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The Malawi Charcoal Project Experience and Lessons

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THE MALAWI CHARCOAL PROJECT

EXPERIENCE AND LESSONS

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ABSTRACT

This paper draws together the experience the Malawi Charcoal Project which was initiated in late 1986, has gained until mid-1989. With a total installed capacity of 9,500 tons per year, the Project not only is the largest semi-industrial charcoal production program which has been implemented in SubSaharan Africa to date, but also has gathered a comprehensive set of data on various matters that similar activities would have to cope with.

A unique feature of the Project is that its feedstock is provided by softwood wastes generated on large government plantations. Given this unusual resource base and its location, the Project had to seek for new solutions regarding the logistics and organizational set-up of production schemes, the choice of carbonization technologies, and the marketing of a product which, in terms of primary and secondary fuel properties, has little in common with traditional hardwood charcoal. Also, the Project had to come to terms with disadvantages at which softwood charcoal is placed due to large transport distances and handling difficulties.

While softwood charcoal can be used by households for cooking, combustion trials conducted in the industrial and agroindustrial sector have shown that there is an additional market potential in non-household applications. Particularly promising are the test results from the tobacco curing industry where the use of softwood charcoal, rather than fuelwood, helps improve the quality of cured tobacco.

All in all, the Project has demonstrated that softwood charcoal in many instances is a technically feasible and economically viable alternative to fuelwood and/or coal. However, additional marketing initiatives and a stronger policy support will be required to foster a wider use of softwood charcoal.

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List of Abbreviations

cif	=	cost, insurance, freight
FD	=	Forestry Department
ha	=	hectare
kg	=	kilogram
mcwb	=	moisture content wet basis
MJ	=	megajoule
MK	=	Malawi Kwacha (mid 1989: 1 MK = 0.4 US$)
m^3	=	solid cubic metre
SFC	=	specific fuel consumption
sm^3	=	stacked cubic metre
t	=	metric ton
tpy	=	(metric) tons per year

1. Introduction

The Malawi Charcoal Project was initiated in late 1986 when the Malawi Government and the World Bank agreed to undertake an action-research project on the viability of charcoal production from wood wastes generated on government forest plantations.

The idea underlying the project was that charcoal made from wood wastes could substitute for woodfuels supplied from customary land and, thus, reduce the gap between sustainable woodfuel supply and demand. Another role charcoal was hoped to play was that of an economically attractive substitute for imported and domestic coal.

The Pilot Phase of the project which was carried out between October 1986 and January 1988 established convincing evidence on the technical feasibility of converting softwood residues into high-quality charcoal. It also identified potential market outlets in the residential, industrial, and agro-industrial sector and concluded that the prospective demand for softwood charcoal could be met in an economically viable and environmentally sound manner. What remained to be accomplished was the formidable task of commercializing all operations involved in the manufacture and distribution of the new fuel, while at the same time creating both the administrative framework and the policy instruments that would be required to effectively integrate its production and utilization into a national energy supply strategy.

Therefore, the decision was made to discontinue financing the activities from the Wood Industries Restructuring Credit and embark on a commercialization phase as a special component of the Energy I Project which was launched in 1989 (World Bank, 1989). The commercialization phase which was funded out of advances for project preparation granted by the World Bank ended in August 1989, with mixed success. Of the total installed charcoal production capacity, 3,000 tpy have been contracted out to the private sector, with the balance of 6,500 tpy operating under a treasury fund account. While the tobacco curing industry is expected to purchase about 2,500 tons of charcoal in the 1989/90 curing season, and Portland Cement has agreed to take delivery of charcoal fines at an initial rate of 200 tons per month, only a small fraction of the output finds its way to household markets. Moreover, a comprehensive national solid fuel supply strategy with charcoal from plantation-derived waste wood as an integral component still needs to be developed and implemented. Thus, further efforts have to be made to consolidate and upgrade the achievements of the project. However, with the Malawi Charcoal Project now being under way for almost three years, it may be the right time to draw together the project experience and findings and to pinpoint the lessons which can be learned from the activities carried out to date. There is a variety of features Malawi has in common with other Sub-Saharan countries, such as the heavy reliance on woodfuels and the environmental threats posed by a degrading natural resource base. But Malawi's situation is also unique in several respects so that the approach the Charcoal Project has followed may not be applicable to other countries. Anyhow, a great deal of experience the Project has made is in itself worth telling, and much of the

knowledge that has been acquired in the course of implementing the Project may be relevant to similar undertakings in Sub-Saharan Africa.

The present report summarized the technical performance of the Project, reconsiders the institutional/organizational arrangements it has faced or created, provides an overview of the potential markets for softwood charcoal and the attempts made to penetrate these markets, assesses the constraints on softwood charcoal use in the residential, industrial and agroindustrial sectors, and reviews the prospects and objectives the Project has aspired to meet. Various insights gained and conclusions drawn from the success stories and failures the Project has experienced may help enhance similar activities in the area of charcoal production and marketing which are underway or envisaged in other developing countries.

2 Charcoal Production from Waste Wood

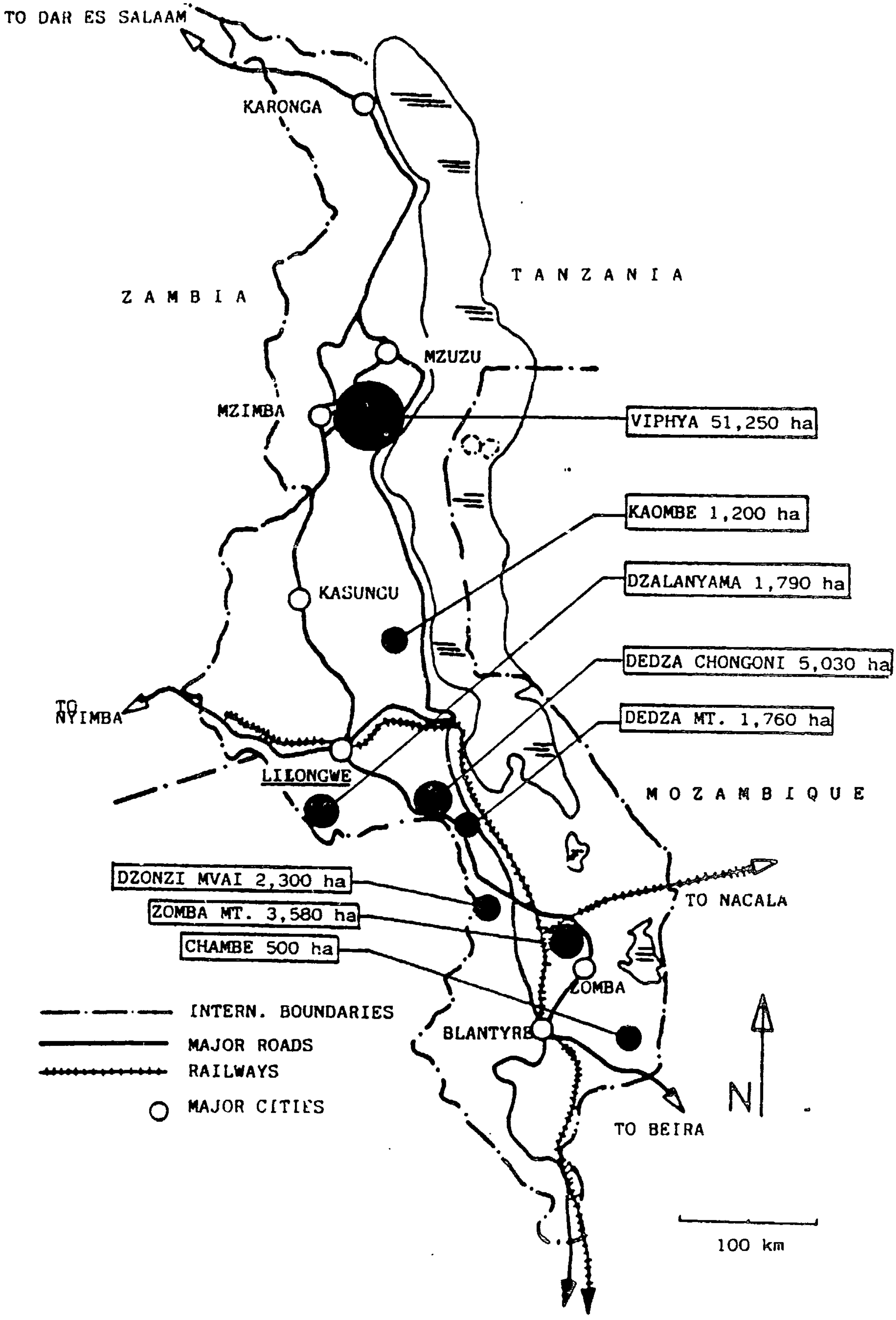
2.1 The Resource Base

A unique feature of the Malawi Charcoal Project is that its feedstock comes from large, underutilized government timber plantations. Altogether, these plantations cover a total of about 90,000 ha. and are located throughout the country (see Figure 1.1). More than 80% of the publicly managed industrial forest areas are covered with softwood pine species, mainly pinus patula.

By far the largest plantation is the Viphya forest (53,250 ha.), the stands of which are almost entirely composed of softwood species. Planting activities started in the early 1950s and discontinued by 1983. Due to economic constraints the initial idea of using the Viphya resources as a feedstock for pulp/paper production never materialized. The only outlet for Viphya wood is a recently constructed sawmill and plywood factory (Viply) served by a concession area of 9,000 ha.

Under the premise that the entire Viphya plantation eventually can be put into productive use, government policy has -and still is - to preserve the resource base through proper silvicultural treatment. Given the age structure of the stands, such a program would be feasible for another 12 to 15 years, resulting in a steady flow of thinnings of about 130,000 tpy. Additional waste wood will be generated on the Viply concession area and from unavoidable clearfellings of overmature stands. Altogether the plantation can be expected to annually supply a minimum of 200,000 tons of non-marketable softwood over a period of at least 12 years.

Figure 1.1: Major Softwood Plantations



If the country's other timber plantations are taken into account, the total volume of non-marketable softwood from thinnings and sanitary clearfellings may prove as high as 390,000 tpy (see Table 2.1). To put this figure into perspective, it suffices to note that the sustained yield from customary land is estimated at 1.5 million tpy, whereas the sustained yield from existing woodfuel plantations may be around 40,000 tpy.

Table 2.1: Estimated Waste Wood from Non Fuelwood Plantations (tpy) */

	Viphya	Chambe	Others	Total
Low Case	200,000	3,500	27,500	231,000
High Case	275,000	7,000	105,000	387,000

*/ Available over a period of at least 12 years.

Source: IPC (1988)

If the available feedstock were converted into charcoal on the basis of brick kiln technologies used by the Project, the potential charcoal output would range between 72,000 tpy (low case) and 120,000 tpy (high case). For comparison, current industry demand for coal works out at 40,000 tpy, while urban household charcoal consumption is estimated at 50,000 tpy. Clearly, there is no a-priori reason to carbonize the total waste wood generated on government plantations (In some locations it would be more economic to use at least part of the resources as fuelwood [1]). Nor would it be feasible to immediately embark on a large-scale charcoal production program. What the figures show, however, is that there exists a large, untapped, and hitherto neglected biomass resource base that could be exploited:

- to redress imbalances in woodfuel demand and supply,
- to reduce the level of coal imports, or
- to lower the rate at which domestic coal reserves are extracted. (At the current output of 30,000 tpy, the Kaziwiziwi/Mchenga deposits are likely to be exhausted within the next five to six years).

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1 For instance, at current costs the breakeven transport distance for Viphya charcoal varies between 100 km and 170 km, depending on the differential between the efficiency of charcoal and fuelwood use.

According to government policy objectives, highest priority should be given to the first option. Even though a comprehensive biomass inventory has yet to be prepared, there are reasonably accurate figures available indicating that the currently prevailing level of woodfuel demand cannot be met on a sustainable basis. As is shown in Table 2.2, the potential for sustainable woodfuel supply lies in the vicinity of 5 million m^3, while overall demand is estimated to range between 8 and 10 million m^3 per year. With total biomass stocks amounting to more than 300 million m^3, Malawi's woodfuel resource gap is probably not as alarming as in other African countries; but this does not relieve policy makers of the need for mitigating action. More importantly, while approximately 50% of the sustainable supply is located in the northern region, woodfuel demand is concentrated in the central and southern parts of the country. Thus, in closing the woodfuel resource gap, it becomes a major task to channel surplus wood from the north to deficit areas in the south. Clearly, in order to stem a further detoriation of the country's biomass resource base, a wide range of initiatives can and should be taken (and already are underway), ranging from improved woodland management to smallholder afforestation programs. There is, however, no immediate alternative to the option of supplying charcoal from government plantations: Waste and surplus wood generated on government timber plantations is the only additional source of woodfuel which is readily available; and since the lion's share of this resource base is located far away from major market outlets, its conversion into charcoal becomes an economic imperative (which not necessarily implies that this option is economic).

2.2 Feedstock Valuation

With the commissioning of the Project there arose an intense debate over the economic value that should be attached to the feedstock used for charcoal production. Different concepts and interests affected the discussions. As far as the government was concerned, pressing revenue needs were advanced in favor of high stumpage fees. But what would be the warranted level of fees, and how should they be implemented? Energy planners raised the question of whether feedstock valuation should be aligned with the replacement-cost principle. Policy makers, on the other hand, argued for valuation schemes that conform with uniform woodfuel pricing rules applied throughout the country. Agreement was finally reached on the Project's proposal to determine stumpage fees on the basis of net-back considerations. The rationale underlying this decision is as follows: At Viphya, where the charcoal production activities are concentrated, as well as on other government plantations, the economic value of thinnings and sanitary clearfellings should be inferred from their potential use as woodfuel, since alternative uses (e.g. methanol production) are economically less attractive (IPC, 1988, Chapter 10). In fact, in the absence of the woodfuel option the price waste wood could command would be zero, if not negative (since silvicultural treatment incurs costs that cannot be recovered).

Table 2.2: Woodfuel Potential Malawi, 1988 [a]

Source	Region Northern	Central	Southern	Total
Forest Reserves	400,000	414,000	258,000	1,072,000
Customary Land	1,640,000	730,000	250,000	2,620,000
Private Forest plantations	-	105,000	153,000	258,000
Subtotal	2,040,000	1,249,000	661,000	3,950,000
Government Plantations	643,000	231,000	192,000	1,066,00
Total	2,683,000	1,480,000	853,000	5,016,000

a/ m^3 per annum. In the case of forest reserves, private forest plantations and customary land, the potential is equal to the estimated sustained yield. For Government plantations the potential covers thinnings and sanitory clearfellings (low case), plus the sustained yield from fuelwood and non-timber plantations (about 70,000 m^3). Not included are agricultural residues and wastewood from timber processing.

Source: IPC (1988a)

Replacement-cost considerations, on the other hand, have been dismissed because the plantations are designed and run as timber, plywood or woodpulp production schemes with thinnings as a by-product. The cost of replacing thinnings with plantation-grown fuelwood would only matter if the decision were made to abandon the currently prevailing management regimes. Also, the imposition of gazetted stumpage rates which the Forestry Department uniformly applies to fuelwood put into commercial uses would make little sense, because the yardstick for fuelwood production schemes, in terms of which these rates are defined, does not even remotely resemble the conditions under which fuelwood could be grown at a location like Viphya.

So the Project advisors have proposed to derive the stumpage fees from the sales revenues borne by woodfuel markets, i.e. to net the price charcoal commands at major market outlets back to the stump. Unfortunately, charcoal markets are not only spatially distinct; they also differ in terms of prices at which charcoal is traded and sold. In particular, prices tend to be highest in Blantyre, which not only accounts for 60% of overall urban household consumption of hardwood charcoal (and, in addition, is in the center of potential industrial charcoal users), but also is most distant from the Viphya plantation as the major source of softwood charcoal. Therefore, the Project Management has applied as pricing principle a kind of minimum welfare requirement, according to which in Blantyre the landed costs of softwood charcoal coming from Viphya should not exceed the price at which hardwood charcoal can be obtained at the wholesale level.[2] Given this price cap provision, the stumpage fees levied on the wood equivalent of, say, one ton of charcoal delivered to Blantyre should be equal to the value charcoal commands on the stump after the costs of charcoal production (plus overheads and profits) and the expenditures for charcoal transport/handling are netted out. One advantage this formula has is that adjustments in the level of stumpage fees are only required if

-- the Blantyre price cap changes while the charcoal production and transport costs remain constant, and/or

-- there is a change in charcoal production and transport costs the price cap does not replicate.

