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# FINAL REPORT

# Crop Wastes as Feedstock for Gasification

## A Survey of the PTA Region

## - With Special Emphasis on Zimbabwe -

Gibson M. Mandishona

Harare, August 1991

UNIDO Project XA/Raf/90/602 : Statistician : Demonstration programme on the use of Indigenous Biomass Resources for meeting energy needs

# Acknowledgement

The author wishes to thank Messrs. L.Palm, B.Kjellström and J.W. Ascough; for providing valuable advice, guidelines and materials for the current study. I gained fruitful insights from a pre-feasibility study (D. Bond and L. Lacrosse, 1986) for a pilot gasification plant based on crop wastes. In addition, some national statistical agencies and international organizations, readily supplied information and data on various aspects of the subject-matter.

The views, opinions, errors and omissions in the text, remain my responsibility.

**G. Mandishona, August 1991.**

## CONTENTS

# 1. Introduction

## 1.1 The Case for Appropriate Technology

(i) The rural community has generally a low resources base resulting in a low capacity for productivity and hence income creation. An appropriate or "people's" technology may assume a variety of forms:

- transplant of a foreign technology or hardware;
- adapted foreign equipment or ideas,
- indigenously developed technology, which requires greater resources in R and D work.

(ii) So much has already been said about development technology. It now suffices to mention that for a technology to succeed and to be acceptable, there must be an enabling environment to make people aware of the alternatives; viz relevant information, technical training, skills and management development programmes.

(iii) Six basic attributes have been identified as ideal for technological innovation and change:[1]

- end-user relevence and suitability
- technology to be managed by the users
- employment creation
- local resource inputs and tools
- sound/technical engineering
- conservation of environment

These criteria have been likened to a chain with strong linkages and interdependence. But for the technology to work, the rural folk should abandon the so-called "poverty spiral", where women who constitute some 70% of the peasant farmers, are often sceptical and reluctant to adopt new and modern technologies. Rural family members practise different roles at different times of the day; be it farming, water supply, child-care, transport, etc.

(iv) The realization that deforestation, drought and desertification have led to woodfuel shortages, has turned the attention of several PTA countries to other types of biomass fuel. Agricultural residues are an obvious option. because they arise in fairly large quantities in the rural areas which are currently experiencing the worst pressures of woodfuel shortage.

## 1.2 The Need For Energy in Rural Areas

(i) As the 1990's unfold there is a new air of optimism, as regards overall development within the sub-region. Good ideas, information and energy technologies are evolving. Enlightened sustainable energy options are proving to be reliable and desirable solutions for both the developed and the developing worlds. Who benefits from the energy technology? The choice of energy technology should be driven from end-user needs, rather than from supply considerations.

(ii) A rural energy strategy should promote productivity in the agricultural, industrial and commercial sectors, and to meet basic needs, e.g. vis-a-vis the alleviation of drudgery of women. Who selects the technology? Technologies should not be imposed on the end-user. However, the social and environmental impact of energy technology extends beyond the individual end-user, and

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[1] *"Development Technologies for Zimbabweans for the 1990's" "Dev. Tech. Centre, University of Zimbabwe. National Seminar Series; Ranche House College, November 1990.*

hence decisions should ensure exceptance by the target communities. Efforts should be made to develop indigenous capabilities for decision making and selection of technologies, within the framework of sustainability.

(iii) In the context of gasification technology, the need for technical and skilled personnel need not be over-emphasized;
- necessity for presence of basic manufacturing knowhow,
- local production to generate employment, income, self-reliance and secondary industries (repair and maintenance).
- rural industrialization to stem the urban drift
- energy alone does not ensure rural transformation, although the latter demands energy. Thus, rural energy inputs would need to be suitably packaged with credit, know-how and training.

(iv) What are the economic costs and benefits? Renewable energy technology must be viable in terms of its economic cost (local and foreign) and externalities such as environmental impacts. Modularity and short gestation are important characteristics of sustainable energy, so it can be adapted to local needs.

(v) In the PTA sub-region, there is great energy deprivation, especially in the communal lands. This is compounded by a variety of societal and economic factors:

- depletion of forests and hence fuelwood, through massive deforestation and climatic changes.

- rapid rates of population growth and migration impacts

- high and prohibitive fossil fuel procurement costs, especially for impoverished and debt-ridden economies.

- general economic inflationary pressures, and lack of forex.

- costly nature of extending the electrical grid into the rural areas.

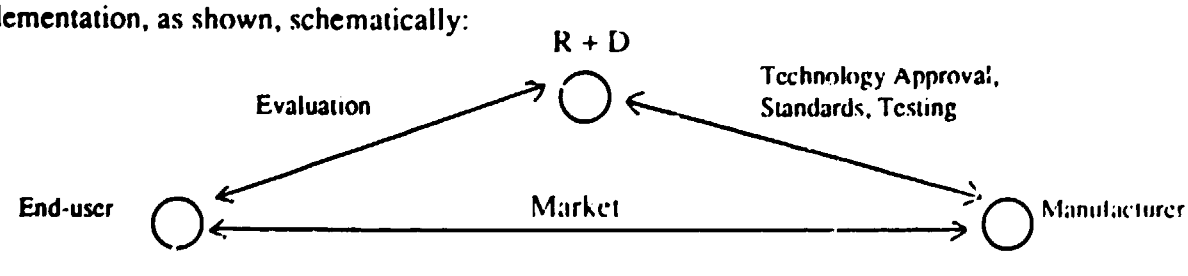
For the above reasons, inter alia, Zimbabwe and other PTA member-states have embarked on economic structural adjustment programmes; geared to create a self-sustaining economy. To this end there is an urgent need to create viable rural energy strategies.

(vi) Gasification using crop wastes and agricultural residues could be looked upon as a technology that is pollution-free and environmentally benign. Indirect benefits would include:

- raising rural living standards through electrification, etc.
- source of employment generation (energy-dependent industries, manufacture/repair/maintenance, training, information processing, for gasifier technology).
- creation of general economic awareness.

(vii) The transfer of rural energy technology:

Energy technology transfer will involve interaction between Research and Development (R & D), the end users and the manufacturers. There are several inputs to each of these key components of implementation, as shown, schematically:



There are often difficulties in maintaining all aspects of this dynamic process of implementation. These include:

- involvement of manufacturers right from the start; many technologies have failed to develop further than demonstration prototypes because local manufacturers were not involved until at a late stage. Commercially viable products should interact closely with industry.

- local infrastructure: this is vital to the successful implementation of gasification technology: cooperatives, industry/ university linkages, R & D.

- standards: standards of quality and reliability are essential so that end-users and investors have confidence in products. Local manufacturers must be supported by local quality control agencies.

(vii) Constraints:

- Role of national/international organizations: to make commitment to long-term involvement, in R & D work; to encourage development of sustainable energy technology and enhancement of local expertise.

- Incentives for local industry to participate in gasification technology: the establishment of suitable fiscal incentives for market development.

Infrastructure: need for adequate human, physical and organizational infrastructure both in DC's and also in donor agencies.

- Baseline statistical data on technologies, resources and needs:

- evaluation of local resource base in relation to R & D work.

- inventories of local expertise, and of successes and failures.

## 1.3 The Pilot Gasification Project

(i) The pilot study is to use carefully selected agricultural wastes as feedstock for the gasifier; i.e. densified coffee husks, groundnut shells and maize cobs. The sources of the residues are the Banket Depot, the Cleveland Dam Depot and the Nijo Estate (also the location of the project).

(ii) The pilot gasifier engine generator was a module of net output 50 kwh/hr electricity. The densified waste feed required was about 145 kg/hr; the gasifier output was to be 1800 MJ/hr cold, clean producer gas; the diesel engine, retrofitted for spark ignition.

(iii) The major goal of the pilot project is to investigate the viability of gasification technology using indigenous agricultural wastes, and the overall potential of the technology towards meeting the sub-region's rural energy needs.

(iv) The pilot study was also to survey availability and suitability of crop residues, consideration of feedstock preparation and gasification process, as well as analysis of the economic, social and technical feasibility.

(v) Overall, there has been need to evaluate the utilization of crop wastes as a source of energy for productive activities, particularly in view of the contributions that such residues could make in the sub-region.

### 1.4 Crop Residue Conversion

(i) Once it has been realized that agricultural wastes can be converted into a variety of energy sources, it becomes expedient to identify the available technologies. There are several agricultural residue conversion technologies: [2]

- gasification
- pyrolytic conversion
- carbonization
- direct combustion
- densification
- anaerobic digestion.

However, the main object of this paper focusses on the gasification process, as the basic technology for agricultural residue conversion into useful energy.

(ii) Biomass gasification or producer gas history as a source of energy and power production spans almost a century. Producer gas technology is generally cumbersome to use as regards fuel preparation, operation and maintenance. Thus, firstly biomass gasification must show substantially low operating costs and higher supply reliability than the petroleum option. Secondly, there must be strong incentives for the operators to use this technology; vis-a-vis safety, reliability and sustainable availability of fuel.

(iii) The pilot study's major goal is thus to identify where and under what conditions and circumstances, biomass gasification is best able to contribute to the energy development effort. The PTA Ministerial Council (Kampala 1987) endorsed: "that PTA Member States should intensify their efforts in R + D activities testing and in establishing pilot demonstration projects for biomass production." It had been noted that although the subregion does not possess immense domestic resources of hydrocarbon fuels, it nevertheless produces a variety of crops (maize, groundnuts, cotton, coffee, barley, sugarcane, wheat); whose wastes and residues could be converted into energy by means of gasification.[3]

(iv) The PTA countries need to achieve self-sufficiency in energy supply, thereby reducing dependence on imported fuels. Energy resources such as coal, petroleum, hydroelectricity and geothermal exist in some member states, but their exploitation and transformation into useful energy are constrained by poor infrastructures and high investment costs. In the rural areas wood-fuel is being depleted, leaving as the practical option - the development of new and renewable sources of energy: solar, wind and biomass.

(v) Hence, overall, the present statistical project is tasked to determine the viability of establishing a project for generation of rural energy from agricultural wastes by means of gasification.

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[2] *Utilization of Agricultural Residues as Energy Source for productive Activities: (UNDP/ESCAP Workshop Papers, Bangkok 1985).*

[3] *Pre-feasibility Study for a Pilot Gasification Plant to be Based on Agricultural Wastes (1986; UNIDO; based on D. Bond and L. Lacrosse).*

# 2. Crop Production and Potential Crop Wastes in PTA Region

## 2.1 Introduction

(i) The Gasification Pilot Study recommended that "The required agricultural crop and waste production, as well as stationary equipment specifications and energy consumption data are to be collected in detail for Zimbabwe, and in as much detail as feasible, from other countries of the subregion". Not all the twenty member states of the PTA sub-region are extensive grain producers, though it is true to assert that agriculture remains to be the mainstay of the majority of their economies. Table 2.1.1 below shows maize production levels for selected countries of the subregion, for the 1989/90 season.

**Table 2.1.1: Maize Production in Selected Countries 1989/90 (see also Annex 1)**

| | (000' tonnes) | |
|---|---|---|
| Angola | 180 | low income, food deficit, civil strife. |
| Botswana | 8 | land-locked, droughts, East/South East agric. base. |
| Lesotho | 111 | land-locked, low income. |
| Malawi | 1344 | land-locked, importer/exporter of grain |
| Mozambique | 453 | low income, food deficit, civil strife |
| Namibia | 34 | low-income, food deficit |
| Swaziland | 130 | land locked, imports through S. Africa |
| Tanzania | 2775 | Cereal surplus in South/Southwest, deficits in North West. |
| Zambia | 1768 | land-locked, low income, food deficit |
| Zimbabwe | 1994 | land locked, exporter /importer of grain. |
| **Total** | **8797** | |

*[Source: Food Security Technical/Administrative Unit, Harare, June 1991]*

(ii) The model to be followed is to split the PTA member states into three categories: countries with adequate and potential crop wastes; those with scanty resources; and lastly those for which data and agricultural information are not readily available. Countries with potential agricultural residues are characterized by presence of fairly heavy rains and a preponderance of such grain crops as maize, groundnuts and coffee. Although cotton is a common crop in the PTA, there is legislation in several member states whereby cotton residues have to be buried underground by specific dates. Thus, although cotton's thermogram is highly suited for gasification applications, it will not be advisable for practical reasons to utilize its wastes as feedstock for producer gas generators.

(iii) It will be found necessary in specific circumstances, to identify potential locations of gasifiers within the individual countries. Such locations will be identified using criteria cited in (ii) above. In addition, one would want to investigate markets for energy products of gasifiers, and potential for further R & D work.

(iv) Amongst the eighteen or so PTA member states, only ten country profiles will be presented. These have been selected on the basis of high maize-crop output, which is an indicator of gasification potential. Groundnut and coffee production were also considered. The data upon which selection criteria were based is exhibited below for the chosen member states:

**Table 2.1.2: PTA Crop Production : Selected Countries : 1988 (see also Annex 3)**

| | (in 1000 metric tons) | | | |
|---|---|---|---|---|
| | Maize | Groundnuts (shell) | Cotton (all types) | Coffee (green) |
| Angola | 345 | 30 | 99 | 53 |
| Burundi | 240 | 120 | 20 | 45 |
| Ethiopia | 2250 | 44 | 215 | 338 |
| Kenya | 3975 | 14 | 81 | 188 |
| Malawi | 2061 | 270 | 134 | 3 |
| Mozambique | 525 | 98 | 156 | 2 |
| Tanzania | 3315 | 89 | 402 | 74 |
| Uganda | 600 | 173 | 77 | 293 |
| Zambia | 1668 | 23 | 93 | 15 |
| Zimbabwe | 3819 | 108 | 605 | 18 |

Source:*[FAO Production Yearbook: vol.45, 1989]*

The selection criterion is the Maize Production Index (MPI).

(v) Although agriculture is not the largest sector in terms of its contribution to GNP, yet about 3/4 of the subregion's population live in the rural areas. If rapid growth in the employment, output and income of the rural population is to be achieved, agriculture should receive increased emphasis in national development plans. This development would increase abruptly the output of grain crops, which in turn would have corresponding increases in crop wastes and residues. Accordingly, Five-Year Development plans for most of the sub-region's major crop growers, have projected annual agricultural growth at an average of 5% through the 1990's.

(vi) Reinforcing and supporting activities in the procurement of crop residues would include:

- post-harvest loss reduction
- regional inventory of the crop residue resource base.
- regional crop residue information systems.

(vii) Finally, although our focus is on gasification, one observes that the regional strategy for increased crop production is designed to reinforce the capacity of members states to feed their people, to provide productive employement, to reduce external food dependence; and to enhance the capacity of the agricultural sector to speed up economic transformation.

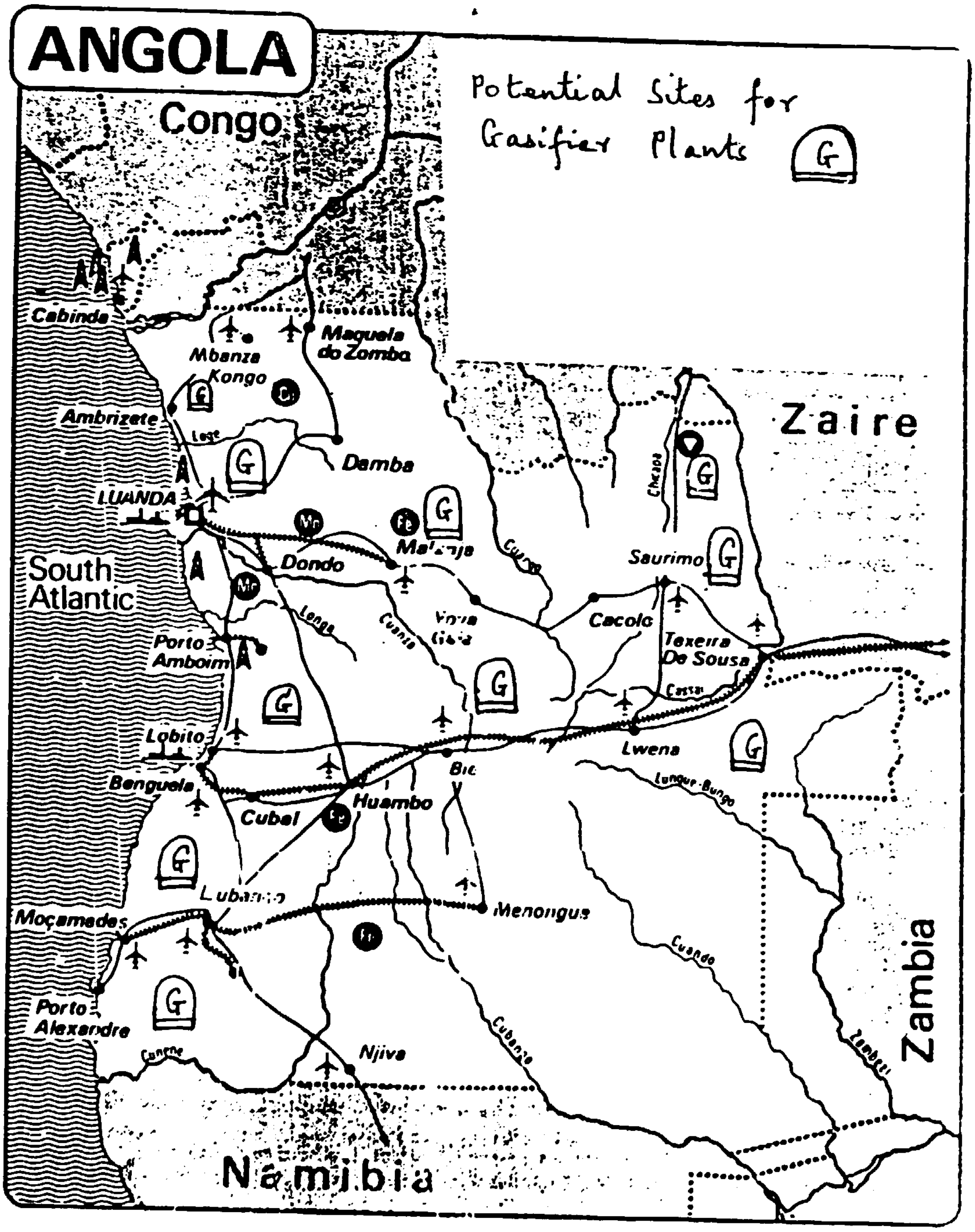
A brief summary of selected country profiles follows:

## 2.2 Angola

(i) War and unrest has constrained agricultural production over the years. The country has a high agricultural potential for grain crops such as maize, coffee and wheat. Per capita food production declined by about 15% between 1981 and 1989. Although the major exports for Angola are crude oil and rock minerals, coffee is also being exported in appreciable quantities (4% of export bill, 1981-1989). In 1989 Angola exported in excess of 35,000 metric tons of coffee. In contrast, Angola imported some 50,000 metric tons of maize during the same year. The fertile coastal region is highly ideal for coffee growing, while the hinterland is suitable for maize and cereals in general.

(ii) If political stability is restored Angola is potentially fertile for maize and cotton. The Central Plateau receives adequate rainfall, as well as along the Kwanza River, in the North-West and North-

Map 2.2


ANGOLA
Potential Sites for Gasifier Plants
Congo
Zaire
Zambia
Namibia
South Atlantic
Cabinda
Mbanza Kongo
Maquela do Zombo
Ambrizete
Damba
LUANDA
Dondo
Saurimo
Cacolo
Texeira De Sousa
Porto Amboim
Lobito
Benguela
Cubal
Huambo
Lwena
Menongue
Moçamedes
Porto Alexandre
Njiva
Zambeze
Cuando
Cubango
Cunene
Lungue-Bungo

East districts. Potential sites for gasification are indicated on the map. The coastal region and locations in the North-East and North-West are quite ideal, because of maize and coffee agriculture. However, ten well-spaced gasifiers would suffice. Localities around Luanda, Lubango, Lwena, Saurimo, Mbanza Kongo are particularly ideal. A potential market of some 500 plants are conceivable.

(iii) The potential for using crop wastes as gasification feedstock currently lies in coffee husks, as no other major grain crops are being currently produced in Angola. Furthermore, there are no sizeable coffee processing plants in the country, making it even more difficult to secure the coffee residues.

## 2.3 Burundi

(i) Agriculture accounts for 95% of the economy and engages 90% of the national population. Coffee is overwhelmingly the most important crop, accounting for 85% of the country's total exports. Other crucial crops are cotton, tea and hides. The main staple food crops are maize, cassava, beans, sorghum and bananas.

(ii) Burundi experiences a usually long rainy season, with maximum ranfall in March - April. In the plateaux average rainfall is 1200 mm, but declines to about 760 mm in the lower plains. The fertile lands are around the shore plains of Lake Tanganyika, which have forested savannah.

(iii) Test gasification plants could number 5; and they could be located around the shore plains of Lake Tanganyika and the neighbouring region. With the projected plans of increasing maize and coffee output, there is a real potential for gasifier usage, especially in the rural areas. Coffee husks as gasification feedstock are particularly attractive. If the pilot gasifier plants are successful, there is a future possible market of some 1000 of them, located mostly in the coffee growing localities.

## 2.4 Ethiopia

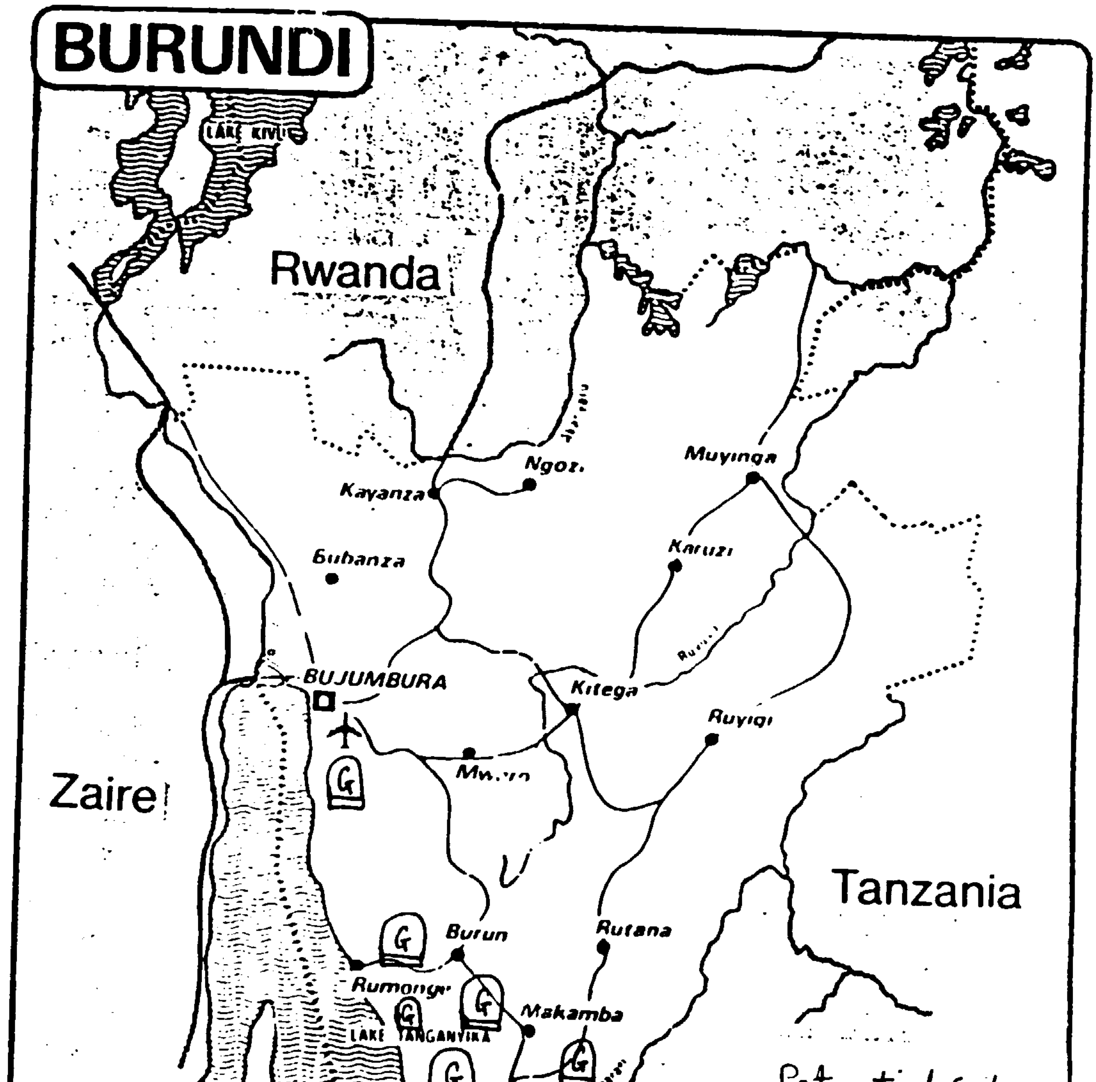
(i) Ethiopia is typically an agrarian country, with 90% of its population dependent on crop production. The main crops are maize, coffee and cotton; the first two being gasifier feedstock candidates.

(ii) Major rains fall from mid-June to early September. Rainfall diminishes with distance from the Equator. In the east the highlands are barren; but to the west they become forested. In the Ouiona Dega region there is a Mediterranean type climate which favour the growth of coffee, cotton and olives.

