210,000
Grand Total	Z$ 364,000 (US$ 200,000)

Annex I:

Area Statements of Timber Producers

I

Forestry Commission

Estate	Species (ha) Conifers	Wattle[1]	Gum	
Mtao/Mvuma	141	0	2,590	
Nyangui	1,910	0	0	
Erin	5,389	977	37	
Stapleford	3,976	0	140	
Maswera	1,660	0	17	
Cashel	2,484	0	0	
Tarka	4,446	8	30	
Chisengu	4,166	15	19	
Martin	3,159	1	2	
Gwendingwe	2,886	103	409	
Total	30,217	1,104	3,244	34,565
Rotation period (years)	30	N.A.	10	
MAI m^3/ha/year	17.5	N.A.	20	
Total volume used m^3/ha/year	8.7	-	15	
Total waste m^3/ha/year	8.8	-	5	
Total supply m^3/year	528,797		64,880	
Total waste m^3/year	265,909		16,220	

1) Wattle plantation not utilized

Border Timbers

Estate	Species (ha) Conifers	Wattle	Gum	
Charter	10,957	0	864	
Tilbury	7,958	0	1,092	
Imbeza	1,564	0	543	
Sheba	3,513	0	410	
Total	23,992	0	2,909	26,901
Rotation period (years)	25	N.A.	10	
MAI m^3/ha/year	19.0	N.A.	20	
Total MAI utilized m^3/ha/year	13.2	N.A.	16	
Total MAI waste m^3/ha/year	5.8	N.A.	4	
Total volume m^3/year	455,848	-	46,544	
Total volume wasted m^3/year	139,153	-	11,636	

Wattle Co.

Estate	Species (ha) Conifers	Wattle	Gum	
Nyanga	3,752	2,989	0	
Penhalonga	2,088	427	0	
Vumba	0	208	576	
Chimanimani	0	7,235	0	
Chipinge	0	1,940	0	
Mt. Selinda	0	359	0	
Total	5,840	13,158	576	19,574
Rotation period (years)	25	10	10	
MAI m^3/ha/year	17.0	8.6	25	
Total MAI utilized m^3/ha/year	15.5	8.0	20	
Total MAI waste m^3/ha/year	1.5	0.6	5	
Total volume supply m^3/year	99,280	113,158	14,400	
Total volume waste m^3/year	8,760	7,895	2,880	

Mutare Board and Paper

Estate	Species (ha) Conifers	Wattle	Gum	
Penhalonga	2,719	47	30	2,796
Rotation period (years)	14	10	10	
MAI m^3/ha/year	22	–	–	
Total MAI utilized m^3/ha/year	19.8	–	–	
Total MAI waste m^3/ha/year	2.2	–	–	
Total volume m^3/year	59,818	–	–	
Total volume waste m^3/year	5,981	–	–	

Annex II:

Persons Contacted During Mission

H.S. Makina	Director, Department of Energy Resources and Development
C.E. Chimombe	Assistant Director, Department of Energy Resources and Development
J. Chazingwa	Undersecretary, Department of Energy
M. Samunyay	Assistant Director, Department of Energy
T.T. Chikwada	Department of Energy
C. Marima	Department of Energy
M. Tirivanhu	Department of Energy
K.K. Kujinga	Divisional Manager, Forestry Commission
M. Chihambakwe	Manager State Forestry, Forestry Commission
J. Wiltshire	Projects Coordinator, Forestry Commission
D.S. Sitole	Principal, Zimbabwe College of Forestry, Forestry Commission
J. Phiri	Manager, Rural Forestry, Forestry Commission
L.T.V. Cousins	Director, Tobacco Research Board of Zimbabwe
I.C. Mlambo	Trade Promotion Secretary, Confederation of Zimbabwe Industries
D. Kewada	Consultant, Intercontact (PVT) Ltd., Harare
W.A. Ward	Managing Director, Institute for Development Programmes
C.H. Simuyemba	Consultant, Eastern and Southern African Management Institute
T. Mutiti	Marketing Manager, Wankie Colliery, Harare
P. Chigumira	Divisional Director, Cairns Holdings Limited, Harare
D.M. Mollat	Chief Executive, WS & G Hi-Tech, Harare
G. Lewis	Sales Manager, Border Timbers, Harare
M. van der Thyt	Manager, Border Timbers, Mutare
M. Smith	Industrial Manager, Wattle Company, Mutare

