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ROLE, PROBLEMS AND RESPONSE TO CHARCOAL UTILIZATION AS A SOURCE OF ENERGY IN AFRICA

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GHANA 1980

* The views and suggestions contained in this document are those of the author and do not necessarily reflect those of the Economic Commission for Africa.

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THE ROLE, PROBLEMS AND RESPONSE TO CHARCOAL UTILIZATION AS A SOURCE OF ENERGY IN AFRICA

By J. Brookman-Amissah

1. Introduction:

World attention is begining to focus on a search for renewable energy sources as fossil energy resources diminish. This search for alternative energy sources and the appropriate technologies to put them on line, is particularly pertinent for the developing countries of Africa, already plagued with very high oil bills. For some of these countries the forests and woodlands appear to offer a potential solution to the energy crisis.

This paper reports on a study of charcoal consumption in Africa, at the instance of the Energy Resources Unit, Natural Resources Division of the Economic Commission for Africa.

2. Charcoal as a Source of Energy and its Utilization in the World

Charcoal has been used for many centuries as a source energy. Together with round wood it was the major energy source for industrial development and domestic cooking and heating until under-priced non-renewable energy resources were substituted for them, in the developed countries. In spite of the current dependence of the developed countries on other energy sources, woodfuel continues to be a major world energy source and Earl (1975) states that world consumption of energy from fuel-wood is greater than that from hydro-electric schemes, nuclear power and geothermal sources combined.

The situation remains so because of continued and increasing demand for woodfuel by the developing countries, which are largely deficient in fossil energy resources, and in which technologies for the use of alternative energy resources are either undeveloped or too expensive to put on line and importation of fossil energy is too much a burden on the already strained national budget.

2.1. World Woodfuel Production and Consumption Levels

Reliable data on charcoal production and consumption are not available, particularly for the developing countries, as considerable proportion of production is by an unorganized rural population and un-recorded.

FAO statistics on production of fuelwood plus charcoal gives estimates for 1978 as below:-

Table 1

Region	Production in 1000 m^3	
	1968	1978
Africa	232,683	343,626
N.C. America	49,110	49,088
S. America	142,865	162,086
Asia	465,425	533,725
Europe	56,735	38,970
Oceania	7,255	6,681
U.S.S.R.	86,500	77,000
World	1,090,623	1,217,976

(Source: FAO Yearbook of Forest Products 1978)

The above indicates a trend towards increased production of woodfuel in the developing countries of Africa, South America and Asia, while in the developed countries; North Central America, Europe and USSR there is a negative trend.

Earl (1975) emphasises the point that the production of wood charcoal cannot be estimated with any degree of accuracy. He however estimates that total recorded production of charcoal in 1970 was about, 3,000,000 tonnes, stressing that the exact figure is unknown because of lack of adequate statistics and is expected to be much higher. He lists some of the biggest charcoal producing countries as Brazil, 1,000,000 tonnes in 1969, Malaysia, 272,000 tonnes in 1967, Argentina 130,000 tonnes in 1971 and France 90,000 tonnes in 1965 (Earl, 1975). Other estimates include Ethiopia 150,000 tonnes annually (FAO, 1980 Report No. 4/80 DDC ETH.4), Uganda 80,655 tonnes consumed in 1972 made up of 17,000 tonnes of imported material and 63,655 tonnes of domestic production (Sackman, 1980) , Kenya 1,412,000 tonnes (Rukuba 1980) and Ghana 160,000 tonnes in 1977 (Forestry Department Records).

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2.2. Charcoal as an Energy Source

Charcoal finds an outlet in both the domestic and institutional sectors as an energy source for cooking, laundering and heating, particularly in the developing countries blessed with plentiful wood resources. In these developing countries wood is cheaper than other energy sources and charcoal is preferred to fuelwood, particularly by the urban population, because it is more convenient and cleaner to use and has a higher calorific value per unit volume than fuelwood. Institutions dependent on charcoal, as an energy source, include schools and boarding houses, hospitals, restaurants and prisons. Domestic and institutional use of charcoal for barbecues in developed countries is currently considered a luxury.

Industrial uses of charcoal, as an energy source, include use for drying and curing of hops, tobacco, fish and other commodities. (Earl 1975) states that in the United Kingdom nearly all hops drying was done with charcoal until shortage of supplies led to an increase in prices and its replacement with cheaper fuels. Charcoal also finds uses in lime and cement manufacture and metal extraction in the iron and steel industries. Earl (1975) lists charcoal-iron industries working successfully as those situated in Brazil, Argentina, Malaysia, Australia and India. It is anticipated that the iron and steel industry in Ghana will use charcoal and a fuelwood plantation to meet requirements is planned. Outside the energy sector charcoal has uses in water purification and sewerage works, as an extractor in the sugar industry and also in production of cyanide, carbide, carbon disulphide, gun powder, pigments, paints and plastics and in the poultry and rubber industries.

2.2.1 Charcoal Consumption Relative to other Energy Sources

Charcoal has been largely replaced by other energy source including fossil fuels and other finite energy sources. This situation is particularly prevelent in the developed countries and is gradually gaining ground in the developing ones. Recorded world energy consumption 1967 - 1970 is given below:-

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Table 2

World Recorded Energy Consumption 1967-70 in Million Tonnes Coal Equivalent

Energy Source	1967	1970	Annual Growth
Finite Resources			
Coal	2171	2419	2½%
Oil	2213	2350	7½%
Natural gas	1092	1413	7½%
Uranium	5	10	15%
Renewable Resources			
Geothermal	1	1	–
Wood & Charcoal	477	437	1%
Dung	90	90	–
Agricultural waste	10	10	–
Total	6195	7435	6-7%

(Source Earl, 1975)

Other sources of renewable energy include tidal and solar, currently insignificant in the energy scene. The table indicate 1% growth in the consumption of wood and charcoal; well below the over all growth in recorded energy consumption. This small global growth in consumption of wood and charcoal is the result of increased consumption in the developing countries where growth is estimated between 2-3%

Earl (1975) states that the rational of growth based upon the utilization of under-priced non-renewable resources is now being challenged because it will inevitably result in irreversible depletion of the world's stock of finite energy. He further states that at the annual rate of increase in energy consumption (1967-70) all mineral coal reserves will be exhausted by AD 2100, oil reserves, which on present estimates are expected to last seventeen years, will be extended to AD 2002, if indicated and inferred reserves and oil from tar sands and oil shales are included. Natural gas reserves are expected to last until 2012.