(iii) The ideal crop waste feedstock for gasification is coffee husks and residues. Maize cobs are available in fair quantities, only in selected areas. The staple millet "injera" hardly possesses any wastes/residues suitable for gasification purposes.

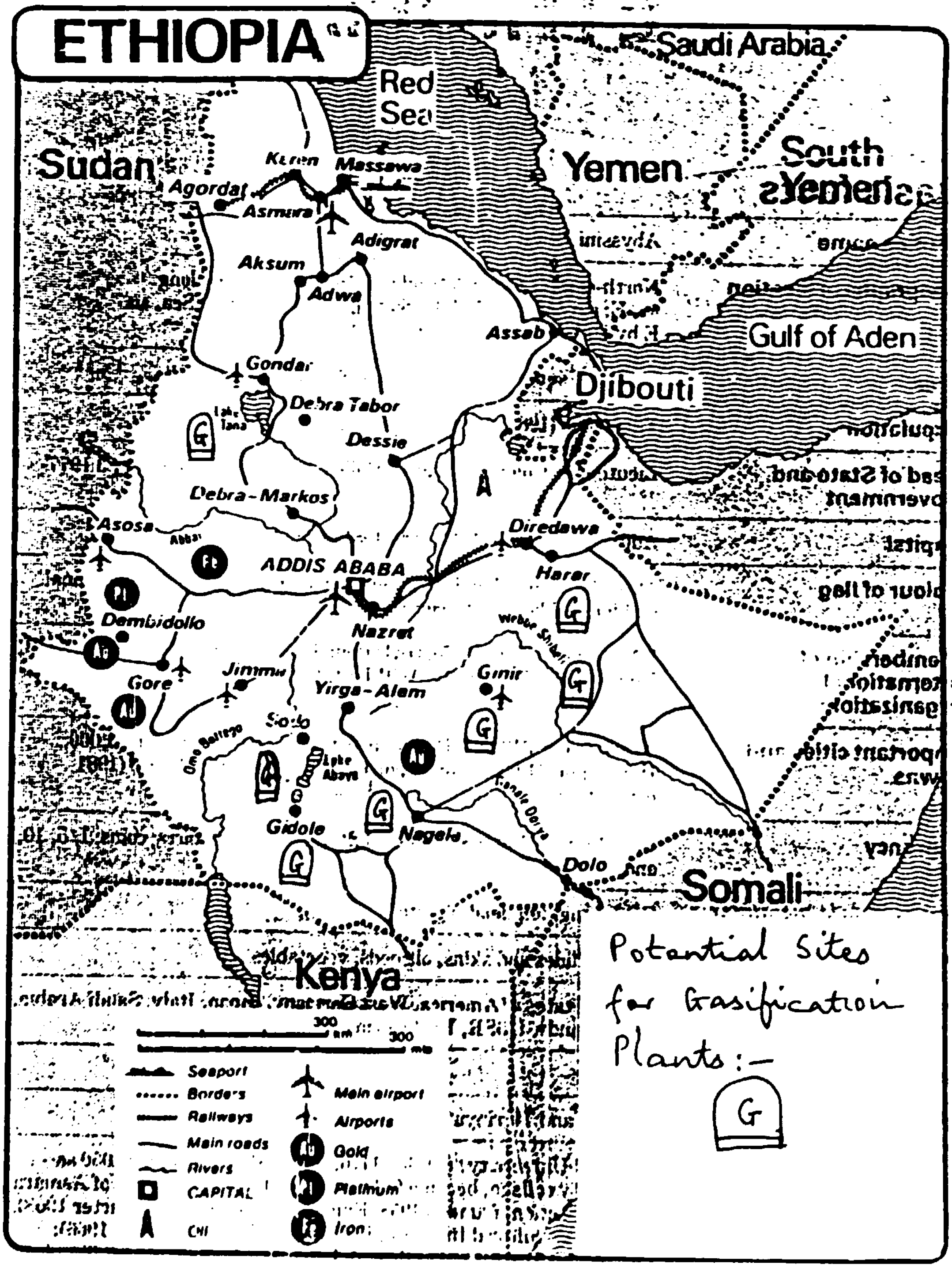
(iv) In a pilot gasification project, about 10 gasifiers could be located throughout the country, especially in the South and South East; around Gidole, Nagela, Lake Abaya, Ginir, Harar and near the basin of Webbe Shibeli river. In the forseeable future it is possible to market 500 gasifiers countrywide, in coffee regions.

Map 2.3



BURUNDI
LAKE KIVU
Rwanda
Zaire
Tanzania
Ngozi
Muyinga
Kayanza
Karuzi
Bubanza
BUJUMBURA
Kitega
Ruyigi
Rutana
Burun
Rumonge
Makamba
LAKE TANGANYIKA
Nyanza Lac
Borders
Main airport
Potential sites for gasification Plants :

Map 2.4


ETHIOPIA
Red Sea
Saudi Arabia
Sudan
Yemen
South Yemen
Gulf of Aden
Djibouti
Somali
Kenya
Keren
Massawa
Agordat
Asmara
Adigrat
Aksum
Adwa
Assab
Gondar
Debra Tabor
Dessie
Debra-Markos
Asosa
ADDIS ABABA
Diredawa
Harar
Nazret
Dembidollo
Gore
Jimma
Yirga-Alem
Ginir
Gidole
Negele
Dolo
300 km
300 mls
Seaport
Borders
Railways
Main roads
Rivers
CAPITAL
Oil
Main airport
Airports
Gold
Platinum
Iron
Potential Sites for Gasification Plants:-
G

## 2.5 Kenya

(i) Most of Kenya has a mean rainfall of less than 765 mm. The better watered regions include the cost, where rain falls throughout the year, except in January and February. Rainfall is up to 2032 mm around Mount Kenya and the Aberdares. Here, agriculture is predominant; maize and coffee being the principal crops.

(ii) The main watershed runs close to the eastern wall of the Rift Valley, with the drainage of a chain of lakes pouring into Lake Victoria.

(iii) Agriculture is the mainstay of the economy, securing basic self-sufficiency in food, often with surplus to export. The principal crops are maize, coffee, wheat, tea and sugar-cane. The most fertile land is situated in the South West corner of the country, near Fort Hall district.

(iv) Pilot gasifier plants have had some fair success in Kenya, where a few different models have been tested. An assessment of the market for gasifiers can be based on the number of diesel generator sets of about 10 kW, which indicate a potential market of over 20,000 units.

(v) Further pilot gasifier plants could be located in the neighbourhood of Magadi, Lake Victoria, Butere, Eldoret, Machakos, Kitui and Garissa, and near the basins of Lake Rudolf.

## 2.6 Malawi

(i) Malawi is self-sufficient in food. October to April rainfall averages 90%-125% of normal. Maize and rice production have increased due to hybrid varieties and increased use of fertilizers.

(ii) Maize continues to be the chief staple food for Malawi. As regards export crops, tobacco and tea persist to be the mainstay of the agricultural economy, accounting for 50% and 25% respectively, of the total share of exports. Other important crops grown in Malawi are sugar, groundnuts, cotton and oil seeds, rice, pulses, cassava and potatoes. However, for gasification purposes, only maize cobs are the potential feedstock.

(iii) Agriculture locations consist of Mlanje, Nyika, Zomba, and around Lake Malawi, Lilongwe and Karonga.

Crop production during 1981-1985 is shown below in Table 2.6.1.

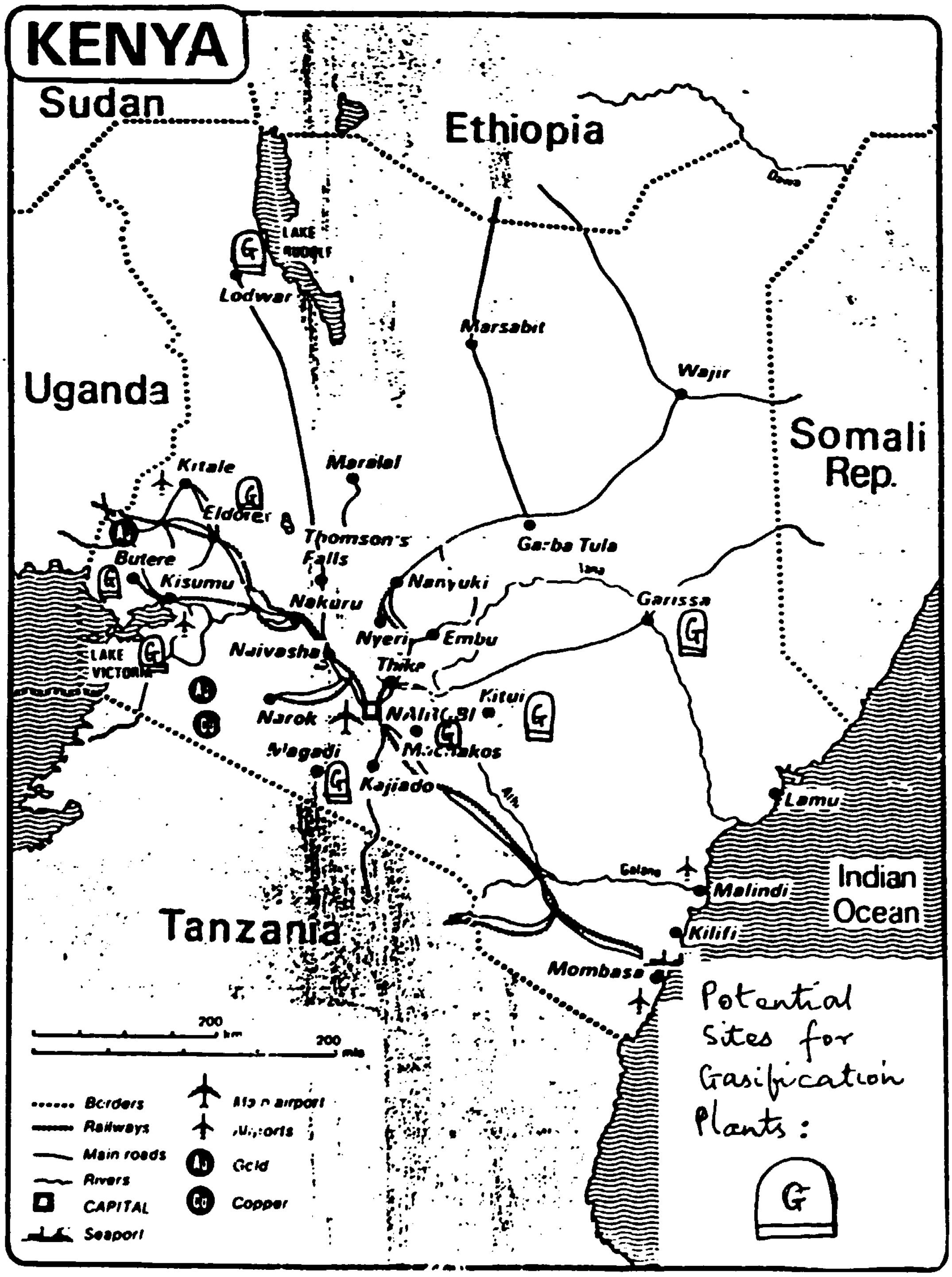
**Table 2.6.1: Malawi : Crop Production of Maize and Groundnuts in Smallholder Agricultural Sector**

| | (thousand tonnes) | | | | |
|---|---|---|---|---|---|
| | 1981 | 1982 | 1983 | 1984 | 1985 |
| Maize | 1186.2 | 1200.2 | 1080.5 | 1315.4 | 1294.9 |
| Groundnuts | 61.4 | 39.6 | 39.9 | 42.8 | 75.7 |

*[Source: Central Statistical Office, Zomba, May 1991] (see also Annex 2)*

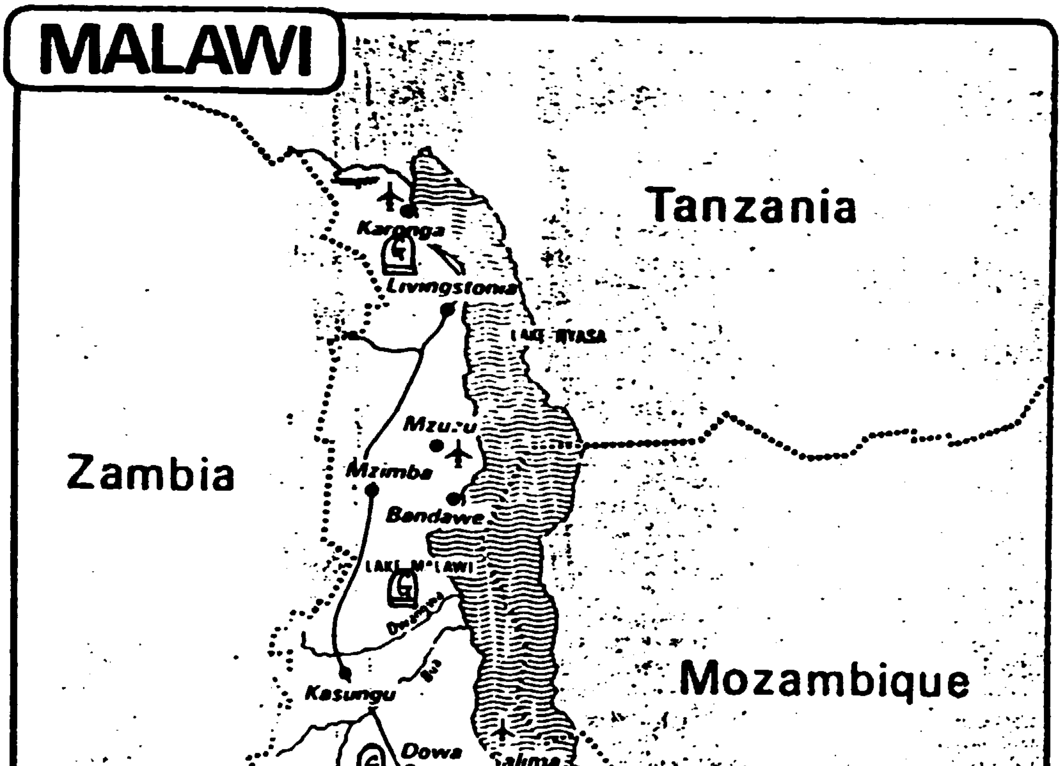
There is a fairly great potential to use crop residues as gasification feedstock in the fertile parts of Malawi. The basic crops would be maize, cotton, groundnuts and coffee. Sugarcane is also a major crop in the country, but its product wastes are utilized in sugar related energy and chemical processes.

Map 2.5



KENYA
Sudan
Ethiopia
Uganda
Somali Rep.
Tanzania
Indian Ocean
LAKE RUDOLF
LAKE VICTORIA
Lodwar
Marsabit
Wajir
Kitale
Eldoret
Marslel
Thomson's Falls
Garba Tula
Butere
Kisumu
Nakuru
Nanyuki
Garissa
Nyeri
Embu
Naivasha
Thika
Kitui
Narok
NAIROBI
Machakos
Magadi
Kajiado
Lamu
Galana
Malindi
Kilifi
Mombasa
200 km
200 mls
Borders
Railways
Main roads
Rivers
CAPITAL
Seaport
Main airport
Airports
Gold
Copper
Potential Sites for Gasification Plants:

Map 2.6


MALAWI
Tanzania
Zambia
Mozambique
Mozambique
Zimbabwe
Karonga
Livingstonia
LAKE NYASA
Mzuzu
Mzimba
Bandawe
LAKE MALAWI
Kasungu
Dowa
LILONGWE
Salima
Maganga
Dedza
Mangoche
LAKE CHIUTA
Ncheu
Zomba
LAKE CHILWA
Blantyre
Limbe
Chiromo
125 km
125 mi
Borders
Railways
Main roads
Rivers
Main airport
Airports
CAPITAL
Potential Sites for Gasification Plants:
G

(iv) A pilot gasification project is feasible, with about 5 gasifier plants located at Mlanje, Zomba, Lake Malawi, Lilongwe and Karonga. Eventually a market for about 5000 gasifiers can easily be achieved.

## 2.7 Mozambique

(i) Mozambique experiences food deficits, as food production and distribution have been seriously affected by civil strife.

(ii) Agriculture occupies 90% of the country's population, and generates the bulk of the country's GDP and exports. The main cash crops are cashew nuts, cotton, copra, tobacco, sugar, tea, sisal and citrus fruits. The two major export crops are cashew nuts and cotton; and food crops consist of maize, sweet potatoes, rice, groundnuts and cassava. Over the past few years, the overall economy of Mozambique was bleak, due mainly to political strife and droughts (alternating with floods).

The 1988 Mozambique Food Balance Sheet stood as follows:

**Table 2.7.1: Mozambique : Food Balance Sheet (1st May 1987 to 30 April 1988)**

| | Maize | Wheat | Rice | Total |
|---|---|---|---|---|
| Gross Supply | 313,750 | 193,933 | 125,683 | 633,366 |
| Net Supply | 266,685 | 164,843 | 115,316 | 546,844 |
| Total Requirements | 624,076 | 159,888 | 94,168 | 878,132 |
| Net Food Surplus (+)/Deficit (-) | -357,391 | +4,955 | +21,148 | -331,288 |

*[Source: Food Situation Report: October 1987, Ministry of Commerce, Maputo] (see also Annex 4)*

(iii) From the above, it would seem that maize is not being grown in large quantities to warrant utilization of the waste cobs in gasification plants. However, one would look at the possibility of using rice husks as producer gas feedstock. If and when political stability is restored, and agricultural activity resumes to normal levels, it would be possible to procure in large quantities, crop residues from maize, groundnuts, cashew nuts, and rice. Thus, about 5 gasifiers would suffice as pilot plants in the maize, groundnuts and cashew nuts growing areas. When normality resumes, there is a great potential for gasification of crop residues; and a promising market.

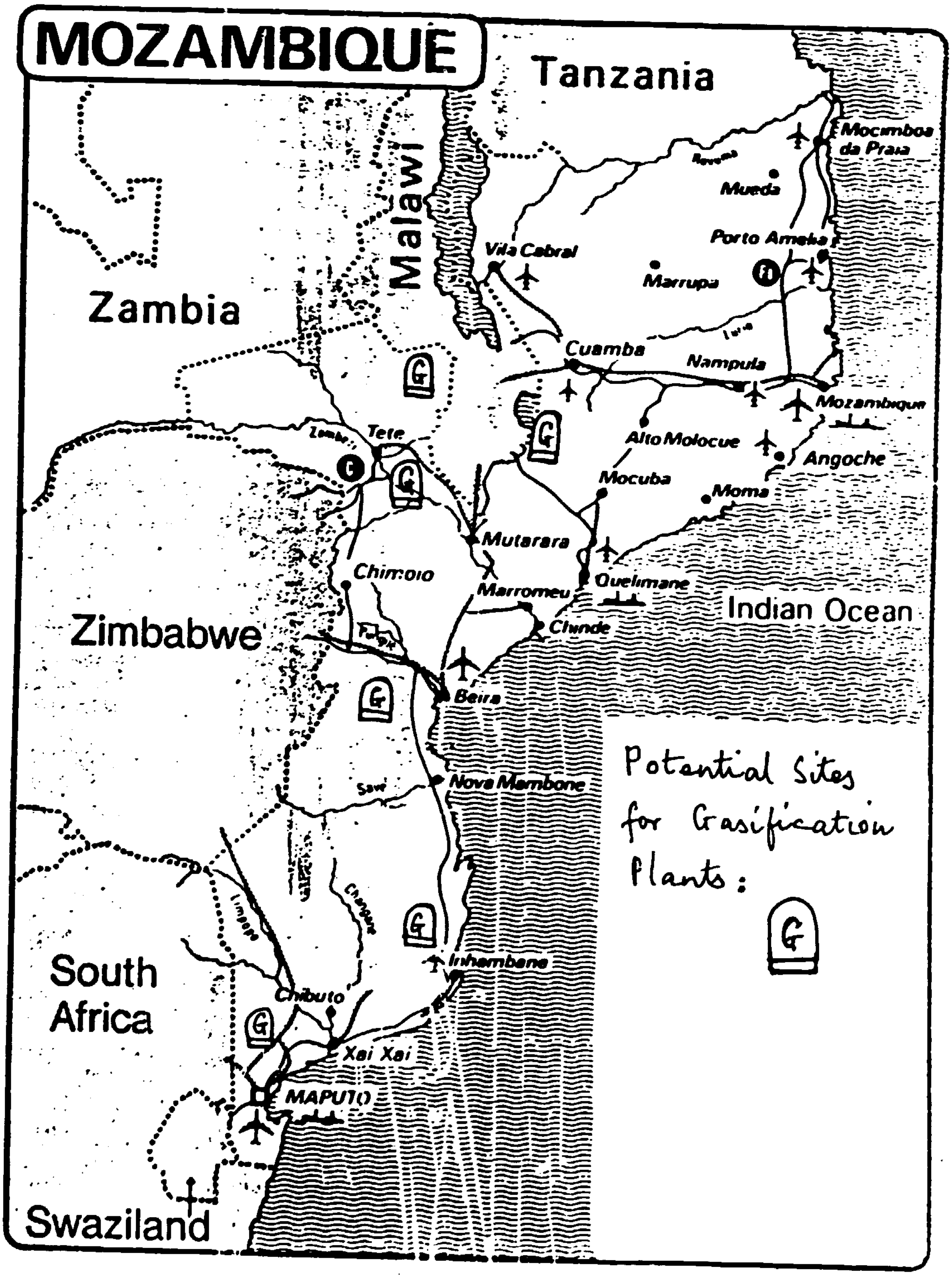
## 2.8 Tanzania

(i) Tanzania is marginally self-sufficient with maize and rice surpluses. There are severe internal food distribution problems.

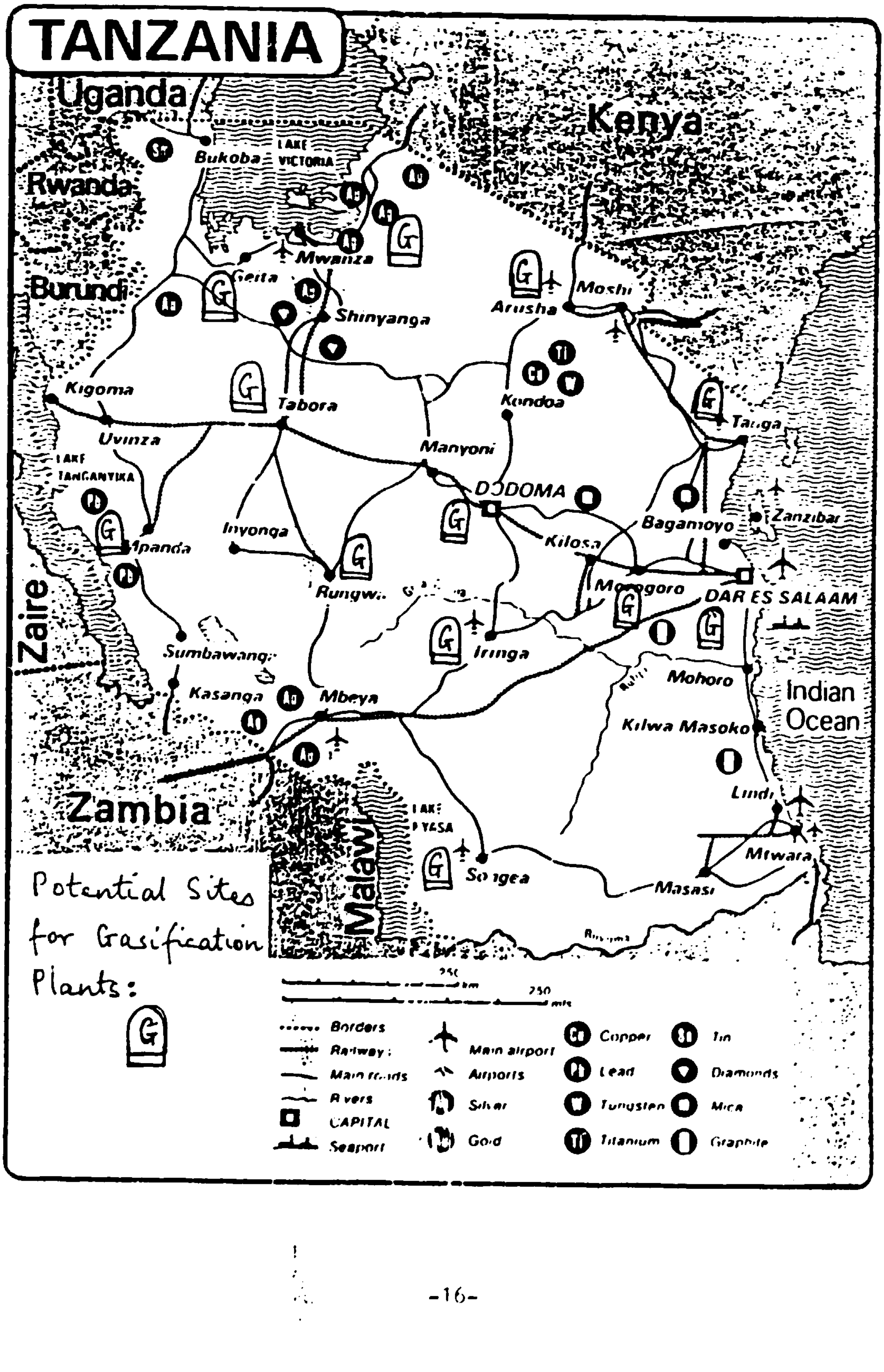
Over the past few years, Tanzania has increased food production due mainly to good rains, timely availability of agricultural inputs and favourable producer prices. The main crops grown are maize, rice, wheat, coffee, cotton, tobacco, pyrethrum, tea and cashew nuts. Purchases of the major crops by the National Milling Corporation are shown in Table 2.8.1:

(ii) The fertile land, where much rains abound, are close to the Kilimanjaro and Lake Victoria regions.