D. King	Divisional Manager, Wattle Company, Mutare
C.B. Thornton	Research and Development Director, Hunyani Paper and Packaging Ltd.
W.M. Ferris	Chief Executive, Zimbabwe Pulp and Paper Ltd., Harare
K.A. Viewing	Head, Institute of Mining Research, University of Zimbabwe
R. Fernandez	Senior Mineralogist, Institute of Mining Research, University of Zimbabwe
S. Tareka	Metallurgist, Institute of Mining Research, University of Zimbabwe
I. Hilton	Production Manager, Leyland Manufacturing Ltd., Mutare
R. Marsch	General Manager, Zimalloys Gweru
G.R. Smythe	Production Manager, Zimalloys Gweru
J. Akhurst	General Manager, ZIMASCO Kwekwe
U. Flown	Chief Chemist, Zimbabwe Sugar Refineries, Harare
P. Prinsloo	Agricultural Sales Manager, W.S. Craster Ltd., Harare
G.M. Strobel	Technical Manager, NEI Cochrane Engineering Ltd., Harare
M. Cochrane	Sales Director, NEI Cochrane Engineering Ltd., Harare

Annex III:

Participants of the Mutare Field Seminar and Work Program

Name	Organisation
C. Mavima	Ministry of Energy, Water and Development Dept. of Energy
R. Tirivanhu	Ministry of Energy, Water and Development Dept. of Energy
C. Sibanda	Forestry Commission
D. King	Wattle Company
K. Kujinga	Forestry Commission
C. Manyenyeni	Forestry Commission
R.S. Maya	Zimbabwe Institute of Development Studies
T.T. Chigwada	Department of Energy
P. Mutasa	Zimbabwe College of Forestry
C. Bhero	Zimbabwe College of Forestry

Work Program

11 August 1988

15.00	Travel Harare Mutare

12 August 1988

8.00 - 10.00	Opening Session, Discussion of Program
10.00 - 13.00	Training Construction Tools for Charcoal Kilns
14.00 - 17.00	Discussion: Charcoal as a Fuel in Zimbabwe, Objectives of Project

13 August 1988

8.00 - 13.00	Kiln Construction, Practical Training
14.00 - 17.00	Discussion ZIDS/IPC Draft Report: Resource Assessment

14 August 1988

8.00 - 13.00	Kiln Construction, Practical Training
14.00 - 17.00	Discussion ZIDS/IPC Draft Report: Feedstock Properties and Costs

15 August 1988

8.00 - 13.00	Kiln Construction, Practical Training
14.00 - 17.00	Discussion ZIDS/IPC Draft Report: Charcoal Market Outlets

16 August 1988

8.00 - 13.00	Kiln Construction, Operation and maintenance, Practical training
14.00 - 17.00	Discussion ZIDS/IPC Draft Report: Financial Viability of Charcoal Production, Alternative Uses of Waste Wood

17 August 1988

8.00 - 13.00	Practical Training Charcoal Production, Small Scale Industries
14.00 - 15.00	Final Session
15.00	Travel to Harare

Annex IV:

Smokeless Fuel for Zimbabwe

- Utilization of Large Coal Reserves
Northwest of Bulawayo -

Smokeless Fuel for Zimbabwe

- Utilization of the large coal resources Northwest of Bulawayo -

Introduction

The main fuel for domestic heating and also for many industrial and farming applications is still wood. This has resulted in a serious deforestation, especially around towns and in the more arid parts of the country. Therefore, it was proposed (and tried) to use coal instead. However, the Zimbabwean coals have high contents of volatile matter and contain much tar (even more so, if using briquetts) and sulphur. Therefore, they burn with much smoke, sooth, tarry-sulphurous vapours, causing severe air pollution.

It is therefore desirable to promote the use of a smokeless solid fuel.

If there is no low ash, low sulphur anthracite available, as it is the case in Zimbabwe, low temperature coke = semi-coke = char, made from high-volatile, weakly caking bituminous coals is the only other choice, according to broad experiences in Great Britain and Germany. High temperature coke - blast furnace or foundry coke, as produced by Hwange Colliery, is unsuitable for domestic use, because of its high ignition temperature. Furthermore, it is a scarce and expensive commodity which should be reserved for metallurgy, iron making and other industrial use.