This calls for increased attention to the renewable energy resources and the current fossil oil crisis and consequent sharp rise in oil prices have brought this forcibly home to even the developed countries. For most of the developing countries in Africa importation of the so called under-priced non-renewable resources has always been a drain on their meagre foreign exchange earnings and current price increases have been a big shock. The need to look for an alternative energy source is therefore imperative.

Okefe (1973) lists some of the alternative technologies for renewable resources as solar energy, bioconversion, water energy and wind energy. To this list may be added geothermal energy sources. He draws attention observations made by the U.S. National Academy of Sciences (1976) after consideration of these technologies, as given below.

i) A variety of energy sources and technologies is indeed available as alternatives to conventional power systems

ii) With the exception of a few devices (e.g. homemade windmills, solar dryers) there are no cheap technologies of significance for either industrialized or developing nations and there will not be any in the near future.

iii) It is not enough that an energy source be available; the technology to put it to use must also be available,

The listed renewable energy sources are indeed available to some of the developing countries. Water energy is already being tapped by a number of developing countries and efforts are being made to use geothermal energy sources in Kenya. The major problem is the needed technology and finance to put such energy sources on line to meet the energy requirements of the predominantly rural populations, as exist in the developing countries. This problem is not likely to be solved in the near future. It appears therefore that, at least for the developing countries of Africa and other parts of the world, the way out of the current fossil fuel crisis lies in an increased and efficient use of forest energy (woodfuel). Charcoal production may be seen as a step toward efficient use of woodfuel.

3. Charcoal Consumption in Africa and its Role in Rural/Urban Energy needs in African Countries

Charcoal has been produced and used in Africa for many decades. Nigerian blackmiths are reported to have used charcoal for moulding hunting and war implements, during the period of inter-tribal war-fare and also for the manufacture of agricultural and house-hold utensils. Other records mention the use of charcoal in small scale rural industries in pre-colonial Africa, by gold and silver smiths and other metal workers. Morgan (1930) oberves that the manufacture of iron tools and weapons, the smelting of copper and brass and the development of the jewellery industry have all demanded charcoal. It is in current years becoming increasingly used as a source of domestic and institutional energy for cooking and heating, particularly in the urban centres of developing Africa.

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This preference stems out of the fact that charcoal is considered cleaner, more convenient and usually more readily available to the urban dweller, in densely populated zones, removed from wooded areas. He also finds charcoal cheaper than the other energy sources, including electricity, kerosine and bottled gas for cooking the traditional African dishes which demand plenty of cooking time. The urban low income groups can usually not afford the investment in appliances needed for the use of such energy sources; gas cookers and electric stoves and rely on charcoal. The urban middle and high income groups use charcoal to supplement electricity and gas. It is estimated that about 90% of the urban population in Ghana use Charcoal, at least for part of their domestic needs (Forestry Department Records). The pattern may well be similar in other urban areas in West Africa.

3.1. Charcoal Consumption Levels

Grut (1972) states that in many towns in the coastal region of West Africa, charcoal is the preferred household fuel and quotes annual household consumption of 100kg per capita for some towns in Southern Togo. About 40% of woodfuel used in the Sudan is in the form of charcoal (Hellman & Christy, 1980) and charcoal consumption is reported to have increased five times in Tanzania in the past five years (Mnzava, 1980).

Although there is a general increased use of charcoal in Africa, the rural dweller continues to be dependent on wood, relatively abundant in his surround and available at no cost, except the effort spent on collection by wives and children; ~~labour to which he~~ attributes no opportunity cost. Comparative estimates of urban and rural consumption of charcoal for selected regions are given below:-

Table 3 Per Capita Charcoal Consumption

Country	Zone/District	Per Capita Consumption			Source
		Country	Urban	Rural	
Kenya	Arid	0.14			Akinga, 1980
	Savanna	0.09			"
	Forest	0.07			"
	Nairobi		0.02		"
	Machakos			0.03	Openshow, 1980
	Machakos		0.14	0.03	Anon, 1977

Nigeria	South		0.09		Earl, Nagle & Sirois, 1974
	North		0.02		"
Tanzania	Whole Country	0.01			Arnold, 1969
	Mwanza		0.11	0.03	Anon, 1976
Gambia	Whole Country	0.01			Arnold, 1974
	Whole Country		0.13	0.02	Openshaw, 1973
Zambia	Lusaka		0.13		Forestry Dept. 1973
Somalia	Mogadishu	0.16	0.12	0.04	Uhart, 1975
Sudan	Bara Region			0.04	Digeenes, 1975
	Whole Country	0.12			Arnold
Ethiopia	Whole Country	0.01	0.06		Uhart, 1975
	Addis Ababa		0.03		FAO, 1980

3.1.1 Domestic and Institutional Charcoal Consumption

The level of domestic consumption varies considerably both between and within states. It appears to be dictated by availability, ethnic preference and the socio-economic status of the community; their income levels and type of homes and dwelling houses. Hellman and Christy (1980) record that about 40% of woodfuel used in the Sudan is in the form of charcoal, while charcoal is not considered a traditional fuel of any importance in malawi, since fuelwood, until recently, has been available all over the country within reasonable hauling distance (World Bank, 1979, Report No. 2625-MAI). This underscores the important role charcoal, more economically transportable, assumes with diminishing access to fuelwood. The report however observes that some charcoal is produced in the northern region on a small scale using earthen kilns and that with development in forestry practice and large scale agriculture, in tobacco growing areas, it is envisaged that the charcoal industry will be expanded as a means of putting to productive use the vast amount of forestry and agricultural wastes.

Ther is considerable variatiation between the levels of urban and rural consumption, per capita rural consumption being about a tenth of urban consumption. Among the urban population in Kenya, Kahuki (1975) distinguishes between urban low income, middle income and high income and observes that while the urban middle income household uses 2 bags (64kg) of charcoal, consumption among the high income communities is negligible. Ojo (1980) draws attention to the influence of the type of dwelling house on the choice of energy source in Nigeria. The rural population, cooking in open spaces, find fuelwood quite convenient while the urban low income, who live in single-room apartments and have to cook on verandas or in enclosed and shared kitchens, find smokeless charcoal more convenient. . .

Domestic consumption in Uganda, 1977, is estimated at 101, 344 tons (rural - 10,384 tons and urban - 90,460 tons) (Sackman 1979). Domestic consumption in Kenya is estimated at 1,060,333 tons (6,363,000 m^3) in addition to 255,566 tons (1,534,000 m^3) commercial and institutional consumption (Akinga, 1980).