Map 2.7


MOZAMBIQUE
Tanzania
Malawi
Zambia
Zimbabwe
South Africa
Swaziland
Indian Ocean
Mocimboa da Praia
Mueda
Porto Amelia
Vila Cabral
Marrupa
Cuamba
Nampula
Mozambique
Alto Molocue
Angoche
Mocuba
Moma
Tete
Mutarara
Chimoio
Marromeu
Quelimane
Chinde
Beira
Nova Mambone
Inhambane
Chibuto
Xai Xai
MAPUTO
Potential Sites for Gasification Plants:
G

Map 2.8


TANZANIA
Uganda
Rwanda
Burundi
Kenya
Zaire
Zambia
Malawi
Indian Ocean
LAKE VICTORIA
LAKE TANGANYIKA
Bukoba
Mwanza
Geita
Shinyanga
Arusha
Moshi
Kigoma
Tabora
Kondoa
Tanga
Uvinza
Manyoni
DODOMA
Bagamoyo
Zanzibar
Inyonga
Kilosa
Morogoro
DAR ES SALAAM
Iringa
Sumbawanga
Kasanga
Mbeya
Mohoro
Kilwa Masoko
Lindi
Mtwara
Masasi
Potential Sites for Gasification Plants:
Borders
Railways
Main roads
Rivers
CAPITAL
Seaport
Main airport
Airports
Silver
Gold
Copper
Lead
Tungsten
Titanium
Tin
Diamonds
Mica
Graphite

(iii) Pilot gasification plants have been successfully implemented by NGO's in a few selected areas. A market potential of 10,000 gasifiers is quite feasible.

## 2.9 Uganda

(i) The equator crosses Southern Uganda; the climate is equatorial throughout the country, with fairly high rainfall. It rains almost throughout the whole year, around the northern shore of Lake Tanzania.

(ii) The country's economy is predominantly agriculture, with the followong major crops: coffee, maize, groundnuts, millet, sorghum, sugar cane and potatoes.

(iii) Swampy and fertile zones occur between Lake Victoria and lakes Kyoga and Mobutu Sese Seko; as well as south of Lake Edward on the Zaire border.

(iv) With Uganda returning to normal civilian rule, agricultural output will increase rapidly; with residues of coffee, maize and groundnuts becoming potential feedstock for gasifiers. There is a highly promising future market for gasifier plants in the rural areas of Uganda. A pilot gasification project involving 20 gasifiers in selected areas, shown on the map, can easily generate a market demand of over 20,000 gasogens in the not-too-distant future.

**Table 2.8.1: Tanzania: Purchases of Food Crops by the National Milling Corporation: 1987/88, 1988/89**

| Food Crop | 1987/88 (tons) | 1988/89 |
|---|---|---|
| Maize | 280,000 | 301,000 |
| Rice | 22,500 | 25,000 |
| Wheat | 50,000 | 55,000 |
| Sorghum | 15,000 | 16,000 |
| Cassava | 40,000 | 45,000 |
| Beans | 30,000 | 36,000 |
| Sugar | 120,000 | 123,000 |

*[Source: Economic Survey, 1989; Ministry of Finance, Economic Affairs and Planning, Dar es Salaam.] (see Annex 5)*

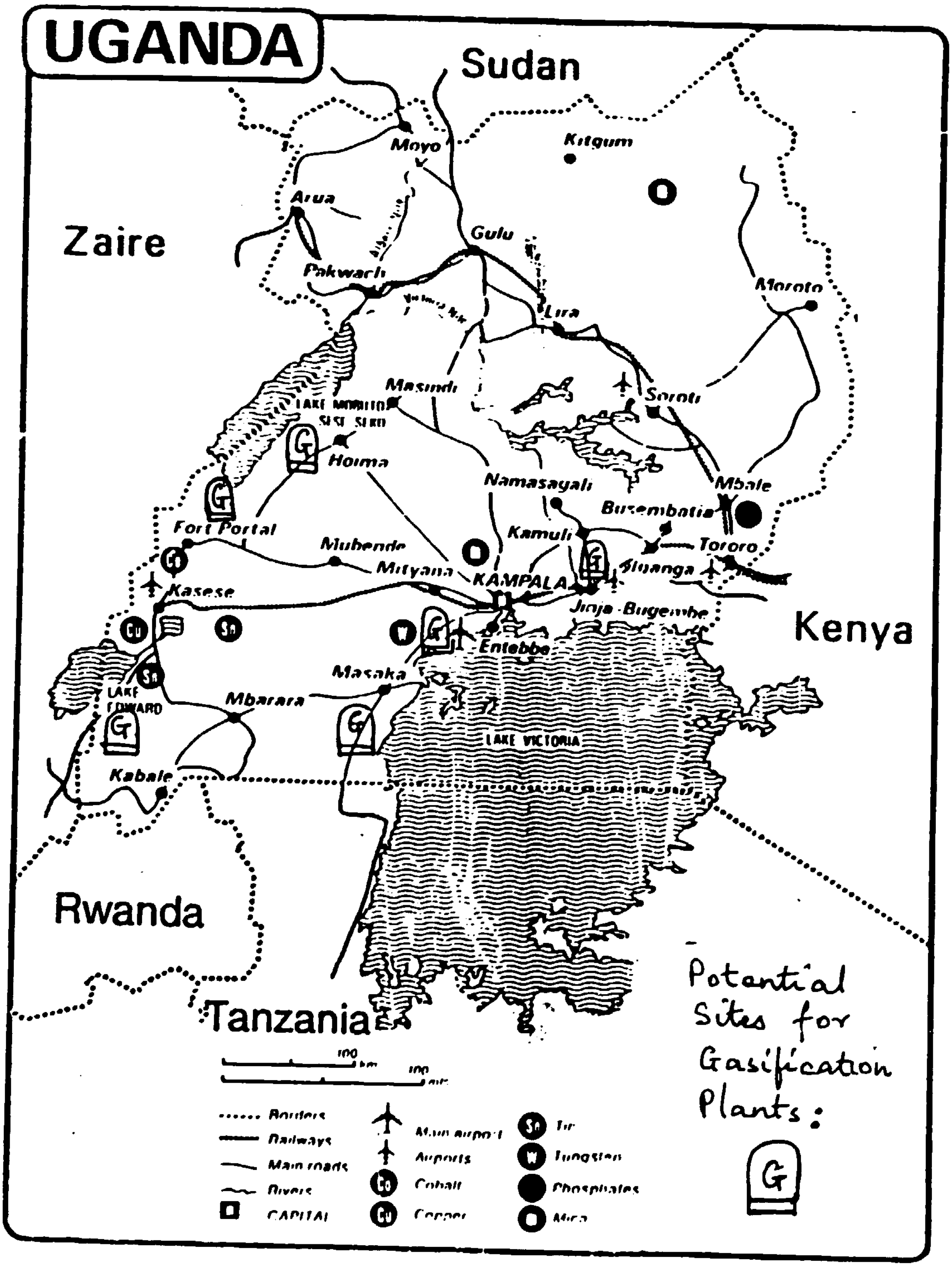
Purchases of cash crops (1988) from farmers included: coffee (50,000 tons), cotton (400,000 bales), and Cashewnuts (25,000 tons). Potential crop wastes for gasification purposes would derive from maize, rice, wheat, coffee, cotton and cashewnuts.

## 2.10 Zambia

(i) Zambia is marginally self-sufficient, with irregular maize surpluses. Agricultural growth areas are around the Copperbelt and east Zambia.

(ii) Maize purchased from farmers by the national grain board (NAMBOARD) for 1988/89 exceeded 700 thousand tons. In general, food production indices 1982-89 (taking 1980 as base) do indicate stagnation in this sector. The 1988/89 production of principal grains was as follows: maize (1 020 thousand tons), wheat (25 thousand tons), rice (10 thousand tons). Other crops grown are cassava, millet, sorghum, coffee and groundnuts. Cereal production has increased by over 30% between 1990/1991.

Map 2.9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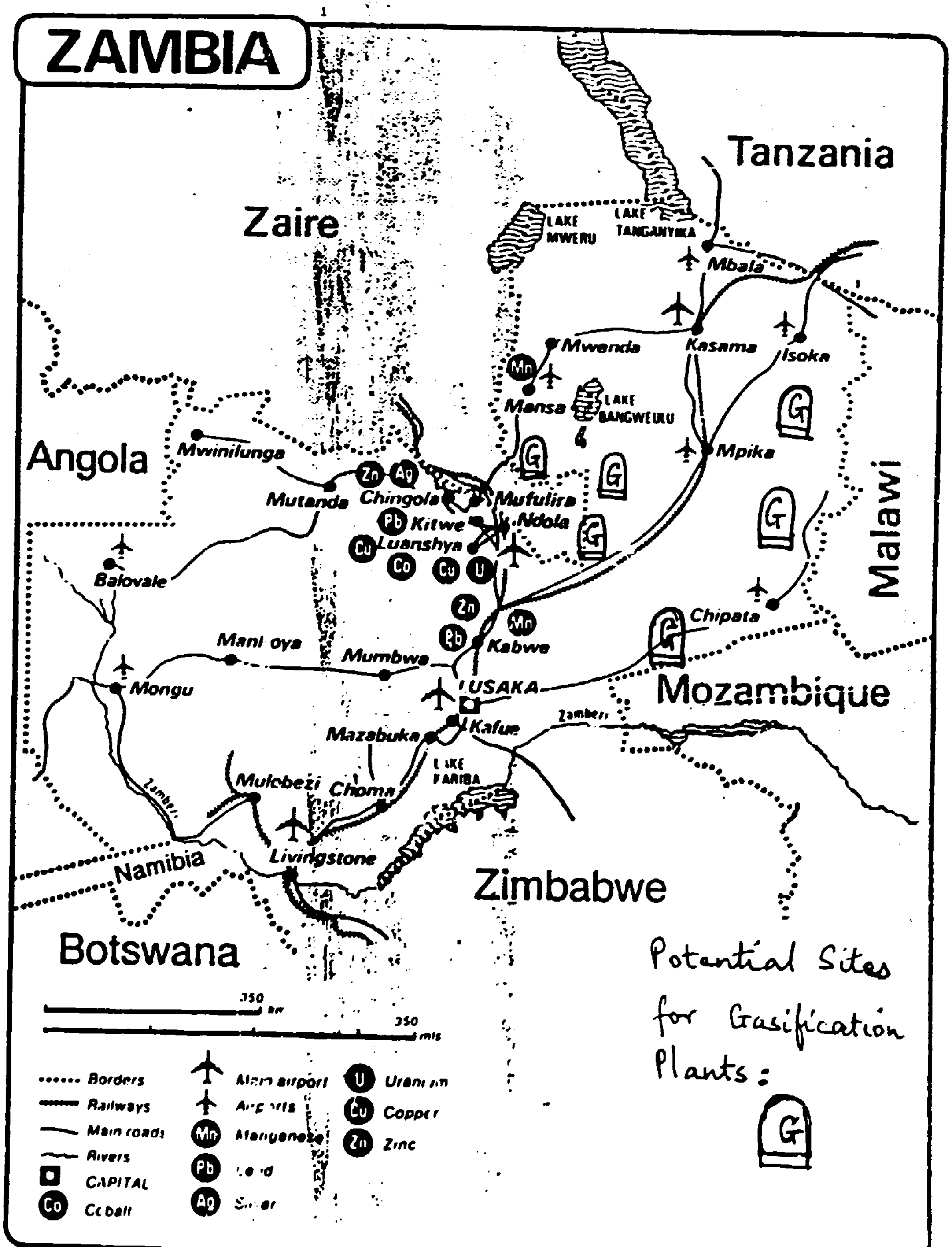
Sudan
Zaire
Kenya
Rwanda
Tanzania
Kitgum
Moyo
Arua
Gulu
Pakwach
Moroto
Lira
Masindi
Soroti
Hoima
Namasagali
Mbale
Fort Portal
Kamuli
Tororo
Mubende
Mityana
KAMPALA
Kasese
Entebbe
Masaka
Mbarara
Kabale
LAKE VICTORIA
Potential Sites for Gasification Plants:
G

Map 2.10


ZAMBIA
Tanzania
Zaire
Angola
Malawi
Mozambique
Zimbabwe
Namibia
Botswana
LAKE MWERU
LAKE TANGANYIKA
LAKE BANGWEULU
LAKE KARIBA
Mbala
Kasama
Isoka
Mwenda
Mansa
Mpika
Mwinilunga
Mutanda
Chingola
Mufulira
Kitwe
Ndola
Luanshya
Balovale
Chipata
Kabwe
Mumbwa
Mongu
LUSAKA
Kafue
Mazabuka
Choma
Livingstone
Zambezi
Borders
Railways
Main roads
Rivers
CAPITAL
Main airport
Copper
Zinc
Potential Sites for Gasification Plants:

Potential crop wastes for gasifier feedstock would be from maize, wheat and rice.

(iii) Gasification plants could be fed with maize cobs, groundnut shells and coffee husks. In a pilot project, 10 gasifier plants would be adequate. A future market of several plants, say 10,000, is well within reasonable speculation.

# 3. Crop Production and Potential Crop Wastes in Zimbabwe

## 3.1 General

(i) Zimbabwe has a population of some 10 million inhabitants (June 1990), and total land area of 390,759 sq. km. The GDP (1990) has been estimated at Z$4 414 million (at constant 1980 prices). The climate is generally temperate due to the country's altitude (65% of the land area is above 900m) and proximity to the Indian Ocean. There are three major seasons: hot season (August to November); rainy season (November to March); and cool/post rainy season (March to August). Generally, Zimbabwe has a relatively dry climate, with two-thirds of the country receiving less than 750 mm of rain.

(ii) Agriculture is the major foreign exchange earning sector, heavily relying on the export of tobacco. Because of inadequate rains in recent years, it has been necessary for the agricultural sector to diversify into drought resistant and quicker yielding crops, coupled with improved irrigation techniques.

(iii) Zimbabwe has a wide variety of crops, whose wastes or residues are potential biomass feedstock for gasification technology. The main crops produced in the country are: maize, groundnuts, cotton, coffee, barley, beans, rice, sorghum, sugar, tea, tobacco and wheat. In terms of availability and viability of gasification feedstock using crop wastes, only wastes from maize, groundnuts, cotton and coffee, will be considered.

During 1988 the Zimbabwe agricultural system was disintegrated as in Table 3.1.1:

**Table 3.1.1: Zimbabwe Agricultural System Breakdown (1988)**
**(Maize, Groundnuts, Cotton, Coffee) ('000 tonnes)**

| | National Production | Commercial Farms | ADA * Estates | Resettlement Areas | Communal Lands |
|---|---|---|---|---|---|
| Maize | 850 | 829 | 4 | 9 | 8 |
| Groundnuts | 20 | 16 | 2 | 1 | 1 |
| Cotton | 255 | 222 | 30 | 1 | 2 |
| Coffee | 15 | 14 | 1 | - | - |

*[Source: ADA; 1988]*    ** [ ADA : Agricultural Development Authority] (see Annex 6)*

(iv) The maize yield (kg/ha) and percentage distribution of the national production are reflected in Table 3.1.2.

**Table 3.1.2: Maize Yield and Percent of National Production (1989) (see Annex 7) (Large Scale Commercial Farms)**

| | Manica-land | Mash. West | Mash East | Mash. Central | Mat. North | Mat. South | Mid-lands | Masvi-ngo |
|---|---|---|---|---|---|---|---|---|
| Yield (kg/ha) | 2500 | 3500 | 3000 | 5000 | 3390 | 1700 | 1650 | 1600 |
| % Nat. Prod. | 2.1 | 46.2 | 16.9 | 31.4 | 0.9 | 0.2 | 1.9 | 0.4 |

Maize yield is thus relatively high in Mashonaland Central, Mashonaland West and Matabeleland North, but the share of production is highest in Mashonaland West followed by the Mashonaland Central and Mashonaland East. Hence gasification using maize cobs should be most viable in these areas.

(v)The contribution of Agricultural Development Authority (ADA) estates, communal lands and Resettlement Areas to total maize production has become significant in recent years: but the areas of high yields by province remain the same as those for Large Scale Commercial Farms.

The latest figures (1990/1991) on volume/value of the principal crops are shown in Table 3.1.3.

**Table 3.1.3: Volume/Value of Principal Crop Sales to Marketing Authorities (see Annex 8a, b)**

| | maize | | groundnuts | | coffee | | cotton | |
|---|---|---|---|---|---|---|---|---|
| | Vol. (tonnes) | Value (Z$000) | Vol. | Value | Vol. | Value | Vol. | Value |
| 1989/90 | 900230 | 247970 | 19155 | 12009 | 14601 | 53761 | 264409 | 232542 |
| 1990/91 | 784862 | 172960 | 17956 | 13400 | 14314 | 40525 | 186770 | 209879 |

*[Source: Quarterly Digest of Statistics, CSO, Harare, June 1991].*

It can be inferred that volumes of production for the four major crops declined slightly during 1989-1990. Nevertheless, the crops are still being produced in large quantities, to warrant their wastes' use for gasification purposes.

## 3.2 Maize

(i) In Zimbabwe 615,900 metric tons of maize were dilivered to the GMB by farmers (October 1991 - March 1992); which is about 200,000 MT short of total demand.

The Crop forecasting Committee (1990) made the following production level estimates by producer type:

**Table 3.2.1: Maize Production Estimates (1990) (see Annex 8c)**

| | (tonnes) |
|---|---|
| Large Scale Commercial | 681750 |
| Small Scale Commercial | 61280 |
| Communal Lands | 1061680 |
| Resettlement areas | 126500 |
| **Total** | **1931210** |

*[Source: Grain Marketing board: Report and Accounts: 1990]*

Thus, there is a great potential in communal lands to use maize cobs as fasifier feedstock. It is also viable to utilize the same crop residue for gasification in the Large Scale Commercial areas.

(ii) In the Agricultural Development Authority's estates, approximately 1000 tonnes of corn cobs are available for gasification; with a cobs: grain weight ratio of approx. 3:10. In this way, the ADA estates can generage their own electricity to cut down costs on electrical consumption from the grid, or from diesel generators. It is also feasible to mount gasifiers on tractor units, thereby displacing an appreciable amount of diesel fuel.

Sales of maize crop by customer 1989/90 are shown in Table 3.2.2 below (crop utilization):

**Table 3.2.2: Maize Sales by Customer 1989/90 (see Annex 9)**

| | (tonnes) |
|---|---|
| Millers and stockfeed manufacturers | 571420 |
| Stockfeeds | 42832 |
| Poultry Producers | 30926 |
| Brewers | 42454 |
| Social Welfare | 62927 |
| Others | 8271 |
| **Total** | **758830** |

During the same period, the maize production percentage distribution by major area was as follows: Mashonaland (45.7%), Matabeleland (25.7%), Midlands & Masvingo (17.4%), Manicaland (11.2%).

### 3.3 Groundnuts

(i) Apart from the tar nuisance, groundnut shells are quite ideal as producer gas feedstock. The whole nut consists of 35% waste (shell) and 65% kernel (recovery). Groundnut shelling depots are located at Masvingo, Rusape and Cleveland Dam site. The Grain Marketing Board (GMB) depot at Cleveland Dam shells an annual quantity (March-October) of about 5,000 tonnes of groundnuts, yielding approximately 1750 tonnes of shells.

(ii) The GMB used to sell the shells to a cattle feed factory at about $10 per tonne; or they used to make them into briquettes at a selling price of $1 per lorry-load. Little interest was shown (1985-89) in procuring the briquettes, and large quantities of these are being destroyed by incineration.

It is thus feasible to supplement Cleveland Dam Depot's electricity and power needs from gasification of the groundnut shells.

During 1989/90 purchases by and delivery of groundnuts to the GMB is as shown in Table 3.3.1.

**Table 3.3.1: Groundnut Deliveries to the GMB (1989/90) (see Annex 10)**

| | (Tonnes) |
|---|---|
| Groundnut purchases (unshelled) | 18875 |
| Groundnuts (shelled) delivered to GMB | 12974 |
| **Total** | **31849** |

(iii) In the Large Scale Commercial Farming Area groundnut yields and percentage of national production are highest in the Mashonaland East Province. In the Communal Land, Manicaland and Mashonaland East both have high yields of groundnut production, though Mashonaland East still contributes a higher proportion of the national production, compared to other provinces. Groundnut production in the Resettlement Area is well pronounced in Manicaland and Midlands provinces, with a higher contribution to national production in the Manicaland Province. These results are reflected in Table 3.3.2.

**Table 3.3.2: Groundnut Yield and Production by Province (1989) (see Annex 11)**

| | Manicaland | Mash. West | Mash. East | Mash. Central | Mat. North | Mat. South | Midlands | Masvingo |
|---|---|---|---|---|---|---|---|---|
| *L.S.C.F.* | | | | | | | | |
| yield (kg/ha) | 3000 | 2500 | 3500 | 2000 | - | - | 1500 | - |
| % national prod. | 4 | 27 | 53 | 14 | - | - | 2 | - |
| *Communal Land* | | | | | | | | |
| yield (kg/ha) | 3500 | 3000 | 4000 | 3200 | 2500 | 1500 | 200 | 1500 |
| % national prod. | 14 | 23 | 39 | 10 | 1 | 2 | 8 | 3 |
| *Resettlement Area* | | | | | | | | |
| yield (kg/ha) | 200 | 150 | 100 | 20 | 20 | - | 200 | 75 |
| % national prod. | 30 | 5 | 20 | 4 | 1 | - | 25 | 15 |

*[Source: GMB Annual Report and Accounts, 1990]*

(iv) Groundnuts are a fairly common crop in Zimbabwe, being grown in most parts of the country. However, the groundnut yield (kg/ha) varies from province to province, and is generally higher in the Manicaland and Mashonaland provinces. Gasification using groundnut shells has a great potential because the quantities of shell residues are quite large.

## 3.4 Cotton

(i) Cotton residues in the form of stalks and husks are difficult to transport and centralize in one area. Cotton legislation stipulates that the crop be slashed by mid - August, and burnt and buried into ground by mid - September.

In terms of cotton yield and percentage production the data for 1989 is tabulated below:

**Taole 3.4.1: Cotton : Yield and Percentage Production (1989) (see Annex 12)**

| | Manicaland | Mash. West | Mash. East | Mash. Central | Mat. North | Mat. South | Midlands | Masvingo |
|---|---|---|---|---|---|---|---|---|
| *L.S.C.F* | | | | | | | | |
| yield (kg/ha) | 4000 | 1500 | 1450 | 2500 | - | - | 1050 | 3450 |
| % production | 15 | 32 | 3 | 44 | - | - | 1 | 5 |
| *Resettlement Area* | | | | | | | | |
| yield (kg/ha) | 1500 | 300 | 350 | 600 | - | - | 400 | 30 |
| % production | 9 | 15 | 4 | 30 | - | - | 40 | 2 |

*[Source: Cotton Marketing Board Bulletin, 1989]*

(ii) The ADA estates have contributed significantly to overall national production of cotton. Antelope, Middle Sabi and Chisumbanje produced the highest cotton crop (Table 3.4.2).

**Table 3.4.2: ADA Estates Cotton Production (1989) (see Annex 13)**

| | Antelope | Jotsholo | Ngwezi | Chisumbanje | Middle Sabi | Nandi |
|---|---|---|---|---|---|---|
| yield (kg/ha) | 3500 | 2500 | 2700 | 2800 | 2900 | 2200 |
| | Fairacres | Mushumbi | Mzarabani | Sanyati | Tsovana | |
| yield (kg/ha) | 1500 | 1650 | 2250 | 3000 | 2650 | |

## 3.5 Coffee

(i) Coffee production in Zimbabwe is mainly concentrated in five provinces; viz Manicaland, Mashonaland West, Mashonaland East, Midlands and Masvingo. Coffee yields and contribution to total production by province (1989) are exhibited in Table 3.5.1.

**Table 3.5.1: Coffee Production : Yield and Percent Contribution (1989) (see Annex 14)**

| | Manicaland | Mash. West | Mash.Central | Midlands | Masvingo |
|---|---|---|---|---|---|
| Yield (kg/ha) | 2050 | 1805 | 1050 | 1530 | 1850 |
| % of total Prod | 74 | 19 | 3 | 2 | 2 |

During 1989/90 total coffee purchases from farmers were some 20,000 tonnes.

(ii) There are three GMB coffee dehulling depots, located at Chipinge, Mutare and Banket. The first two locations cater for the Manicaland Province, which is the main coffee - producing area. Coffee hulling normally takes place during June - February annually. A single depot such as the one at Banket hulled 5000 tonnes of green coffee in 1990. The hulling process has two phases; at the farms by the wet process (65% wt), and at the depot by the dry process (35% wt). The first phase removes some parchment from the bean; and the second phase removes the remaining parchment and husk.

Parchment : bean = 1 : 5
Husk : bean = 1 : 1

At the Banket depot, allowing for waste and losses, about 1750 tonnes of husks and 800 tonnes of parchment are available annually.