We propose to produce smokeless fuel from the coals of the large and well explored deposit of Gwaai-Lubimbi at the railway and road Bulawayo - Hwange (about 230 km NNW Bulawayo).

Resource Basis

The Sebungwe Coal basin, North of Bulawayo, West of Kadoma, South of Lake Kariba contains a potential of several hundred billion t of suitable coals. Similar coal qualities are also encountered South of Bulawayo near the Limpopo River, but with much smaller resources. The Hwange basin coals are either higher in rank, typical coking coals, and therefore reserved for this purpose, or high in ash and inertinite, and not caking, as required for the production of good smokeless fuel. The Sabi basin in the far South carries mainly high ash semi-anthracites, only useable for power generation on site.

One of the most favourable coal areas is the Lumbibi-Gwaai sector of the Sebungwe basin:

- big coal body of 20 - 30 m extractable thickness;

- explored by several 100 boreholes, drilled during various campaigns between 1900 and 1976, and by test shafts, adits and experimental open pits;

- proven reserves of more than 500 million t with a typical stripping ratio of 1:1 or similar;

- several technological studies and pilot plant tests in Zimbabwe, Great Britain and Germany (1949 - 1977);

- existing infrastructure: railway, main road, HT-power, sufficient water, but low farming potential.

Figure 1: Central African Coal Belt
Sebungwe-Botswana-Waterberg Basin West of Bulawayo