3.1.2 Industrial Charcoal Consumption

Charcoal has been a source of part of the industrial energy requirement in developing Africa and the current oil crisis is increasing the desire to use it in yet more industrial establishment. Among the industries, already or may become dependent on charcoal, may be listed tea factories, tobacco, sugar mills, oil mills, brickworks, soap factories, bakeries, calcium carbide plants and the iron and steel industry. Industrial consumption of charcoal in Kenya is estimated at 12,000m^3 of fuelwood equivalent. Estimated industrial charcoal demand for Ghana is 166,000 tons for 1982 and 300,000 tons for 1990 (Forestry Department Records) and some 11,267 tons are used in industry in Uganda (Sackman, 1980). Estimates, for 1980 and 2000, are 50,000 tons and 118,000 tons respectively.

3.2 Charcoal Production Levels

There is very little data on charcoal production in Africa. National annual production in Ethiopia is estimated at 150,000 tons (FAO Report No. 4/80 DDC ETH4, 1980). Production in Ghana, in 1976, is estimated at 1,063,153 m^3 (637,972 tons) approximately 10% of total woodfuel production (Annual Report, Forestry Department 1976). Production in Somalia is estimated at 43,510 tons (Forestry Department Records). These estimates are usually based on data available to the Forestry Departments in the various countries on removals from the permanent forest estate (Forest reserves) and do not take full account of production by scattered peasant communities. They should as such be deemed to be underestimates. There is a growing tendency for charcoal production from prunings of hedges and amenity plants, in back-yards, for domestic use in some of the large towns in Ghana. This goes to augment total production. This situation is unlikely to be peculiar to Ghana.

FAO year book of forest products gives the figures for total production of fuelwood including what is converted to charcoal. The estimated total for Africa, in 1978, is given as approximately 344 million m3. It may be fair to assume that between 10-20% of this total is in the form of charcoal.

The year book also gives evidence of inter-state export and import trade in charcoal. Among the importing countries are Algeria, Benin, Djibouti, Libya, Nigeria, Rhodesia, South Africa, Tanzania, Uganda, Zaire and Zambia and the exporting ones are Ethiopia, Kenya, Mozambique, Rhodesia, Somalia, South Africa, Tanzania and Tunisia. It is noticeable that countries such as Rhodesia, South Africa and Tanzania are listed as both exporters and importers.

This apparent paradox depicts zonal variation in availability, accessibility and quality within specified countries. Barrot (1972) reports of importation of fuelwood from the Republic of Niger for sale in Urban Katsina in Northern Nigeria. This may well be the situation with charcoal too. Ghana imports small quantities of activated charcoal. For the countries favoured to be net exporters, increased production of high quality charcoal is thus not not only a means of meeting part of their energy requirements but could be an added source of foreign exchange earnings.

3.3 Factors which Influence the Choice of Charcoal as an Energy Source in Africa

Earl (1975) lists among the advantages in the use of woodfuel the fact that in developing countries, it is the cheapest available fuel, not only per tonne but also per unit of heat, that when properly dried it burns safely and easily so that semi-skilled labour may soon be taught to use it with economy, that no storage facilities are required apart from space and it is perfectly safe to store for long periods. Among the disadvantages he lists the labour intensive nature of its production which makes it expensive in regions where wages are high, depletion of the forest capital when not accompanied by sound forest management, uncertainty of sustained production, low calorific value compared with fossil fuels and large extent of required stocking space near the place of use.

3.3.1 Forest Energy Resource Availability

Although some African countries may be poorly wooded the majority have vast stretches of closed forest and open woodlands, which renders woodfuel readily available. In these countries fuelwood is regarded in the rural areas as a free good, the only cost to the consumer being the labour he expends on collection and this is invariably freely done by wives and children. Table 4 gives the extent of wooded areas in Africa.

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Table 4

Natural Forests in 1000 Hectares

Country	Year of Estimate	Closed Forests	Other Forests	Open Wood-land
Algeria	1971	490	..	..
Angola	1963	1000	2760	70,000
Benin (Dahomey)	1971	200	50	6,500
Botswana	1967	..	1000	(30,000)
Burundi	1971	100	..	(200)
Cameroun	1971	17500	..	12,500
Central African Rep.	1971	3000	..	(40,000)
Chad	1971	..	..	(16,500)
Comoro Islands	1964	42	..	..
Congo	1971	17,000	..	10,000
Egypt	1971	..	..	..
Equitorial Guinea	(1971)	1120	..	..
Ethiopia	1971	5000	..	23,000
Fr. Terr. of Afars Issas	..	6	..	..
Gabon	1970	21,500	..	3000
Gambia	..	25	..	275
Ghana	1970	1,800	..	10,000
Guinea	1971	700	500	14,000
Guinea Bissau	1965	760	130	130
Ivory Coast	1966	9,000	..	10,000
Kenya	1972	922	..	75
Lesotho	..	..	..	..
Liberia	1963	2,500	..	..
Libyan Arab Rep.	1972	70"	..	..
Madagascar	1964	6,000	..	7,000
Malawi	1972	20	..	7,000
Mali	1972	..	..	(4,500)
Mauritania	1972	..	..	(15,000)
Mauritius	1967	2	..	7
Morocco	1971	400	3,300	..
Mozambique	1963	1,500	..	65,000
Namibia	1972	..	..	10,000
Niger	1972	..	..	(12,000)
Nigeria	1970	4,400	..	30,000
Reunion	..	..	..	100
Rhodesia	..	..	800	23,000
Rowanda	1971	300	..	(1,000)
Senegal	1971	220	210	5,100

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Country	Year of Estimate	Closed Forests	Other Forests	Open Woodland
Seychelles	1970	..	..	4
Sierra Leone	1970	285	..	44
Somalia	1972	160	..	..
South Africa	1971	255	..	2,700
Sudan	1962	300	..	39,000
Swaziland	1971	..	..	40
Tanzania	1975	1,020	..	32,600
Togo	1971	380	70	3,000
Tunisia	1969	180	70	..
Uganda	1972	722	..	8,500
Upper Volta	1971	..	..	(4,100)
Zaire	1972	90,000	..	90,000
Zambia	1972	..	650	37,500
	TOTAL	188,879	10,090	648,375

(Source:- Persson,1977. Forest Resources of Africa)

3.3.2 Productive Capacity of the Forests

The wooded areas of Africa may be divided into four broad categories, the natural closed forests, woodlands, shrub formations and man-made forests. Lanly and Clement (1979) estimated that in 1975 tropical Africa was covered by 645 million ha of tropical hardwood forests, made up of 44 million ha of open forest and 202 million ha of closed forest. It is beyond the scope of this study to estimate the volume available for fuel from these forests. It is however to be observed that the forests are made up of a heterogenous mixture of species of all age and diameter classes. Lanly and Clement estimate that although the standing volume of trees exceeds 300m^3 per ha (all species more than 20 cm DBH, bole plus branches) only 6-10 m^3 are presently extracted as commercial timber.