(iii) The coffee hulling process is performed by equipment and machinery which consume a lot of energy (some 250 kw connected loads at each depot). The stationary energy consumers consist of hullers, separators, graders, conveyors, blowers, lighting and stackers. If the wastes from coffee processing (parchment and husk) are used as gasifier feedstock at the processing depots, to supplement the available energy, the overall savings on energy consumption will imply higher economic returns.

## 3.6 Gasification Potential in Zimbabwe

(i) In Zimbabwe a number of gasification plants have been run successfully by NGO's and research establishments. Problems associated with "tars" when using crop wastes as gasifier feedstock, have been persistent.

(ii) Gasifier plants should be installed and tested at most of the established "growth points", whenever these are in close proximity to maize, groundnut and coffee growing areas. There are also agro-processing plants (coffee dehulling and groundnut shelling) for coffee and groundnuts. It is highly recommended that gasifiers be installed at these localities to supplement the energy bill.

(iii) With maize cobs as gasifier feedstock, one should look on the North-East trail for the Zimbabwe maize belt. Zimbabwe, like Kenya, has great potential for gasifier usage. If problems of tar-charring associated with crop residues, are resolved, gasification using agricultural wastes will go a long way towards easing the energy demand in the rural areas. However, a lot of work remains to be done in the areas of feedstock treatment, gas cleaning and cooling, as well as the close matching of engine systems with gasifier plants.

(iv) Zimbabwe's Communal Lands

The communal lands cover about 42% of the country and are farmed in the traditional manner by the indigenous rural population. The population density here is considerably higher than in the commercial farming areas. The total population of the communal areas in 1990 was 7 million. About 60% of these people live in the provinces of North and South Matabeleland, Midlands and Masvingo, which cover the drier south and southwest of the country.

In the communal lands, the majority of farms are small. The average size is 3 ha. Land tenure is on a traditional basis and is allocated to farming families by local community authorities. Families also have access to communal grazing areas, but in many areas these are badly overstocked.

The main food crop is maize, with groundnuts being the other favourite crop. About one million tonnes of maize are consumed internally and in a good year production is about double this. The surplus is exported to neighbouring countries. Formerly, the bulk of the maize crop was produced by large-scale commercial farmers. Major advances have since been made in the traditional farming sector in recent years, and these farmers now produce about 50% of the total crop.

In the communal areas maize and groundnut growing areas are located around the north-east, north-west and south-east of Harare. These areas include Mutoko, Murehwa, Marondera, Bindura and Mazowe. Coffee is grown around Bindura, Mutare and Chipinge. In the Masvingo and Midlands provinces, with good rains, there could be an appreciable output of maize and groundnuts. Although cotton grows abundantly in the Chegutu and Gokwe areas, it is not conceivable as yet, to use cotton residues for gasification, for legislative reasons cited earlier.

In the rural areas around Mutare and Chimanimani, there has been increased activity in the growth of macadamia nuts, giving rise to large quantities of shells which are suitable for gasification. It will be noted that a lot of crop residues become available only during harvest periods, and therefore have a **seasonality** dependence. However, it is still considered prudent to gasify crop wastes and residues, and procure some energy, if and whenever they become available. The alternative would be to destroy "energy-rich" tons of groundnut shells or the like, by burning them into the atmosphere, and thus also adding to the environmental damage.

(v) Potential Sites for Gasifiers in Communal Lands

Zimbabwe has scattered needy areas in terms of gasifier technology. Most of the rural areas would need this type of technology, although the main constraint would be COST.

However, it is recommended to selct the potential sites that would be representative of the whole country, and where agricultural activity is more or less hectic. The potential sites are grouped according to priority, with respect to need, location and appropriateness. The target rural areas will be close to the urban centres cited below:

Group I Priority

Chegutu
Mutoko
Murehwa
Bindura
Masvingo
Gokwe
Mutare

Group II Priority

Harava
Chipinge
Mazowe
Zvishavane
Shamva
Marondera

Group III Priority

Chiredzi
Nkayi
Gwanda
Mwenezi

## 4. Residues from Principal Crops

### 4.1 General

(i) The Zimbabwe agricultural structure has a three-pier system:

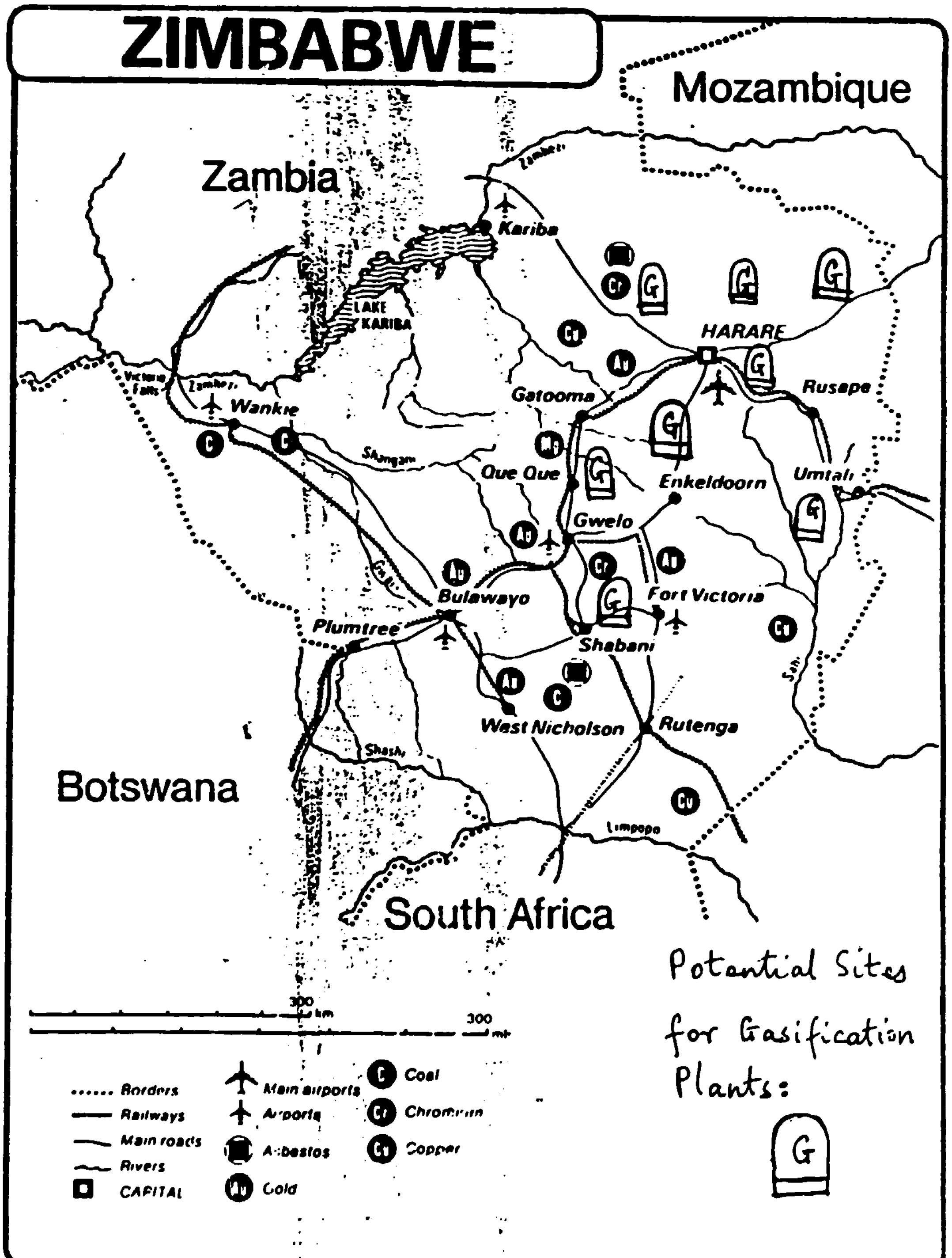
- resettlement and communal lands; large proportion of nation's farmers; scattered with no formal infrastructure; inadequate energy but demand growing in view of deforestation and growth of agro-industries; pilot project suitable.

- Large/Small Scale Commercial Farms; reasonable energy resources.

- ADA Estates: potential candidate for pilot gasification plant. In general, all agricultural output is delivered to the GMB depots, whence to marketing outlets.

(ii) The pre-feasibility study, as well as the pilot gasification project, determined the need to harness indigenous sources of energy; of which one option would be to utilize crop wastes/residues. From a wide-ranging list of crops grown in Zimbabwe, a shortlist was arrived at as viable feedstock for gasification : maize cobs, groundnut shells, cotton stalks/husks, coffee parchment/husks. Thus "principal crops" will refer to maize, groundnuts, cotton and coffee. A screening mechanism for selecting viable crop wastes for gasification should be based on technical, socioeconomic and practical criteria: crop size, availability, geographic location, ease of waste collection and storage, current use of residue, value, physical/chemical properties, legal aspects.

Map 2.11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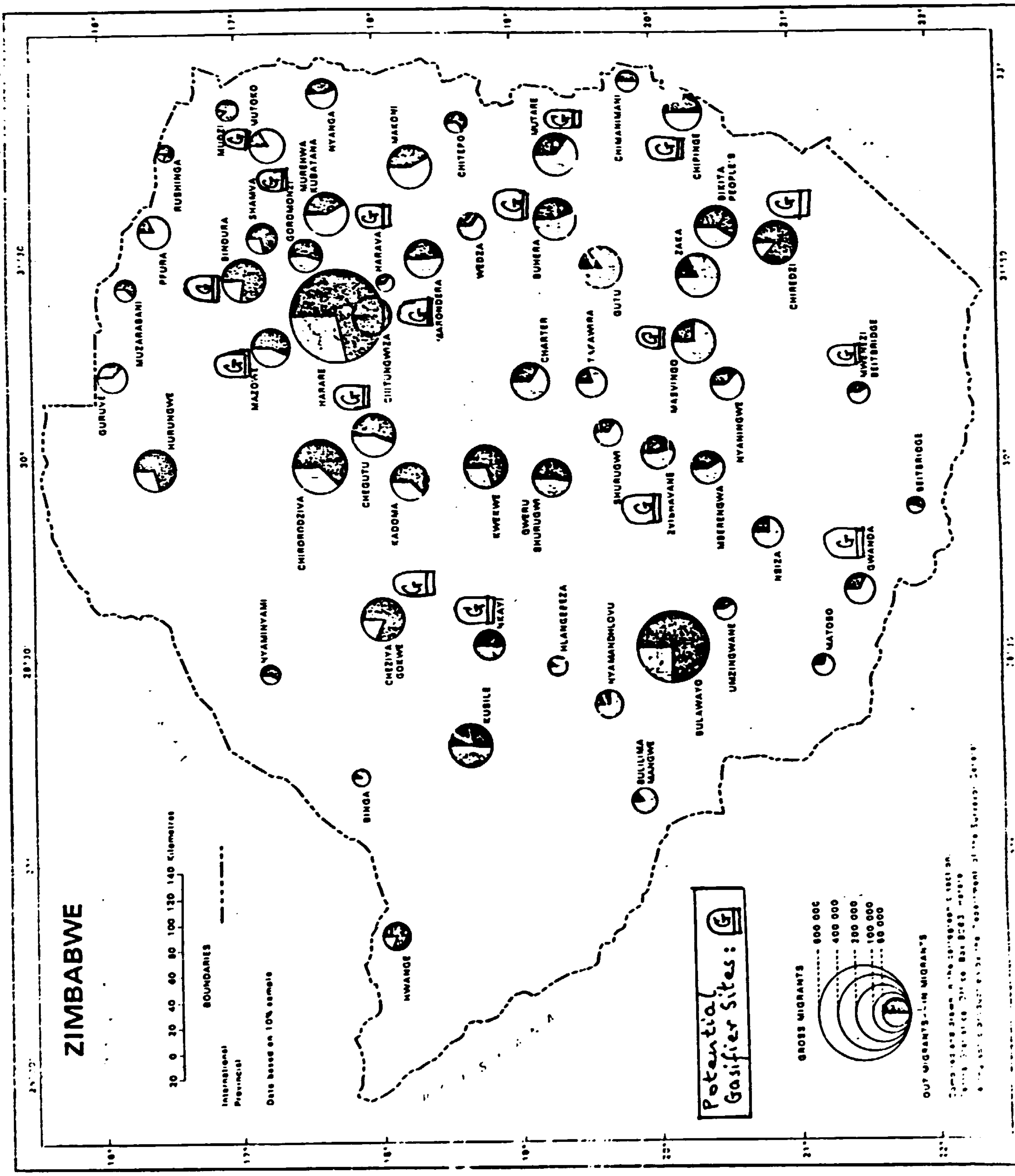
Mozambique
Zambia
Botswana
South Africa
Kariba
LAKE KARIBA
HARARE
Rusape
Gatooma
Wankie
Que Que
Enkeldoorn
Umtali
Gwelo
Bulawayo
Fort Victoria
Plumtree
Shabani
West Nicholson
Rutenga
Limpopo
300 km
300 mi
Borders
Railways
Main roads
Rivers
CAPITAL
Main airports
Airports
Asbestos
Gold
Coal
Chromium
Copper
Potential Sites for Gasification Plants:
G


ZIMBABWE
BOUNDARIES
International
Provincial
Data based on 10% sample
20 0 20 40 60 80 100 120 140 Kilometres
Potential Gasifier Sites:
GROSS MIGRANTS
800 000
400 000
200 000
100 000
50 000
OUT MIGRANTS-IN MIGRANTS
GURUVE
MUZARABANI
RUSHINGA
MUDZI
MUTOKO
NYANGA
MAKONI
MUTARE
CHIMANIMANI
CHIPINGE
CHITEPO
PFURA
BINDURA
SHAMVA
GOROMONZI
MUREHWA
UZUMBA MARAMBA
HURUNGWE
MAZOWE
HARARE
CHITUNGWIZA
MARONDERA
HARAVA
WEDZA
BUHERA
CHARTER
GUTU
ZAKA
CHIREDZI
MASVINGO
NYANINGWE
MWENEZI
BEITBRIDGE
SHURUGWI
ZVISHAVANE
MBERENGWA
CHEGUTU
CHIRORODZIVA
KADOMA
KWEKWE
GWERU
MBIZA
GWANDA
NYAMINYAMI
CHEZIVA GOKWE
NKAYI
LUPANE
HLANGEZEZA
NYAMANDHLOVU
UMZINGWANE
BULAWAYO
MATOBO
KUSILE
BINGA
BULILIMA MANGWE
HWANGE

(iii) Using the above criteria, the following crops have been identified as ideal bases for gasification:

- *maize:* Large quantities of cobs available, high ash content, awkward to collect/store, also used as animal feed. It is convenient to "collect" maize cobs before they have dropped to the ground where they get into contact with sandy matter. Sand increases ash content and creates clinker formation which inhibits gasification process.

- *groundnuts*: GMB depots and farmers produce large quantities of shells; small quantity of shells is used as cattle feed.

- *cotton*: Substantial crop produced with high residue; residue has no current usage; difficult to collect/store, stalks and roots have high ash content. For disease control, cotton legislation requires residue to be burnt for destruction and buried into ground soon after harvesting.

- *coffee*: Residue consists of parchment and husks, readily available in large quantities at processing depots; residue properties suitable as gasifier feedstock.

-*sugarcane:* Sugar bagasse is used for steam boilers on the sugar estates.

- *tobacco:* Waste has prohibitively high tar content; not suitable for gasification.

(iv) During 1989 the ADA estates alone produced the following quantities:

**Table 4.1.1: ADA : Principal Crop Production 1989 (000'kg) (see Annex 15)**

| | |
|---|---|
| maize | 2 663 |
| Groundnuts | 431 |
| Cotton | 15 966 |
| Green coffee | 2 560 |

It is strongly recommended that ADA establishes gasifier plants at their estates to supplement fossil fuel and/or grid usage.

v) To derive quantities of crop residues available for gasification, we multiply crop production figures by assumed residue/crop ratios. It must be noted that such estimates are only approximate, because they give little consideration to the bulky form of the residues or the spatial area over which they are initially distributed. Such estimates, which represent the residues in terms of the total volume of material generated, are likely to lead to their over-estimation as a source of energy.

vi) The quantity of residue from a given crop will depend upon cropping patterns and yields. The following table shows average per capita residue production from cereal crops (Sudan) :

**Table 4.1.2: Agricultural Residues in the Sudan (1978/79)**

| Crop | Area (ha) | Yield Factor t / ha | Total 1000 tons | Availability Factor | Net Amount 1000 tons | Calofic Amount GT / t | Energy Potential (toe) |
|---|---|---|---|---|---|---|---|
| Maize | 140 | 1.8 | 350 | 0.6 | 150 | 11.6 | 40 000 |
| Groundnuts | 2 300 | 1.2 | 2 760 | 0.6 | 1 660 | 23.3 | 906 000 |
| Cotton | 1 000 | 1.0 | 1 000 | 0.8 | 800 | 13.3 | 249 000 |

*[Sources : Barnard G. and Kristoferson L., 1985]*[4]

[4] *Agricultural Residues as Fuel in the Third World, Barnard G. and Kristoferson L, Beijer Institute, London : 1985.*

The crop residues have an average heat content of 12-20 GJ/ tonne. It is often assumed that crop residues are wastes, and therefore "free" for collection by anyone. In view of the depletion of woodfuel in the rural areas, an increasing number of households are using maize cobs and other crop residues for cooking and similar chores. Thus inevitably, anything which has use, acquires a monetary value.

In open fields, crop residues can be bulky (cotton residues : 130kg/m$^3$), which implies that their transportation to domestic households can become increasingly tedious and expensive as the distance from the field to a house increases.

vii) One of the criteria for selecting a good biomass feed for gasification, is energy content - which can be quantified in terms of **calorific value**. This is the amount of energy per kg a substance gives off when burnt. For most crop residues the calorific value is calculated as:

Net Calorific Value (NCV) = $19 \times (1-A-M) - 2.5M$ MJ/kg

where A = ash content
M = moisture content

Using the above formula, one arrives at the following NCV's:

| | |
|---|---|
| Maize cobs | 18.2 MJ/kg |
| Maize stalks | 17.0 MJ/kg |
| Groundnut shells | 20.0 MJ/kg |
| Cotton stalks | 16.0 MJ/kg |

### 4.2 Maize

i) The GMB reported maize sales for the month of January 1991 as:

| | (tonnes) |
|---|---|
| To millers, brewers, etc | 24544 |
| Sales of "dust" to millers, stock feeders, Poultry etc. | 60636 |
| Total | **85180** |
| (annual forecast : | 800,000 tonnes) |

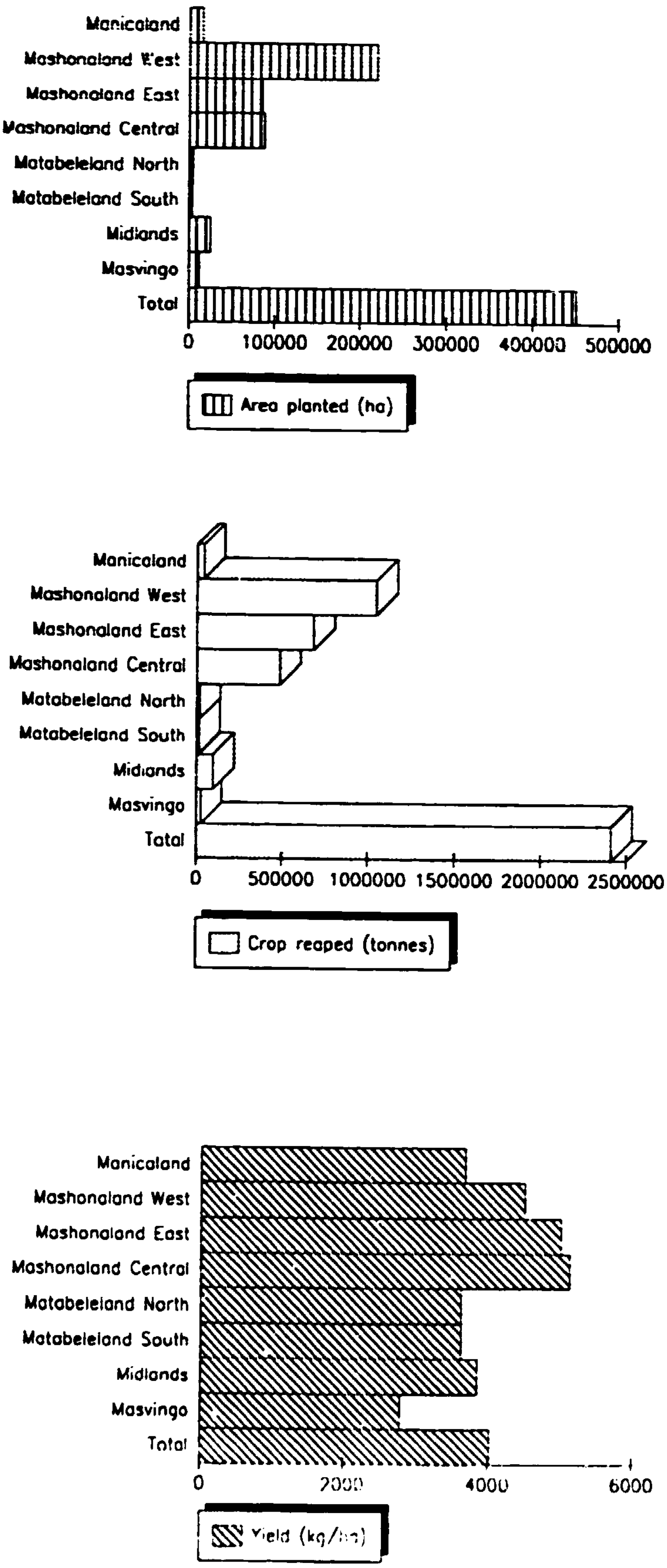
These figures, though for a single month, indicate an immense availability of maize cobs in major areas of production.

In essence, an average maize cob measures 23-25cm long, with about 600 seeds on it. Harvesting of maize is done mostly by hand (in rural areas), or by machines (commercial farming). Farmers sell their produce to the GMB, which has grain depots in different parts of the country. Maize grain is stored in sacks at the depots, or in concrete silos.

ii) To quantify maize crop wastes, one can assume the cob to be 30% of the maize grain ; and the stalk to be 200% of the grain. These figures suggest large quantities of maize crop residues available for possible gasification. A summary of maize cob characteristics is as follows :

Chart 4.2.1

## Area and Production of maize by Province



| | |
|---|---|
| Maize (kernel) production | 5-6 tonnes/ha |
| total residue : crop | 1 : 1 (wt) |
| cob : total residue | 1 : 10 (wt) |
| bulk density of cobs | 150 kg/m³ |
| Net Calorific Value | 17.5 MJ/(dry)kg |
| Ash content | 2% (wt) |
| Season (availability) | generally March - April |
| Collection | manual or combine harvester |
| Use | small amount cattle feed; or harrowed into ground for disposal. |
| Feed Preparation | shredding and densification. |

iii) An agro-residue is characterized for its utility for gasification in terms of several variables. The diagram below is a **Thermogram** representing maize cob:

(F.C. = fixed carbon, VM = volatile matter, C-H = carbon/hydrogen)

*Proximate Analysis* : F.C. = 16.2%, VM = 80.2%, Ash = 3.6%

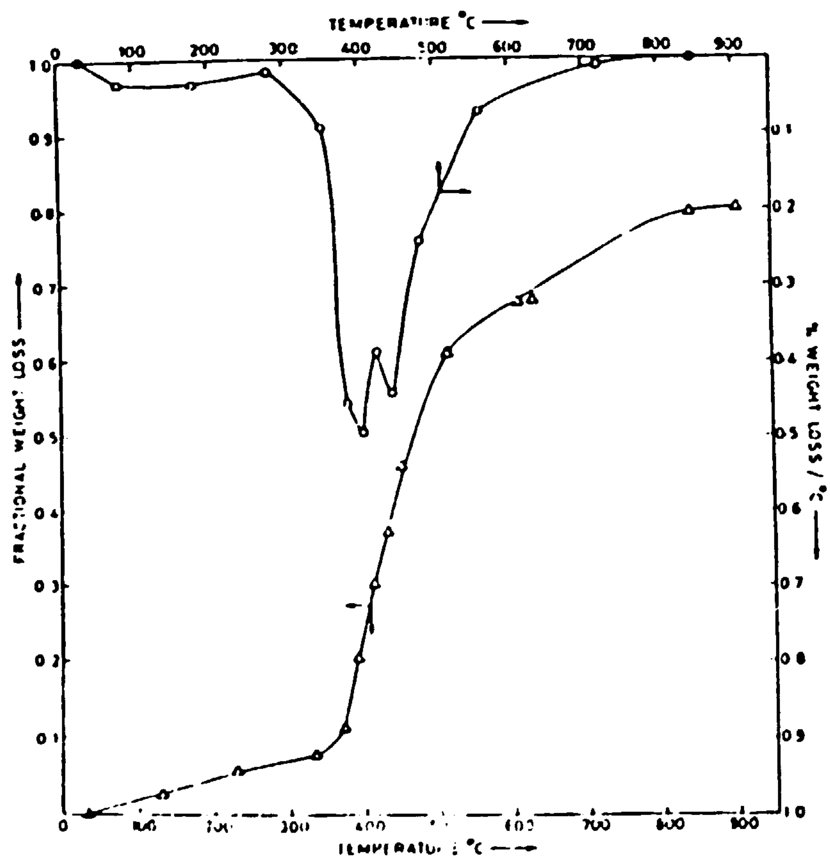
*C-H Analysis* : C = 45.3% H = 7.2%

*Calorific Value (NCV)* : 17.5 MJ/kg

*Ash Characteristics* : temp. 800° C - 900° C. Fusion temp 950° C - 1050° C.