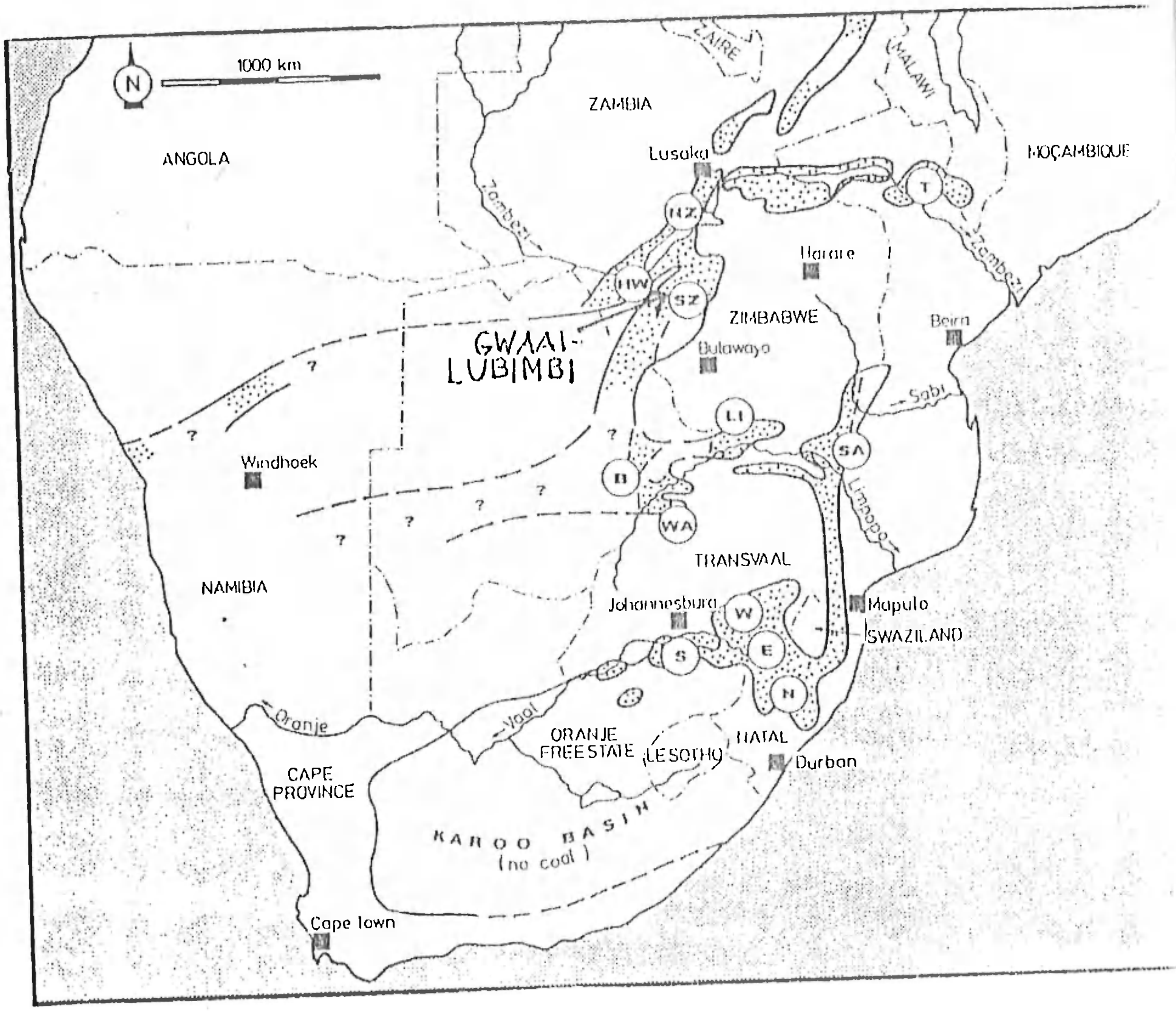
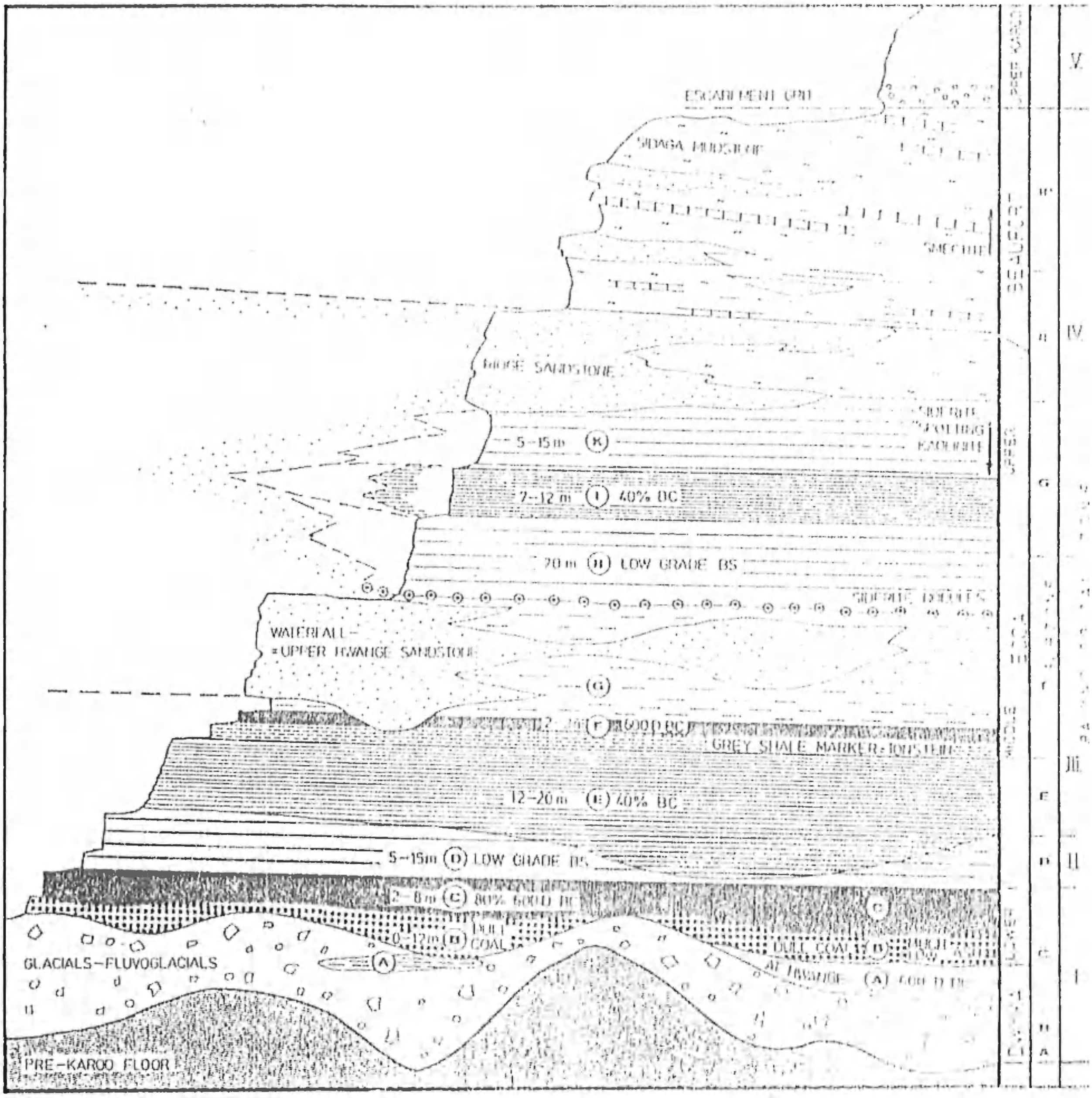