This should throw some light on the huge volume available for fuel, even discounting contribution from shrub formations and scattered trees in farms and fallows. To this may be added production from plantations (final felling in fuelwood plantations and thinnings and final felling by-product from industrial plantations). Industrial plantations are estimated at 910,000 ha for 1975 (Lanly and Clement, 1979). Most countries have embarked on an expansion of the existing man-made forests. Attention must also be drawn to the huge volumes of other forestry and agricultural wastes (sawmill offcuts, sawdust, coconut husks, cocoa pods, bagasse etc.) that are available for charcoal production.

3.4 Value of Charcoal Relative to other Energy Source

Labour in Africa is generally cheap, thus rendering woodfuel relatively cheap compared with other energy sources, even for the urban dweller, who has to pay some price for it. The major constraints to the use of woodfuel are accessibility particularly to the urban population, cost of transportation and storage space in the congested urban situation. African countries are therefore in an overall favourable position for the use of woodfuel and in the forest lies the major soluation to their energy problems.

Other qualities that determine the choice of energy source include handling convenience, high calorific value, cleanliness in use and cost. Carbonization seeks to enhance these qualities in woodfuel and does achieve it except cost, which is for charcoal higher than fuelwood. Charcoal has higher heating value per cubic metre than wood and is cheaper to transport- wood loses up to 75% in weight and 50% in volume on charring- (Standard Handbook for Mechanical Engineers, 7th Ed, 1967). Earl (1975) estimated that at distances shorter than 32 kilometres the marginal value of heat from fuelwood is higher than that obtainable from charcoal and that the position is reversed above this distance. Charcoal is transported over distances ranging from 100 kilimetres to 600 kilometres to urban centres in Africa.

The average heating value of charcoal is 6000 kcal/kg (Standard Handbook for Mechanical Engineers, 7th Ed, 1967). Ayitey and Gogo (1973) estimate the heating values of Ghanaian timbers between 4000-4400kcal/kg. Calorific values of some common fuels used in Africa are given below:-

Table 5

Fuel	Calorific Value
Paraffin	10.4
Fuel Oil	9.8
Charcoal	7.1
Coal (bituminous)	6.9
Wood, oven-dry (0%mc)	4.7
Dung, air-dry	4.0
Wood,air-dry (25-30%mc)	3.5

(Source Earl 1975)

Relative costs of fuels and power in Kenya are given in table 6 to demonstrate how cheap charcoal could be compared with other energy sources in the African situation.

Table 6

Relative costs of Fuels and Power Compared on the same Calorific Value Basis in Kenya (Fuelwood taken as unity)

Fuel	Cost
Fuelwood	1.0
Charcoal	1.6
Fuel Oil	2.0
Paraffin	4.0
Electricity	3.9
Butane	19.8

(Source Earl, 1975)

Added to the advantages in the use of charcoal over fuelwood are handling convenience, reduced storage space per unit of energy, cleanliness in use and reduced atmospheric polution.

4. Charcoal Production Methods in Africa

4.1 Organisation of Production and Marketing

Charocal production was in the past considered a mean job for the lowly placed peasant farmer, who embarked upon it to supplement earnings from other farm produce. Ay (1978) in an analysis, of incomes of farmers in villages around Ibadan, Nigeria, ranked earnings from woodfuel, including charcoal, fairly high- sixth after cocoa, oil palm, cassava, maize and kola nuts among 45 products. In spite of its high position on the scale, income from woodfuel accounts for a rather low percentage, 4.5% of total income. How much of this is due from charcoal is uncertain.

Production is gradually being organised and some middle level entrepreneurs are beginning to show interest in production and marketing. The East African Tanning Extract Co. (EATEC) is recorded as the only organised charcoal producer in Kenya. Rukuba (1980) reports of 24,000 tonnes by the company, in a survey conducted in 1979-80. He recommends the establishment of a Charcoal Development Division within the Forestry Department and a resumption of charcoal export. The Forestry Department of Ghana has embarked on large scale charcoal production with the assistance of FAO/UNDP and a few entrepreneurs have taken up charcoal production in the vicinities of sawmills, using sawmill off-cuts.

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Marketing on the other hand has been fairly well organised, at least in West Africa, for a longer period. There has always been a chain between the rural producer, the bulk purchaser and transporter, the wholesaler and the retailer in the larger towns and cities. Many entrepreneur has made a fortune on charcoal marketing with support from the banks.

4.2 Production Methods

Charcoal production methods include the simple earth or pit kilns, retorts, continuous kilns and furnaces. The last two are unusual in developing Africa. Traditionally charcoal production in Africa is in earth mounds or pits. The method is adequately discribed in various literature on charcoal production in Africa. Earl (1975) sees an advantage in this method, which requires minimum handling of wood and demands little or no capital expenditure on equipment. Among the disadvantages, he lists low and uncertain yields, variable quality, contamination with sand and stones, a lengthy carbonization period and inadequate control. Reported yields vary from 8-22%. Nigeria reports 8-12% yield with the pile method, 12-15% yield with the pit method, 15-22% yield using masonry kilns and 15-20% in continuous kilns (Egbuta, 1980).

4.2.1 Improving Production Methods

Good charcoal needs to be free from impurities, should not be damp, should ignite readily, should not smoke in use and should be of sizeable lumps. These qualities are determined by the type of wood used; species, moisture content and size, carbonization method; type of kiln and expertise of the operator.

4.2.2 Choice of Species

Some tree species yield charcoal which sparks when heated, some yield charcoal with low calorific value and charcoal from some species turns out in small pieces. Irvine (1961) lists some sixty species suitable for charcoal production in Ghana. The dense woods, of the savanna woodland zone of the country, are particularly favoured. Among the favoured species may be mentioned Lophira lanceolata, Butyrospermum parkia, Anogeisus leiocarpus, Maytenus senegalensis, Pericopsis laxiflora, Afzelia africana and some Acacia spp. Species preference appears to be the same in The West African zone. Egbuta (1980) lists the preferred species in Nigeria as Lophira lanceolata, Butyrospermum parkia, Anogeisus leiocarpus and Afzelia africana. The acacias are particularly favoured in East Africa. Many tonnes of charcoal are produced from the Rift Valley Acacias in Kenya and Ethiopia. Mnzava (1980) lists Trema guinensis, Brachystegia spp, Acacia spp, Eucalyptus spp and Cassia siamea among the favoured species in Tanzania.