Residue has low ash content and low ash fusion temperature, which causes clinker formation in gasifier. To avoid clinker formation, ensure reaction temperatures are below the ash deformation temperature; hence the need to modify gasifier design.

Maize Cob Thermogram



### 4.3 Groundnuts

i) Groundnut production is dominated by communal farmers. Retentions are high, and only a small proportion of the production reaches the GMB. During 1988/89 groundnut (unshelled) production from the Large Scale Commercial Farming Sector was 20,500 tonnes; and from the Small Scale Commercial Farming Sector (and others), over 80,000 tonnes. The GMB groundnut intake at the major depots for 1989/90 was: (see Annex 16)

| Depot | (tonnes) Shelled | unshelled |
|---|---|---|
| Cleveland Dam | 0.4 | 4852.6 |
| Rusape | 11.3 | 3820.8 |
| Masvingo | 41.3 | 125.8 |
| Total | 53.0 | 8799.2 |

The Cleveland Dam depot (10km East of Harare) is the second largest groundnut depot, handling an average of 1000 tonnes of shells per year.

ii) The characteristics of groundnut shells which make them crucial for consideration as suitable gasifier feedstock, are :

Groundnut shells

| | |
|---|---|
| availability: | mainly at GMB depots |
| Shells: Nuts ratio | 0.55 : 1.00 (wt) |
| Low Heating Value (NCV) : | 17.8 mj/(dry) kg |
| Ash content | 6% (wt. as received) |
| Moisture content | 10% (wt, as received) |
| Composition | carbon 46%, oxygen 40%, hydrogen 6%, others 8% |
| Season: | March - October; shelling May/June |
| Use: | Small quantity as cattle feed; remainder briquetted or burnt. |

iii) In general, about a quarter of any dry crop feedstock is a residue. In the case of groundnuts about 45% of it is shell.

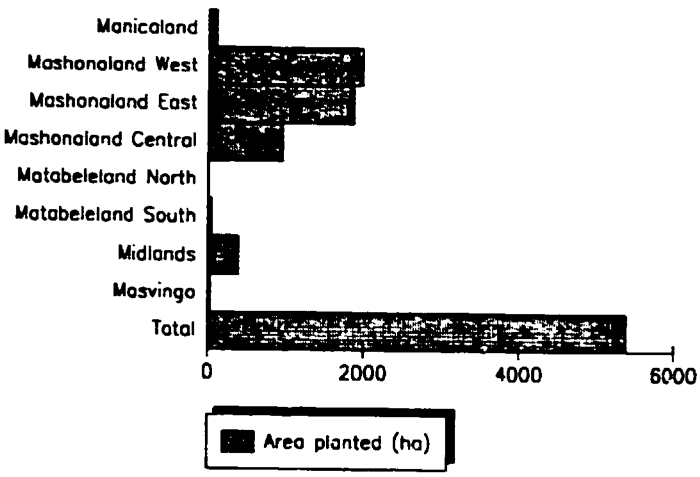
Thermal properties of groundnut shells suggest that they are suitable for gasification. This is mainly due to the high fixed carbon content, medium range ash content and ash fusion temperature, as shown below :

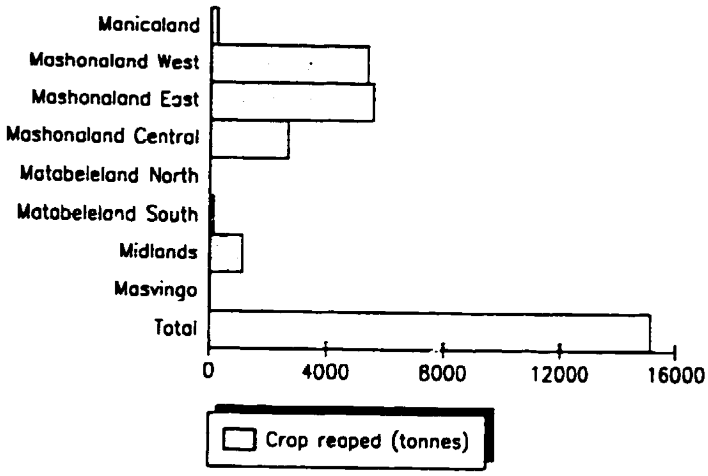
Groundnut shell:

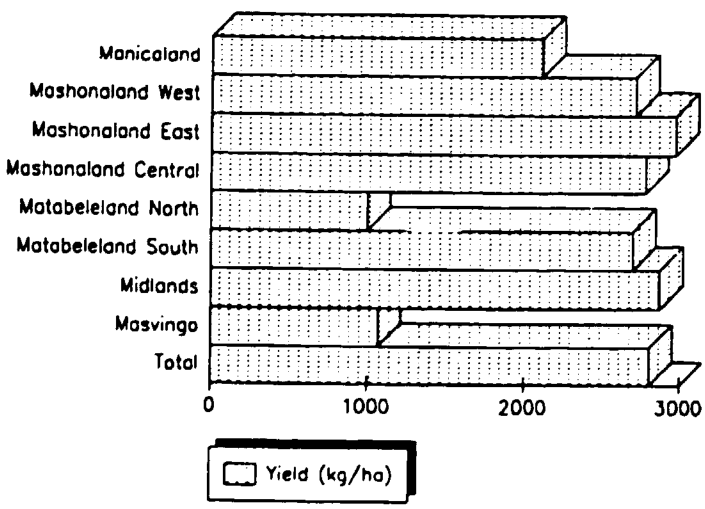
| | |
|---|---|
| Proximate Analysis: | F.C = 25%, V.M = 68.1%, Ash = 6.9% |
| C - H Analysis | C = 44.78%, H = 6.08% |
| Net Calorific Value | 17.20 MJ/Kg |
| Ash characteristics: | deformation temp. 1180$^0$ C - 1200$^0$ C, fusion temp. 1220$^0$ C - 1250$^0$ C |

Chart 4.3.1

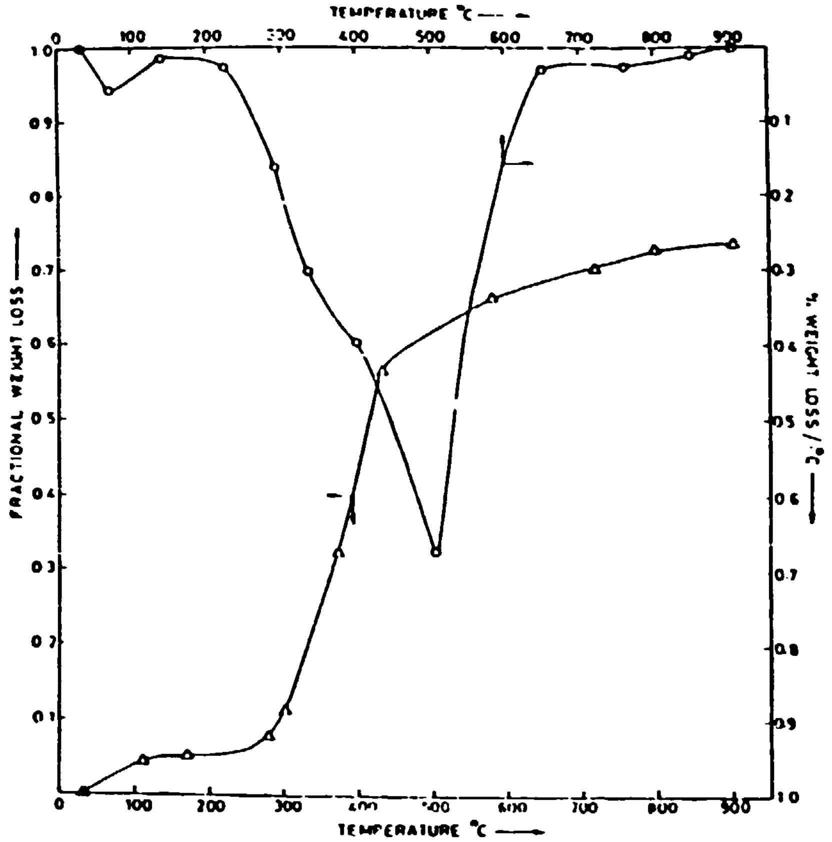
# Area and Production of groundnuts by Province



Groundnut Shell : Themogram




### 4.4 Cotton

i) The Agricultural Marketing Authority (AMA) reported the following figures pertaining to cotton production (1990):

**Table:** 4.4.1 Cotton Production in Zimbabwe (1990) (See Annex 17)

| | Large Scale-Commercial Sector | Others | Total |
|---|---|---|---|
| Area (ha) | 40566 | 187385 | 228051 |
| Crop (tonnes) | 84602 | 140632 | 225234 |
| Yield (kg/ha) | 2080 | 750 | 988 |
| % crop of national output | 37.4 | 62.6 | 100.0 |
| Seed cotton purchases by CMB | 71850 | 116150 | 188000 |

*(Source AMA : Cotton situation and Outlook Report : 1990 - 91)*

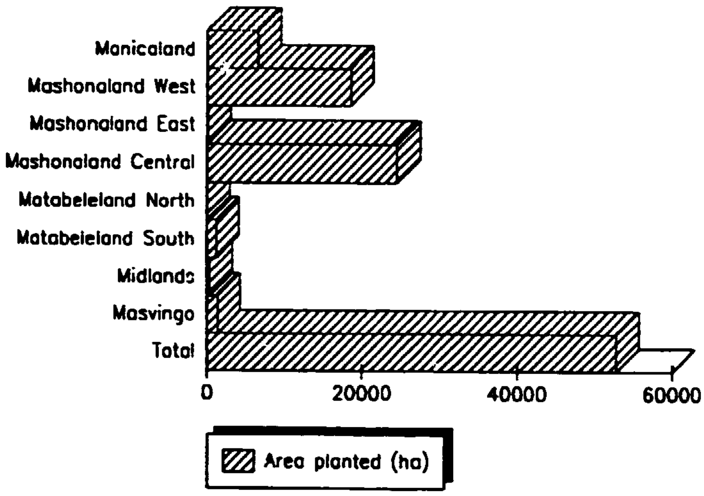
Cotton growing is increasing in intensity throughout Zimbabwe. The breakdown of cotton growers during 1989/90 is shown below : (See Annex 17)

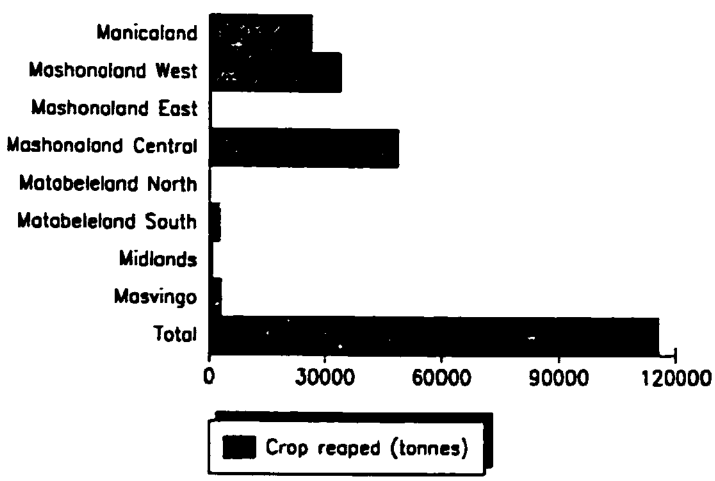
| | Number of cotton growers (1989/90) | Yield (kg/ha) |
|---|---|---|
| Large scale Commercial/ADA | 569 | 1972 |
| Small scale Commercial | 1790 | 558 |
| Communal Areas | 103047 | 784 |
| Resettlement Areas | 7714 | 753 |
| | **113120** | |

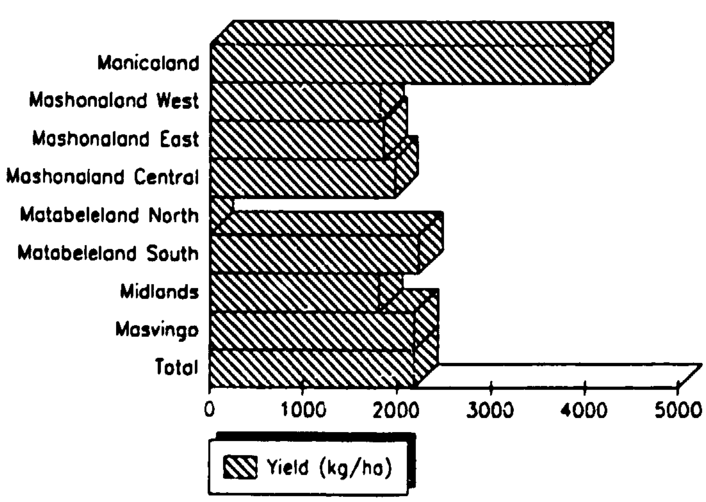
ii) Currently there are more than 250 000 registered cotton growers in large-scale commercial, communal and resettlement farming areas. The Cotton Marketing Board (CMB) operates transit depots at 9 areas in the country, with 8 ginnery depots. The ginning process separates the fibre from

Chart 4.4.1

# Area and Production of cotton by Province



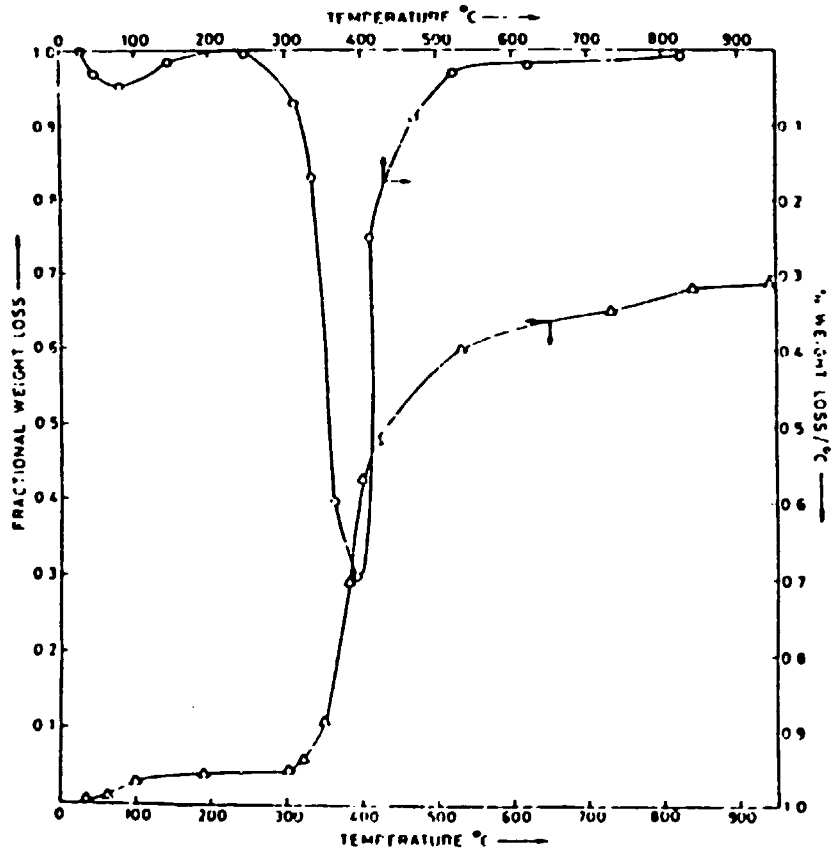
the cotton seed. The "ginned seed" or simply cotton seed, contains about 20% edible oil, which is the basis for cooking oil, margarine, etc. Cotton lint accounts for the second largest foreign exchange earner in the agricultural sector. Cotton seed is also used for stockfeed and other byproducts.

iii) The CMB operates transit depots (where seed is received and graded, but not ginned) at Manot, Nemangwe, Tchoda, Karoi, Guruve, Mount Darwin, Mahuwe, Nyamaropa, and Birchenough Bridge. Ginnery depots are located at Sanyati, Kadoma, Chegutu, Banket, Glendale, Bindura, Tapfuma (Shamva), Mutare and Triangle. Thus, cotton residues should be plentiful in all the above depots.

Cotton picking for delivery to CMB depots is normally done from the month of April; more than two-thirds of the lint is exported.

iv) Commercial cotton seed is sold to oil expressors and the residue to stockfeeders. Cotton stalks are burnt and ploughed into the ground by mid - August, as required by legislation.

**v) Cotton Stalk : Thermogram**




| | |
|---|---|
| Proximate Analysis : | F.C = 22.4%, V.M = 70.9%, Ash = 6.7% |
| C - H Analysis : | C = 43.64%, H = 5.81% |
| Net calorific Value: | 18.26 MJ/Kg |
| Ash characteristics: | deformation temp. 1320° - 1380° C, fusion temp: 1400° - 1450° C |

Cotton stalk is suitable for gasification because of its high fixed carbon, high fusion temperature, low-to- medium ash content, and high ash deformation temperature.

## 4.5 Coffee

i) The GMB had the following 1990 coffee intake at its principal depots : Table 4.5.1 (See Annex 18)

| | 1989/90 (tonnes) |
|---|---|
| Chipinge | 9811 |
| Mutare | 2600 |
| Banket | 2197 |
| Total | 14608 |

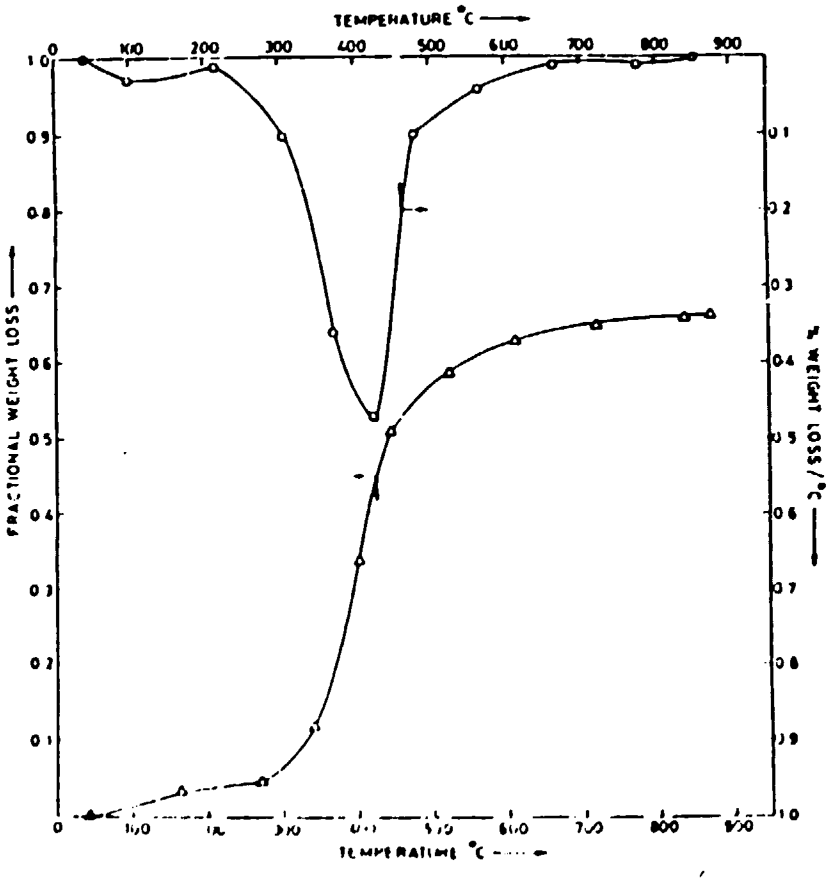
Coffee husks and parchment available as wastes, at the Banket GMB depot (100 km North-West of Harare) are estimated at about 1000 tonnes annually.

ii) Coffee Husks and Parchment: Properties

| | |
|---|---|
| availability: | GMB depots |
| Husks: bean (wet process) | 1:1 (wt) (approx. 35% of crop is wet) |
| Parchment: bean (dry process) | 1:5 (wt) |
| Net calorific Value (low Heating Value) | 17.8 MJ/(dry) kg |
| Ash content: | 1% -5% (wt as received) |
| Moisture content: | 11% (wt as received) |
| Season: | husks and parchment removed June through December and January-February, respectively at depots. |
| Use: | small quantity used in animal feed by densification; the rest destroyed by incineration. |

Coffee residues in the form of husks and parchment would be suitable for gasification.

**Thermogram**

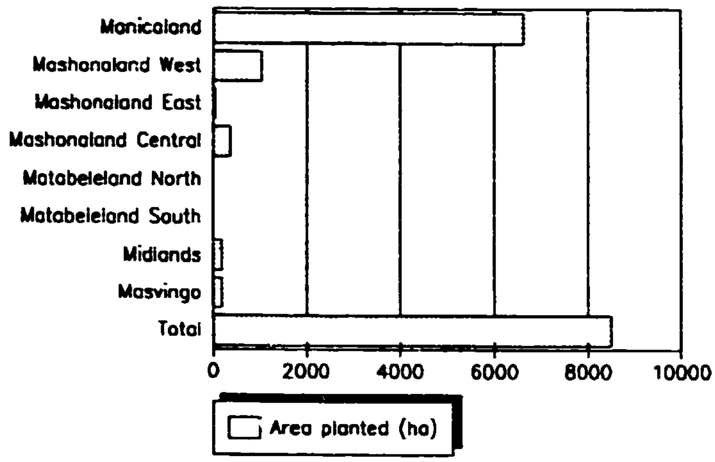


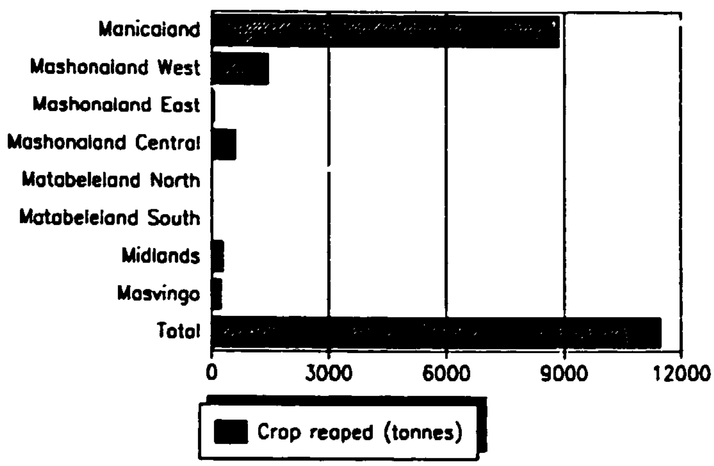
## CHARACTERISTICS OF BIOMASS

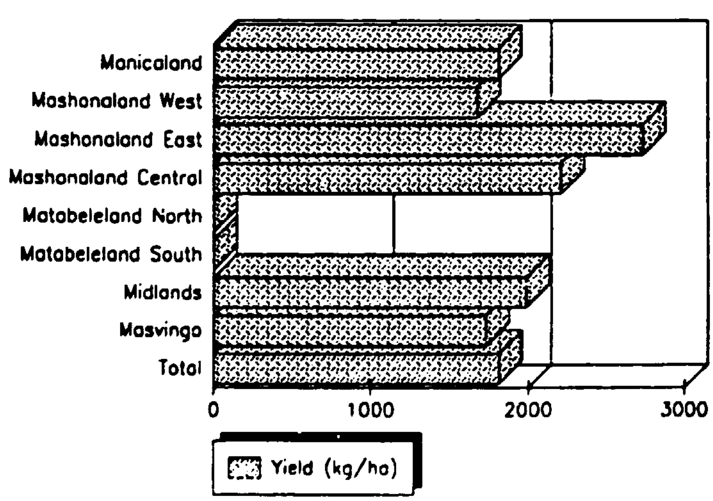
| S. No. | Biomass | Volatiles (%) | Fixed carbon (%) | Ash (%) | Carbon (%) | Hydrogen (%) | Higher heating value (HHV) (MJ/kg) | Lower heating value (LHV) (MJ/kg) | Ash deformation temp. (°C) | Ash fusion temp. (°C) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | | 9 | 10 |
| 1. | Arhar stalk | 83.47 | 14.76 | 1.77 | 46.75 | 6.55 | 15.00 | 14.85 | 1250-1300 | 1460-1500 |
| 2. | Bagasse | 75.10 | 16.87 | 8.03 | 45.71 | 5.89 | 19.50 | 19.37 | 1300-1350 | 1420-1450 |
| 3. | Bamboo dust | 75.32 | 15.59 | 9.09 | 43.86 | 6.64 | 16.02 | 15.87 | 1300-1350 | 1400-1450 |
| 4. | Cotton stalk | 70.89 | 22.43 | 6.68 | 43.64 | 5.81 | 18.26 | 17.85 | 1320-1380 | 1400-1450 |
| 5. | Coconut coir | 70.30 | 26.77 | 2.93 | 47.17 | 6.54 | 18.20 | 17.79 | 1100-1150 | 1150-1200 |
| 6. | Corn cob | 80.20 | 16.20 | 3.60 | 45.31 | 7.16 | 15.58 | 15.23 | 800- 900 | 950-1050 |
| 7. | Dhaincha stalk | 80.32 | 17.01 | 2.67 | 56.45 | 8.99 | 19.63 | 19.43 | 800 | 800- 900 |
| 8. | Groundnut shell | 68.12 | 24.97 | 6.91 | 44.78 | 6.08 | 17.20 | 17.06 | 1180-1200 | 1220-1250 |
| 9. | Jute stick | 75.33 | 19.00 | 5.67 | 54.77 | 8.20 | 19.45 | 19.01 | 1300-1350 | 1400-1450 |
| 10. | Kikar (Acacia) | 77.01 | 22.35 | 0.64 | 45.89 | 6.08 | 20.25 | 19.79 | 1300-1350 | 1380-1400 |
| 11. | Mustard shell | 70.09 | 14.48 | 15.43 | 46.20 | 6.21 | 17.61 | 17.47 | 1350-1400 | 1400-1450 |
| 12. | Pine needle | 72.38 | 26.12 | 1.50 | 43.21 | 6.57 | 20.12 | 19.97 | 1250-1300 | 1350-1400 |
| 13. | Rice husk | 60.64 | 19.90 | 19.48 | 40.10 | 6.03 | 13.38 | 13.24 | 1430-1500 | 1650 |
| 14. | Sal seed leaves | 60.03 | 20.22 | 19.75 | 46.74 | 6.72 | 18.57 | 18.42 | 1200-1250 | 1350-1400 |
| 15. | Sal seed husk | 62.54 | 28.06 | 9.40 | 48.12 | 6.55 | 20.60 | 20.13 | 1450-1500 | 1500-1550 |