This advantage, however, comes with the problem that some kind of reviewing procedure needs to be established in order to ascertain whether the level of stumpage fees fixed in the past continues to be consistent with both the costs of charcoal supply and the wholesale prices prevailing in Blantyre. In particular, there is no single wholesale price that clears the market. Rather, wholesale prices vary within some range, and this price range may widen/narrow or move upwards/downwards. Moreover, since charcoal is a potential substitute for coal (at least in industrial uses), the relationship between the landed costs of coal and (softwood) charcoal matters as well. In practice, though, the proposed stumpage fee formula would have been less difficult to apply than these

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2 From a statutory point of view, most of the hardwood charcoal entering urban markets is "illegal" since it evades the gazetted stumpage tax levied on wood coming from customary land. In this respect, the minimum welfare requirement implies that consumers switching from hardwood to softwood charcoal should not be worse off. For all practical purposes, however, the requirement means that softwood charcoal should not price itself out of the Blantyre market.

problems suggest. (Note that stumpage fees have not yet been collected since so far the responsibility for the charcoal operations has been with the Forestry Department).

As is shown in Table 2.3, in early 1988 the stumpage fees would have worked out at MK 10 per ton of Viphya charcoal (which is equivalent to MK 0.75 per sm3 of pinewood thinnings), relative to "cheap" hardwood charcoal that wholesalers could obtain at 165 MK/t. Also, with landed costs amounting to 165 MK/t, Viphya charcoal would have been competitive vis a vis (domestic) Kaziwiziwi coal. One year later, however, a dramatic rise in transport costs as well as increases in the expenditures for charcoal bagging and charcoal production would have resulted in landed costs of 280 MK/t, if the stumpage fees had been kept at the 1988-level, and if charcoal producers at Viphya had sought to recover a profit/overhead margin of 10 MK/t. This figure would have exceeded the landed costs of "cheap" hardwood charcoal by 15 MK/t, but would not have eroded competitiveness of softwood charcoal vis a vis Kaziwiziwi coal.[3]

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3 While the parallel increase in the landed costs of Kaziwiziwi coal can almost exclusively be attributed to higher transport rates, hardwood charcoal became more expensive mainly because of the growing scarcity of its resource base and the threat of confiscation posed by tighter controls of the inflow of "illegal" charcoal.

Table 2.3: Cost Structure of Viphya Charcoal Delivered to Blantyre (MK/t)

	Landed Costs Kaziwiziwi Coal (1)	Wholesale Price Range Hardwood Charcoal (2)	Transport cost Viphya Charcoal (2)	Cost of Charcoal Bagging
early 1988	170	165-180	100	15
early 1989	290	265-290	200	25
mid 1989	290	265-290	200	15

	Charcoal Production Costs	Profits & Overheads	Stumpage Fees	Landed Costs Viphya Charcoal (1)
early 1988	30	10	10	165
early 1989	35	10	10	280
mid 1989	50	10	10	285

(1) Blantyre, (2) Viphya-Blantyre by road (630 km)

Thus, with unchanged stumpage fees, in early 1989 Viphya charcoal would have found it more difficult to penetrate the Blantyre charcoal market; yet this obstacle might well have created an incentive to cut production costs.

In mid-1989 the delivered costs to Blantyre would have further increased to 285 Mk/t, since government raised the administered minimium wages by 100%. It is assumed, however, that this wage push could have been offset by a cut in packaging costs (see section 2.6 and 4.2).

So there is some evidence that the stumpage fee formula proposed for Viphya charcoal, with Blantyre as the principal market outlet, could be maintain..d even in the presence of escalating costs and prices. Two questions, though, remain .. be answered: What should be the stumpage fee for Viphya charcoal shipped to outlets other than the Blantyre market? And what value should be placed on thinnings from other government plantations that may also serve as a feedstock for charcoal production?

As regards the first question, the principle choice is between

(a) a system of uniform stumpage fees set equal to the netback value "earned" by Viphya charcoal shipped to Blantyre with the effect that the landed costs at different market outlets would vary in direct proportion to the transport distance, and

(b) a system of discriminating stumpage fees set in accordance with the final destination of Viphya charcoal so that the landed costs throughout the country would be uniformly kept at the level prevailing in the Blantyre market.

At first sight the latter option appears to be most attractive since it may help maximize government revenues from charcoal production at Viphya. On second thought, however, there are at least three shortcomings that render this approach undesirable.

Firstly, discriminatory stumpage fees would encourage cheating. For instance, charcoal which is supposed to go to Blantyre and, therefore, would be charged with a comparatively low stumpage rate could be sold more profitably, say, in Lilongwe. Secondly, the implementation of a scheme of market-outlet-dependent stumpage fees would place a significant administrative burden on the Forest Department. In particular, the measures and manpower required to monitor and control the flow of softwood charcoal between Viphya and different market outlets such that retrading is impeded, would certainly exceed the institutional capacities of the Government. Thirdly, in terms of the consumers' surplus, uniform stumpage fees would be economically superior to a system of discriminatory fees. If, in addition, charcoal demand were price-elastic, government revenues from uniform stumpage rates would even exceed the aggregate revenues generated by discriminatory fees. (A more detailed discussion of these issues is provided in ANNEX I.)

In view of the above described drawbacks of the discriminatory stumpage fee approach, the Project has opted for a system of uniform fees. Uniform stumpage rates that are based on the netback value of charcoal supplied to the most distant Blantyre market will eliminate incentives to retrade, are easy to collect, and tend to maximize the social welfare from charcoal production at Viphya.

The stumpage fee formula recommended for Viphya thinnings is also the key to the second question, i.e. how to value wastewood that other softwood plantations generate. Should non-Viphya thinnings be converted into charcoal, the economically most compelling comparator price for feedstock valuation would be the landed costs which Viphya charcoal has at the market outlet nearest to the resource base under consideration. In fact, as can be seen from Figure 2.1, for each potential market outlet there exists a reasonably large plantation (>2,000 ha.) which, in terms of transport costs, enjoys a comparative advantage over Viphya charcoal (but also over charcoal which could come from other non-Viphya plantations). So if at each softwood plantation the stumpage fees imposed on charcoal production are brought into line with the netback value the charcoal would have relative to the costs at which Viphya charcoal can be delivered to the nearest market outlet, the following could be achieved:

Firstly, there would be no market outlet to which Viphya charcoal could not be supplied competitively. Secondly, incentives to retrade would be precluded. Thirdly, government revenues would be maximized subject to the uniformity constraint imposed on stumpage fees that would be collected from Viphya charcoal hauled to different markets.

So far, the only site other than Viphya where charcoal has been produced from wastewood is the Chambe Plantation located on top of the Mulanje mountain. With Blantyre as the nearest market outlet, in early 1988 the proposed feedstock valuation scheme would have led to stumpage fees of about 50 MK/t. In early 1989, though, the netback value of Chambe wastewood would have increased to MK 120 per ton of charcoal. Thus, contrary to the stumpage value of Viphya thinnings, the changes that took place with respect to the costs at which Viphya charcoal was supplied to Blantyre would have required an upward adjustment of the stumpage fee levied on Chambe wood.

Finally, there is the question of how to design a mechanism for collecting site-specific stumpage fees once a concession agreement with private charcoal producers has been struck. Basically, the choice is between five different options. Government could levy

(a) a specific fee (per unit of output)
(b) an ad valorem fee (sales commission)
(c) a profit fee
(d) a per unit-of-input fee
(e) a capacity fee

What the first four options have in common is the difficulty of precisely defining and monitoring the quantitative variable relative to which the fee is calculated. Moreover, in cases a), b) and c) the imposed fee does not encourage the efficient use of the feedstock. Therefore, the Project advisors suggested a capacity fee: If the installed capacity is "taxed", the contractor will be provided with an incentive to fully utilize the installed capacity and to achieve high charcoal yields by operating the kilns in an efficient way. The installed capacity of a production camp is a well-defined basis of measurement. Since the potential annual output of a kiln is known, the capacity fee can be set at a level at which Government captures the net back value of the charcoal which the camp would produce under normal (average) operating conditions. For instance, based on a net-back value of MK 10 per ton of charcoal and assuming that the effective capacity of a standard production site is equivalent to 1,000 tpy, the stumpage fee commitment of the production camp would simply amount to MK 10,000 per annum.

2.3 The Cost-Competitiveness of Viphya Charcoal

The question whether Viphya charcoal is an economically viable source of fuel depends above all on the costs involved in alternative solid fuel supply options. In the following lines we compare Viphya charcoal with the options of using domestic/imported coal, charcoal from plantation-derived fuelwood and charcoal made from wood grown on customary land.

The small size of the proven reserves, its poor (sub-bituminous) quality and logistic difficulties restrict the use of Malawi coal to domestic markets. Its economic value therefore rests on the cost of imported coal of similar quality. Because of disruptions in the supply of comparatively cheap Moatize coal from Mozambique, for some time to come Malawi has to resort to higher cost coal from Zambia and Zimbabwe which is imported by road via Lilongwe. In mid 1989, the costs of Zambia/Zimbabwe coal delivered to Lilongwe amounted to 90 US$/t or 225 MK/t. This compares with 205 MK/t for domestic pea sized coal from Kaziwiziwi landed in Lilongwe (transport distance to Lilongwe 450 km; costs ex Kaziwiziwi mine: 70 MK/t). Strictly speaking, however, Malawi coal should be charged with a depletion premimum since the Kaziwiziwi deposits are likely to be exhausted within 6 years. Thus, if a 12% discount rate is applied, the premium works out at 12.7 MK/t (in mid 1989 prices) and will rise to 25 MK/t over a period of 6 years. As a consequence, the current costs of Malawi coal cif Lilongwe would have to be adjusted to 217.7 MK/t (8.7 MK/GJ), thus exceeding the landed costs of Viphya charcoal (188 MK/t or 6.3 MK/GJ) by almost 30 MK/t (2.4 MK/GJ). Farther in the south, say, in Blantyre the cost differential may prove somewhat smaller (see Table 2.3). But it is likely to remain large enough to compensate for the higher handling and storage costs incurred by softwood charcoal and the inconvenience of having to blend charcoal with coal in industrial applications (see Section 3.1).

As regards the option of producing charcoal from indigenous wood supplied from customary land, it is assumed that the organizational set up would resemble the conditions that characterize traditional charcoal making in earth mound kilns (charcoal conversion effieicney: 12%, labor input: 1 man-day per 32 kg bag). Currently, the stumpage fee traditional charcoal makers would have to pay amounts to MK 4.50 per sm^3 of unplanted fuelwood (cut and stacked by the purchaser) which works out at MK 12.5 per ton of fuelwood. Given the earth mound kiln's conversion efficiency and shadow pricing the labor input in terms of government minimum wages (MK 2 per man-day), the econmics of traditional charcoal making work out as follows: If traditional charcoal is supplied to Blantyre, it will outprice Viphya charcoal as long as the transport radius is less than 331 km. However, if Lilongwe is the market outlet, the economic transport radius for traditional hardwood charcoal reduces to 40 km.

The gazetted stumpaged fees, though, which currently apply to indigenous wood from customary land do not correctly reflect the economic value of the resource in question. According to the pricing formula used by the Forestry Department, the fees would have to rise to 20 MK/sm^3 (in 1989 prices) by 1996, a figure which is supposed to indicate the costs of replacing indigenous wood with plantation grown wood. However, a more plausible assumption is that fuelwood from small farmer woodlots (rather than plantation grown wood) will substitute for indigenous species used as a source of fuel. World Bank (1989) estimates suggest that the economic value of fuelwood grown by small farmers amount to 9.2 MK/sm^3 (in 1989 prices) which is equivalent to 22 MK/t. Based on this figure, the economic transport radius for traditional charcoal delivered to Blantyre proves as low as 20 km. And in the case of Lilongwe, Viphya charcoal will outbid traditional charcoal even if the latter is produced in close vicinity to the urban center.

On the other hand, if plantation grown fuelwood (e.g. Ecualyptus) is used as a feedstock for charcoal production, stumpage costs of 20 MK/sm^3 (53 MK/t) have to be accounted for. The organizational set up and the cost of charcoal production will by and large be similar to the conditions prevailing at Viphya. Under these assumptions, the economic transport radius of plantation-derived charcoal works out at 110 km if Blantyre is the market outlet. In the Lilongwe market, however, Viphya charcoal will outprice plantation-derived charcoal from any location.

It should be borne in mind, though, that the direct use of fuelwood supplied from peri-urban plantations competes with its use as a feedstock for charcoal production. At stumpage costs of 20 MK/sm^3, the selling price of plantation grown fuelwod amounts to 65 MK/t (cut and stacked, ex-collection point). Moreover, let us assume that, based on the differential in end use efficiencies and heating values, charcoal is 2.5 times more efficient than fuelwood. Then, the economic transport radius for plantation grown fuelwood that competes with Viphya charcoal in the Blantyre market, amounts to 145 km.

This implies that, wherever the plantation is located, it will be more economic to use the resource as fuelwood rather than as charcoal. And as fuelwood the resource will have a cost advantage over Viphya charcoal, if its production site is not farther than 145 km away from Blantyre (for Lilongwe the break-even distance is 30 km, respectively).

Concerning the non-Viphya woodfuel options, the results can be summarized as follows (see Table 2.4):

Table 2.4: Economic Transport Distance for Non-Viphya Woodfuel a/

Market Outlet	Charcoal from Indigenous Wood Case I b/	Case II c/	Plantation Grown Wood Charcoal	Fuelwood
Blantyre	331	20	110	145
Lilongwe	40	-	-	30

a/ in km, defined relative to Viphya charcoal with landed costs of 290 MK/t in Blantyre and 188 MK/t in Lilongwe. Unit transport costs: 0.35 MK/t/km.

b/ stumpage fee: 4.50 MK/sm^3

c/ stumpage fee: 9.20 MK/sm^3

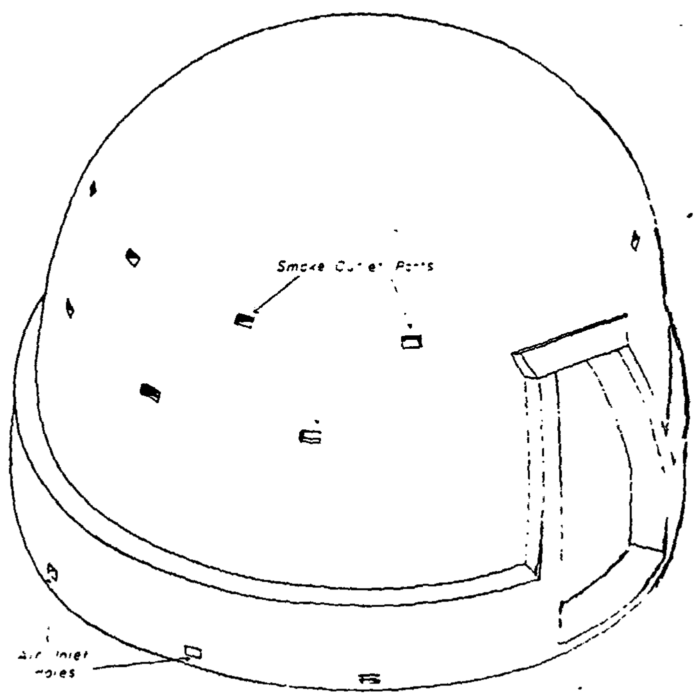
For the Lilongwe area, the Viphya plantation proves the least cost source of charcoal. The same result holds, ceteris paribus, for the central region where most of Malawi's flue-cured tobacco is produced. In the Blantyre market, Viphya charcoal has a clear cost advantage over traditional charcoal made from indigenous wood as long as the resource base of the latter is properly priced (except for the negligible case where the resource base is available in the immediate vicinity of the urban center). Also, charcoal produced from plantation grown fuelwood fails to be an economically viable alternative to Viphya charcoal. Fuelwood, however, which is cultivated on plantations not too distant from the market outlets under consideration may prove less costly than Viphya charcoal. Yet this option is constrained by the availability of peri-urban land that cannot be put into uses which are more profitable than fuelwood production.