Efforts are being made to identify the species most suitable for charcoal production. Among the stated objectives, of the FAO/UNDP project in Ghana, is a programme to determine species suitability for charcoal production, especially whether the local species meet the stringent specifications for price, quality and quantity, needed for the various industrial uses envisaged (UNDP Report No. GHA/74/013), Mnzava (1980) reports on studies conducted at the University of Dar-es-Salaam on the use of charcoal from softwoods. The study is reported to have indicated that even though the effective calorific value was almost the same for softwoods and hardwoods, the market was not willing to accept the soft woods as a substitute for the traditional species, in spite of the fact that cost of production was the same and the price of softwood charcoal was 50% less than the hardwood. Preference thus appears not to stem out from species suitability only but also from local prejudice, which needs to be eradicted by education.

4.2.3 Carbonization Methods

The traditional carbonization methods is the earth or pit kiln as previously stated. This is a rather inefficient method yielding at best 15-20%. The method is described as labour-intensive, because of the kiln work involved and the fact that more wood has to be cut to provide the same amount of charcoal as could be obtained from metal and masonry kilns and retorts (UNDP Report No. GHA/74/013). Egbuta (1980) observes that it takes 5 days- 1 month to complete a cycle compared with 2-3 days in a metal kiln. Current work towards improvement of carbonization methods include determination of optimum wood moisture content for carbonization, indentification of the most suitable kilns (high yield, short carbonization cycle, labour saving and reduced contamination) and education of the indigenous operator in the use of the improved methods.

4.2.4 Problems Related to Charcoal Production

The major problem related to charcoal production appears to be provision of the raw material and its impact on the forest resources base and the environment. This problem may not be considered serious in the tropical rain forest and the moist semi-deciduous forest zones. primarily, because there is an abudant supply of un-utilized wood and secondly, because charcoal production in these zones is not as intensive as it is in the less densely wooded savana and arid zones. The demand for woodfuel in the arid zone together with shifting agriculture and wild fires have been the major cause of degradation of the woody vegetation resulting in impoverished sites with low fertility status and high rate of erosion and surface run-off. In these critical zones cow dung and other agricultural wastes; millet stalks, groundnut husks et. which would have returned some nutrients to the soil become standard source of fuel, thus aggravating the situation.

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It is reported that some 20 million m^3 of wood mainly from uncontrolled cutting from natural forest is consumed annually in Ethiopia (UNDP Report No. 4/80 DDC ETH.4, 1980). This uncontrolled cutting and consequent deforestation the report remarks is not only destroying the ecological balance in many areas and causing serious erosion and silting of waterways but is taking wood supplies beyond the limit from which it could be economically transported. It is estimated that charcoal production accounts for the destruction of about 60,000 ha of acacia woodlands in the low rainfall Rift Valley of Ethiopia.

Rukuba (1980) writing on Kenya regrets that destruction of the woodlands is being blamed on charcoal production and claims that charcoal production has only followed the cutting of forest for other purposes; agriculture, livestock development, human settlements and reforestation projects. Be it as it may, there is no doubt that uncontrolled charcoal production contributes to the degradation of the savanna woodlands in Africa. Vast streches of savanna woodlands in northern Ghana and Nigeria have been turned into poor acacia scrub, studded with isolated individuals of a few protected tree species, the result of a quest for woodfuel, shifting agriculture, over-grazing and indiscriminate burning.

Other problems associated with production and consumption of charcoal are transportation of the raw material to the production site and of the product to the consumer, wood is a rather bulky commodity, marketing and organisation for large scale production without undue destruction of the resource base. These problems are however not insurmountable. In the general over-view of charcoal consumption it is perhaps also pertinent to think of the efficient use of charcoal as affected by stove design and efficiency.

5. Analysis of Possibilities for Improvement of Charcoal Production Methods

Charcoal production using the traditional earthen pile or pit kiln, as already indicated is inefficient, yielding rather low conversion ratio. Morgan (1980) quoting Ki-Zerbo and de Lepelaire (1979) also draws attention to the fact that a lot of wood is left to rot because lack of suitable cutting tools debars operators from the use of trunks and thick branches. When such material has been used in the traditional kilns the result has been incomplete corbonization, needing considerable improvement. Other areas that call for improvement include organisation of production such that the maximum amount of the available wood resource is utilized without detriment to the environment.

5.1 Improvement of Burning Methods

The aim here should be to obtain the maximum yield per unit weight of wood ensure that the charcoal produced is of the highest quality. Earl (1975) observes that the method of manufacturing charcoal in earth or pit kilns has the advantages of reduced wood handling and low capital expenditure for equipment. These are advantages which cannot be ignored if charcoal production should be made to benefit the rural producer, with limited capital. It is important that any method devised to improve carbonisation be that which is within the means of such rural producers.

Various kiln designs, including portable metal kilns and masonary ones, have already been introduced in certain parts of Africa. Among these may be mentioned the Tranchant kiln, the Misouri kiln; a large stationary, re-inforced concrete kiln and various designs of portable metal kilns. Asmah (1963) gives the yield of the Tranchant kiln as 12.9 - 19.1% weight of wood (19.1% - 25.7% oven-dry weight of wood) compared with 4.2% (5.9% oven-dry weight of wood) for the earth mound kiln. Efforts have been and continue to be made to determine the optimum wood size and moisture content for highest production. It is essential that efforts at such investigations be intensified and the knowledge gained transferred to the charcoal burner.

There is also plenty of scope for the introduction of the more sophiscated methods, including retorts and pyrolytic converters, so as to extend the raw material base to small dimension forest and agricultural waste and also to derive the fullest benefits of the by-products of carbonization.

5.2 Charcoal Production and Environment Degradation

The impact of production on the environment is by far the most publicised problem associated with woodfuel production. The examples of Ethiopia, Kenya, Northern Ghana and Nigeria have already been give. Other areas affected by excessive forest or woodland removal include Western Senegal, Southern and Central Upper Volta, the Kikuyu Highlands of Kenya, Rowanda, Southern Malawi, Western Zimbabwe, Sudan and Somalia (Morgan 1980). Furness (1979) states that the quest for woodfuel is the major factor for depletion of indigenous woodland in Zimbabwe and that some rural areas have been so denuded of timber that the local people resort to burning of cow dung. He points out that alternative fuels; coal, paraffin and gas are relatively recent and expensive. It is evident that there will be continued dependence on what woodfuel is available, hence continued degradation unless the situation is arrested.