Chart 4.5.1

# Area and Production of coffee by Province



# Crop Production in Large Scale Commerical Farms 1989/90

1.

| Area of farms ('000 ha) | Farm employees number | Area under crops (ha) | Grain maize (tonnes) | Groundnuts (tonnes | Cotton tonnes |
|---|---|---|---|---|---|
| 11 309 | 136 860 | 504 673 | 716 872 | 15 124 | 115 539 |

## 2. Area and Production of the Principal Crops by Province

| Maize Crop | Mani-caland | Mash West | Mash East | Mash Central | Mat North | Mat South | Mid lands | Masvi-ngo | Total |
|---|---|---|---|---|---|---|---|---|---|
| Area Planted (ha) | 14 442 | 219 810 | 84 697 | 88 169 | 3 998 | 3 303 | 24 788 | 11 355 | 450 562 |
| Crop Reaped (tonnes) | 42 343 | 1 049 082 | 682 706 | 486 192 | 16 254 | 14 532 | 95 452 | 26 736 | 2 413 297 |
| Yield (kg/ha) | 3 682 | 4 502 | 5 005 | 5 125 | 3 624 | 3 622 | 3 845 | 2 795 | 4 025 |

### Cotton

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Area Planted (ha) | 6 565 | 18 603 | 96 | 24 658 | - | 1 197 | 306 | 1 376 | 52 801 |
| Crop Reaped tonnes) | 26 384 | 33 904 | 178 | 48 759 | - | 2 676 | 555 | 3 010 | 115 466 |
| Yield (kg/ha | 4 056 | 1 823 | 1 854 | 1 977 | - | 2 236 | 1 814 | 2 188 | 2 189 |

### Groundnut (unshelled)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Area Planted (ha) | 104 | 1 982 | 1 875 | 958 | 3 | 44 | 388 | 28 | 5 382 |
| Crop Reaped (tonnes) | 220 | 5 390 | 5 581 | 2 666 | 3 | 119 | 1 115 | 30 | 15 124 |
| Yield (kg/ha) | 2 115 | 2 719 | 2 977 | 2 783 | 1 000 | 2 705 | 2 874 | 1 071 | 2 810 |

### Coffee

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Area Planted (ha) | 6 636 | 1 045 | 42 | 386 | 3 | - | 192 | 192 | 8 496 |
| Crop Reaped (tonnes) | 8 852 | 1 462 | 41 | 610 | - | - | 294 | 225 | 11 484 |
| Yield (kg/ha) | 1 811 | 1 675 | 2 733 | 2 210 | - | - | 1 986 | 1 731 | 1 813 |

(Source: Central Statistical Office Report, 1990)

# 5. Settlement Patterns and Agricultural Practices

## 5.1 General

i) Zimbabwe is divided into eight provinces, each of which is further divided into:

- District Councils (peasant farming areas and small commercial centres)
- Rural Councils (commercial farms, mines and semi-urban areas)
- Municipalities and Town Councils.

ii) Surveys relating to the estimation of crop production have been carried out by the Central Statistical Office, using six sampling strata for each province:

- Communal areas
- resettlement areas
- Small Scale Commercial Farming Areas
- Large Scale Commercial Farming Areas
- Forests, Parks and Wildlife
- Urban/Semi-Urban areas

iii) In terms of agricultural organization, one identifies the first 5 natural regions. Commercial farms are private holdings in high-fertile areas, and hence in the intensive farming region. Communal lands are small holdings owned by government within the semi-intensive farming regions. The Agricultural Development Authority (ADA) is a government parastatal which coordinates agricultural development through the establishment of state farms (estates).

About 3 million hectares of commercial farming area has been acquired by Government since independence, and 80% of this consists of Resettlement Areas.

iv) A major factor affecting agricultural productivity is farm inputs. It is therefore necessary, when evaluating farm input data, to disaggregate as follows:

| | |
|---|---|
| seed | imported, local |
| fertilizer | none, manure, chemical |
| field preparation | hand (hoe) cultivation, oxen ploughing, tractor. |

## 5.2 Practices Affecting Production of Agricultural Wastes

*(i)- Shifting Cultivation*

Cultivation whereby farmers clear a piece of land and cultivate crops, after which the area is abandoned when soil fertility is exhausted. The same piece of land can be cultivated at a later date after soil fertility has been restored. This system of agriculture poses problems in the estimation of crop areas and crop yields; and hence in estimating available crop residues and wastes. As this system deviates from that of "settled agriculture", it is not feasible to procure sizeable and appreciable quantities of crop wastes.

*(ii)- mixed cropping*

This is cultivation when two or more different crops are grown simultaneously on the field. Crop productivity estimation is difficult due to problems of allocating crop areas in mixed cropping. Criteria for area allocation could be based on seed quantity, plant density, production volume, commercial value, major/minor crop, etc.

Collection of agricultural residues and wastes from different crops in the same field, can be tedious and cumbersome, as such wastes will possess different characteristics and features. Mixed cropping, involving mixed crop residue end-products, could be an interesting area of research, as one would consider a mixed crop residue as a gasification feedstock. It is also possible that such a mixed crop residue feedstock, might combine the best attributes of some basic crops for gasification purposes.

*(iii) - continuous planting/harvesting*

Continuous planting can be performed annually or more than twice a year, or at any regular/irregular intervals. Quite often it can involve successive planting of the same or different crops on the same plot; or replanting the same crop after failure or damage; or expanding the planted field to include additional crops. Crop yield estimation is done by means of multi-round surveys. This type of cultivation can boost peasant farming, where the staple crop no longer dominates agricultural output, as new crops are being planted. It also ensures continuous employment for the farm labour force, and offers extra food security and income, by minimizing dependence on staples. Crop wastes are available on a continuous basis, and will therefore be independent of seasonality, a welcome situation for gasification.

*(iv)- Incompletely Harvested Crops*

Part of the crop yield can remain unharvested for a variety of reasons :

- poor market prospects
- poor agricultural mechanization
- harvest area inaccessible (e.g. soil too wet)
- crop used as "reserve" in shifting cultivation.
- abandoning crops prematurely, eg. bad season, etc.

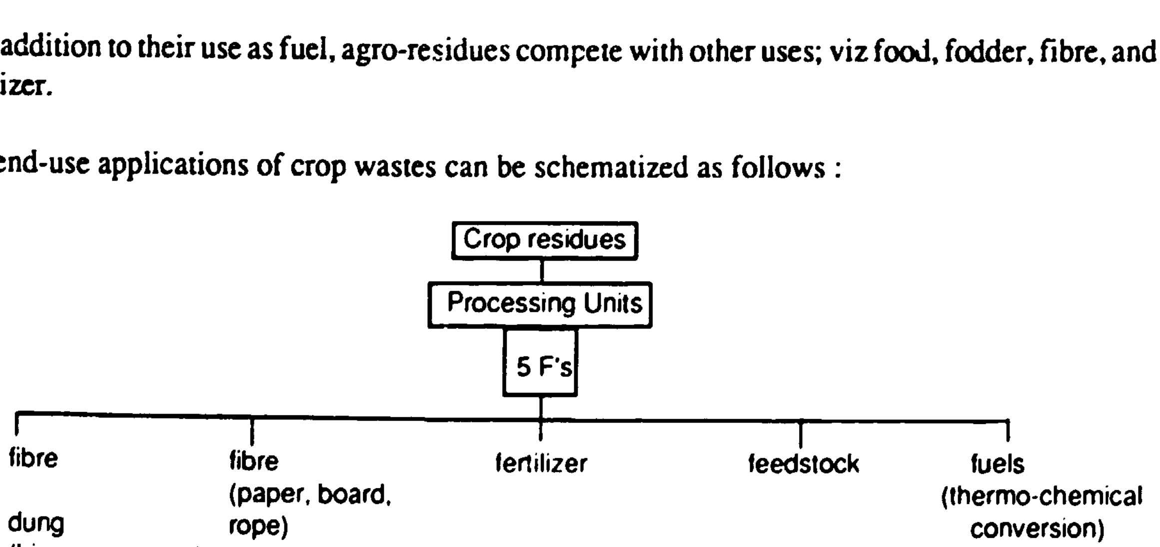
Such crops will not mature properly, and can be regarded as wastes, constituting a rich "harvest" for gasification.

(v) According to a Beijer Institute Study,[2)] low-income households consume 58% of all Zimbabwe energy; the household being the most important end-user of energy. Over 90% of the energy consumed by households is in the form of woodfuel for cooking.

## 6. Utilization of Crop Wastes

i) In addition to their use as fuel, agro-residues compete with other uses; viz food, fodder, fibre, and fertilizer.

The end-use applications of crop wastes can be schematized as follows :

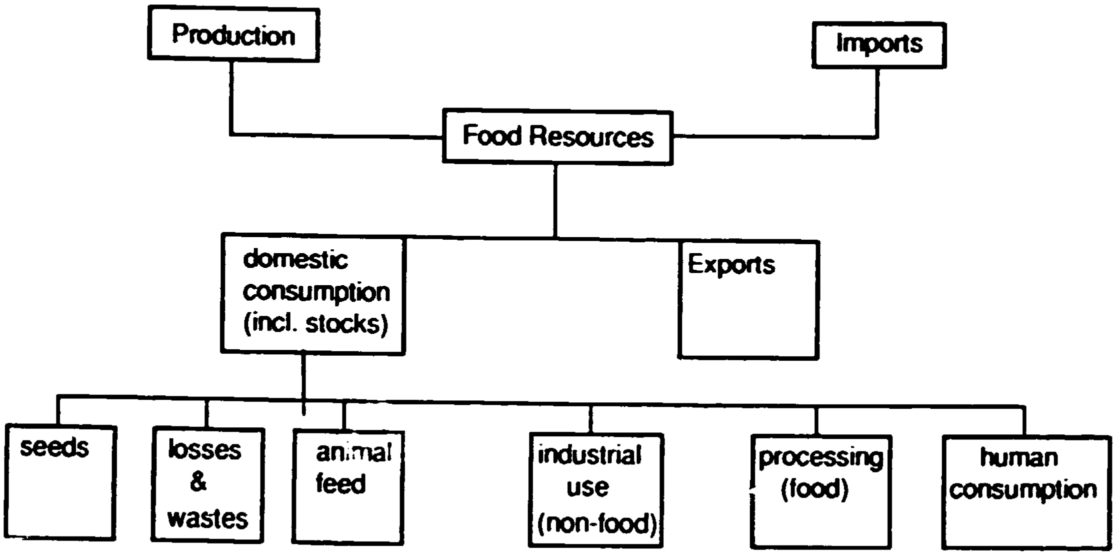


ii) Thus, agro-residues have use as animal feed, fertilizer, fuel, etc, or can be regarded as waste for gasification. With respect to gasification technology, several problematic issues can arise; collection, transportation and storage problems, logistic problems (eg. cotton legislation), man-power and technology constraints, seasonal variations, material handling (size-density, ash - moisture content, drying).

iii) The utilization and end-use of crop residues, as by-products of agricultural grains, within a socio-economic context, are visualized in the following schema :

**Crop Production : Supply Balance Sheet System**

Basic Equation (for a given period):
Production + Imports = Domestic Consumption + Exports




iv) From the above, one realizes that crop residues should be conceptulized within a techno-spectrum of several other interdependent variables. Within this context, it is thus observed that gasifying crop residues gives us not only a benign energy resource, but is one of several ways for recycling the natural biomass.

# 7. Crop Wastes as Feedstock for Gasification

## 7.1 Crop Wastes

(i) Preparation crop residues to meet gasification requirements calls for information on their types, location, quantities, seasonal availabilities, physical/chemical properties, and socio-economic values. "Crop residues" are the plant materials remaining in the field after the removal of the main crop produce. "Agro-processing residues" are the by-products of the industrial processing of crop raw materials. Crop residues are therefore diffuse, making their collection (often unmechanized) time consuming and expensive. Mechanization of crop residue collection can substantially alter the economics of utilizing the residues. Agro-processing residues have a greater potential, since they are produced at a central site and their accumulation can present a disposal problem. The problem of "diffuseness" or of low-bulk density of crop wastes, which makes them uneconomical to store or transport, can be overcome by mechanical compaction or **densification**. In addition to their relatively low bulk density, agro-residues suffer from two additional constraints; those of high moisture content, and the scattered locations in which they are disposed. For agricultural residues to be viable as a source of gasification energy, a large amount of it must be concentrated at the place of use.

ii) Crop wastes must be characterized for their utility in gasification, with respect to :

- *proximate analysis:* moisture, fixed carbon (F.C), volatile matter (V.M), and ash content.
- *ultimate analysis:* carbon, hydrogen, oxygen content (C-H-O).
- *ash deformation and fusion temperatures* :
- *calorific value:*
- *rate of devolatilisation* (pyrolysis thermograms)

The last aspect is of special concern. Volatile components evolved in the temperature range of 320° - 500° C are a potential tar forming volatile (PTFV), ending up as condensable tar in the final gases. Gasification systems are enhanced if materials with high PTFV, higher rates of devolatilisation during the temperature range 320° - 500° C may be partially pyrolysed before using them in gasifiers. Removal of PTFV will make the biomass highly suitable for gasification; resulting in relatively tar-free gases.

iii) Feedstock Preparation and Storage

*- Maize Cobs*

Preparation of feedstock should be by densification using preferably a screw press. Corn shredding by a ball mill should precede densification. In general with respect to maize cobs, both size reduction and densification should be applied. Storage of densified residues should be on a clean, firm base, with protection from precipitation; eg. low-rimmed concrete base, covered by a secure roof shelter.

*- Groundnut Shells*

These require densification before being fed into a gasifier. A screw press is a suitable densifier. The average moisture content is tolerable (10% wt)

*- Coffee Husks and Parchment*

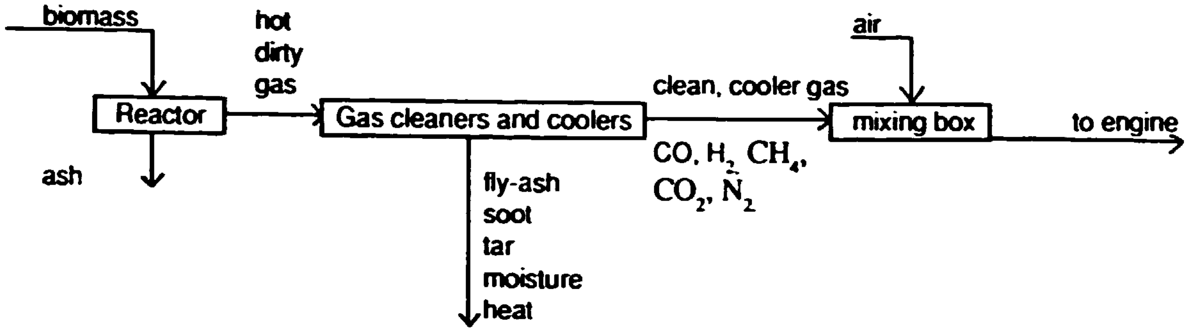
Coffee husks and parchment require densification prior to using them as gasifier feed. At the G.M.B. depot in Banket, 35% of the coffee beans are from the "dry" process, giving as byproduct; husks and parchments. The balance 65% is from the "wet" process, resulting in parchment only as byproduct. Parchment forms 25% of the total residue. The moisture content of coffee residues (11% wt.) is suitable for both densification (by screw press) and gasification.

## 7.2 What is Gasification?

(i) Energy in biomass can be harnessed either by direct burning or by gasification. The former is not desirable for several reasons, such as high "unburnable" water and oxygen contents; hence the need for gasification - the production of combustible gas from biomass. There are two methods of gasifying with the application of heat : viz heating the fuel material in the absence of air (or oxygen), thus without igniting it (**pyrolysis**); or burning the material in limited air (or oxygen), which is termed **gasification**. Gasification is the more viable method for application with internal combustion engines, and the device for this purpose is the **gasifier** or producer gas generator.

The gas produced, or producer gas, consists mostly of carbon monoxide ($CO$), hydrogen ($H_2$), methane ($CH_4$) and the incombustible components : carbon dioxide ($CO_2$) and nitrogen ($N_2$). Gasification process has three major functional components: reactor, gas cleaners and coolers, and the mixing box.

Schematic Diagram of the Gasifier process:



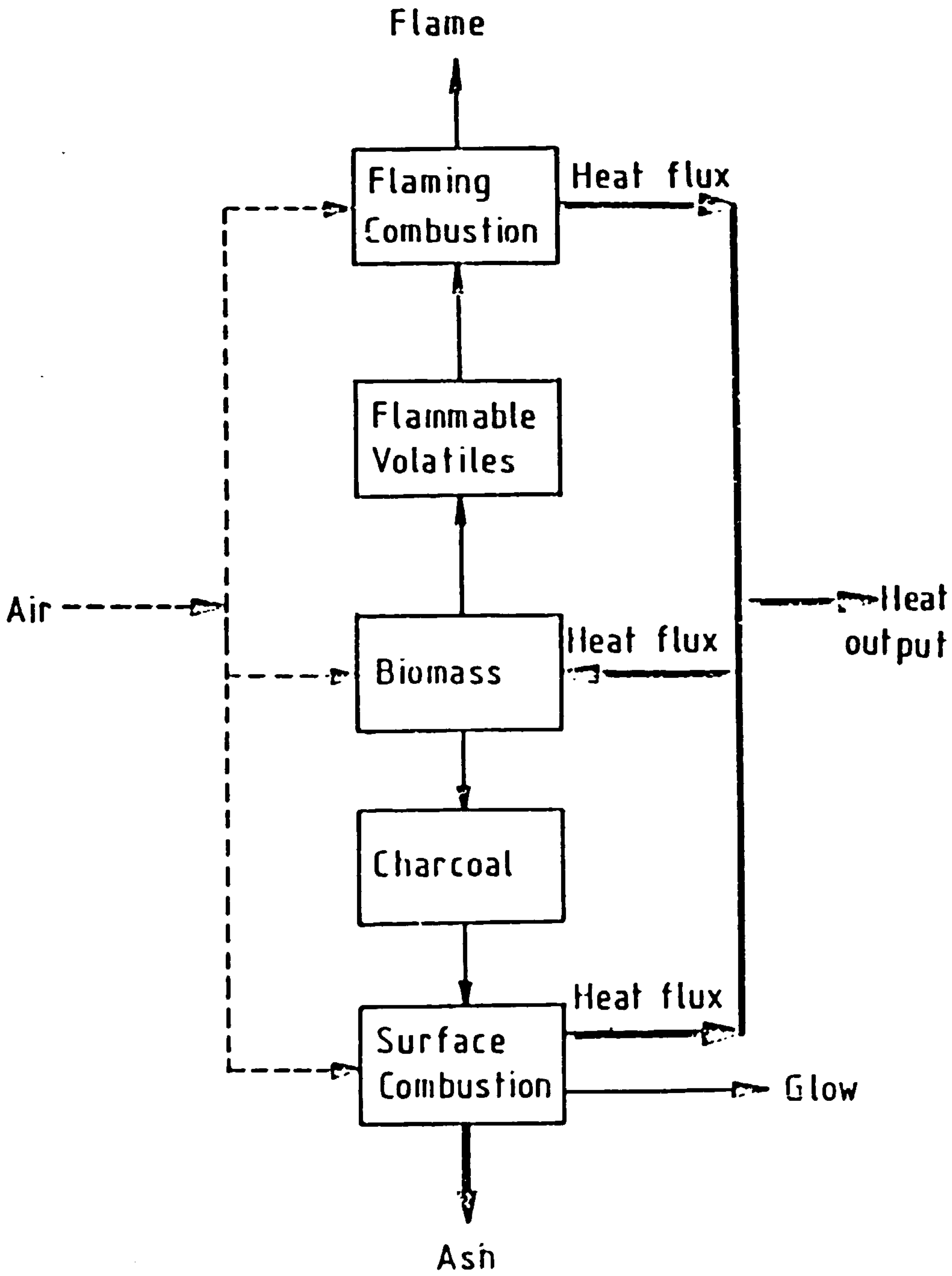

(ii)- In the foregoing, the terms "densification" and "gasification" have been mentioned, but with little substantiation. Densification is the process of compacting materials of low-bulk density to obtain a denser product, which occupies less volume for a given weight; and is therefore more convenient to handle and cheaper to transport and store. Densified fuels can be produced in various forms : briquettes, pellets, cubes, etc.

- Gasification is the thermochemical conversion of carbonaceous materials in the presence of a restricted supply of oxygen to produce a combustible gas. In air gasification, oxygen comes from air, and the product gas, or producer gas, is of low heating value because of dilution with nitrogen. Producer gas can displace petrol fuel completely, or up to 80% of diesel. Because of its low calorific value, producer gas does not develop as much power as that from either petrol or diesel alone. Hence gasifiers function optimally with stationary engines.

- The main problems associated with gasifiers point to the need for rather elaborate gas cleaning/ cooling to prevent tar condensation in engine parts, separation of solid particles from the product gas, increased engine maintenance requirement, feedstock preparation, regulation of moisture content, etc.

- Agricultural residues are generally less suitable than charcoal or wood, for gasifier applications. Furthermore, crop residue gasification systems are still being evaluated and researched into. The ideal producer gas generator is one with the best techniques for removing particulates, and tars, and for gas cooling. Select feedstocks with low content of ash, moisture, sulphur and tar. For instance, rice husks are difficult to use in gasifiers due to the high ash content and structure of the husk, which result in a small change in volume during the gasifying combustion. In general, if feedstock is crop residues then densification should precede gasification.

COMBUSTION OF SOLIDS



### 7.3 Gasifier Problems

(i) Problems related to operations with gasifiers include the following :

- high tar- and dust- content in the gas, causing engine problems (poor gas cleaning equipment);
- bunker flow (bridging) problems in the product gas, causing large fluctuations in gas heating value;
- slag formation in the gasifier, requiring frequent shut-downs for slag removal;
- poor gasifier design (unreliable operation of valves, fans, fuel feeding system, grate control);
- rapid deterioration of gasifiers and accessories due to corrosion and heat stresses.

The first three problems arise from the properties of the biomass feedstock; the last two are associated with engineering deficiencies. Other minor constraints relate to lack of trained gasifier personnel and insufficient motivation of the end-users of the product gas.

(ii) Additional problems associated with the use of crop wastes in gasifiers are as follows:

- high costs associated with collection, preparing and storing crop residues.
- risk of slagging and engine clogging.
- agricultural residues should naturally be returned to the soil to improve and enrich soil fertility.

(iii) The tar-charring problems caused by gasifiers on engines, consist of stuck pistons and corrosion in the fuel injection system. These problems may be partially overcome by using dissolving lubricants and materials resistant to corrosion for the injection nozzles. Methanol and alcohols may be added to improve fuel injection.

(iv) In summary, a reliable and dependable gasifier should possess some desirable criteria:

- simple design, user-friendly.
- inexpensive to manufacture.
- availability of spare parts and workshop facilities.
- need for continuous supply of feedstock material.

(v) The methodology for introducing producer gas technology consists of a hardware development system, integrated with a software development and an operating system:

*Hardware:* reactor, engine, feedstock, manufacturing/maintenance.
*Software:* loans, marketing, installation, training, R & D.
*Operating System:* simplicity, user-friendly, durability, reliability.