2.4 Kiln Design and Conversion Efficiency

The principle kiln design introduced by the Project resembles that of a Half Orange Fire Brick Kiln which is widely used in Brazil. The kilns constructed at the Viphya and Chambe Plantation have a diameter of 3.5 m and their nominal (geometrical) capacity amounts to 16 m^3. Under normal operating conditions the effective capacity works out at 13.3 sm^3. Apart from a steel bar which is needed as a door frame, the kiln can be made entirely from ordinary fire bricks and clay soil (see Figure 2.2), resulting in investment costs about U.S.$150 (9.4$/m^3).

In the two and a half years since the charcoal-making operations were initiated, more than 4,000 kiln-loads of wood have been carbonized at camps in the Viphya Forest, and this operational experience has generated sufficient empirical data to answer conclusively the question of how efficiently brick kilns perform under field conditions. Based on the results of the projects's production monitoring program which covered well over 2,000 kiln runs, the average weight-based conversion efficiency of Half Orange kilns constructed and used by the Project amounted to 31.2%. In this context effieciency is defined as the percentage rate which expresses the ratio of the weight of the charcoal output to the weight of the wood input. The average moisture content of the feedstock was around 20% wet basis, and the average carbonization cycle lasted approx. 70 hours (see Figure 2.3). These figures apply to pine and cyprus logs with an average diameter of approx. 20 cm and a density of 250 kg/sm^3.

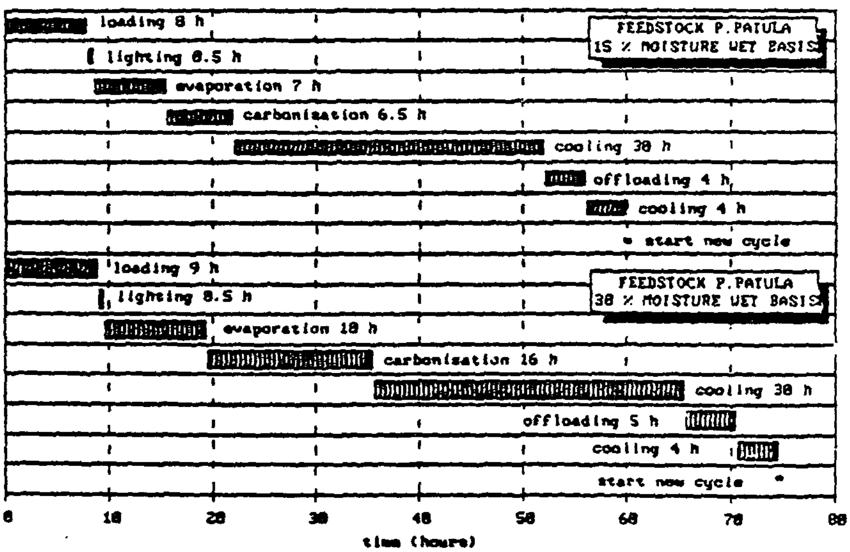
Figure 2.2 Half Orange Fire Brick Kiln



Extensive trials were also conducted with waste material from the Viply sawmills (slabs) and practically the same results were achieved. The only major difference was in the cycle time, which was approx. 10 hours shorter because on average the slabs were much thinner than the logs.

The data compiled by the project indicate that, given the carbonization technology, the two most important determinants of conversion efficiency are the <u>moisture content of the feedstock</u> and the <u>proficiency level of the kiln operators</u>. It can be concluded that personnel must have had between 3 and 6 months of practical experience in the utilization of the technology in order to be able to regulate the carbonization process in such a way that optimal results are achieved. Operators who have just completed their on-the-job training course achieve average conversion efficiencies that are approx. 25% lower than the levels attained by more experienced workers. The data also show that the conversion efficiency is subject to seasonal fluctuations: average charcoal yields decline slightly during the cold, rainy months of the year.

Figure 2.3: Production Cycle Half Orange Kiln

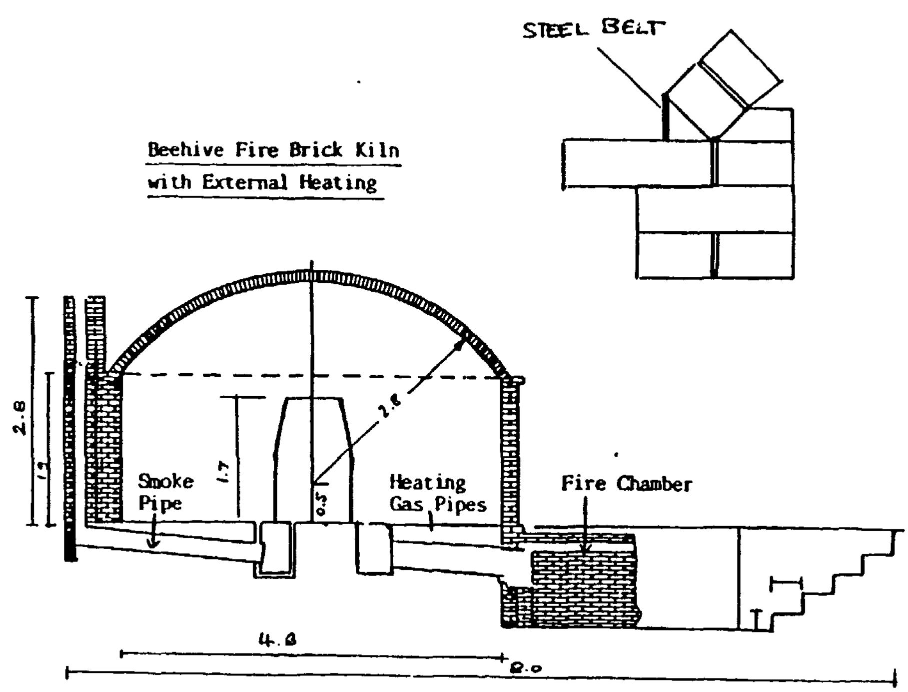


Source: IPC (1988)

For experimental purposes, the Project has also built two Beehive Brick Kilns (see Figure 2), with an effective capacity of 35 sm^3 (compared to a nominal capacity of 46 m^3). Total investment costs amounted to US$600 (13$/m^3). While the kiln's conversion efficiency was in the vicinity of 30%[4], with an average carbonization cycle of 84 hours, the recovered by-products were not suited as a substitute for high-value commodities such as creosote. Further processing would have been required to upgrade the condensates to marketable by-products. However, the trials have shown that externally heated kilns equipped with simple distillation facilities are capable of recovering a significant fraction of potentially harmful emissions released during the carbonization process.

To sum up: The brick kiln has proved a thoroughly appropriate carbonization technology for semi-industrial charcoal production from forestry wastes in Malawi. The average yield with brick kilns is roughly 50% higher than that obtainable with steel kilns, which, moreover, would be prohibitively expensive in Malawi (specific investment costs: 5 times as high as for the

Figure 2.4: Beehive Brick Kiln



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4 One would expect a somewhat higher conversion efficiency but since the low figure of 30% is based on a limited number of runs undertaken with unexperienced operators, generally valid conclusions cannot be drawn from the trials conducted by the Project.

Half Orange kiln; lifetime when in continuous operation: less than one year). Based on the experience of the Malawi Charcoal Project, it can be stated that brick kilns will invariably prove the least-cost option if (a) wage rates are low enough to justify the use of labor intensive methods; (b) production operations must be carried out on a semi-centralized basis (e.g. within plantations) and need to be closely supervised; (c) the feedstock costs are relatively high; and (d) plans call for the establishment of a medium-to-large-scale charcoal production scheme, i.e. one whose output will be large enough over time to make it feasible to recoup the rather sizable costs incurred for technology transfer and manpower training.

2.5 Fuel Properties

Primary Fuel Properties

Laboratory tests by Degussa AG, Frankfurt, conducted during the pilot phase of the project to determine the fuel properties of softwood charcoal yielded the following results:

Lower heating value at 5% moisture content w.b.	30 MJ/kg
Fixed carbon content	≥ 85%
Volatile content	≤ 12%
Ash content	3%
Bulk density	200 - 230 kg/m^3

Laboratory testing of the charcoal output of the various centers continued as the Project went ahead, and the figures obtained have invariably been so close to those yielded by the original Degussa tests that the above set of values may be regarded as a quality standard for pine charcoal which can be guaranteed to users.

The data derived from over two years of production experience demonstrate that, given the homogeneity of the input material, even fairly significant changes in the key aspects of the carbonization process have little if any impact on the fuel properties of the output. Whenever sizeable variations have been observed, they have almost entirely been attributable to "external" factors such as increases in the feedstock moisture content. However, even when very wet wood was used, the drop in the fixed carbon

content never exceeded 5%. And only in cases where the charcoal samples contained fairly large amounts of clay soil and sand, were ash content values higher, but even then the maximum deviation measured was only 6%. The bulk density of run-of-the-kiln charcoal, on the other hand, is primarily a function of the properties of the specific type of raw material used. For example, older wood produces charcoal with a higher bulk density than young wood, and the utilization of cypress and pinus kesiya gives lower bulk densities than those achieved with pinus patula.

The combustion trials and other utilization tests carried out by the Project have demonstrated that, in terms of specific applications, the primary fuel properties of Viphya charcoal have the following characteristics:

Softwood charcoal has a lower share of volatile matter than the grades of (sub) bituminous coal available in the region. This is a disadvantage in potential industrial applications (steam boilers, cement kilns), for softwood charcoal will be more difficult to ignite than the high-volatile coals that are currently being used. On the other hand, the low ash content of Viphya charcoal is beneficial in cement production; acceptable overall ash content values were achieved when charcoal was utilized in fuel blends with local coal. The fact, however, that softwood charcoal has a lower bulk density than both coal and traditional hardwood charcoal poses a problem whenever it is used in furnaces, boilers, or kilns. If such facilities are supposed to be run at their maximum thermal output, and their fuel feeding system is designed to handle denser fuels with a higher volumetric heating value (e.g. coal), charcoal cannot provide the required energy input. This is a less serious drawback in the household sector than it is in industrial and agro-industrial applications; for when softwood charcoal is substituted for hardwood charcoal in cooking applications, users can easily compensate for its low bulk density (on average 30% lower than that of the hardwood-based charcoal) by more frequent stoking or by utilizing improved charcoal stoves with vent controls (i.e. simple gates), e.g. those stoves which are being disseminated by the Wood Energy Project.

Secondary Fuel Properties

While the suitability of softwood charcoal in various uses is determined above all by the primary fuel properties discussed above, its friability and hygroscopicity may matter as well. Whether or not these two secondary fuel properties will in fact imperil the competitiveness of Viphya charcoal in specific applications depends less on what happens during the charcoal production process than on what is or is not done during handling, transport and storage. Generally speaking, hygroscopicity appears to be a more serious problem than friability. When charcoal is stored in the open, it has a tendency to absorb a significant quantity of water from the ambient air, and in cases where it is exposed to rain the mcwb can rise as high as 67.5%, which not only significantly reduces its heating value but also makes the fuel considerably more difficult

to ignite. For example, the utilization of very moist charcoal in tobacco curing leads to a substantial rise in specific fuel consumption levels since the net heating value of the fuel at 50% mcwb is only about 14.5 MJ/kg. On the other hand, if charcoal has been protected from the rain during storage, it will absorb comparatively little water from the air, and its mcwb content will not rise much above the 15% level.

Compared to both hardwood charcoal and coal, softwood charcoal is a relatively friable fuel, and, thus, if it is not handled carefully during the production process and in the course of transport operations, a substantial amount of fines can be generated. Obviously, the presence of small quantities of fines -although perhaps annoying will not pose any serious problems for most users. In certain applications, though, the combustion efficiency of the fuel will be reduced if it contains a large share of fines. Such problems can be avoided by grading the charcoal prior to use. This, however, prompts two questions: a) What - if anything - can be done with the fines that are screened out? (depending on the size of the mesh used in the sieve, the fines "yield" will range between 15-50%); and b) where should grading be done?

As it turns out, the two questions are interrelated in the Malawian context, and in answering the first one, one has in effect already answered the second one as well. As regards a), there is only one practicable option, namely the utilization of fines in the cement factory, which in any case must pulverize all fuel before feeding it into the kilns. However, as a potential large scale user, Portland Cement would clearly prefer to purchase fines from one large supplier rather from several small ones, and thus the establishment of a central grading facility located as near as possible to the charcoal production centers would be the logical solution. A special test conducted in December 1988 and January 1989 which was designed to determine the percentage of fines generated during transport and handling, showed that the bulk of all such material is produced "at the source", i.e. in the production process. Thus, if it is assumed that Portland Cement should sign a long-term purchase contract for fines, screening can be done at the charcoal camps. The project is currently looking into ways of increasing the efficiency of charcoal grading, which up until now has been performed with simple hand sieves.

To recapitulate: Although the specific primary and secondary fuel properties of Viphya charcoal could cause certain problems for end-users in Malawi, these problems would not be pervasive enough to rule out the use of softwood charcoal in the various potential applications. Based on the results of the combustion and laboratory tests conducted by the Project, it can be claimed that the specific fuel properties would have the least serious consequences in the household sector, where charcoal would not be a new fuel (hardwood charcoal is already in widespread use there). From the standpoint of specific fuel properties, the second most promising candidate for a complete or partial switch to charcoal would be the tobacco industry, where only relatively minor changes in

barn and furnace design and in curing procedures are required to create optimal conditions for charcoal use.

2.6 The Organizational Setup

At an early stage of the Project a survey of the potential production sites helped devise a standard charcoal production camp, taking into account the available resource base, its accessibility, the internal transportation costs, economies of scale and consolidation, and the level of managerial skills required. The result was a prototype production center with a catchment area of approximately 1,000 ha that consists of 14 Half Orange brick kilns of which two units serve as stand-by capacity. It also requires a charcoal store, three water tanks (each with 2 m^3 capacity), seven pairs of oxen and four ox-carts to be used for internal feedstock transport. The firm charcoal output of the camp would be 1,000 tpy, equivalent to an annual feedstock of 13,300 sm^3. The proposed organizational set-up has worked well at the existing camps and it will also be utilized at a number of the new camps that are scheduled to be established. Nevertheless, a detailed analysis of potential future sites has shown that, if maximum cost-efficiency is to be achieved in charcoal production, a more flexible approach must be employed in planning and designing additional camps - one which makes adequate allowance for the specific set of topographical and other conditions found at each individual location.

Given the topography of the Viphya Forest, site selection usually involves a tradeoff between the cost of feedstock transport and the production center's operating life which is a function of feedstock supply. Generally speaking, one can choose either a location which is linked by good, easily traversable roads to a catchment area of only limited capacity, or one which is surrounded by "high-capacity" compartments which will yield an adequate volume of wastes over a longer period of time but which are accessible via less easily traversable roads that make feedstock transport more expensive.

Based on the investigations that have been carried out by the Project, it has become obvious that a dual strategy should be pursued as charcoal production is expanded. In the areas where a supply of wood that will last for several years of operation (consecutive thinnings over a period of several years) is available close to a favorable production site, large-scale production centers can be established which utilize the standard operational set-up. However, in designing centers to process the wastes generated in areas where there are no favorable sites available for production facilities or where an adequate volume of feedstock is available for only a relatively short period of time, two modifications of the current configuration would be required in order to permit cost-efficient charcoal production:

First, it would be necessary to build relatively large centers (capacity: approx. 2,000 tpy) just outside those areas in which the terrain is unsuitable for the establishment of kiln centers but which can be expected to yield a sizeable volume of wastes over a relatively long period of time. This would involve the construction of a charcoal storage barn and the use of a tractor to transport the feedstock. Second, it would be necessary to build smaller units directly in areas where large quantities of feedstock are available in the immediate vicinity, but only for a limited period of time. Such smaller units would also be set up in areas where the terrain is difficult to access, with oxen or tractor being used to haul the charcoal to a more easily accessible central store. Centers of this type would be built without a charcoal storage barn and oxcart transport would be used for feedstock supply. Charcoal transport to the central barns would have to be provided on a continuous basis with a tractor or oxen. When the feedstock supply is exhausted, the kilns would be dismantled and the bricks would be moved to another site and used to build other kilns.