Figure 2: **Diagrammatic Section Through the Coal Bearing Ecca Series at Gwaai-Lubimbi**
BC-banded coal, BS-bituminous shale



The above diagram shows the composition of the coal body. We propose to mine the layers C - F, where close to surface, i.e. where G - K, the sandstones and higher strata are eroded. C (2 - 8 m) is a coal seam in the strict sense, but especially E and F contain many layers and lenses (each 5 cm - 3 m thick) of low ash "banded coal" intercalated in bituminous, fuel-rich shale. The "Gray Shale Marker" (a valuable kaolin clay) and (where low grade) D would be discarded.

In this way, a coal-shale mixture of 50% caking coal (BC) and 40% bituminous shale (+10% low grade "waste") could be mined as plant feed.

If seam C only would be mined, only 20% of the total (pure) coal could be recovered!

Proposed Process

The proposed process has been designed on the basis of experimental and pilot plant work and using industrial experiences in Germany and Scotland. Involved were Industrial Development Corp. Zimbabwe, Lurgi, Didier, Bergbau-Forschung and Dr. C. Otto of Germany. There are no unit operations proposed, which have not been used successfully in the past and appropriate technology has been applied to minimize any risk factors.

- Mining: open cast, selective, discarding low grade material.

- Feed preparation: removal of visible "stones", screening of duff (0 - 3 mm) to be used as boiler fuel (process steam).

- Retorting: low temperature carbonization (550 °C) in vertical chamber ovens (standard design in Germany), indirect firing with gas, strong flushing steam. During this process, gas and oil components are removed from coal and shale; the caking purer coals are swelling, resulting in a porous, light-weight semi-coke or char; the shales loose most of the combustible substance = heavy spent shale.

- Condensation - gas treatment - synthesis - distillation - refining: condensation of vapours, heavy and light oils, LPG, tail gas. Gas cleaning (S-removal), use for in-plant heating. Distillation and refining to produce motor fuel (gasoline, diesel), some fuel oil, road tar, LPG and phenols. Perhaps, production of low sulphur electrode coke.

- Preparation of smokeless fuel: cooling of oven discharge, (light) crushing, separation of low ash char (floating on water) which is the smokeless fuel, and heavy high ash spent shale.

- Ancilliary plant: steam boilers, gas producers, effluent treatment, workshop, laboratory, administration, social amenities.