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The answer to this problem lies in well organised and controlled production along with sound forest management. The actual mode of control and management should however be regulated by the circumstances of each locality, as affected by the extent and productive capacity of the wooded area, the pattern of landuse, population density and its pressure on the available land and consequently the extent of land available for energy plantation.

The critical zones are the densely populated areas in the low productive arid and semi-arid regions. where demand for woodfuel far exceeds resource availability. In such areas there should be protection and management of the natural vegetation to ensure sustained yield and the establishment of fuelwood plantations, using fast growing species to supplement production from the natural woodlands.

As Rukuba (1980) points out charcoal production follows land clearing for other purposes including agriculture, population settlement and forest plantation establishment. Charcoal production should be carefully planned to follow such operations to avoid wastage that arises from burning off the debris as a site preparation method. The natural vegetation should be protected from dry season fires and over-gracing, which are major factors of woodland degradation checking development of woody vegetation. Brookman-Amissah et al (1980) demonstrate increased basal area of woody vegetation with fire exclusion. The economics of complete fire exclusion has not been examined and this should be given attention.

Fuelwood plantations have been established in several of such arid regions to supplement production from the natural woodland. The present level of afforestation is rather low and should be stepped up. The major constraints to increased afforestation have been finance and expertise. It is not intended to go into the economics of woodfuel plantation establishment except to say that it is usually expensive and may not yield adaquate returns on investment. It is necessary therefore to evolve methods that would reduce establishment cost. Charcoal burning its-self, using the site preparation debris, offers an opportunity for indirect reduction of establishment cost. Other methods include employment of agro-silvicultural methods. The establishment of village woodlots should be encouraged. This has the added advantage of involvement of the rural population in an effort to supply their needs. International aid for financing large scale afforestation projects to supply the needs of industry and densely populated urban centres should be exploited.

There are however zones where site productivity and pressure on the land for other forms of land-use, may hinder the development of energy plantations. For these zones the answer lies in a change to other energy sources or dependence on the more favoured zones for charcoal supply. One advantage of charcoal over fuelwood is the fact that it can be transported economically over longer distances than is possible with fuelwood. Inter-state export and imports, though on a limited scale, have already been mentioned. The financial benefits that would accrue to the exporting countries through increased production and export is here stressed. For the importing countries it is a way of meeting their energy requirements without undue damage to their environment.

The need to economise in the use of charcoal through the use of efficient stoves is stressed for all areas, particularly the critical zone. Mnzava (1980) reports that clay charcoal burning stoves require 50% less charcoal than metal ones to bring the same amount water to the boil.

6. Charcoal Utilization in Selected African Countries.

6.1 Case Study - Ghana

Woodfuel is considered the major domestic energy source in Ghana. About 80 per cent of the population, estimated close to 12 million, live in the rural areas, where wood is the chief source of fuel because it is cheap and readily available. It is estimated by FAO in 1974 that the annual per capita consumption of fuelwood, including that subsequently converted to charcoal was 0.93 cubic metres (Forestry Department Records). This amounts to 9.3 million cubic metres which according to department records is equivalent to cutting down and burning over 50,000 hectares of forest per annum. Fuelwood is regarded as a free social good, by the rural population that live close to the forest.

6.1.1 Charcoal Consumption

While the rural population continues to be largely dependent on fuelwood the urban population, removed from the sources of wood supply, are becoming increasingly dependent on charcoal as an energy source because it is more easily available than fuelwood, more convenient to use in the congested urban environment, being smokeless and generally cleaner than fuelwood and cheaper than the other energy sources. The urban growth rate is estimated at 5.5% per annum and this has been increasing the domestic demand for charcoal at the expense of fuelwood.

In the industrial sector charcoal has been used in forges by blacksmiths and in the jewery industry by gold and silver smiths. It has not yet been used on a large -scale in heavy industry. There is however a wide scope for industrial use and the indication that there will be a shift away from fossil fuels as a result of increasing oil prices.

Among the existing and potential industrial activities that may make demands on charcoal are the projected iron and steel industries at Open Mansi and Shieni, exploitation of limestone deposits at Nauli, Bongo Da and Otopkolu, for the manufacture of Portland cement and the production of calcium carbide. Plans have already made to establish fuelwood plantations to meet demands for the projected iron and steel industry. L'Air Liquide Ghana Limited have demanded a feasibility study for the establishment of fuelwood plantation to meet demands for calcium carbide production and have had tests made on charcoal produced from mixed tropical hardwoods to determine its suitability for their purpose. According to the Forestry Department the returns from an investment in charcoal for industrial use are potentially very large as within the next five years the market for charcoal could approach 400,000 tons per annum, representing an import saving of approximately 27,000,000 US dollars per annum as well as opening opportunities for employment.

Data on domestic charcoal consumption is rather unreliable. Production in 1976 is estimated at 637,372 tons, while consumption in 1977 is given as 160,000 tons. Present and forecasted demand is given in the table below:-

Table 7

Sector	1977	1982	1990
Rural	23,000	25,000	27,500
Urban	137,000	175,000	257,000
Industrial	-	166,000	300,000
Total	160,000	366,000	584,000

Industrial charcoal requirement in 1982 is estimated as follows:-

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Table 8

Market Outlet	Tons
Iron and Steel	100,000
Ferro-silicon	30,000
Calcium carbide	30,000
Foundry work	6,000
Total	166,000

(Source Forestry Department)

Among the factors which encourage the domestic use of charcoal by the urban population is the relative low cost compared with other energy sources. Unfortunately the price of charcoal has escalated in recent times and this has caused, it is hoped, a temporary shift to the use of gas and electricity, by sections of the urban population. The table below gives comparative prices for 1977 and 1980.

Table 9

	1977 - Cedis	1980-Cedis	Increase %
Price of 32 kg bag	·10	·50	400
Daily wage rate	2.30	4.00	74

6.1.2 Wood Resources Base for Charcoal Production

The country may be divided into two broad ecological zones. The tropical high forest, covering a third of the country to the south-west and the savanna zone mainly to the north and extending south to the sea in the south-east. The high forest is a luxuriant forest, a heterogenous mixture of species of which very few are currently exploited for timber. Within this zone the wood resource base is large, both in the reserved Forest, 16, 788 km^2 or 20.41% of the total area and outside. Stocking in the savanna zone varies in density ranging from fairly dense savanna woodland in southern section of the zone, to sparcely wooded scrub in the north, particularly the north eastern corner, where there is a deficit in wood resources. The overall picture for the country is sufficiency in wood. The major charcoal production areas are in the transition between the tropical high forest and savanna and the southern sections of the savanna zone.