The first option would presumably be more suitable for an investor with a longer time horizon, i.e. one who is willing to accept a longer payback period and would be prepared to take a larger financial risk in order to get a higher return on his investment. The second option would probably be more attractive to risk-averse investors, who would require a shorter payback period and would be satisfied with a smaller, but certain, return on their investment.

2.7 Charcoal Production Costs

In 1988, the total investment costs for a full-size production center (14 Half-Orange kilns, 4 ox-carts, 7 pairs of oxen, 1 charcoal store, water tanks, tools) averaged MK 25,000. The experience gained over the past two years has led to considerable improvements in construction efficiency, and cost reductions have been achieved by modifying certain design features of kilns, storage sheds and other facilities. Assuming a lifetime of 5 years and applying a discount rate of 12%, the annuitized investment costs work out at MK 6,700. The costs of maintaining a standard charcoal production camp numbered, on average, MK 5 per ton of firm output. This includes expenditures for kiln repair, replacement of tools, fodder and veterinary services for oxen, etc.

Labor costs, on the other hand, proved to be a much more critical variable. As is shown in Annex II, labor productivity has varied considerably depending on site-specific conditions, seasonal impacts, managerial skills, the level of supervision, and the mode of payment employed (government wages, piece rate system, bonus scheme). In fact, whenever close supervision was relaxed, the incentive structure of the reward system installed became the main determinant of the performance of the labor force.

On a pro-forma basis, the system of regulated (low) wages that applies to the public sector appears to be the least cost solution. During the pilot phase when the Project was stuck with the government wage system the total labor costs per ton of charcoal should have been as low as MK 15, assuming that the labor force had performed efficiently. This, however, was not the case. The low wages the Project was obliged to pay exacerbated the major drawback associated with the incentive structure underlying a system of fixed wages, namely the difficulty to motivate unmonitored effort. As a consequence, the employed labor force underutilized the installed production capacity to the point that the effective labor costs soared beyond the 30 MK/t level. In fact, the Project's experience with the government wage system seems to confirm what the so-called "wage-productivity hypothesis" claims to prevail under the conditions found in many developing countries (see, for instance, Stiglitz, 1988): With the level of wages being sufficiently low, the workers' productivity tends to improve in response to rising wage rates. Stated differently, higher wages may help reduce the costs per effective unit of labor.

In view of the incentive problems caused by the government wage scheme the Project decided to introduce a linear piece rate system that makes payment contingent on output. The results of this experiment, by and large, were positive. As long as there were no disruptions in the supply of essential inputs (e.g. feedstock, spare parts, packaging material) the effective labor costs went down to about 25 MK/t. Indeed, the piece rate system can be considered the first-best solution to the incentive problems that a fully commercialized production system run by the private sector would have to cope with.

The conditions that prevailed at Viphya, however, were not in favor of the continued use of a piece rate reward system. As a government venture, the charcoal operations were exposed to financial constraints and a lack of supervision, resulting in frequent disruptions that were out of workers' control. Since output-based remunerations would have placed an unduly high burden on the labor force, the Project has developed a bonus scheme that reconciles income security provided by government minimum wages with incentives to perform efficiently. Essentially, the scheme guarantees the laborers a certain minimum payment which they receive independently of the amount of charcoal produced. This sets the workers free from the risk that their income drops below some predetermined floor. At the end of the month their salary will be "topped up" if capacity utilization exceeds some threshold level (e.g. 40%). The bonus schedule adopted by the Project is linear in output.[5]

5 Strictly speaking, the schedule presumes that the marginal supply of effort required to produce an additional unit of output is constant.

In summary, it can be stated that in early 19P9 an average labor input of 10 man-days was required to process 1 ton of charcoal (assuming that there are uninterrupted operating conditions), resulting in labor costs of 12 MK/t. In addition, feedstock extraction and transport incurred labor costs of about 11 MK/t. Total production costs (excluding profits/overheads, stumpage fees and packaging costs) therefore amounted to MK 35 per ton of firm output. This is 10 MK/t higher than the average production costs recorded in 1987. Almost the entire increase can be ascribed to a decline in average labor productivity. It therefore seems that the significance of close supervision and incentives was underestimated in the original calculation, giving an unrealistically low specific labor cost figure.

In May 1989, administered government wages were raised by 100%. This increased the labor costs (including the bonus payments) from 23 MK/t to 38 MK/t. However, as can be seen from Table 2.5, the total ex-camp costs of (ungraded) charcoal could be kept roughly at the level that prevailed in early 1989 due to a drop in the expenditures for charcoal packaging.

Table 2.5: Charcoal Production Costs at Viphya, 1989 [a]

	early 1989	mid 1989
Capital Costs	7	7
Maintenance and Repair	5	5
Labor Costs	23	38
Total Production Costs	35	50
Stumpage Fee	10	10
Profits and Overheads	10	10
Packaging Costs	25	15
Total Ex-Camp Costs of Ungraded Charcoal	80	85
Grading Costs	5	5
Ex-Camp Production Costs of Lump Charcoal [b] (> 10 mm)	85	90
Ex-Camp Production Costs of Charcoal Fines [c] (< 10 mm)	60	65

a/ in MK per ton of firm output
b/ 80% of output
c/ 20% of output

3. The Market Potential for Softwood Charcoal

3.1 The Industrial Market

During the Project's pilot phase, a great deal of effort to delineate prospective markets for Viphya charcoal focused on industrial users, i.e. on the potential for replacing both imported and domestically mined coal with softwood charcoal. A market analysis which covered all relevant coal users in the country estimated both the current and future demand for solid fuels. (For details, see Annex III). Also, a series of combustion trials was carried out designed to provide practical evidence on the technical feasibility of substituting softwood charcoal for bituminous and subbituminous coal in key industrial applications. By and large, the results of the trials were encouraging. Test firings conducted in standard steam boilers (chaingrate stoker), for example, showed that acceptable steam production rates can be achieved if the units are run on fuel blends containing up to 50% charcoal (on a volumetric basis) and the charcoal size is similar to that of normal pea-size coal (10-35mm). The response to the Project's efforts in this area was positive, and various firms indicated that they would definitely consider the option of using a domestically produced alternative to coal.

Indeed, David Whitehead Textiles, which is the country's single largest consumer of steam boiler coal, felt that the benefits of a partial fuel switch to charcoal (foreign exchange savings, increased security of supply) would be so substantial that it decided to actively support the project's activities by agreeing to purchase a sizeable quantity of Viphya charcoal.

The results from combustion trials carried out at Portland Cement Limited, Malawi's only cement producer, were promising as well. Even though certain problems were encountered when charcoal was utilized in the company's outmoded attrition-mill kilns, Portland Cement is confident of several advantages from the use of coal-charcoal blends: The company reckons that charcoal use would not only lead to increased security of supply and a reduction of its current dependence on external sources, but also, by lowering the ash content of its fuel, improve cement quality and help eliminate ash-induced kiln operating problems. In view of its positive assessment of the potential financial benefits from charcoal utilization, Portland Cement decided to conduct a second combustion trial in order to ascertain whether the old attrition mill could be operated successfully with fuel blends containing 15-30% charcoal. The second trial demonstrated that no serious operating problems are encountered when a blend of 83% Kaziwiziwi coal and 17% softwood charcoal is used. The company's interest in the charcoal blend option - and its willingness to make the financial commitment required to assess its feasibility - was attributable above all to the fact that the commissioning of the new ball mill, which had originally been scheduled for 1987, has had to be postponed repeatedly: in fact, there is little likelihood that the attrition mill will be replaced in the near future. As

long as the old mill continues to be in operation, cement production can only be expected to absorb around 3,400 tpy of softwood charcoal per year. Once the new ball mill unit comes on steam, Portland Cement is capable of absorbing as much as 10,000 tpy of softwood charcoal. In order to acquire more operational experience with softwood charcoal, the company recently decided to purchase fines from the project on a regular basis. Initially, 200 tons per month (2,400 tpy) will be supplied to Portland Cement.

Despite the fact that all major industrial consumers of coal (both imported and locally mined) expressed interest in utilizing charcoal as a substitute fuel, it has not proved possible to develop this market (steam boiler operators alone could be expected to use some 13,000 tpy) as quickly and widely as was originally anticipated. The delays and obstacles that have been encountered are attributable, above all, to typical problems which are prompted by the introduction of a new fuel which, on account of its specific properties, cannot be readily utilized without a variety of modifications in operating and fuel handling procedures. With respect to steam boilers, the key factors are:

(a) the necessity of providing dry fuel storage facilities (hygroscopicity);

(b) the necessity of monitoring the combustion process more closely, which pushes up labor costs; and

(c) the unavoidable reduction in the thermal capacity of the boilers when coal/charcoal blends are used.

Although the provision of dry storage facilities poses no major technical problems (it would be sufficient to expand and build roofs over the existing coal bunkers), extra expenditures of about MK 8 per ton of charcoal used would be required which the owners are not willing to undertake until other impediments to the utilization of coal/charcoal blends have been overcome. For example, the combustion trials conducted at the David Whitehead plant (with the assistance of a representative of John Thompson Ltd., the manufacturer of the boilers), showed that the ignition problems caused by the charcoal's low share of volatile matter could be solved either by utilizing the boilers' down-draught system or by creating positive furnace pressure at the fuel entry point. However, in order to implement these relatively minor changes in the normal firing procedure, the firm would have to provide additional training to boiler operating personnel, and, at least in the beginning, close supervision by the plant engineers would be required.

Finally, when boilers are run on coal/charcoal blends, there is a decrease in the specific energy input due to the lower bulk density of charcoal. This drawback could only be overcome with the help of a boiler retrofit: the chaingrate gear would have to be modified so as to increase the operating speed of the travelling grates which

are designed to handle the common types of steam coal, thus permitting an increased fuel throughput in volume terms. So far, however, David Whitehead and other standard boiler operators have been reluctant to carry out the requisite modifications (which would give rise to costs probably in the range of US$3,000-5,000 per boiler) mainly because the boiler manufacturer has not yet provided the company with a definitive technical lay out of the proposed retrofit. In other words, David Whitehead - and other standard boiler operators - cannot be convinced at this point that the investment required to implement the modifications would pay off. This issue will remain unclear until the results of an additional series of combustion trials have been evaluated.

In sum it can be stated that the initial picture the Project had drawn of potential industrial charcoal users was overly optimistic. Partially successful combustion trials had stimulated the Project to reach the conclusion that the industrial market was easy to penetrate. It underestimated the extent to which risk aversion, imperfect technical information, uncertainty, and the need to undertake additional investments would impede entry into industrial fuel markets. While the prospects for charcoal use in industrial applications are certainly not as dismal as the limited marketing success thus far suggests, the Project has to accept that a number of problems have yet to be resolved before the industrial market potential can be fully developed.

3.2 The Tobacco Industry

In 1985/86 the overall fuelwood consumption of the flue-cured tobacco growers amounted to 300,000 tons, of which not more than 40% was supplied from plantations. Even then, the tobacco industry found it increasingly difficult to obtain the hardwood needed to meet the remaining 60% of its annual fuel requirements (180,000 tons) at acceptable costs. It was becoming obvious that the days when an ample supply of firewood was available in the immediate vicinity of the tobacco estates were gone forever. Although a number of producers had begun to improve the efficiency of their curing barns and reduce specific fuelwood consumption with the assistance of the Tobacco Industry Energy Efficiency Project, there was no doubt that, over the medium-to-long term, the industry would have to chose between three options. It could either:

(a) stop producing flue-cured tobacco altogether when the supply of cheap fuelwood was exhausted,

(b) embark on a large-scale tree production program, or

(c) switch from indigenous hardwood to alternative fuels such as coal, charcoal or plantation wood from government forests.

Against this background, much hope was placed on combustion trials the Project initiated on several estates using softwood charcoal as a substitute for fuelwood. However, the results of the first trials that were conducted during the 1986/87 curing season with the help of General Farming, the country's largest tobacco grower (6,000 tpy), failed to be convincing. It was not feasible to efficiently use charcoal in traditional barn designs. Nonetheless, the findings indicated that refurnished barns might help improve the performance of charcoal. In a second trial that took place during the 1987/88 curing season, a total of 412 tons of charcoal was combusted in single-furnace barns equipped with internal chimneys, fire bars and redesigned furnaces. On average, the specific fuel consumption (SFC) amounted to 5.1 kg of charcoal per kg of made tobacco, a figure which was not as good as had been expected. At this rate charcoal firing would be twice as expensive as the use of "home-grown" fuelwood. In some cases, though, the SFC had been brought down to 2 kg/kg. Moreover, there was some evidence that improvements in tobacco quality could be achieved by replacing fuelwood with charcoal. Therefore, the Project and General Farming decided to undertake a third, large-scale test program.

In this final field test which was conducted during the 1988/89 curing season, a total of 275 barn loads were cured using charcoal from softwood plantations. Specific fuel consumption ranged from 2kg/kg to 4kg/kg, and the average SFC for all estates worked out at 2.91 kg of charcoal per kg of made tobacco. A total of 28 cures were also conducted in wood-fired barns on 4 estates, and the average SFC for wood was 14.1 sm^3 per ton of made tobacco (7.6 kg/kg).

With the data base acquired it was also possible to quantify the impacts which various barn improvements will have on fuel consumption. As can be seen from Table 3.1, among the measure suited to curtail fuel consumption the switch from a standard double-furnace barn to a single-barn device will achieve the most pronounced fuel savings. On the other hand, the use of fans which is the most costly modification, would result in surprisingly small fuel savings. Taken together, the different retooling options would reduce fuel consumption by 60%.

Table 3.1: Fuel Savings from Barn Improvements

Type of Barn Improvement	Investment Costs (in MK of 1989)	Charcoal Savings*/ (%)
Single Furnace	500	30
Welded Flue Pipes	55	15
Proper Furnace Door	105	15
Internal Chimney	360	5
Billie Barn Fan	1,750	10
FD Fan	600	5

*/ as a percentage of the charcoal consumption level associated with a standard, unmodified double-furnace barn, 20X40 ft, 5 tiers.

Source: IPC (1989)

The trials also revealed that management-related factors such as maintenance and supervision significantly affect the SFC. For instance, improper sealing or stoking procedures have resulted in efficiency losses in the range of 20%.

Most importantly, the field tests have gathered compelling evidence of the potential for improvements in tobacco quality as a result of the use of charcoal. Based on 11 samples taken from both charcoal- and wood-fired barns loaded with tobacco from the same field and the same reaping, it could be demonstrated that the share of lower grade leaves was much higher in the wood-fired barns. The Project estimated the total revenues which the various grades in each of the samples would have yielded if they had been sold at the auction prices prevailing in 1987/88. The results of this comparison indicate that, on average, the returns from charcoal-fired barns would have exceeded those from wood-fired barns by 20%.

There is a simple explanation for the observed improvement in cured tobacco quality: charcoal is a much more homogeneous fuel than wood. Thus, what is regarded as the optimal temperature curve for tobacco curing can be more closely approximated with charcoal than with fuelwood. In particular, excessive temperature fluctuations, which cause "sponging" - the most serious quality problem for tobacco since it results in the greatest monetary losses - can easily be avoided if charcoal is used.

The findings established in the course of the third combustion trial significantly improve the outlook for charcoal use in the flue-cured tobacco industry. An assessment of the economics of charcoal firing for General Farming, whose expenses for firewood are indicative of energy cost levels in the flue-cured tobacco industry as a whole, suggests that - at current supply costs - charcoal may prove an attractive alternative to fuelwood. This result rests on the assumption that, on average, the landed costs of Viphya charcoal amount to 150 MK/t [6], whereas indigenous wood from customary land can be delivered at average costs of 16 MK/t. It is also presumed that the SFC is 4.3 kg/kg for wood and 2.16 kg/kg for charcoal. As is shown in Table 3.2, both the specific fuel (per MJ) and energy costs (per kg of made tobacco) will be higher with charcoal than with wood. As a consequence, wood firing would appear to be economically more attractive if the use of charcoal would fail to improve the tobacco's quality. However, with a 5% improvement in quality, charcoal would be on a par with wood, and if a 20% increase in tobacco quality could be achieved (as the test results indicate), charcoal clearly turns out to be the financially more attractive option.