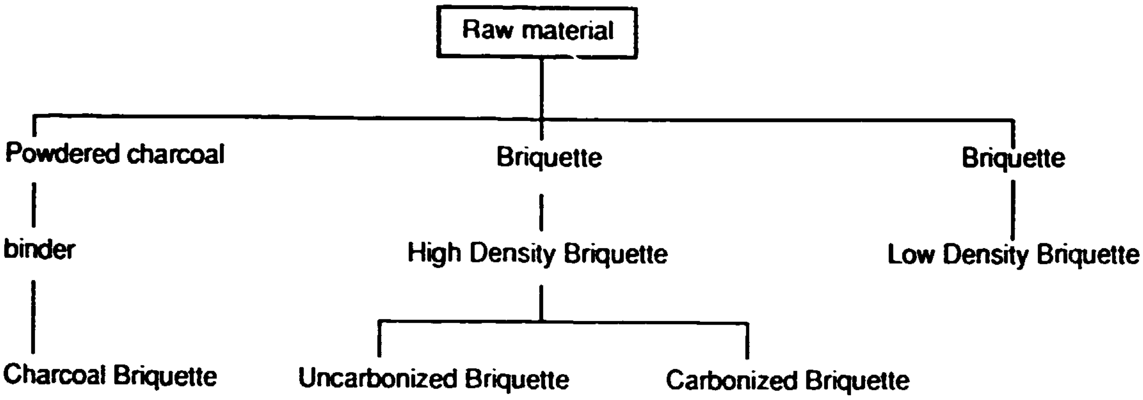
(vi) Gasifiers, coupled with diesel or petrol engines, are an invaluable source of energy especially for communal farmers and rural-based establishments: grinding corn mills; water pumping; electrification for homes, schools, clinics and cooperatives; agro-industries; secondary industries (repair and maintenance workshops).

### 7.4 Briquetting

(i) - **Briquetting** is one of the densifying processes, whereby biomass residues are converted into a form more readily usable as fuel. Industrial briquetting date back to the second part of the nineteenth century. Types of briquetting machines include piston presses, screw presses and pellet presses.

(ii) There are different routes to produce a variety of briquettes, as exemplified by the following chart:

**Schema: Production of Briquettes**




- In Char Briquetting the raw material is first partially pyrolysed to produce a char, which is further reduced in size and purified, and then mixed with a binder and/or water; and finally dried (density : 0.3 - 1gm/cm$^3$). High pressure (Density) briquettes are produced from the biomass directly after pre-processing (drying, chipping, etc) without a binder (density : 1.2 - 1.4 gm/cm$^3$ , difficult to ignite). High Density briquettes can be converted into carbonized briquettes by carbonization in a metal or brick kiln for 2 - 7 days. Low Density Briquetting applies moderate pressure on rather moist feedstock; with less energy requirements. After pressing, binding and drying are required (density : 0.2 - 0.5 gm/cm$^3$).

(iii) - The most promising crop residues for briquetting are : cotton stalks, groundnut shells, maize cobs, coffee husks and saw dust. Briquetting has a number of attractions :

- negligible direct impact on deforestation.
- a cooperative of farmers can purchase a single briquetting machine.
- making combustion of loose biomas residues more efficient and complete.
- no fuel preparation costs (eg. cutting wood).
- reduced ash production, particulate emissions and energy input in fuel handling and transportation (this slows down $CO_2$ build-up in the atmosphere, and thus reduces "global heating").

(iv) - The value-added by briquetting must yield a return in improved efficiency, handling and storage; and reduced health hazards. Problematic aspects of briquetting are : clinker formation in machines, high production fly ash and machine clogging.

- Overall, briquetting can be indigenized, mastered and controlled by local engineers and technicians; as well as supporting the viability of energy-intensive industries in rural areas.

## 7.5 Gasification of Briquettes

(i) - Briquette physical characteristics are determined by their production : uncarbonised high density, carbonised high density, char-, and low-density briquettes ("green fuel"). Chemical characteristics are dictated by the raw material in the briquette (eg. saw dust, groundnut shells, etc). Both the physical and chemical properties of briquettes will determine the behaviour of the fuel during combustion.

(ii) - Gasification of briquettes places higher quality demands on them than does combustion. The fuel bed must be thicker, adding to the weight load, whilst residence times are longer,during which briquettes must be subjected to humidity at elevated temperatures. There are advantages of using briquettes instead of chipped wood, say, for gasification : the briquettes are drier, increasing the calorific value of the producer gas; bulk density is higher, increasing the residence time in the gasifier. Finally, the gas conversion rate and the size of the briquettes, can be selected to match the size and design of the gasifier.

# 8. The Electricity Grid and Power Availability in Zimbabwe

## 8.1 The Zimbabwe Electricity Supply Authority (ZESA)

(i) The Zimbabwe Electricity Supply Authority (ZESA) is developing an electricity grid Master Plan (MP), which is yet to be finalized, and currently in the hands of policy makers. However, the principal GMB depots and ADA estates are connected to the grid. The MP is supposedly geared to cater not only for the industrial/commercial sector, but moreso for the neglected "growth points" and the expansive rural areas. Whilst these developments are a welcome aspect, it should be noted that rural electrification will be both a costly and time-consuming exercise. In the wake of deforestation and depletion of the traditional woodfuel in Zimbabwe and the PTA region as a whole, rural dwellers have resorted to all sorts of substitutes for firewood: animal dung, maize cobs, etc. Hence, there is need to develop other sources of energy to supplement whatever is available in the form of electricity or diesel resources: biogas, producer gas, solar/wind power. Producer gas, which is the result of gasification, is the focus of this study. Large scale and small-scale commercial farmers, who consume considerable energy using diesel or petrol for various agricultural machinery, can realize huge savings by introducing gasifier plants in their holdings.

(ii) Apart from grid electricity, there are other alternative sources of energy operating in Zimbabwe, though on a small scale. The main windmill manufacturers; Stewarts & Lloyds and Tanaka Power, have indicated that there are over 100 working windmills in the country, and there is potential for installing an additional 100 or more. There are also a few solar powered units and biogas plants that have been installed in recent times.

ZESA has three large diesel operating units located at Beitbridge, each 1.5 MW; and smaller units in all its stations, as backup to the hydro/thermal power grids. ADA has three diesel units at Mzarabani, Mushumbi and Katiyo Estates. In addition, a number of smaller diesel generators are used as backup for electricity, by farmers, hospitals and a variety of other establishments.

(iii) In Zimbabwe the main source of grid electricity are six hydro power stations at Kariba South, each 111 MV, and 18.0 kV generating voltage; and thermal power stations with total generating voltage of 500kV, located at the following: Harare (17), Bulawayo (5), Hwange (6), Munyati (7).[5]

Electricity energy sales by major consumer, are shown below in Table 8.1.1.

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[5] *Zimbabwe Electricity Supply Authority : Statistical Yearbook, Vol. 1 : 1990.*

**Table 8.1.1: Energy Sales by Sector (see Annex 19)**

| Sector | 1989/90 (million kWH) | % |
|---|---|---|
| Mining | 1474 | 17 |
| Industrial | 4278 | 48 |
| Farming | 751 | 9 |
| Commercial/Street lights | 900 | 10 |
| Domestic | 1449 | 16 |
| | 8852 | 100 |

*[Source: ZESA Statistical Yearbook, Vol.1 : 1990]*

**Table 8.1.2: Production, Trade and Consumption of Electricity (1988) (see Annex 20)**

| Production (m-kWH) | Imports (m-kWH) | Exports (m-kWH) | Total (m-kWH) | Per Capita (kH per capita) |
|---|---|---|---|---|
| 7750 | 1350 | 0 | 9100 | 997 |

*[Source: UN Energy Statistical Yearbook; 1988]*

From Tables 8.1.1 & 8.1.2, it is clear that total grid electricity consumption outstrips production; and Zimbabwe will have to expand its grid infrastructure, or tape new sources or forms of energy to meet the demands of a rapidly growing population (growth rate 3.0% per annum), especially in the rural areas. Statistics on electrical energy (January - May 1991) revealed that 3563 million kilowatt hours (m-kH) were produced; 3860 m-kH distributed, leaving a domestic production deficit of 297m-kH.

(iv) ZESA's policy and planning for rural electrification, as reflected in the scheme below, incorporates 2 rural centres (Mashonaland East and Midlands) in Group 1, 21 rural centres in Group 2 in all provinces (except Masvingo) and 5 rural centres in Group 3A (in Mashonaland East and Central and Masvingo). However, it should be noted that the first 3 groups (1, 2 and 3A), account for a mere 14% of the total electrification plans. Emphasis for electrification is in groups 3B and 4 (commercial centres, service/administrative centres). Thus, the overall plan falls short of providing adequate electrification for the rural areas, where more than 70% of the national population reside, and which should form an essential target for socioeconomic development. It is hoped that the final Master Plan will redress this situation, by accelerating and boosting rural electrification. Alongside these schemes, Government should encourage the establishment in rural areas, of alternative energy resources such as gasification, solar and biogas generators.

**ZESA: Policy and Planning for Electrification in RuralAreas: 1990 : Table 8.1.3**

| | Group 1 High Growth Centres (High Pop.) | Group 2 High Growth Centres (Med. Pop.) | Group 3A Active Commercial Centres (High Pop.) | Group 3B Active Commercial Centres (Med./ Low Pop.) | Group 4 Service Admin. Centres | Group 5 Stagnant declining Centres |
|---|---|---|---|---|---|---|
| No. of centres | 172 * | 42 ** | 19 *** | 228 | 217 | 39 |
| % of total | 3% | 8% | 3% | 40% | 38% | 8% |
| Average Pop. | 6400 | 1400 | 1850 | 1010 | 300 | 170 |

* *includes 2 rural centres in Mashonaland East and Midlands.*
** *includes 21 rural centres in all provinces except Masvingo.*
*** *includes 5 rural centres in Mashonaland East & Central, and Masvingo*

## 8.2 Village Electrification by Gasification of Agricultural Residues

(i) We have noted the viability of using crop wastes as feedstock for gasifier plants. To come to grips with practical situations, it is expedient to consider a small/average hypothetical village and simulate electrification by gasification. If the village had 2000 inhabitants (each family having 5 persons), and if each family were to have a light bulb of 25W, then the village would need 10 kW. Assuming that light is needed from 6 pm to 11 pm (5 hours daily), the energy required annually would be: 10 x 5 x 365 = 18,250 kWh. Assuming further that 1 kg of biomass (crop residue) yields approximately 1 kWh of mechanical energy, our annual requirements are about 18,250 kg. of biomass.

**Hypothetical Village Electrification Requirements**

| | |
|---|---|
| *Residential Quarters* | |
| Number of homes in the village | 250 |
| Number of inhabitants | 1000 |
| length of distribution line | 1000m |
| number of lamps (outdoor lighting (100w) | 10 |
| number of lamps per house (40 w) | 2 |
| Communal refrigerators | 5 |
| *Small industries* | |
| water pumps (1kW) | 2 |
| maize mill (10 kW) | 1 |
| small industry (10 kW) | 2 |
| irrigation pump (15 kW) | 1 |
| *Clinic* | |
| number of lamps (40 w) | 5 |
| air conditioner (1000 w) | 1 |
| operating light (1000 w) | 1 |
| sterilizing equipment (500 w) | 1 |
| refrigerator (300w) | 1 |
| dental drill (500w) | 1 |

(ii) Maximum load ("peak load")

Estimation of maximum load is a crucial factor in an electrification project. A simple method is to add up all installed equipment, and secure an apropriate generator for the load. Mathematical models can also be used to calculate the maximum load:

e.g. $P = aQ + b\sqrt{Q}$

where $P$ = maximum load (kW)

a and b are factors depending on load type

$Q$ = annual energy required (kWh).

For a system where light is predominant: $a = 1/1700$, $b = 1/14$.

For an average village : $a = 1/4000$, $b = 1/14$.

Another method of calculation is to split up the power requirements into day and night use. The village will have lighting predominant between 6 pm and 10 pm; with no need for industrial load. A module of 2 x 15 kW generators would be appropriate for such village.

(iii) Distribution Lines

An appropriate distribution system in a village with mixed loads is a 4-line 3-phase system (50 $H_z$, 380/220V system). There is no need for **transformation** because distances are relatively short. Standard copper lines can be carried on wooden poles (impregnanted to prevent termites)

## 8.3 The Case for Rural Electrification

(i) General

Over 70%, in general, of the people in the PTA sub-region, are resident in rural areas with no electricity. In Zimbabwe approximately 20% of the households are supplied with electricity from the national grid. The Government's rural development policies are aimed at eliminating the disparity in living standards between commercial farms and communal lands, and at promoting growth with equity. A secondary goal is to slow down the rate of migration to the urban centres.

Rural electrification would bring not only the desirable comfort in households, but a host of other benefits: industry, entertainment, commerce and trade, and the uplifting of general living standards.

(ii) On the Kenyan Experience

- Due to deforestation and the costly nature of electrifying rural areas, Kenya has initiated an intensive fuelwood plantation programme in order to satisfy the rising consumption of wood for domestic purposes. But such a strategy on its own, cannot go a long way towards a self-sustaining strategy for energy creation and conservation. Fuelwood cannot bring in the various beneficial aspects that current electricity would, in a rural environment.

- Pilot gasification work in Kenya has not brought about a tentative programme of action, since the schemes were uncoordinated, and often lacked coherence and transparency between them. It has been suggested that we either have a few **large** gasifier installations in selected locations, or several **small-scale**, decentralized applications. The second option would be preferable due to the existence of several diesel powered units (e.g. grain grinding mills) scattered throughout the country.

- Recent studies on Kenya rural electrification programme point to the need of harnessing electrical energy for rural areas, from a producer gas generator operating a power station, and integrated with a tree plantation. In this scheme a total market for gasifiers in the 10 kW power range, has been estimated at 80,000 units.

- A strong national interest in the development of gasifiers is emerging as a result of foreign exchange savings in diesel oil procurement. It can be shown that 10,000 gasifier units of 10 kW each operating 5 hours per day, using producer gas instead of diesel, would reduce diesel oil imports by 10% - 15%. Such savings would correspond to significant reductions in the overall foreign trade deficit.

(iii) On the Tanzania experience

- Kjellstrom[14] has studied approaches to rural electrification in Tanzania dating from the 1970's, and noted that the strategy so far focussed on the electrification of small and medium provincial towns, agro-industries, cotton-ginneries and sugar factories. By 1990, it turned out that most of the rural villages and rural towns have not been electrified.

- The location of the rural projects and the supply technology being used are shown on Map 8.3.1 below; In 19 of the 37 rural projects that were surveyed in a special evaluation, the electrical supply was achieved by extending the national grid. The other 18 are "isolated generation systems", all of which are served by diesel powered plants.

- In- depth studies were carried out at isolated diesel-supplied towns of Babati, Njombe and Sambawanga - on usage of electricity and socioeconomic characteristics. Results showed that residential and light commercial use (especially lighting), were considered more important; accounting for 60% - 90% usage. Electric cooking was practised by only a handful; the majority preferred kerosene or woodfuel cooking. Only a small fraction of the available electricity was actually used for industry, agriculture or substitution of traditional fuels.

- About 12% of the families in the electrified areas were connected to the service (the most affluent group). However, the benefits of electrification were widely appreciated, even by those who were not connected. The improved security resulting from street lighting is highlighted as one of the crucial benefits.

- Rural electrification in Tanzania using diesel gensets has demanded considerable subsidies from the national electricity utility TANESCO. On the national level, revenue of TANESCO per kWh delivered in 1988 was about 2.1 US cents, whereas the cost per kWh delivered was about 2.6 US cents. Fuel and lubricant costs alone were found to be in excess of three times the average revenue.

- There were inherent problems in the electrical generation, transmission and distribution systems, especially in the rural areas:

- available capacity was insufficient to meet peak demands.
  This situation had to be handled by load-shedding.
- lack of spare parts and inadequately equipped workshops.
- poor engineering materials, insufficient planning, poor supply reliability (large voltage fluctuations).

- The special survey concluded that a new approach to rural electrification was necessary; and training of technical and administrative personnel, rehabilitation of existing systems, and improvement of financial management, should be key issues. In addition, TANESCO should be rationalized to create better incentives for rural electrification; revise project selection criteria for emphasis on the productive uses of electricity; and improve coordination of donor-funded projects.

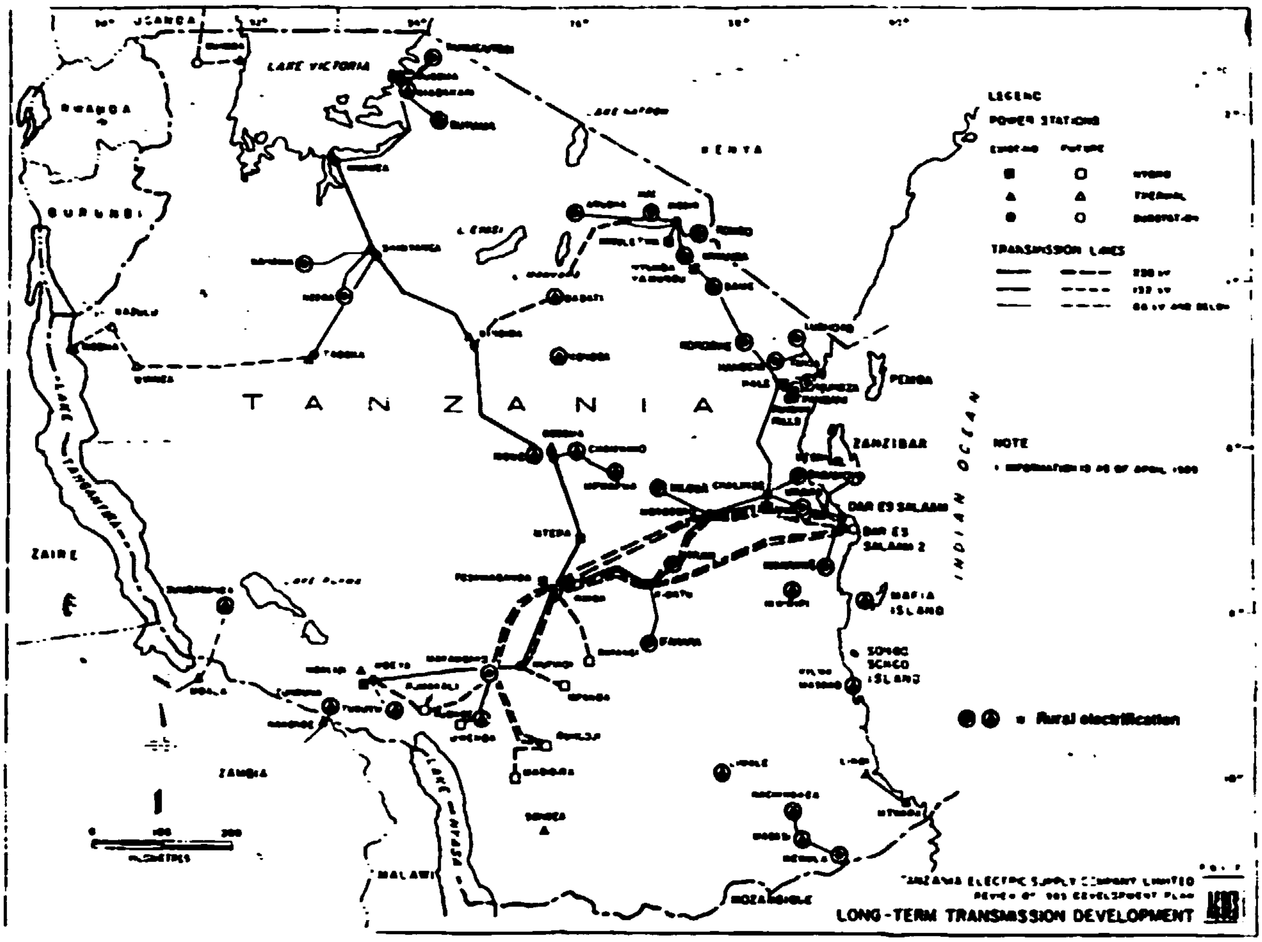
(iv) On the Zimbabwean Experience

- The Zimbabwe National Electricity System:

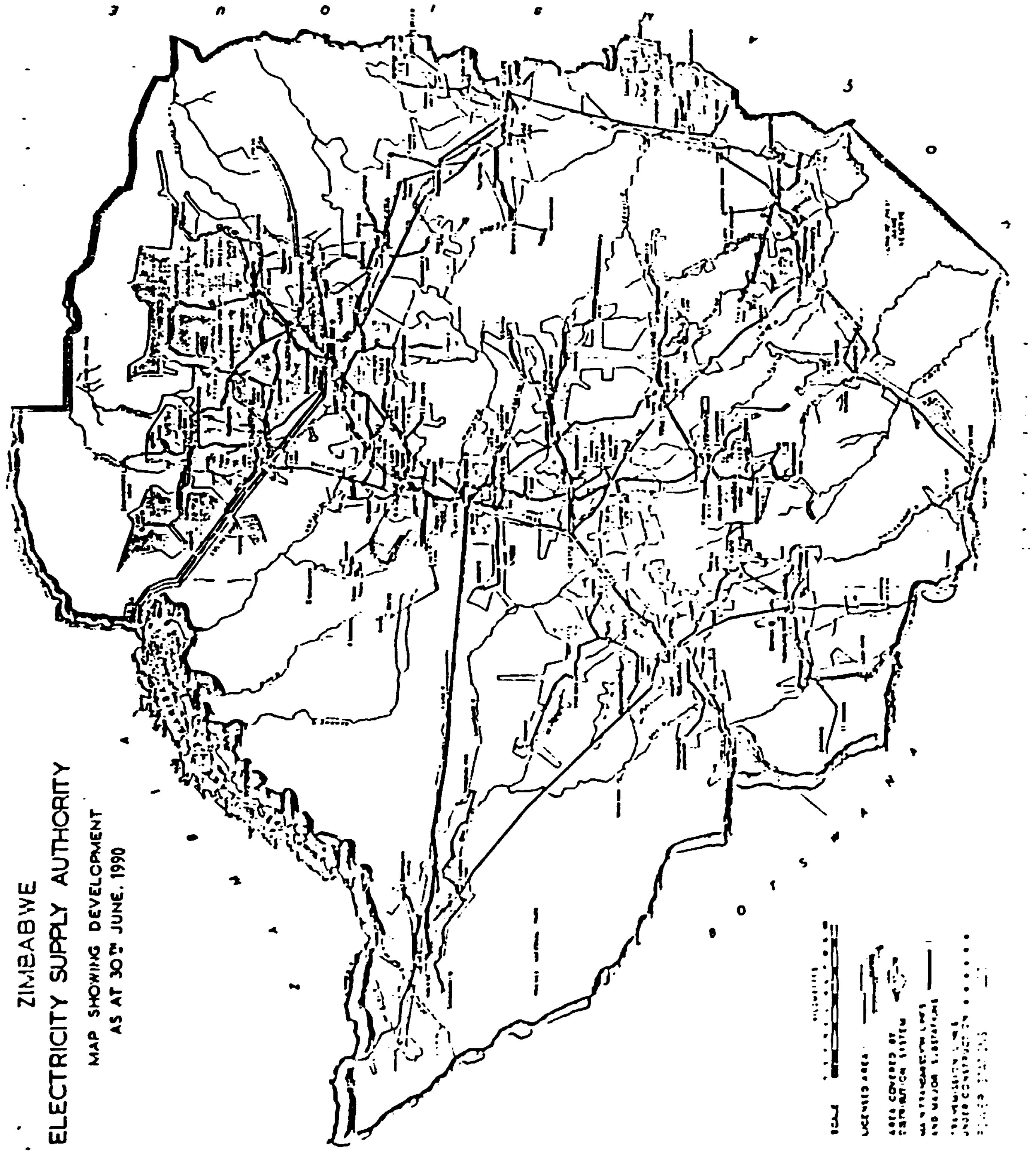
Up to 1950's, the bulk of electricity was generated by coal-fired stations located in Harare, Bulawayo and Mutare. Other smaller towns relied on diesel generators. Kariba Dam hydro-electric power station was built during 1955-1958, and power generation for Zimbabwe and Zambia commenced in 1960. ZESA was established in 1986 to coordinate the electricity functions and utilities.

Map 8.3.1

## TANZANIA: Rural Electrification Programme.



Z.E.S.A. GRID PLAN



- Generation and bulk supply of electricity stood as follows (1987): **Table 8.3.1**

| | total generated (million kWh) |
|---|---|
| Kariba (hydro) | 3154.7 |
| Thermal st ations on grid | 2702.9 |
| Imports from Zambia | 2489.3 |
| Others | 151.5 |
| **Total** | **8 498.4** |

*[Source: Quarterly Digest of Statistics, CSO, Dec. 1987].*

Currently the supply capacity meets the demand with some adequate safe margin. However, the transmission system is close to its maximum capacity, and in some areas, it is over-loaded. This matter is under serious investigation.

- Rural electrification

- During the 1960's electrification extended into some remote areas whose activities ranged from mining and commercial farming, to tourism. Since independence (1980), Government views rural electrification with some serious concern, as it should play the key role in development strategy.

- Phase I target in the rural electrification programme (1984-85), was to electrify 24 rural growth centres at a cost of Z$5.8 million. The target in Phase II (1985-86), was to electrify a further 48 centres. To date, only 36 centres have been electrified, out of the project target total of 72 centres.

- ZESA heavily subsidises the electrical installations, which in the short-run, are a social service; for which positive returns on investment are expected in 10 - 15 years. A further consideration is that the use of indigenously generated electricity will reduce consumption of imported petroleum fuels and hence foreign exchange burden.

- electrification in the rural areas has considerable social and economic impacts:

- lighting is the first and most popular usage.
- electrically-powered grinding mills are cheaper than those driven by diesel oil.
- there will be electrically powered pumps for domestic water and irrigation systems.
- for power tools, agro-industries, bakeries.
- for rural schools, clinics, hospitals.

- There are several constraints to rural electrification:

- electricity is out of the financial reach of the majority of the rural folk; demand is low; positive rate of return on investment 10 - 20 years.