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Within the high forest zone the forest industry makes large volumes of wood, exploitation and sawmill wastes, available for carbonization and a number of burners can be seen around sawmills particularly around Kumasi. Other sources of raw material for charcoal production include debris from plantation areas both in the forestry and agricultural sectors and other agricultural wastes; cocoa pods, coconut shells, ground-nut husks etc. Estimates of agricultural and forestry wastes are as follows:-

Table 10

Kind	Tons per Year
Sawdust	25,500
Rice Straw and husk	317,700
Logging wastes	403,000
Reforestation wastes	1,079,700
Coconut wastes	686,400
Oil Palm wastes	22,800
Total	2,735,100

Ghana therefore is in a favourable situation to meet her energy requirements from charcoal and with improved carbonization methods, make surpluses for export. There is no record yet of exports. It is however suspected that some un-recorded amount filters through the country's borders into Upper Volta and Togo.

Efforts are being made to improve carbonization methods, increase charcoal production, reduce production costs and improve the efficiency of charcoal in use. Early attemps in this direction include efforts to improve the traditional pit kiln by lining it with metal sheets, introduction of various types of portable metal kilns and concrete kilns and education of the traditional burner in the efficient use of the new designs. Agency for International Development (1976) recorded 33 installed kilns. Production from these was estimated at 517 tonnes per annum, rather low in relation to national demand. There is currently a FAO/UNDP project in Dabease aimed at developing the charcoal industry.

The immediate objectives of the project are stated as follows:-

1) To determine the most economic methods of extraction, conversion, transportation and carbonization of wood by the application of work study and the introduction of new machinery. To evaluate the costs of the various components and the final total costs.

2) To establish the suitability of local wood species for the production of charcoal and associated products and to determine whether they can meet the stringent specifications for price, quality and quantity needed for the various industrial uses envisaged.

3) To improve the forest management systems in order to provide for the long-term production of energy and other products.

4) To increase industrial activity and imployment, particularly in the rural areas, by expanding the use of locally manufactured kilns.

5) To establish methods of making charcoal and associated products on an industrial scale.

6) To develop markets for forest fuels.

7) To carry out pre-feasibility studies for the establishment of industrial charcoal production enterprises capable of producing approximately 200,000 tons per year on a sustained basis from the tropical forest.

Efforts towards increasing available charcoal have also been directed towards pyrolytic conversion of wood waste into char and oil. Ocloo and Yeboah (1980) estimate the amount of sawdust generated in sawmills alone at more than 97,000 tonnes a year with an accumulated stock of nearly a million tonnes wet weight, assuming 50% moisture content and state that if organic waste materials could be converted to useful energy forms, the potential exists for the agriculture and timber industrial sectors to provide a large fraction of the countries energy needs. They claim that one tonne of such organic materials is equivalent to nearly one barrel of crude oil and the potential energy from the combined agricultural wastes may exceed million barrels of crude oil a year.

The building and Roads Research Institute of the council for Scientific and Industrial Research assisted by the Georgia Institute of Technology U.S.A. have installed pyrolytic converters, a modification of the type used by the Georgia Institute, in the Philipines, to convert saw dust into char, oil and combustible gasses. Both the char and oil are reported to burn well and have calorific values of 5.72kcal/gm and 5.56kcal/gm respectively. The char can be burnt in the pulverised form (Ocloo and Yeboah 1980). Work is in hand on the development of suitable stoves for the use of the pulverised charcoal produced and manufacture of charcoal briquetts. The Charcoal by-product from the pyrodytic converter has not been priced yet, but Hagan (1980) states that it is expected to be reasonable pointing out that the process produces another saleable fuel, thus reducing the cost of product and by-product.

Although the country, as a whole, currently has adequate resources for production of charcoal, local critical situations exist in urban centres and in the arid north-eastern corner, which is also one of the most densely populated zones in the country. In this arid.north-eastern corner the adverse effects of fuelwood and charcoal consumption is already evident. The local rural population has to travel long distance for wood-fuel, there is some dependence on dung for energy and degradation of the ecosystem is noticeable.

The Forestry Department warns that charcoal may not always be available to meet potential demand without planning because Ghana's forest resources, may become depleted and unable to sustain supplies and there is likely to be other demands upon forest land and timber resources which will tend to increase the opportunity cost of using wood for charcoal.

6.2 Case Study - Nairobi Province, Kenya

The Nairobi Province occupies 684km^2 within the closed Forest Zone in Kenya. Population, predominantly urban, is given as 835,000 according to the 1979 census. Population density is estimated at 1220/km^2. The very dense population exerts great pressure on the natural wood resources. As in other parts of Kenya there, is a high demand for agricultural land by the population which is increasing at 3.5% annually and also land for other forms of land use.

Energy consumption in Kenya is one of the highest in Sub-Saharan Africa. Total energy consumption in 1971 is estimated at 2.006 million metric tons equivalent of coal or 172 kg/capita showing an annual increase of 5.3% from 1960 (Arthur D. Little Inc., 1974). The major sources of energy are paraffin, furnace oil electricity and woodfuel. Akinga (1980) estimates per capita domestic consumption of paraffin within the Nairobi province at 24 litres/annum and some 32,375 litres of furnace oil used by industry. He is not quite clear about the amount of electricity consumed.

Kenya is very dependent on imported fossil oils and very concerned about rising costs. Rukuba (1980) mentions the increase in Kenya's expenditure on oil from K. Shs. 1400 million in 1978 to K. Shs 1800 million in 1979 and expected K. Shs. 3100 million in 1980 (U.S.$192 million, 274 million and 425 million respectively). This increase has caused concern in government circles and the public is being persuaded to conserve energy and establish fuelwood plamtations. Rukuba states that the public has been aware of the energy problem and in the past five years, the use of woodfuel in preference to oil has been increasing.

6.2.1 Woodfuel Consumption

Woodfuel is used both as fuelwood or converted into charcoal. Annual domestic fuelwood consumption in Nairobi Province is estimated at 93,000m^3, charcoal is estimated at 164,900 kg and total woodfuel consumption 1,014,000 m^3 (Akinga, 1980). Per capita consumption is quoted as 1.21m^3/annum. Commercial consumption he estimates at 41,000 m^3 for fuelwood, 42,914,000kg for charcoal, giving total woodfuel consumption of 281,000 m^3, while industrial consumption is given as 1,561,000 m^3 of fuelwood, giving an overall total of 2,856,000m^3.