Table 3.2: Flue-curing with Wood and Charcoal - Indicative Figures on Costs and Revenues

	SFC (kg/kg)	Specific Fuel Costs (MK/GJ)	Energy [a] Costs (MK/kg)	Average Auction Price Tobacco (MK/kg)	Revenues Net of Energy Costs (MK/kg)
Indigenous Wood	4.3	2.03	0.13	5.28	5.15
Charcoal:					
- Case I [b]	2.16	5.02	0.34	5.28	4.94
- Case II [c]	2.16	5.02	0.34	5.54	5.20
- Case III [d]	2.16	5.02	0.34	6.34	6.00

a/ per kg of made tobacco. Costs for charcoal include annuity of additional investments in fireboxes. Both charcoal and wood are used in single furnace barns equipped with welded flues and internal chimneys.

b/ no quality improvement.

c/ 5% quality improvement.

d/ 20% quality improvement.

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6 This figure is based on a ex-camp price of MK 80 per ton of graded charcoal, plus 55 MK/t for transport (160 km), plus 15 MK/t for storage and handling. Not included are profits and overheads since General Farming is assumed to produce the charcoal in a vertically integrated manner.

To sum up, the Project has demonstrated that simple, low-cost barn modifications may cut the specific charcoal consumption in tobacco curing down to 2.1 kg/kg. Interestingly enough, with the same barn improvements the specific wood consumption can also be reduced considerably, from the current 18 sm^3/t to a value as low as 8.3 sm^3/t (equivalent to 4.3 kg/kg). The major breakthrough, however, was the observation that charcoal firing helps upgrade the tobacco quality. In fact, the potential competitive advantage which charcoal has vis a vis wood boils down to its superiority in terms of fuel properties. As a homogeneous, high quality fuel, softwood charcoal used for tobacco curing renders higher yields feasible, both qualitatively and quantitatively.

These positive findings notwithstanding, a rapid, large-scale penetration of the tobacco industry with softwood charcoal is unlikely to take place in the immediate future. More likely, there will be a piecemeal transition to charcoal, depending on site-specific economic parameters as well as on the tobacco grower's willingness and ability to take the risks involved in a fuel switch.

3.3 The Household Sector

Occasional disclaimers to the contrary, it appears that the picture of urban household charcoal consumption which emerged from estimates made in 1988 (IPC, 1988) is still an accurate one. Accordingly, it can be assumed that at present a total of 50,000 tons of hardwood charcoal is consumed per year in the four largest cities in the country (see Table 3.3).

Table 3.3: Consumption of Hardwood Charcoal in Malawi 1989

	tpy	Bags per year
Blantyre	30,000	900,000
Lilongwe	15,000	450,000
Zomba	3,000	90,000
Mzuzu	2,000	60,000

In view of the sharp increase in prices since 1987, per capita charcoal use has presumably declined somewhat from the level that prevailed in 1988, but given the current annual rate of population growth (approximately 3%), consumption may have remained roughly constant in absolute terms. Also, it can be assumed that the Forestry

Department's campaign to reduce illegal charcoal production - which was pursued quite vigorously in 1987, but has for all practical purposes been discontinued in the meantime - has had little if any impact on consumption. The official FD statistics show that a total of 6,722 bags of charcoal were confiscated in the Southern Region during the fiscal year 1987/88, while the figure for the Central Region was only 647. In other words, considerably less than 1% of the country's "illegal" charcoal output was confiscated.

The substantial rise in hardwood charcoal prices between 1986 and 1989 can be attributed to increases in supply costs, For average transport distances to urban markets increased, freight rates went up markedly, and the growing scarcity of feedstock resources in the vicinity of towns and cities forced charcoalers to exploit less easily accessible wood stocks. To some degree, the threat of confiscation may also have contributed to the trend for higher prices. Table 3.4 provides an overview of the hardwood and softwood charcoal prices recorded in early 1989 at different market outlets.

Table 3.4: Average Charcoal Prices in Malawi (early 1989)

	MK/t	MK/GJ
Hardwood Charcoal		
- retail level Lilongwe	290	10.74
- retail level Blantyre	400	14.82
Softwood Charcoal		
- cif Lilongwe	165	5.50
- cif Blantyre	285	9.50
- retail level Lilongwe	278	9.26
- retail PTC/Oilcom Blantyre	650	21.67

Whether or not softwood charcoal will succeed in capturing a share of Malawi's sizeable household fuel market will be determined by three factors:

(a) the degree of consumer acceptance;

(b) the progress which is made in establishing and harnessing an efficient wholesale/retail network for the new fuel; and

(c) the volume and price of hardwood charcoal supplied to the market.

Based on the results of the marketing trials conducted so far, it can be conjectured that, with respect to the fuel properties of softwood charcoal, acceptance problems will be less serious than had originally been assumed. On the other hand, however, it is clear that as long as hardwood charcoal continues to be available at roughly the same price as is charged for the softwood variety, it will remain the first choice for the majority of household consumers. Nonetheless, the marketing trials have shown that the consumers' attitude toward the new fuel, which was highly skeptical at the outset, may slowly change in favor of pine charcoal.

Although newspaper and radio advertisements have had - and will continue to have - a certain impact in terms of stimulating demand for softwood charcoal, it will obviously take more than PR campaigns to bring about a large-scale fuel switch in the urban household sector. Unless the government makes major strides in

(a) implementing the proposed Revenue Collection Scheme (Wood Energy Project), and
(b) strictly enforcing the existing laws regarding the utilization of the country's indigenous forests and woodlands (which, admittedly, is a formidable task),

pine charcoal will only slowly penetrate the household fuel market.

3.4 Medium Term Prospects

The following Table 3.5 summarizes the market potential for softwood charcoal by sector. While maximum potential demand is as high as 90,000 tpy, a market share of 15,000 tpy can be considered a realistic target over the next 5 years.

In the first three market segments listed in Table 3.5, the development of effective demand between now and 1995 will be determined primarily by the prices charged for competing fuels, above all coal.

Table 3.5: Potential Markets for Softwo.)d Charcoal
1990 -1995 (tpy)

Market Segment	Maximum	Possible	Targeted
Cement Production	10,000	5,000	2,500
Steam boiler operators	10,000	3,000	1,000
Small industries	5,000	2,000	500
Flue-cured tobacco growers	20,000	15,000	6,000
Households	45,000	30,000	5,000
Total	90,000	55,000	15,000

At present, Kaziwiziwi coal, which is mined some 100 km north of the Viphya Forest, is sold for MK 70 per ton (ex mine). As a result of the successful rehabilitation programme that was recently carried out at the mine, output has once again reached a level of 36,000 tpy. However, if production is maintained at this level, the existing reserves will be exhausted within the next 5 to 7 years. It appears that the Malawi Government will continue to promote the development of other mines in the country. These new mines, however, will eventually have to compete with coal from Mozambique, where the Moatize coal mine is currently being rehabilitated. Moatize coal is most likely to become the least-cost option for industrial consumers located in the southern part of the country. In any case, the medium-term prospects for industrial charcoal demand will be coal-constrained. Of the targeted 4,000 tpy, the 2,500 tpy envisaged for Portland Cement Ltd. are most likely to materialize.

In the tobacco curing industry, however, the picture is different. A fuel switch from firewood to charcoal can be expected to improve the quality of the output, thus increasing revenues. On this score, softwood charcoal will not necessarily have to be the cheapest source of energy available in order to capture part of the market. So it would not come as much of a surprise, if in the mid-1990s softwood charcoal succeeded in covering a market share of about 6,000 tpy.

Finally, the development of effective demand in the household market will be strongly determined by government policies in the woodfuel subsector. If the specific measures that have been recommended by the Wood Energy Project and those which are called for by the Forestry Act will gradually be implemented, and if continued marketing efforts are made to convince households of the benefits inherent to an improved

stove/softwood charcoal package, it should be feasible to pave the way for annual sales of about 5,000 tons.

4. Transport, Packaging and Handling

4.1 Charcoal Transport

In 1986 and 1987, Viphya charcoal benefited from favorable overall conditions in the road transport sector. On the one hand, with construction work on the Viply sawmill in full swing, additional back haul capacity was available in the Northern Region. On the other hand, the Kaziwiziwi coal mine was producing at a rate of only about 10,000 tpy and, thus, absorbed only a small fraction of the available transport capacity. Moreover, the private trucking firms serving the Viply project preferred to utilize their back haul capacity for charcoal transport not only because loading times were shorter than with coal, but also because they could not always be sure that there wold actually be freight to haul at the mine, which is in any case located more than 100km further north than the charcoal camps. Indeed, the project was able to negotiate freight rates with the transport firms that operate in the northern part of Malawi which were calculated on a per-ton-hauled rather than a carrying-capacity basis. In 1987, between MK 100 and MK 115 per ton were paid for charcoal hauled to Blantyre, which is 650 km from the Viphya forest. Thus, the specific costs worked out at MK 0.16/t/km, which was even lower than the rates set forth in the ADMARC tariffs generally considered to be the benchmark rates for road transport in Malawi.

In 1988, as the output of the Malawi Charcoal Project increased, construction activity at the Viply plant slowed down and the output of the Kaziwiziwi mine expanded, the demand for road transport capacity in the north exceeded the available supply and, as a result, rates went up sharply. In addition, a sizeable new source of demand for road haulage services - one with substantial purchasing power - emerged, namely the aid programs which are responsible for supplying food, clothes and other necessities to the 600,000 Mozambican refugees in Malawi. As more and more of the available road transport capacity was absorbed by the organizations involved in these aid programs, the transport market, which had previously been quite stable, rapidly became supply-constrained. Freight rates rose by more than 100% in 1988. Although the aid organizations brought in a certain number of vehicles of their own to move the relief supplies, thus reducing the truck shortage somewhat, the resulting increase in capacity was far too small to significantly redress the growing imbalances.

For the Malawi Charcoal Project, this meant that road transport costs now have to be calculated on a round-trip basis. Accordingly, specific transport costs (Viphya Forest - Blantyre) are currently in the range of 0.35-0.4MK/t/km.

In view of the sizeable increases in the rates charged by road carriers, haulage by rail (which had to be ruled out in 1987 for economic reasons) can now be regarded as a potentially viable transport option for softwood charcoal. Unlike private trucking firms, though, Malawi Railways does not regularly adjust its rates in accordance with changes in market conditions. Therefore, the cost advantage which the road/rail option currently seems to enjoy (see Table 4.1) may be fallacious. Should the Project enter into negotiations with Malawi Railways, different rates might be set that could well place the rail/road option at a disadvantage.

Table 4.1: Transport Costs for Softwood Charcoal 1987 and 1989 (MK/ton)

Destination	Distance (km)	1987 Road	Road/ Rail a/	Distance (km) b/	1989 Road	Road/ Rail
Lilongwe	280	50	-	280	98	-
Zomba	560	95	124	560	195	160
Blantyre	630	110	132	580	200	170

a/ Road to Lilongwe and rail from Lilongwe to Zomba or Blantyre.
b/ Transport distance to Blantyre reduced owing to construction of new, shorter road link.

In summary, there are three major lessons to be learned from the Project's experience with charcoal transport. Firstly, the fact that Viphya charcoal had to be hauled over distances of more than 600 km did not severely impair the viability of the charcoal operations. However, since transport costs placed a heavy burden on the economic performance of the Project, considerable efforts were needed to efficiently manage the transport activities. Secondly, road haulage which was organized on the basis of contractual agreements with private carriers, proved the most reliable mode of transport. It also kept the administrative requirements at a comparatively low level. Thirdly, given the low bulk density of softwood charcoal, cost efficient road transport should resort to vehicles with a high ratio of bed-surface area to payload capacity (m^2/t). In fact, the optimal solution would be the use of 7-15 t long-bedded lorries in combination with trailers. The Project, however, has to cope with trucks designed for heavy loads (20t-35t). Therefore, the policy was to bargain transport rates based on the

proposition that the carrier would fully use the rated payload capacity (which, technically, was not feasible). Moreover, the rates were determined on a per bag basis. As a consequence, the Project, by-and-large, avoided to pay for carrying capacity (t) that, due to the low bulk density of pine charcoal, could not be utilized, while the transport companies had an incentive to haul as many bags as possible.

4.2 Charcoal Packaging

During the initial stage of the Project, when the combined output of the charcoal centers was still relatively small, charcoal packaging posed no major problems. For approximately 6 months, an adequate supply of second-hand bags (polypropylene) was available at a reasonable price. By mid-1987, however, it became clear that

(a) the quantity of second-hand bags that could be obtained would not be sufficient to package the growing charcoal output;

(b) polypropylene packaging material was generally becoming scarce in Malawi (owing to problems encountered by the bag manufacturer, Blantyre Netting, in the importation of such material), and, as a result, increasingly expensive as well; and

(c) the type of polypropylene that is commonly used for bags in Malawi is not an optimal packaging material for charcoal, especially if the fuel has to be stored outdoors: owing to its sensitivity to ultraviolet radiation, it deteriorates quickly when exposed to sunlight for an extended period of time. The maximum recycling factor for new bags was 3.

Table 4.2: Development of Packaging Costs 1986-1989

	Price per bag MK	Recycling Factor	Packaging Costs [a] MK/ton
1986 [b]	0.6	1.5	8.6
1987	1.76	3.0	15.8
1988	2.48	3.0	22.3
1989 [c]	2.80	3.0	25.2

a/ at 36 bags per ton
b/ November/December
c/ January/February

As can be seen from the Table 4.2, charcoal packaging costs went up by approximately 200% between late 1986 and early 1989. By comparison, the overall cost of living in Malawi rose by only about 40% during the same period.

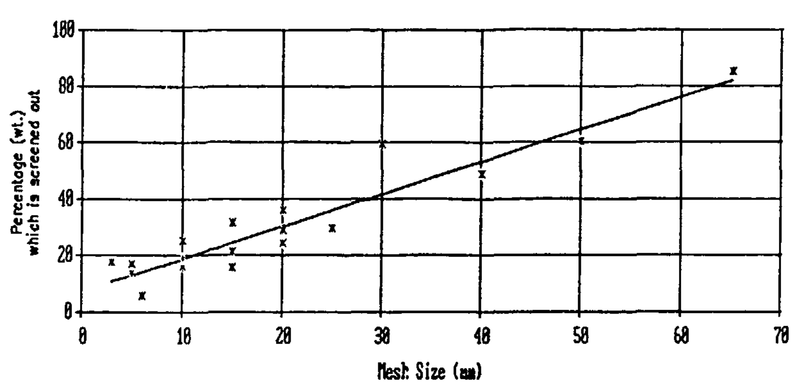
It should be noted in this context that the price increase for packaging material has affected both softwood and hardwood charcoal. At present, hardwood charcoal traders are attempting to maximize the recycling factor, and thus keep outlays for packaging material to a minimum, by requiring customers to turn in an empty bag if they wish to purchase bagged hardwood charcoal. In the meantime, the project has also adopted this practice: customers who have already purchased charcoal must return their empty bags if they wish to purchase additional quantities of the fuel. While a certain percentage of the returned bags are no longer serviceable and must be replaced, many can be re-used several times and it now appears that the project is able to bring average specific packaging costs for 1989 back down to roughly the 1987 level (MK 15/t).

4.3 Charcoal Handling

Grading trials conducted by the Project demonstrated that charcoal fines (< 10 mm) are produced mainly during the carbonization process. Contrary to what had been expected, however, transport and handling generate only a comparatively small amount of fines: charcoal that had been screened prior to transport with a 10-mm mesh was screened again after it arrived in Lilongwe using the same size mesh. The resulting fines share was less than 10% - an acceptable value for most applications.

A series of screening tests was carried out with ungraded charcoal delivered to tobacco estates in the Central Region. Screens with two different mesh sizes - 10mm and 15 mm - were used and sieving losses varied between 20% and 36%. (see Figure 4.1).