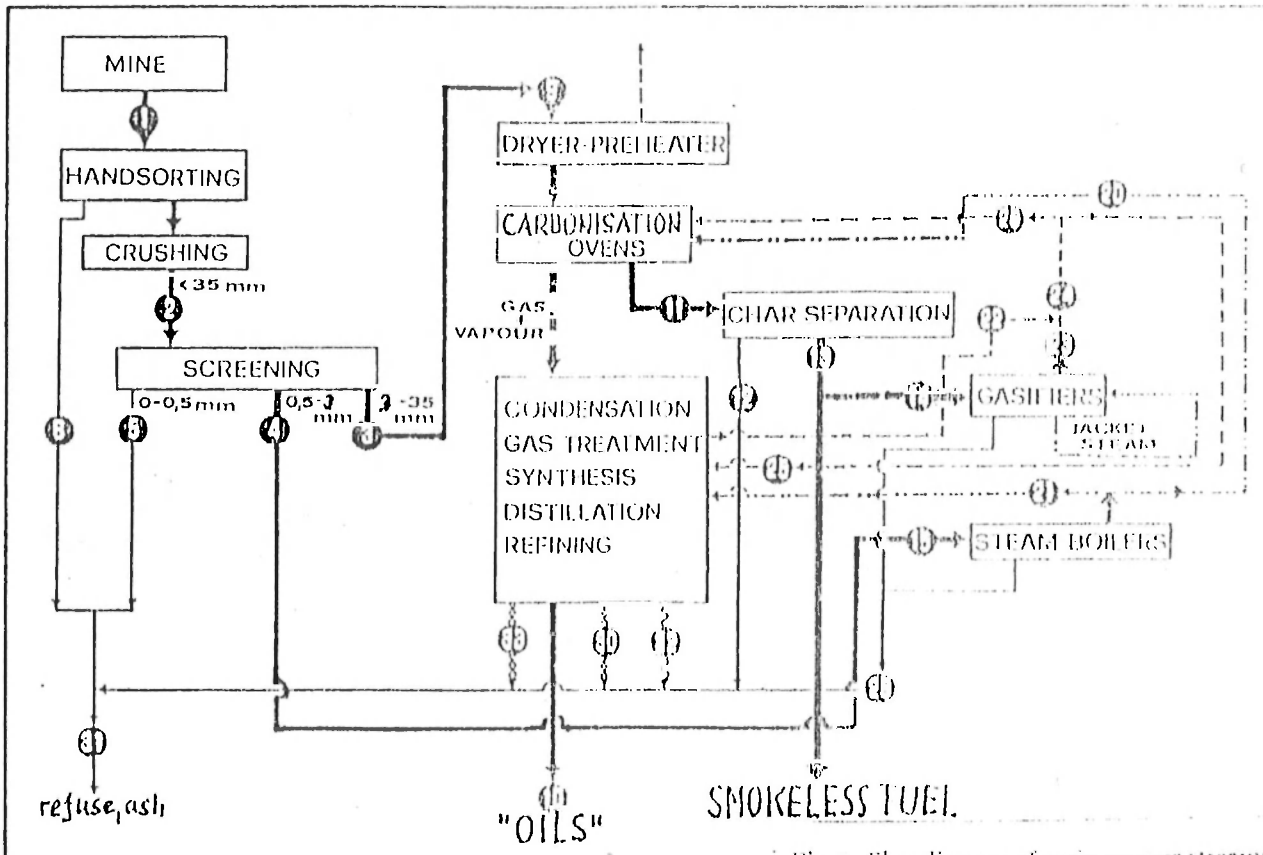


Fig. 3. Flowdiagram of main process stream

Remarks: It was found to be much more effective and cheaper to separate char and spent shale after retorting, than in the raw state, where a proper heavy media coal washery would be required. The extraction of oil and gas from otherwise discarded shales is an extra bonus, and the presence of pieces of heavy, heat conducting shale did improve oven performance, also avoiding "hang-ups".

Expected Recovery of a Model Case:

Run-of-Mine (ROM) to plant (shale-coal mix)	500,000 tpa
(internal waste/inter burden	300 - 400,000 tpa)
(overburden, soil, loose rock	300,000 tpa)
discarded (sorted "stone")	50,000 tpa
duff 0-3 mm, boiler feed	30,000 tpa
oven feed (53 tph = 2 or 3 oven blocks)	420,000 tpa
motor fuel, LPG, oil, road tar ("liquids")	32,000 tpa
gas for in-plant use	23,000 tpa
other condensate (water etc.)	8,000 tpa
oven discharge	357,000 tpa
separator sink = spent shale	234,000 tpa
smokeless fuel	120,000 tpa

Even in times of low international oil prices, the revenue from liquids will cover the major part of costs, as mining is quite simple. Therefore, the price of smokeless fuel is expected to be competitive.

The investments for such a plant, with mines etc. are in the order of US$ 10-25 million. Substantial portions of equipment, buildings and civil work can be made in Zimbabwe, often using local raw materials.

Proposal, how to proceed:

Phase 1: collection and re-assessment of data of previous investigations (available partly in Zimbabwe, partly in Europe), literature study, preliminary plant design study, pre-feasibility study

Phase 2: a. limited laboratory and bench test work in Germany as basis for the design of a pilot plant

b. building of a pilot plant, producing enough smokeless fuel (say 5-10 t per month) for acceptability and marketing tests and for larger scale refining etc. tests with the liquid product

c. acceptability and marketing test

Phase 3: On the results of phase 2, final mine and plant design and full feasibility study

Phase 4: design and building of a production plant, perhaps modular (a. 40,000 tpa, b. 80,000 tpa, c. 120,000 tpa etc.)