Many established industrial concerns in the country already use woodfuel as an energy source, the prominent ones being the agricultural based industries, such as tea factories, sugar factories and lime works Akinga (1980). He lists some twenty-two tea factories for which applications have been submitted to the Forestry Department to set aside fuelwood plantations and estimates their total annual requirement at 167,500m^3 and for industries already using woodfuel he estimates 136,610m^3. Although these figures are related to a wider zone than the Nairobi Province, they paint a global picture of the national situation, which should have an impact on resources available to the Nairobi Province.

Akinga (1980) states that Nairobi has a lot of stored charcoal, which is utilized by the middle class for cooking certain food items. He defines availability index as very scare - 1, scare - 2 and abundant - 3 and rates availability index in Nairobi at 2.304. He however admits that most of the middle class prefer paraffin for its cheapness and the high class gas and electricity for general cooking, emphasizing the point that choice of energy source is related to cost and social status.

Rukuba (1980) gives the retail price of charcoal in Nairobi as K. Shs. 300.45/m^3 and Morgan (1980) observes that the price of kerosine trebled in Nairobi from 1974 - 78 while that of charcoal doubled. He quotes from Mc Granaham __et al__ (1979) to the effect that wood and charcoal accounted for 65% of the energy consumption of the lowest income group, falling to 3% for the highest group.

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The major constraints to increased use of woodfuel is distance and impact of production on the environment. Rukuba (1930) however dismises the assertion that destruciton of forests and woodlands is the result of charcoal production and states that production only follows cutting for other purposes and uses that wich would otherwise be wasted. In spite of what constraints may exist, the trend in woodfuel consumption in Nairobi province is increased consumption and a shift from fuelwood to charcoal.

6.2.2 Woodfuel Resources

The total area of the province has been given as 684km^2, supporting a population of 335,000. This is a relatively small area and as would be expected production potential from existing forests within the province is limited. It is therefore more appropriate to look at the production potential of the whole of closed forest zone which incorporates Nairobi Province. Morgan (1980) asserts that charcoal is supplied to several of the large cities of tropical Africa from sites over 300km away and quotes Trevallion (1963) who states that normal commercial transport distance for fuelwood in northern Nigeria have been claimed at over 160 km. It is expected that the bulk of woodfuel for consumption in the Nairobi province comes from outside the province comes from outside the province. Most of the charcoal comes from the Rift Valley area.

Total wooded areas within closed forest zone, excluding the low productive shrubby formations, has been estimated at 995,000ha and mean weighted productivity 2.11m^3/ha/annum. Productive potential of existing forests, 1,910,000m^3/annum, therefore appears to be grossly inadequate for the demands of the zone. Akinga (1980) gives the total extent of plantations in Nairobi province as approximately 17,210ha of which 3,194ha are for fuelwood. Some 600,000m^3 of fuelwood, including thinnings and by-products of final felling may be expected annually from these plantations.

Nairobi city is very well stocked with avenue trees and hedges and in the suburbs scattered trees are frequent in farms. No estimate is however avaialable as to the contribution these, as well as by-products of agricultural crops, make to the woodfuel resources. It is expected to be significant. In spite of these the province is seen to be in a critical situation and this is likely to worsen with increased population, increased use of woodfuel - and increased pressure on the land for other forms of land use and calls for a systematic effort towards increased woodfuel production.

7. Comments and Recommendations

Charcoal is seen as a major domestic energy source in most developing African countries and will be playing an increasing role in the industrial development of these countries as a substitute for fossil oils in the face of the sharp increases in oil prices. It is therefore vital that efforts be made to improve production and distribution of the commodity on the continent and this should be done without detriment to the resource base and the environment.

The African countries may be classified under two broad groups, those with abundant woodfuel resources and the wood deficit countries. Clement and Laurent (1930) identify six main categories:

1. Zones currently showing deficit in wood resources;
2. Zones in which current supplies meet demand but in danger of a critical future, if no measures are taken immediately;
3. Countries without immediate danger but likely to develop towards a scarcity situation;
4. Countries with adequate supplies in relation to current and potential demands;
5. Countries currently without problems because of weak human pressure;
6. Countries with abundant forest resource.

Among the zones in "category 1" may be mentioned North Sudan, North Mali, North Niger, Oganden Province of Ethiopia, North, Central and West Kenya and Lesotho while in "category 6" fall South Congo, Equatorial Guinea, Gabon, South Cameroon and North Zaire (Clement et Laurent, 1930).

In all zones there is the need for economy in the use of charcoal. This does not necessarily mean a reduction in energy requirement. It can be achieved through the use of efficient stoves and improved carbonization methods, thus increasing the output of charcoal per unit weight of wood. This is particulary vital in the wood deficit zones.

Charcoal production needs to be properly organized. While commercial production, using sophiscated kilns to meet industrial requirement, deserves encouragement, it should be realised that production is an employment avenue for the peasant population. Such peasants should be encouraged to form charcoal production associations and these should be educated in efficient carbonisation methods, including improvement in the traditional kilns. Where metal kilns are introduced they should be designs within the means of the peasant, easy to operate and maintain. The advantages of portable metal kilns over the stationary concrete ones should be exploited.

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Charcoal production should, as much as possible, be made to follow land clearing for agriculture and forestry so as to put to productive use that which would other-wise go to waste. This has the advantages of charcoal production from cheap material and is an indirect way of reducing the cost of plantation establishment.

In as much as possible waste in the timber industry; exploitation and sawmill wastes, including sawdust may be put to productive use by carbonization and this may be extended to agricultural waste where available.

Marketing should be properly organised both within and between states as a way of solving part of the energy problems of the wood deficit zones and a source of additional income for the favoured zones.

Efforts should be made in the favoured zones for increased production over and above national requirements to create surpluses for export.

The potential exists in some countries for the production of high quality charcoal, including activated charcoal. This should be exploited.

The impact of production on the environment must be closely watched. The natural woodland must be properly protected and managed including regulated production to ensure sustained yield. Uncontrolled burning and over-grazing should be avoided.

Where-ever necessary energy plantations must be established to supplement production from the natural forest. This may either take the form of large scale afforestation schemes, by central government and industrial establishments, to meet requirements for industry and large urban centres or scattered woodlots established by the local population perhaps with aid from central government.

Where funds and expertise are not available to central government, for large afforestation projects, internaitonal aid may be sought.

Financial institutions should be educated about the potential of forest energy as an answer to the energy crisis in Africa so as to make them want to finance afforestation and charcoal production projects even though the return on investment may not be as high as it would be in other investment sectors.

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