Figure 4.1: Screening Test



The tests also revealed that 75% of the run-of-kiln charcoal is of a size (> 12 mm) appropriate for use by the tobacco industry. As long as there is no market outlet for the fines, they must be regarded as waste material, thus increasing the production costs of screened charcoal by 33.3%. Clearly, it is advisable to screen the charcoal at the production site, for otherwise the customers would be charged for the transport of waste material.

Another aspect that militates in favor of centralized screening operations at Viphya is that there is only one potential market outlet that could absorb significant quantities of fines, namely Portland Cement Ltd. Downstream screening (e.g. through wholesalers) would thus give rise to higher administrative and handling costs.

The data yielded by the combustion trials in the tobacco industry shed new light on another important aspect of fuel handling: Although the hygroscopicity of the charcoal causes serious problems if the fuel is not protected from rain, the contention that "drier is always better" did not hold. In the range between 5% and 20% mcwb, increases in water content did not lead to a rise in specific fuel consumption. Indeed, charcoal with a moisture content of 20% may prove a more economical fuel for the tobacco industry than is dry charcoal because less carbon will be burnt per kg of tobacco cured at 20% mcwb than would be the case at 5% mcwb. Only when the moisture content exceeded the 25% level were significant increases in specific fuel consumption observed. The positive impact of a higher fuel moisture content (up to 20%) on tobacco curing can be explained by the relationship between the efficiency of heat transfer in the flue pipes and the generated volume of flue gas (average gas speed). In other words, the water vapor produced by the combustion of wet fuel increases the flue gas volume and improves heat transfer in the flue pipes. The enhanced heat transfer is more than sufficient to compensate for the moisture-induced decrease in the net heating value of the fuel.

For household applications, moisture levels should be kept below 15%. Here the effect of convection or heat transfer (between the flue gases and the pot) is less pronounced than in tobacco curing (the direct radiation emitted by the fuel bed also contributes energy for the cooking process). Although the consumers are accustomed to drying charcoal if it has become very wet during transport (especially during the rainy season), household charcoal should be handled in such a way that the absorption of moisture is kept to a minimum.

5. Marketing Trials and Publicity Campaigns in the Household Sector

It is invariably difficult to introduce a new domestic fuel in a developing country, and in Malawi it was clear from the beginning that although conditions are, generally speaking, favorable for a fuel switch in the urban household sector, softwood

charcoal would probably not be immediately accepted by the members of the target group. Acceptance problems are almost always encountered when new fuels are marketed, regardless of whether household or commercial consumers are involved. Indeed, even in Malawi's industrial energy markets, the decisions that are made for or against specific fuels are not based exclusively on cost considerations. However, in the industrial sector, the criteria are at least made explicit and potential users - who can be approached individually - are usually quite willing to listen to, and be persuaded by, rational arguments. This is not quite true in the household fuel market. Household consumers are conservative and skeptical in their attitude toward products with which they are not thoroughly familiar: a new fuel is critically examined, and even the most minor, seemingly unimportant deviations from the "norm", not only in terms of how it burns (primary fuel properties) and how it looks, but also in terms of how it is distributed (retail system), can lead consumers to reject the new product outright. And even if they can be persuaded to use a new cooking fuel, they will have thought long and hard about it before doing so and may have second thoughts about their decision. Experience in other African countries has shown that while a fuel switch is feasible in the household sector, domestic users will as a rule only begin using an alternative to their traditional fuel if shortages of their "first choice" have become so acute, and its retail price has increased so much, that it is no longer affordable, or if the traditional fuel is simply no longer available at all. In any case, in Malawi it became evident that it would not be possible to induce urban households to switch to softwood charcoal unless a) a large-scale marketing campaign is conducted, and b) measures are implemented to impede the flow of traditional charcoal to the country's towns and cities.

Therefore, the Project launched altogether four marketing trials, two of which were still in progress in mid 1989. During the pilot phase, initial marketing activities were carried out in Lilongwe (500 bags sold) in order to evaluate consumer acceptance of softwood charcoal. The feedback from this trial highlighted the principal drawbacks which softwood charcoal - compared with the traditional hardwood variety - has as a household fuel, namely its lower bulk density and greater friability (higher share of fines). Since in Malawi charcoal is usually purchased by volume rather than by weight, the major complaint of the consumers was related to the new fuel's higher volumetric consumption rate (i.e. a stove-load of softwood charcoal does not burn as long as a stove-load of hardwood charcoal). Even though project personnel explained to the consumers that the charcoal was being sold by weight and that, in terms of the price per kilogram, it was less expensive than hardwood charcoal, softwood charcoal was frequently deemed not as good a value as hardwood charcoal. Nor did the dissemination of the results of cooking tests carried out by the Energy Studies Unit, which demonstrated that specific fuel consumption (weight-based) is lower with softwood pine charcoal than with hardwood charcoal, help eliminate the misconception that softwood charcoal is comparatively expensive. Because its bulk density is lower than that of "traditional" charcoal, consumers' tend to perceive pine charcoal as being the more costly option.

Surveys also revealed that, when purchasing fuel, people do not necessarily consider price - even the price per unit of volume - to be the key criterion. In many cases, they expect a given quantity of fuel - e.g. one bag, one tin - to last for a certain period of time, and if it does, they feel that they have got their money's worth. For example, a bag of hardwood charcoal which costs MK 12 (approx. 30-35 kg) is regarded as a 1-month supply, while a tin (MK 0.5 for approx. 1 kg) is considered to be enough for one day. The considerable difference between the price of a kilogram of charcoal when the fuel is bought by the bag and when it is bought by the tin (almost 50% higher) indicates that financial considerations do not necessarily play a decisive role here. The test also showed that consumers regard the new fuel's friability or, as the case may be, its higher fines content, as a less serious drawback than its lower bulk density. Consequently, after the project began grading all charcoal sold on the retail market, and, in addition, offered to take back any bag which, in the purchaser's view, contained an excessive amount of fines, there were far fewer complaints regarding fines.

When the second trial was launched in mid-1987, the initial aim was to forge a new distribution network for softwood charcoal. Although an extensive and sophisticated system of wholesale and retail distribution chains for traditional hardwood charcoal already is in place, harnessing this network proved difficult. So the Project decided to explore the opportunities for marketing softwood charcoal through a "new generation" of dealers who operate independently of the established infrastructure for trading charcoal. Assisted by SEDOM, a financial institution specialized in the promotion of small-scale entrepreneurs, the Project selected 20 businessman interested in retailing softwood charcoal, the majority of whom were located in the Blantyre area. However, this attempt to lay the groundwork for a parallel marketing structure was not particularly successful. The dealers supplied by the project complained that it was very difficult to compete against the illegal charcoal traders. Although this was certainly true, the attitude and the actions of the dealers themselves were responsible for many of the problems they encountered: Most of the persons involved had been clients of SEDOM. In view of the rather generous funding which they had received from SEDOM in the past, the majority of the dealers apparently regarded the charcoal - which was delivered to them with the understanding that they would pay for it within 30 days - as a further subsidy. Indeed, even after the fuel had long since been sold to consumers, many of the dealers had still not reimbursed the project for it. In addition, these retailers expected to reap a very high profit on charcoal sales: Although the fuel had been delivered - pre-packaged and ready for sale - for MK 6 per bag, they sought to re-sell it for MK 12-15 per bag, and, therefore, tended to price themselves out of the market. In fact, even though these trials were carried out at a time when the flow of traditional charcoal to Blantyre had been hampered by partially effective controls set up by the Forestry Department resulting in temporary supply shortages in the local hardwood charcoal market, relatively little softwood charcoal was sold via the SEDOM traders. Moreover, the unwillingness of many of these new retailers to reimburse the Project for the charcoal they had received

gave rise to rather substantial administrative costs that had to be met by the Project in its capacity as the charcoal wholesaler. After approximately 3 months it was therefore decided to discontinue the marketing trial.

The poor performance of the SEDOM retailers aside, a major lesson learned from the second marketing experiment was that bypassing the existing wholesale/retail network should not become an end in itself. Rather, this strategy may at best be a vehicle for penetrating particular market segments that are more easily accessible with the help of a new product image of which the market outlet is a distinguishing feature. In designing the next two marketing trials, the Project thus redirected the focus on a dual approach: One that aimed at comparatively affluent households, using PTC-supermarkets and OILCOM petrol stations as retail outlets; and another targeted at low-to middle income households that should be reached through traditional, already existing distribution channels.

Both approaches were backed up by a large-scale publicity campaign that used newspaper advertisements and media features to promote Viphya charcoal as a household fuel:

(a) consumers were made aware of the fact that softwood charcoal is now available as an alternative to traditional charcoal and told where they could purchase the fuel (retail outlets);

(b) it was pointed out that pine charcoal is made from forestry wastes, and is thus an environmentally sound fuel;

(c) the specific fuel properties of Viphya charcoal were explained and contrasted with those of traditional charcoal and its suitability for use in household cooking was emphasized;

(d) the advantages of the improved stove being disseminated by the Wood Energy Project - the Malawi Ceramic Mbaula -as a cooking device for softwood charcoal were stressed and consumers were urged to buy the fuel and the stove as a package.

The trial aiming at wealthy consumers was conducted in cooperation with the PRESS Corporation in Blantyre. What should be investigated was the scope for marketing a special brand of pre-packed softwood charcoal at fixed prices via a retail system operating outside the traditional supply channels. In order to ensure a high quality standard, all charcoal was carefully graded by the Project before being packed in the 1-,3-and 6-kg plastic bags in which it was delivered to the PRESS Corporation. All bags carried the label "Pine Charcoal". The trial was limited to a total of 20 retail

outlets - 13 PTC shops and 7 OILCOM stations. The PRESS Corporation was supporting the marketing activities with an advertising campaign of its own in the national newspaper and on the radio. The selling price of the charcoal, which covered all distribution and packaging costs plus profit, was set at MK 0.65 per kg, which is higher than the price that consumers pay for hardwood charcoal sold by the tin through conventional outlets.

The other trial was executed in collaboration with Chisawani Enterprises in Lilongwe that assumed both wholesale and retail functions. In addition, the firm intended to utilize the existing network of hardwood charcoal retailers. Thus, traditional traders could offer their customers both types of charcoal: hardwood charcoal as well as pine charcoal obtained from Chisawani Enterprises which is not charged with enforcing government policy and will not report them to the Forestry Department for selling hardwood fuel. In order to create favorable conditions for this trial, INDEFUND, which was providing finance to the wholesaler, requested the Forestry Department to ensure that softwood charcoal would not be sold by its own regional offices at excessively low prices as long as the test marketing activities were in progress. In this trial, it was also considered essential to offer consumers a product of uniform quality, and to this end the Project assisted the wholesaler in grading the fuel. Chisawani Enterprises was also marketing the Malawi Ceramic Mbaula, and in the advertising campaign launched by the firm, the advantages of purchasing the fuel and the stove as a "package" were being stressed.

Both trials were initiated in January 1989, and the results to date (mid 1989) can be summarized as follows:
As regards the PTC/OILCOM outlets, the sales proved disappointingly slow in the beginning, but then picked up considerably. Sales took a turn for the better because:

(a) heavy rains in most parts of the country led to problems in the production and transport of traditional charcoal and, as a result, the hardwood fuel was in short supply. And the quantity of hardwood charcoal that did reach the Blantyre market exhibited a high moisture content and had to be dried before it could be burnt. By contrast, the PTC charcoal, which was packed in plastic bags, was dry and ready for use.

(b) the publicity campaign had obviously convinced a number of people to try the new product that was displayed at PTC stores and OILCOM filling stations, and as more and more consumers found that it was an acceptable cooking fuel, the target group's initially skeptical attitude toward pine charcoal slowly began to change.

(c) reliability of supply played an important role, i.e. consumers became aware of the fact that they would not waste their time looking for fuel if they went to a PTC shop of OILCOM outlet where pine charcoal was on sale.

Although the results of the PTC/OILCOM trial have generally been promising so far, many potential consumers still have reservations about pine charcoal and it will obviously take a considerable amount of time to overcome this problem. Currently, the market segment in Blantyre that can be supplied through PT/OILCOM outlets is estimated at 10 tons per month. In addition, the prices charged for the 1-,3- and 6-kg bags, which include a 30% markup appeared to be too high for middle and even high income consumers, who had been used to purchasing hardwood charcoal in substantially larger quantities (30-35 kg) at a lower price per kg. Thus, the PRESS Corporation will consider reducing its markup, at least during the initial phase of the marketing activities.

On the other hand, less affluent city dwellers, i.e. the typical clientele of traditional hardwood charcoal dealers who sell the fuel in small quantities, do not ordinarily patronize the PTC supermarkets. The tests therefore provide no conclusive evidence on the low-income households' willingness to pay for the charcoal brand distributed through parallel market outlets. The hypothesis, however, that the bulk of the pine charcoal sold at PTC shops and OILCOM filling stations will be purchased by relatively affluent high income households is supported by the fact that the 3-and 6-kg bags sold much better than the 1-kg bags even though the price per kg was the same for all three bag sizes. Consequently, the PRESS Corporation is considering stocking only the 3- and 6-kg bags in the future, and if only the two larger bags are used, specific average packing costs will, of course, drop.

Overall, the results of the Lilongwe trial have not been particularly encouraging. Sales rose from 663 bags in January to 1,084 in February, but then dropped to 501 bags in April and recovered to 825 bags in June. Moreover, with its rather limited manpower and technical resources the firm would not be prepared to meet a major upswing in demand. Also, should market demand burgeon and absorb several thousand bags of softwood charcoal, a more competitive supply structure would be expedient. So far, it was justified to seek some niche within the market for urban household fuels and to establish trial-based evidence on the marketability of softwood charcoal. This task could be accomplished with the help of a single, closely monitored supplier. In the future, though, the challenge will be to transform the "research-constrained" supply schedule into a sales program that draws support from a much larger segment of the existing wholesale/retail network. Consequently, in mid-1989 the Project began mounting initiatives to increase the number of enterprises and individuals willing to supply urban markets with softwood charcoal by utilizing the trade infrastructure already in place.

6. Summary and Conclusions

As for the experience gathered by the Malawi Charcoal Project to date, it is important to distinguish between country-specific factors and constraints on the one hand, and, on the other, more general issues which may be relevant in other countries as well. The country-specific insights gained in the course of the Project will prove useful if further activities are initiated in the biomass sector in Malawi to improve the management of the country's forest resources and exploit the energy potential of forestry and wood industry wastes. Certain insights of a more general nature may prove valuable in the process of identifying, planning, and implementing similar projects in other countries. The lessons that can be learned from the project are quite unspectacular; they do not point to any strikingly new, revolutionary approaches to solving the kinds of problems which countries like Malawi face in the energy sector. However, they are derived from field work and, for that matter, rest on facts and empirical evidence rather than on speculative or discursive reasoning.

6.1 Fuelwood Crisis or Wood Surplus

For some years now, experts have been predicted impending fuelwood shortages in Malawi and developed crisis scenarios for its biomass energy sector. Based on their projections, this small country, whose southern and central regions are quite densely populated, should be completely deforested by now.

There is no doubt that the Southern and parts of the Central Region are facing woodfuel supply problems. And there is also no question that it was easier and cheaper for a large percentage of the population to obtain woodfuels 10 or 15 years ago. But there are still trees in Malawi and both the urban and the rural population still cook their meals using firewood, charcoal or other biomass. What happened? Were all the estimates of stock depletion rates and forest productivity that were made in the 1970s quite simply wrong? Was the demand for woodfuels, i.e. the specific energy consumption of families or individuals overestimated? Most probably, the key figures in both areas were "adjusted" in the relevant studies in order to emphasize the need for action. And action has indeed been taken: a number of projects have been launched by the government and by bilateral and international organizations. Fortunately, the crisis scenarios did not accurately forecast the future: taken together, all of the projects that have been initiated so far would not have been sufficient to stem the fuel crisis that would have resulted if the projected supply deficits had materialized. From this, one should not, of course, conclude that all these efforts have been useless and that they have been directed toward the solution of a problem which does not exist or would never in fact emerge. However, if these activities had been based on a more realistic picture of

woodfuel demand and supply rather than on crude estimates and projections, they might have better seized the opportunities for remedial action.

In this connection, the charcoal project has helped reshaping common perceptions about two pivotal issues. Firstly, by drawing the attention of energy planners and policymakers to a large, hitherto neglected woodfuel resource base which is provided by the flow of wastewood generated on government timber plantations, it has challenged the wisdom that tree planting and (peri-urban) afforestation programs would be the single most important approach to strengthening the woodfuel supply side. Secondly, the Project has demonstrated that a seemingly remote location does not necessarily place this resource base at an overwhelmingly large disadvantage. In fact, for a number of experts it was not conceivable that charcoal made from waste wood available at Viphya would be competitively supplied to markets as distant as Blantyre (> 600 km). While this particular success story may not be replicable in other countries, it nonetheless indicates that "distance" may prove to be an obstacle not quite as forbidding as it might look at first glance. On the basis of the Malawi experience it can be argued that the real challenge placed by woodfuel crisis scenarios is to manage spatially fixed and dispersed biomass resources in such a way that the resulting flow of woodfuels redresses regional imbalances in demand and supply.

6.2 Improved Charcoal Production

The semi-industrial, labor-intensive mode of charcoal production that was selected by the Project (manual feedstock harvesting, oxcart transportation, carbonization using fire-brick kilns and simple wooden storage facilities) has proved cost efficient and appropriate to local conditions. All necessary inputs and materials could be procured locally, and it proved feasible to teach the local labor force the techniques required for the construction and operation of the kilns. As a result there is now a core staff of about 100 trained charcoal makers available.

As regards conversion efficiency, the brick kilns yielded highly satisfactory results (average weight-based conversion efficiency of 31%, which is equivalent to an energy efficiency of 62%). Equally important is the fact that the charcoal produced by these kilns has excellent primary fuel properties which can be kept uniform over time. In fact, the charcoal would find it easy to meet the high quality standards that prevail, say, in European markets. Moreover, the kilns are capable of carbonizing not only hardwood and softwood logs, but also waste material (slabs, off cuts) generated by sawmills.

While it is widely believed that the use of stationary brick kilns is limited to production sites that are endowed with dense stands of woody biomass (e.g.

plantations), the experience of the Project suggests that this view may not result in a proper assessment of the trade-offs involved in the choice of carbonization technologies. In particular, the capital costs of brick kilns tend to be a less decisive factor than is commonly assumed. (In the framework of the Project the annuitized capital outlays account for only 15% of the total production costs net of profits and overheads). So in essence the higher feedstock extraction costs associated with a lower feedstock density should be weighed against the gains brick kilns provide in terms of conversion efficiency, charcoal quality and the uniformity of the charcoal output. These gains could well favor the use of stationary brick kilns even when the feedstock density proves significantly lower than is the case in Malawi. Be that as it may, for medium scale, semi-industrial and labor-intensive charcoal operations the overriding advantages inherent in the use of brick kilns can now be regarded as proven - in the Malawian context and most probably under roughly similar conditions in other African countries.

6.3 Potential Uses of Charcoal

Unlike the various charcoal production activities launched in other African countries, the focus of the Malawi Charcoal Project was not restricted to traditional charcoal uses such as cooking or space heating. Rather, the Project has gathered valuable experience regarding the use of charcoal in industrial and agroindustrial applications.

The technical feasibility of charcoal use was established in cement production (dry process rotary kilns) and steam generation (chaingrate and fixed-grate flame tube boilers). In both cases, though, straight charcoal use should be regarded as an emergency or stand-by option since it has certain drawbacks (reduction of steam capacity and additional input for fuel storage and handling). However, while the kilns and boilers in question are designed to be fired with fuel which has some "standard" properties, these properties can be approximated by blending charcoal with coal. But due to the additional costs involved in boiler retrofits and other necessary equipment modifications and given the more complicated handling procedures which must be introduced, charcoal will not be a truly attractive alternative unless it is significantly cheaper than coal. What the Project has learned is that the mere prospect of (uncertain) cost savings is not sufficient to make a convincing case for the use of charcoal as an industrial fuel.

Field tests in the tobacco curing industry have shown that charcoal is an ideal fuel for use in low-tech curing barns. Generally speaking, it can be concluded that with retooled, single-furnace brick barns the specific fuel consumption lies in the range of 2 to 3 kg of charcoal per kg of made tobacco. This implies that the use of charcoal would be more energy efficient than the operation of similar barns on the basis of

fuelwood. In Malawi, though, the specific fuel costs still are in favor of fuelwood. But since charcoal is the better curing fuel, its higher energy costs are likely to be offset by gains from improvements in tobacco quality, provided that the barns are properly designed, maintained and run.

As is indicated by its fuel properties and has been confirmed by combustion trials, softwood charcoal produced in brick kilns has, technically speaking, no serious drawbacks as a household fuel. In Malawi though, the households' preferences are strongly in favor of traditional hardwood charcoal. Again, the Project had to learn that much more than a cost advantage is needed to induce potential consumers to switch towards softwood charcoal. In fact, the experience has shown that the marketing difficulties lie in the different product image which softwood charcoal has in terms of price, density, friability, origin, etc. Accordingly, the task of penetrating the household fuel market has proved much more difficult and daunting than the Project expected. Attempts to bypass the existing wholesale and retail infrastructure, i.e. to exclusively supply softwood charcoal through new, parallel market channels have failed. More successful has been a dual approach to marketing softwood charcoal in the household sector: There is now a product line sold by "high-end" retailers that rely on better service and value, rather than price, to compete with hardwood charcoal. This strategy is intended to carve out market niches with quality-conscious consumers. Bulk supply, on the other hand, is geared towards the lower end of the retail scale using the network of (hardwood) charcoal traders which is already in place.

6.4 Market Potential and Prospects

Initially, the Project's marketing efforts put much hope on the potential for industrial charcoal use (cement production, steam generation). However, the direction of the marketing activities had to be modified for three reasons:

First, supply constraints for coal (both imported and local) were eliminated in late 1988. The Kasiwiziwi mine increased its output significantly, and with the implementation of preferential trade agreements which allow SADCC member countries to purchase commodities from each other using their own currencies, it became also easier to import coal. Second, from a technical standpoint, the use of charcoal in the existing industrial furnaces and boilers in Malawi proved more difficult than had been assumed. Third, it turned out that other sectors - notably the tobacco industry and urban households - were facing more severe fuel supply problems than the country's industrial sector. Moreover, woodfuel consumption in residential and agro-industrial areas contributed significantly to deforestation. Thus, toward the end of 1988 the time had come for a reorientation of the Project's objectives as regards the major market outlets for softcoal charcoal. The principal focus shifted from a transparent and more or less undistorted segment of the fuel market (industrial coal) to the difficult area of replacing

woodfuels from natural forests, where prices are distorted and consumers are guided by traditions and norms that tend to defy "pure" economic reasoning.

In the tobacco curing industry, for instance, initial efforts to introduce softwood charcoal did not succeed because it was cheaper than fuelwood. Rather, charcoal succeeded in spite of the prevalence of distorted prices that militate in favor of fuelwood. Indeed, the outlook for pine charcoal is now favorable in this market mainly because the Project was able to develop a fuel/curing barn package that yields higher net revenues for the tobacco growers.

In the household sector the situation is somewhat different. Although softwood charcoal turns out to be a cheaper cooking fuel than the hardwood variety, the cost differential proves too small to immediately overcome the sales resistance of most urban households (softwood charcoal is still perceived as an inferior alternative to the traditional hardwood variety). Thus, the medium-term sales prospects for softwood charcoal seems to be most promising in the tobacco-curing industry. Unless governmental pricing policies and/or disruptions in supply happen to drastically increase the costs of producing and using hardwood charcoal, softwood charcoal will hardly be on the verge of capturing a substantial share of the urban household fuel market.

While the overall potential for softwood charcoal to penetrate the industrial fuel market has been dwindling, there remains a quantitatively significant and strategically important "niche" which, in principal, should be accessible to softwood charcoal. In fact, Portland Cement Ltd. could not only absorb several thousand tons of softwood charcoal for annual use as a blend with coal; it would also provide a market outlet for the large share of fines that the carbonization of softwood species is doomed to generate at the production sites.

All in all, the picture looks considerably less promising than earlier conjectures made by the Project had suggested.[7] In this connection, though, it should be mentioned that overly optimistic estimates of the market potential for softwood charcoal have not determined the pace for the capacity expansion program. As a result, the currently installed production capacity is roughly in line with the level of demand that can be expected to prevail in the near future. Should effective demand approach the level

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7 Given the high quality which softwood charcoal has in terms of its primary fuel properties, the Project has also investigated the scope for exports to premium markets (e.g. Europe). However, the additional expenditures for charcoal briquetting (which is a precondition for cost-efficient long-distance transport) as well as logistic constraints have led to the conclusion that the export option cannot be regarded as a particularly attractive one at the moment (see IPC, 1988).

which is now being predicted - on reasonable grounds - for the mid-1990s (about 15,000 tpy), capacity additions could be easily accomplished. The more crucial question is whether there will be enough private entrepreneurs willing and able to finance and, most importantly, to manage the incremental charcoal operations.

6.5 Institutional Issues

In Malawi, the groundwork is currently being laid for a coherent package of energy policies covering both "commercial energies" and firewood cum charcoal, the "traditional household fuels". In most developing countries there is much lip-service paid to energy planning, but few efforts are made to coordinate the activities in these two subsectors. In Malawi, though, the necessity to formulate integrated policies has been recognized and first steps have been taken to implement a variety of measures designed to enhance the performance of the subsectors in question. From this angle, the institutional framework faced by the Charcoal Project can be regarded as exceptionally favorable.

Since its establishment, the Forestry Department was mainly responsible for the operation of government pulpwood and timber plantations. In early 1985, however, it was also given the job of managing all forest resources on customary land. In addition, the FD was made the implementing agency for two major development projects (Wood Energy, Blantyre City Fuelwood). Not surprisingly, this has created an acute shortage of specialized personnel at all levels of the FD, impeding the efforts to more efficiently manage the sector's resource base. In particular, most of the Forestry Department's field personnel is still being employed on government timber plantations. As a result, there is a lack of staff to enforce existing and newly enacted laws regarding the utilization of indigenous forests. This means, among others things, that the "untaxed" feedstock of hardwood charcoal continues to be cheaper than that of environmentally sound softwood charcoal, thus undermining the competitiveness of charcoal produced from waste plantation wood.

Also, the additional and new responsible of the FD were not adequately backed with financial resources and operational autonomy. In particular, the Viphya Plantation Division was not in a position to finance the charcoal operations launched by the Project (In fact, the finance required was advanced by the Project out of a special fund).

Finally, it is worth mentioning that with respect to the country's solid fuel market where, to some degree, locally mined coal, imported coal and softwood charcoal compete with each other, a clear agenda for policy action has not yet been formulated.

Clearly, this policy gap has placed softwood charcoal which, after all, is a new and unusual fuel at a disadvantage within the industrial fuel market.

6.6 Lack of Commercialization

In view of the Forestry Department's limited capabilities to efficiently manage large scale charcoal operations, and given the fact that the Department's available manpower resources and expertise are more urgently needed in other areas of natural resource management, it was the Project's ultimate goal to transform the charcoal production activities into a private sector venture, either by contracting out existing production facilities or by franchising the right to install new capacity and use the available wood waste as a feedstock.

So far, however, only 3,000 tpy of installed capacity have been leased to a single contractor, a tobacco producer. Other candidates from the tobacco curing industry, let alone small-scale entrepreneurs serving domestic markets, have yet to be found. In this respect, the Project has not been able to fulfill one of its main objectives.

One retarding factor was that the existing legal framework did not allow for private sector operations carried out within the traditional domain of the Forestry Department. Matters were complicated by the fact that charcoal operations are frequently deemed a ruthless business. Policy makers, in particular, were concerned about the bad reputation which charcoal production on government plantations could have. As a consequence, a series of interministerial discussions was required to draft a legal framework and prepare a standard concession agreement that sets the rules for privately run charcoal production schemes supplied with waste wood from government plantations. This has deferred the Project's negotiation with potential private contractors until mid-1989.

Due to policy gaps including pricing policies (the latter under consideration by government), there are no entrepreuners queuing up to take over the existing production schemes or to invest in new ones. Additional efforts and, if need be, new policy initiatives may be required to encourage the participation of the private sector in soft wood charcoal operations.

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ANNEX I: Welfare Implications of Uniform and Discriminatory Stumpage Fees

For the sake of simplicity we assume that charcoal consumers are alike, charcoal demand (D), on a per ton basis, is linear in price (P), i.e.

$$D = a - bP, \tag{1}$$

and charcoal consumers are uniformly distributed across the country.

Let f denote the stumpage fee (netback value) per ton of Viphya charcoal inferred from the market price prevailing in Blantyre. If k denotes the unit charcoal production costs ($/t), while c stands for the constant unit transport costs ($/t/ unit of distance), the delivered price of Viphya charcoal hauled over a distance x works out at

$$P(x) = f + k + cx, \quad x \leq R, \tag{2}$$

where R is the transport distance to Blantyre. Clearly, P(R) is equal to the market price charcoal commands in Blantyre, resulting in a stumpage fee f(R) = f.

Equation (2) resembles the conventional "mill pricing" formula (see, for instance, Holahan 1975): Prices are set so as to equal landed costs which encompass the price charged at the production point (= f + k) plus freight to the point of delivery (= cx). Thus, in the present context mill pricing is equivalent to imposing a uniform stumpage fee.

Alternatively, one can impose a uniform price throughout the country, leading to discriminatory stumpage fees at Viphya. Assuming that the market price prevailing in Blantyre is charged across the country, stumpage fees (per ton of charcoal) at transport distance x amount to

$$f(x) = f + cR - cx, \quad x \leq R. \tag{3}$$

Clearly, the total stumpage fees which accrue from charcoal sales at price P(x) are a function of demand. Substituting (2) into (1) yields

$$D(x) = a - b[f + k + cx], \quad x \leq R. \tag{4}$$

Disregarding the uniform consumer density, the sum of stumpage fees that can be collected under a system of mill prices is therefore given by

$$SFM = \int_0^R fD(x)\, dx = fD(R) + cR[1-R/2]bf \tag{5}$$

On the other hand, the total amount of discriminatory stumpage fees that can be collected under a regime of uniform fees is determined by

$$SFU = \int_0^R [f + cR - cx] \, [D(R)] \, dx \qquad (6)$$

$$= fD(R) + cR\,[1 - R/2]D(R)$$

Let us standardize the transport costs so that $1 < R < 2$. Then, SFU $\gtrless$ SFM if D(R) $\gtrless$ bf.

As can easily be verified, the condition D(R) $\gtrless$ bf is equivalent to

$$e(R) = -\frac{dD(R)}{df}\,\frac{f}{D(R)} \lessgtr 1, \qquad (7)$$

where e denotes the elasticity of charcoal demand with respect to the stumpage fee that is imposed on a unit of charcoal sold in Blantyre. Consequently, if charcoal demand in Blantyre is stumpage-fee-inelastic ($e < 1$), a system of uniform delivered prices will maximize the total amount of fees collectable at Viphya, whereas in the case of stumpage-fee-elastic demand the mill-pricing approach will maximize revenues from stumpage. The rationale underlying this result is obvious: <u>If demand in Blantyre and, thus, throughout the country ($x \leq R$) proves inelastic, aggregate stumpage fees can be increased by rising the level of fees charged per unit of charcoal</u>.

Moreover, since the areas under the demand curve are triangles, the aggregate consumers' surplus is defined as

$$CS = [1/2b] \int_0^R [a - bP(x)]^2 dx \qquad (8)$$

(Note that we neglect the uniform consumer density). Substituting P(R) into equation (8) yields the total consumers' surplus generated under a system of uniform delivered prices:

$$CSU = \frac{b}{2}\left[\frac{a}{b} - k - f - cR\right]^2 \qquad (9)$$

On the other hand, integrating Equation (8) by parts, yields the consumers' surplus associated with a mill pricing regime:

$$CSM = CSU + \frac{b}{2}\left[\frac{c^2 R^3}{3} - c^2 R^2\right] + \frac{b}{2}\left[\frac{a}{b} - k - f\right]\left[2cR - cR^2\right] \qquad (10)$$

Clearly, CSM > CSU if inequality

$$\frac{b}{2} cR \left\{ \frac{cR^2}{3} - R \left[\frac{a}{b} - (k+f)\right] - cR + 2 \left[\frac{a}{b} - (k + f)\right]\right\} > 0 \qquad (11)$$

holds. Since R > 1, a sufficient condition for (11) to hold is

$$\frac{cR}{3} - \left[\frac{a}{b} - k - f\right] > cR - 2 \left[\frac{a}{b} - k - f\right],$$

which can be rearranged as

$$\left[\frac{a}{b} - k - f\right] > \frac{2cR}{3} . \qquad (12)$$

Inequality (12) is implied by the fact that charcoal demand in Blantyre is positive (i.e. D(R) > O). It can therefore be concluded that charcoal consumers will be better off with mill pricing (or, what comes to the same, with uniform stumpage fees).

Furthermore, if charcoal demand proves elastic (e > 1) the social surplus (consumer surplus plus aggregate stumpage fees) generated under a mill pricing regime exceeds that associated with uniform prices.

However, with inelastic demand, discriminatory stumpage fees will be socially superior to a scheme of uniform fees unless the netback value of charcoal sold in Blantyre significantly exceeds the transport costs. In fact, subtracting [1-R/2]bf>0 from equation (11) yields the net gains obtainable from mill pricing in the presence of inelastic demand:

$$SSM - SSU = \frac{6/R - 3}{9/R - 4} - \frac{cR}{f}, \qquad \text{with } e < 1, \qquad (13)$$

where SS stands for social surplus.

Since 1 < R < 2, we have $\frac{6/R-3}{9/R-4} < 1.$

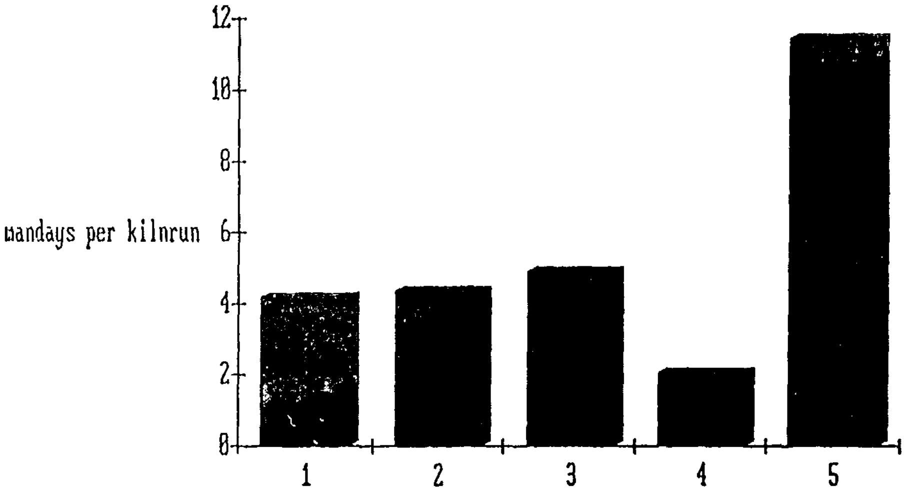
Thus, for the net gains from mill pricing to be positive the condition f > cR must be fulfilled. Currently, however, transport costs to Blantyre (200 MK/t) number twenty times the stumpage fees (10 MK/t) so that with inelastic demand mill pricing would be socially inferior to a system of uniform prices. Clearly, the picture might change in favor of mill pricing if:

(a) the consumer density would be a decreasing function of the transport distance, and/or

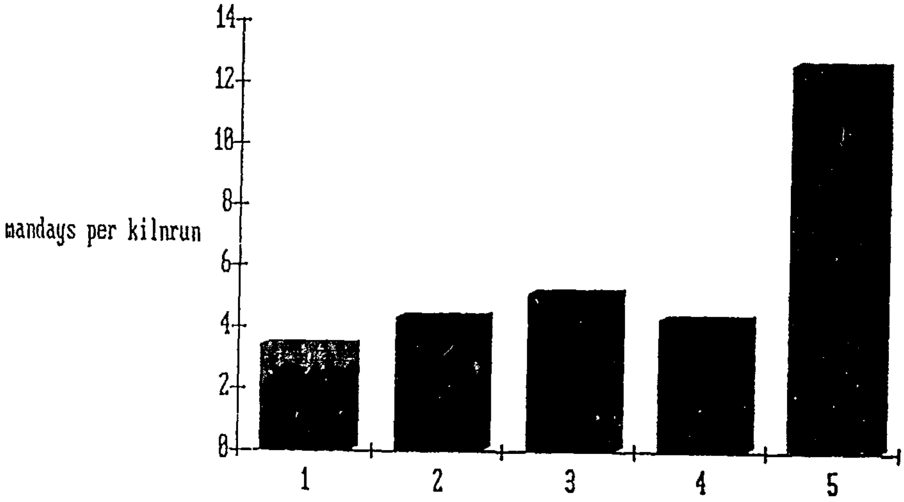
(b) the elasticity of demand would be inversely related to the transport distance.

ANNEX II: Performance Indicators of Charcoal Production at Viphya */

Oxen Handlers

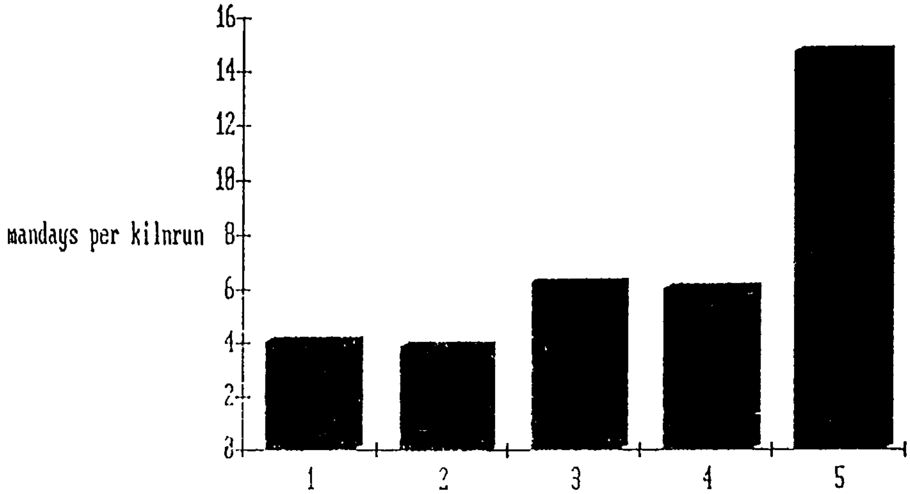


Oxen Handler Assistants

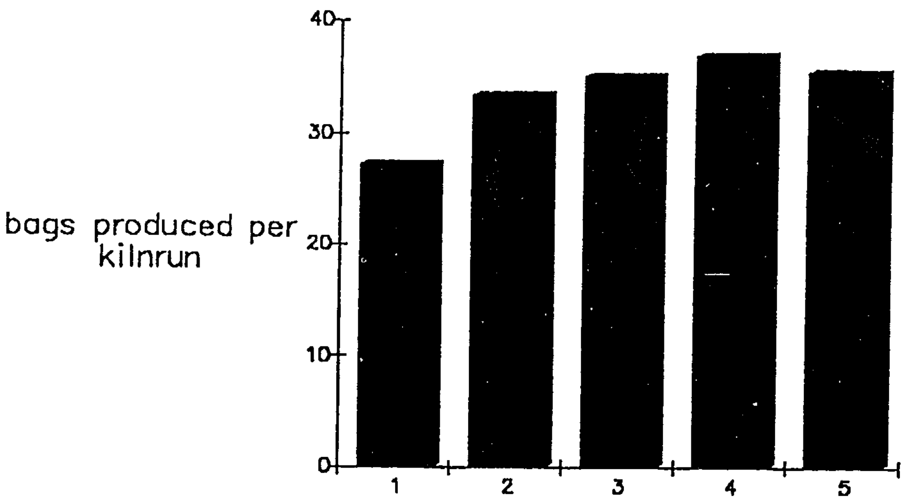


*/ average figures for 1987-88 at five different production sites (1 kilnrun 1 ton of charcoal).

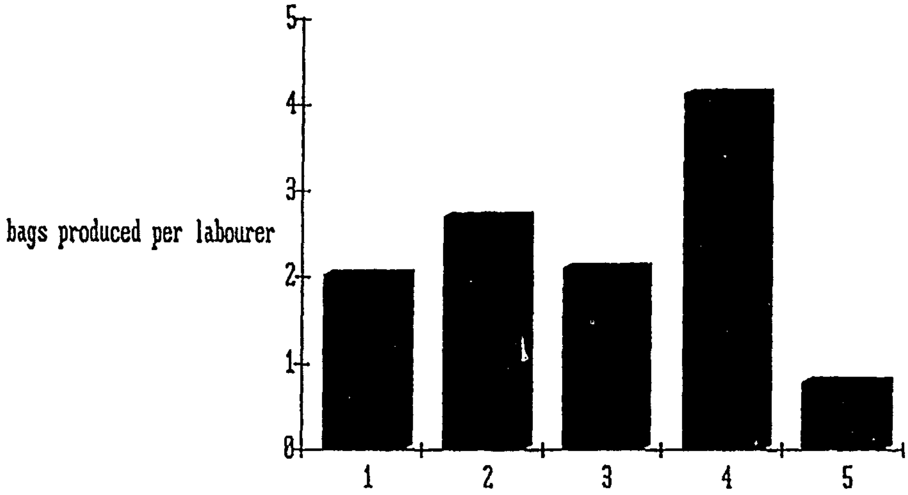
Woodcutters



Conversion Efficiency



Labor Productivity of Carbonization



Output of Viphya Charcoal Production Centers

	Output (No. of Bags)	(t)	Capacity (t)	Capacity Utilization (%)
1986/87				
January	1,246	33.6	80	42.0
February	2,742	74.0	80	92.5
March	2,272	61.3	160	38.3
Subtotal	6,260	169.0	320	52.8
1987/88				
April	1,944	52.5	160	32.8
May	2,942	79.4	240	33.1
June	481	13.0	240	5.4
July	1,945	52.5	240	21.9
August	1,304	35.2	240	14.7
September	3,480	94.0	240	39.2
October	7,091	191.5	320	59.8
November	7,909	213.5	320	66.7
December	4,058	109.6	320	34.3
January	3,256	87.9	320	27.5
February	2,626	70.9	400	17.7
March	2,223	60.0	400	15.0
Subtotal	39,259	1,060.0	3,440	30.8
1988/89				
April	2,573	69.5	400	17.4
May	2,830	76.4	400	19.1
June	1,892	51.1	400	12.8
July	2,534	68.4	400	17.1
August	7,716	208.3	400	52.1
September	6,160	166.3	400	41.6
October	7,509	202.7	400	50.7
November	9,798	264.5	480	55.1
December	4,814	130.0	560	23.2
January	3,752	101.3	640	15.8
February	6,948	187.6	640	29.3
March	7,558	204.1	640	31.9
Subtotal	64,084	1,730.3	5,760	30.0
1989/90				
April	6,085	164.3	640	25.7
May	8,128	219.5	640	34.5
June	8,816	238.0	640	37.2
July	13,088	353.4	640	55.2
Subtotal	36,117	975.2	2,560	38.1
Total	145,720	3,934.4	12,080	32.6

ANNEX III: Industrial Fuel Consumption in Malawi

Company	Classification	Equipment in Use	Fuel	Consumption tons
Chibuku Brewery Lilongwe	food and drinks	1 three pass flame tube chaingrate stoker boiler 1.2 tons per hour steam capacity (J.Thompson)	coal	600
		1 oil fired flame tube boiler 0.8 tons per hour steam capacity as stand by (J.Thompson)	diesel oil	-
Limbe Leaf Lilongwe	tobacco	2 three pass flame tube chaingrate stoker boiler 10 tons per hour steam capacity (J.Thompson)	coal	2,500
Stancom Lilongwe	tobacco	2 water tube chaingrate stoker boilers (power station boiler) 12 tons per hour steam capacity (Babcok)	coal	2,000
Southern Bottlers Lilongwe	food and drinks	1 oil fired flame tube boiler 1.0 tons per hour steam capacity (J.Thompson)	diesel oil	30
Kamuzu Central Hospital	others	2 oil fired flame tube boilers 1.2 tons per hour steam capacity (Norwegian)	diesel oil	18
Portland Cement Zomba	ceramic products	2 dry process front end fired rotary kilns with attrition mill pulverizer 20 tons per hour raw material capacity	coal	18,000
Zomba Prison	others	2 vertical stationary grate water tube steam boilers, 0.5 tons per hour steam capacity	firewood coal	150
Malawi Milk Mzuzu	food and drinks	1 fire box boiler, 0.3 tons per hour steam capacity	diesel oil	25
D.Whitehead	textile	7 three pass flame tube chaingrate stoker boilers 5.6 - 10 tons per hour steam capacity (J.Thompson)	coal	11,500
Lever Brothers Blantyre Limbe	chemical products and food	2 three pass flame tube chaingrate twin stoker boilers 4.5 tons per hour steam capacity (Dansk)	coal	3,000
		1 vertical soap powder slurry dryer	diesel oil	120
Chibuku Brewery Blantyre	food and drinks	1 three pass flame tube chaingrate stoker boiler 1.2 tons per hour steam capacity (J.Thompson)	coal	300
		1 oil fired flame tube boiler 1.2 tons per hour steam capacity as stand by unit	diesel oil	-
Limbe Leaf Blantyre Limbe	tobacco	1 three pass flame tube chaingrate stoker boiler 10 tons per hour steam capacity (J Thompson)	coal	1,000

Company	Classification	Equipment in Use	Fuel	Consumption tons
Southern Bottlers Blantyre Limbe	food and drinks	1 three pass flame tube chaingrate stoker boiler 1.2 tons per hour steam capacity	cotton seed husks, waste wood	240
Malawi Milk Blantyre	food and drinks	2 oil fired flame tube boiler 1.0 tons per hour steam capacity (Dansk)	diesel oil	100
Malawi Match Blantyre	wood products	2 stationary grate vertical steam boilers 1.2 and 0.5 tons per hour steam capacity (Cochrane)	wood	350
Queen Elizabeth Hospital Blantyre	others	2 stationary grate three pass flame tube boilers 1.0 tons per hour steam capacity; 1 three pass chaingrate stoker boiler 2.0 tons per hour steam capacity (J.Thompson)	coal	300
Cold Storage Blantyre	food and drinks	2 oil fired three pass flame tube boilers 0.5 tons per hour steam capacity (J.Thompson)	diesel oil	80
Packaging Industries Blantyre	paper products	2 stationary grate three pass flame tube boilers 4.0 tons per hour steam capacity (J.Thompson)	cardboard and wood waste	250
Tobacco Processors Blantyre Limbe	tobacco	2 water tube stationary grate steam boilers, one dutch oven retrofit 5 tons per hour steam capacity (Babcock Wilson)	saw dust	400
Advanx Blantyre	chemical products	2 oil fired three pass steam boilers, 0.5 tons per hour steam capacity (J.Thompson)	diesel oil	50
Carlsberg Brewery Blantyre	food and drinks	1 stationary grate three pass flame tube boiler 5 tons per hour steam capacity (J.Thompson)	cotton seed husks	500
		2 chaingrate stoker boilers 3 tons per hour steam capacity as stand by units (Kedel, Denmark)	coal	-
Campbell Tobacco Blantyre Limbe	tobacco	1 three pass flame tube chaingrate stoker boiler 2.5 tons per hour steam capacity (J.Thompson)	coal mixed with cotton seed husks	250
Chibuku Brewery Mzuzu	food and drinks	1 oil fired three pass flame tube steam boiler 1.0 tons per hour steam capacity (J.Thompson)	diesel oil	50
Chibuku Brewery Mangochi	food and drinks	1 three pass flame tube chaingrate stoker boiler 1.2 tons per hour steam capacity (J.Thompson)	coal	300

Total coal consumption 1986: 39,900 tons
Total diesel consumption 1986: 473 tons

Source: IPC(1988)

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