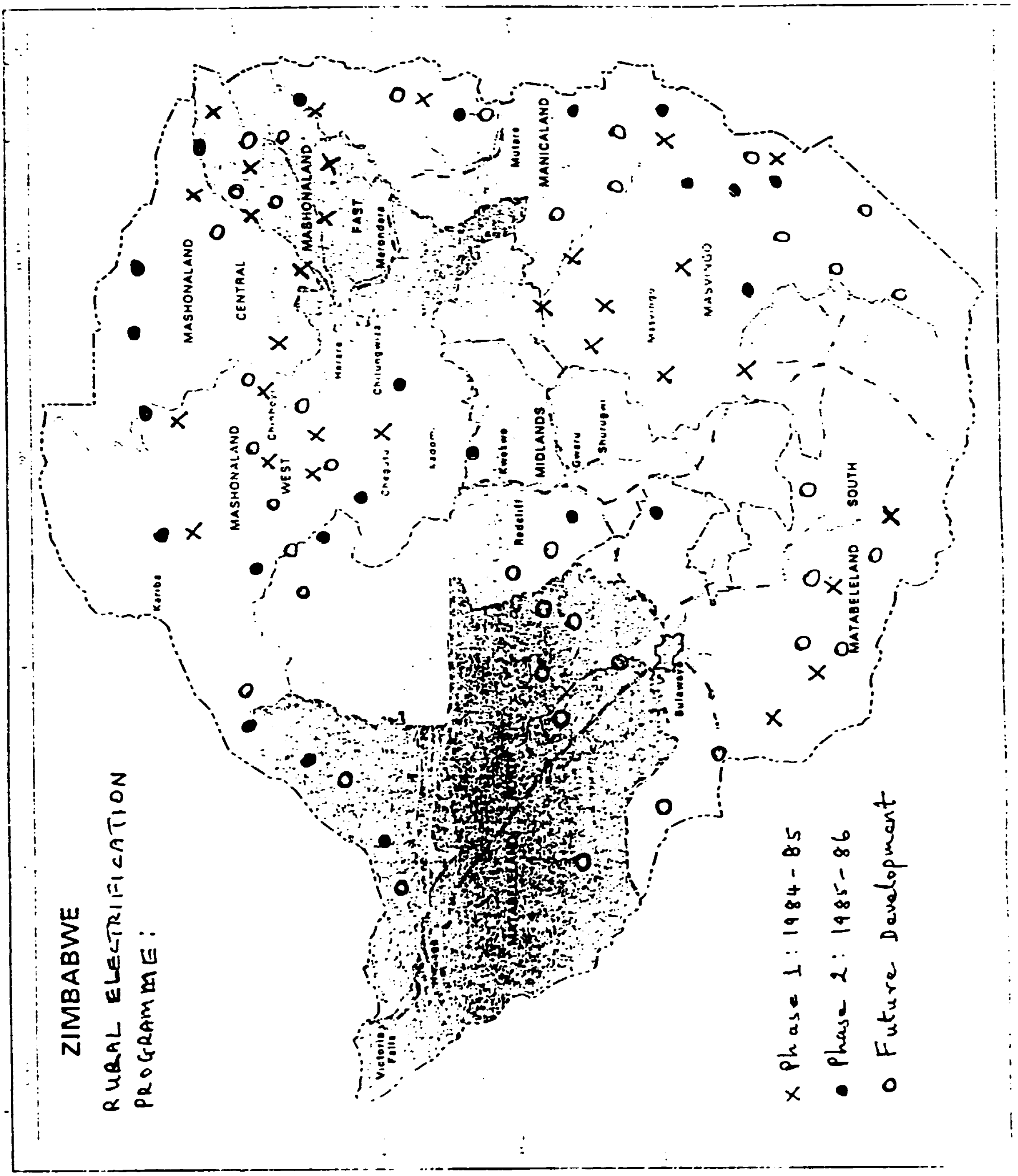
-lack of freehold titles to farms and dwellings is a deterrent to investment in electrical installation and permanent improvements to buildings.

-funding for rural electrification is very limited, since urban dwellers and commercial farmers are resistant to any tariff increases for provision of cross subsidies.

- Several questions need addressing:

- What priority does rural electrification have at the local community?

Map 8.3.2


ZIMBABWE
RURAL ELECTRIFICATION PROGRAMME:
x Phase 1: 1984-85
• Phase 2: 1985-86
o Future Development
MASHONALAND CENTRAL
MASHONALAND EAST
MANICALAND
MASVINGO
MASHONALAND WEST
MIDLANDS
MATABELELAND SOUTH
Mutare
Marondera
Harare
Chitungwiza
Chinhoyi
Chegutu
Kadoma
Kwekwe
Gweru
Shurugwi
Redcliff
Masvingo
Kariba
Bulawayo
Victoria Falls

- What constraints lie in the supply options, with respect to grid extension, diesel, solar, wind or biomass technologies?

- Are there incentives or credit arrangements for rural consumers to ease the electrification costs?

- What role should ZESA, Government agencies, NGO's and local communities play in defining and implementing rural electrification policies?

- Thus, bringing electricity to Zimbabwe's rural communities remains a fundamental challenge. Part of the problem is cost: ZESA charges US$125 per house for a hookup, plus a security deposit; which recaptures only 18% of the grid connection cost. A low-cost "One Amp Tariff" service providing a load-limited supply sufficient for several light bulbs and TV still requires the US$125 hookup charge. This approach would provide an institutional alternative to expansion of coal-fired, greenhouse gas producing, central power plants.

- for a successful implementation of the rural electrification project, we need:-

- development of an infrastructure, utilising existing institutions, to assist in market development, promotion, advertising and establishment of community-based loan programmes and incentive schemes.

- technical and financial assistance to support manufacturers of energy devices, and establishment of public sector consumer financing schemes, including "seed money" in the form of revolving funds.

- training of technicians in the electrical installations and repair/maintenance work.

- establishment of public awareness programmes on electricity usage (using newspaper, radio/ TV, school programmes, group workshops)

- Zimbabwe rural electrification programme is receiving considerable attention by both national and international authorities. The World Bank has plans for a new Power Distribution Loan of US$25 million (IBRD) in the next two years; which includes a joint UNDP - Global Environment Fund component for photovoltaic rural electrification. Further, the Government is negotiating an ADB loan of approximately US$97 million for rural electrification, whereby 72 growth centres would be electrified by 1993.

## 9. The Potential for Gasification using Crop Residues

### 9.1 Potential for Investment in Gasifier Technology

(i) Rural population in the PTA region constitutes about 3/4 of the national populations. Grid electricity rarely extends to these areas, and coupled with the rapid depletion of woodfuel and frequent droughts; member states are strongly urged to devise alternative sources of energy; e.g. gasification. Gasifier technology is clean, environmentally benign and user-friendly technology that can be popularized in rural areas, to spearhead economic and social development.

(ii) Information required for setting up gasification plants (using crop wastes) is basic, but requires concerted efforts to provide the needed resources:

-estimates of residue quantities (cropwise, industry-wise, season-wise, spatial distribution, potential availability)
-existing alternative uses of crop residues (quantities used, value of surplus materials)

Thus the **Pilot Gasification Plant** should be conceived in terms of:

*technological environment:* does need exist? will the local population appreciate and use the technology? is there expertise and knowhow to utilize the technology? consider locally available raw materials for manufacture of gasifiers.

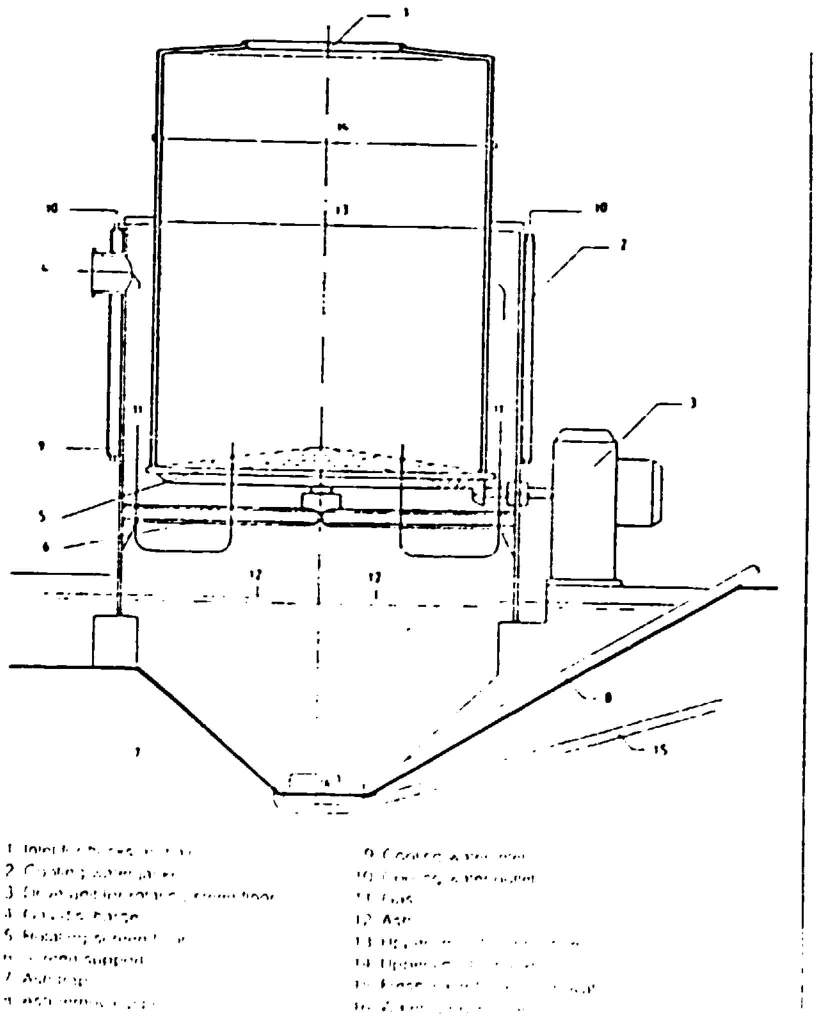
*appropriate technology:* the need to produce/maintain gasification equipment using indigenous materials and manpower.

*energy resource:* can we supplement available energy resources with gasification? gasification will go a long way in alleviating the plight of rural energy demands.

(iii) It was noted that, due to high ash content of coffee or rice husks during gasification, severe ash fouling and engine slagging problems are encountered. An improved design of a gasifier uses a cylindrical reactor with an open top, but with no narrow throat or air intake nozzles. Air enters through the top of the gasifier, and is pulled down through the husks by suction from the system's engine. Ash falls through a slowly rotating grate, and is removed by an ash auger.

The gas evolves from the bottom of the gasifier and is cleaned in a train typically consisting of a cyclone, a wet scrubber and a dry filter.

Improved 140 kW gasifier design.



- to reduce tar levels in producer gas:

- add a tar condenser or centrifugal tar separator
- incorporate a water-cooled ash removal system
- incorporate an agitator in the fuel bed.
- instal a device for grate rotation.

(v) Producer gas can be an energy boon for rural areas:

- crop wastes would be used to produce fuel for rural electrification and industrialization, improved living, as substitute for costly imported fuel (away from outside fuel cartels, monopolies and pricing).

- the disadvantages of using gasifiers are overwelmed by the derived benefits. Often, people look upon biogas as "dirty, smelly, take time to start up, feed and close down; danger from fire and carbon monoxide poisoning." Hence proper management of gasification plants is very essential.

## 9.2 Technical and Socioeconomic Aspects

(i) The three basic resources needed for gasification technology are abundantly available in Zimbabwe and in the sub-region:

- manpower (skilled, or need training)
- equipment fabrication knowhow
- biomass feed (agricultural wastes, etc.).

(ii) Before installing a gasifier plant, one needs to consider the following criteria for site selection:

- ready access to viable agricultural wastes.
- need for power generation.
- available transport and storage facilities for feedstock.
- access to infrastructure for repair/maintenance.

(iii) There is need to enforce a gasifier performance monitoring programme, whilst operating a gasifier plant:

-document the installation according to a standardized format;
-document data on gas composition, dust or tar in gas, emission of pollutants, etc.
-use log-books to document inputs/outputs for an extended period of operation.

(iv) To facilitate the above monitoring aspects, a gasifier with flexible controls is preferred; which would enable quantification of detailed variables, such as: gasification air feedrate, moisture ingression rate, power demand response, ash removal frequency and efficiency of gas cleaning/ cooling apparatus.

(v) For feed material using maize cobs, coffee parchment and husks, and groundnut shells, an average Net Heating Value of 17.85 MJ/dry kg. will be required. This average is well within the bounds of these crop wastes. A suitable diesel engine retrofitted with spark plugs should be used in conjunction with a gasifier. Apart from spark plugs, retrofitting further consists of installing a gas mixing throttle, a magneto and a governor system on the gas mixer outlet. Thus the need for dual fuel, or feeding an auxiliary liquid fuel, is eliminated.

(vi) Laboratory analysis of producer gas

Producer gas must be analysed either online by a gas chromatograph, or it can be collected in an airtight vessel (e.g. vehicle wheel inner tube). The University of Zimbabwe, Tobacco Research Board, Department of Research and Specialist Services and other public/private establishments, should have facilities for analysing producer gas.

### 9.3 Gasifier Economics and Constraints

(i) We have mentioned the need to know the electricity requirements, say, for a specific rural community. With a gasification project in hand, it is assumed we have advance information on:

-maximum/minimum and average energy consumption (by day or month)
-peak energy demand levels, their duration and frequency
-the forms of energy already available (electricity, diesel, etc.)
-unit costs of the available energy systems
-plans for changes in energy consumption levels or forms.

(ii) For rural electrical power requirements no single capacity of system is optimal for all situations, which will satisfy daily variations in energy demand and supply. Hence, a modular system is desirable; which can provide the flexibility of being able to supply almost any level for a range of capacities based on the number of synchronised units operating in parallel. A modular system, as contrasted from a single-unit energy system, has several advantages:

-modules not required can be on standby or could be shut down; with those online operating at full load.
-in the event of equipment failure, only a module would need to be shut down with the rest of the system operating efficiently.
-ease of training for operating/maintenance personnel.

In most rural communities a system with a net output capacity of 50 kWh/hour electricity, is adequate.

(iii) A crucial factor in gasifier economics is the initial cost. The cost of gasification equipment varies widely, with a locally fabricated unit costing cheaper than an imported equivalent. Some constraining factors are annual operating period costs, system lifetime and repair, maintenance and labour costs. However, the cost of electricity produced by a gasifier appears to be lower than that from a diesel engine system or grid supply.

### 9.4 Introducing the New Technology

The first requirement for introducing the new technology will depend on the success or failure of a pilot gasification project. The results of the pilot plant will highlight the constraints (if any) and/or advantages of adopting gasifier technology in a particular locality. The second consideration, based on the pilot plant, should focus on a few selected villages, which would host gasifiers for an extended period (one or two years). Monitoring and evaluation of plant operations should be in force. A third aspect is the desirability to train a crop of gasifier technicians and operatives, to act as a conduit for the dissemination and diffusion of the technology. Governments and policy makers are encouraged to introduce incentives in the form of tax relief, credit/loan facilities to cooperatives, and subsidies; to popularize gasifiers in the rural areas.

## 10. The Case for A Rural Energy Centre (REC) for The PTA.

### 10.1 Objectives

(i) Gasification technology, alongside other renewable technologies, requires of necessity, the existence of a national or regional rural energy centre (REC), which will develop appropriate technologies for small and medium-sized rural-based establishments.

(ii) The REC could be active in three major fronts:

- R & D work on gasification systems, with crop wastes as feedstock.
- consultancy to manufacturers of gasifiers, Government, and consumer groups, on the utilization of producer gas.
- dissemination of information and training on gasifiers and related technologies.

(iii) The REC will look into appropriate socio-technical needs of the rural communities, and act as a bridge between the needy in gasification energy and the known sources of expertise.

(iv) Above all, the REC should be conceived as a non-profit organization aimed at uplifting the socio-economic conditions of communal and marginalized farmers.

### 10.2 Importance of Electrification by Gasification

(i) Gasification electricity will impact on rural areas in a four-fold manner:

- rural clinics and rural health centres
- science education in rural schools
- rural household/domestic electrification
- water pumping, irrigation and agro-industries.

(ii) The REC is a goal-oriented project, broadly aimed at;

- identification and analysis of the "gasification" needs of different village end-users (households, institutions, villages).

- identifying economic and financial constraints on the popularization of crop-residue gasification.

- organizing a common platform for gasifier manufacturers, end-users and maintenance artisans.

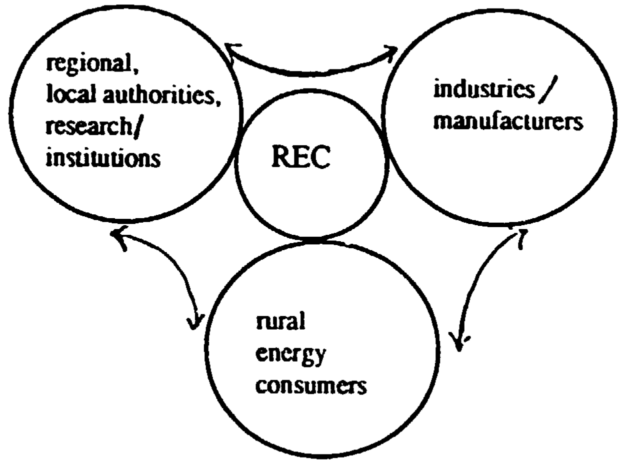
- training and orientation of end-users and the public.

- providing inputs to planning and policy development, as regards utilization of crop residues for gasification.

### 10.3 Some REC activities

(i) REC will stimulate rural development through transfer of "gasification" technology. It will serve as a framework to promote R + D in the rural energy technology sector, and to foster its market penetration and diffusion.

(ii) There will be regular consultations between farmers, cooperatives and other rural-based institutions, on the scope and potential of gasification technology. It is expected that the REC will play a crucial role in the implementation of gasifier usage, and in establishing linkages amongst the public, research, industry and rural farmers. These interactions are displayed in the following schema:




(iii) From its institutional set-up, REC will receive support from administrative authorities, and from industry and end-users. It should be constituted by a dynamic and creative team, to channel know-how onto local manufacturers, consumers, politicians, etc.

(iv) REC will have facilities for:

- experiements; workshop and test facilities for gasification
- measurements and draughtsmanship
- service and maintenance
- training facilities
- publications (desktop): manuals, brochures, leaflets.

(v) Tentative activities will include:

- gasifier plants for households, farms, cooperatives, industries.
- co-generation systems for producer gas
- pyrolysis of crop residues and other wastes
- briquetting of agricultural wastes
- systems for lighting, power, heating, irrigation.
- integrated energy systems (cum biogas and wind).
- training and orientation modules.

(vi) REC personnel should have a variety of professional expertise: engineers, architects, workshop technicians, information/training specialists, and financial administrators.

- It is of necessity to establish REC as the major catalyst to the successful progagation of gasification technology in the PTA subregion.

## 11. Conclusion and Recommendations

### 11.1 General

(i) The economies of PTA member states are dominated by the agrarian sector, which employs over 65% of the economically active labour force, and contributes substantially to the value of GDP. Whereas grain crops are grown abundantly in the sub-region, the effective utilization of agricultural residues remains to be a complex matter, requiring not only technological parameters, but also a variety of local, socioeconomic and environmental factors. The PTA countries, in spite of their diversity, have similar agricultural practices. Agriculture is the main source of income for the majority of the people. Thus large quantities of a range of crops are grown for food, and also large quantities of agricultural residues are produced as byproducts or wastes.

(ii) Gasification of crop residues for energy needs in rural areas, is what may be termed appropriate technology, which is not new in the subregion; but rather it's a different view of existing technology and the end user. What is "new" is the idea of providing information and knowhow to people, especially in the rural areas. Studies in various parts of the world, have revealed that there is a close correlation between the level of energy use and that of industrialization and technological development. The African Ministers of Energy in Harare (June 1989) called for increased agro-industrialization, and noted that; "human muscle power alone can no longer feed Africa's growing population where 90% of the people are forced to live in silence and poverty because they do not speak the language of technology and progress."

(iii) A major constraint to the effective use of crop residues, through the deployment of appropriate technologies, is the lack of basic information on the quality and quantity, patterns of production, and end-use of the available agricultural wastes. Therefore, while making plans for the exploitation of residues for energy purposes, other options should be taken into account, to maximize overall social, economic and environmental gains. There is need to develop standardized quantification and measurement methodologies to enable inter-country comparisons possible and meaningful.

(iv) Currently there is general reluctance to use crop waste energy conversion technologies, because of poor motivation, as seen from the relatively high investments, the high cost of capital and a general lack of support from the "grassroots." Hence governments must be seen to initiate action for the identification of essential policy considerations, incentives, concessions and regulatory measures; as required for the better motivation of the residue energy conversion technology users.

For successful residue energy conversion technology; dissemination and acceptance, training of personnel at all levels to take care of planning, design, operation, repair and maintenance, is important. Within the PTA region, it is recommended that an exchange of personnel, visits and study tours in the field of residue energy conversion should be encouraged.

(v) Activities aimed at popularizing residue energy conversion technologies should be pursued: research and development, demonstration and testing, standardization, manufacturing and marketing. These activities ought to give priorities to cost reductions of viable technologies; and to refine and improve gasification, say, for reliability and acceptability.

Very often, the failure of new and proved technologies, is linked to the lack of awareness on technological options, cost-benefit ratio, economic implications and environmental impact. There is also the overwhelming lack of suitable linkages between agro-industry and research/development institutions. An infrastructure should be instituted for the coordination of activities relating to production, conversion, utilization and conservation aspects. Such an infrastructure inevitably addresses itself to set conditions:

-collection, compilation and dissemination of field reports, residue-wise.
-identification of R & D problems.
-setting up of demonstration centres at selected locations; formulation of schemes for incentives and subsidies for gasifier commercialization.
-planning and organizing workshops at various levels.
-publishing a newsletter/journal, to create awareness amongst those interested in crop residue gasification.

## 11.2 The Intergrated Energy System

(i) Producer gas technology should be looked upon in the context of a wider integrated energy system and techno-spectrum, involving other energy sources: electricity grid, solar, biogas, hydro - and wind energy. For a pilot plant, it is advisable to select a few ideal locations as testing grounds. These locations can be cooperatives establishments, commercial farms, ADA/GMB/CMB/ depots, or agricultural research stations. The pilot gasification locations should be in areas with a high production concentration of the 4 principal target crops (maize, groundnuts, cotton, coffee). Thus, instead of using maize cobs, say, as substitutes for firewood, such cobs should be densified/ briquetted and used as gasification feedstock for the production of a much larger energy resource base.

(ii) Preparation of crop waste gasification feedstock should be by way of densification/briquetting, preferrably using manually operated briquetting machines (which can be fabricated locally and are also labour-intensive). R & D work is most wanting in several areas of gasification technology; treatment/prevention of clinker formation and tar-charring; design of tar-free gasifiers; improvement of cleaning/cooling apparatus; engine retrofitting and modification; pre-treatment of feedstock, handling tars of diverse crop wastes, disposal of gasifier wastes, etc. Thus, university researchers and gasifier technicians, are encouraged to share and exchange ideas to improve overall gasification techniques.

(iii) There is need to popularise gasifier technology through various media; and to launch training programmes for gasifier promoters, manufacturers, operators and repair/maintenance technicians.

(iv) To reiterate emphasis, it is proposed that pilot gasification plants be established in the selected areas, already mentioned. Such pilot work will be closely evaluated and monitored by professional artisans, using up-to-date physical/chemical techniques, as well as other economic/social criteria.

(v) Traditionally the supply of energy in the rural areas has been largely dependent upon two resources: biomass (fuel-wood, crop residues) and animal power. It has been estimated that 14% of the world's energy, equivalent to 25 million barrels of oil per day, is derived from biomass sources. To date, conventional energy sources have been water (hydro), geothermal, nuclear and fossil fuel (oil, coal, natural gas). The first three sources are mainly applicable for central station electricity generation, while oil is used for stationary power plants and vehicles.

Over the years, problems relating to high fossil fuel procurement costs, deforestation and environmental impacts, have forced nations to search for alternative, non-conventional energy sources: solar, biomass, wind energy.

### 11.3 Gasification and New and Renewable Sources of Energy (NRSE)

(i) Gasification with agricultural wastes should be conceived in terms of the overall New and Renewable Sources of Energy (NRSE). On its own, it does not constitute the solution to the energy plight of the rural areas. Coupled with other components of NRSE, gasification energy from crop wastes is a cheap and safe resource that can be relied upon, if and when available.

(ii) There are, however, problems and constraints to the rational implementation of NRSE:

- political and institutional problems: there must be the correct socioeconomic setting and encouragement from governments for the transfer and diffusion of NRSE into communal lands.

- there should be adequate capital and finance to fund gasifier installations and running costs.

- the rural community should be socialized to adapt to new life-styles, employing novel sources of energy.

- it follows that the integration of available energy sources, ought to be part of the regional energy policies and the focus of future rural development.

- gasification energy from crop residues strikes a creative balance between rural energy development and environmental concerns, which will reduce greenhouse gas emissions, whilst at the same time creating electricity supply.

(iii) A pilot gasifier project is essential, in as much as it will provide energy technology to a sufficiently large number of rural households, to allow for valid assessment and demonstration of the technology. Further, it will allow us to determine effective approaches to its promotion and provision, by comparing several promising possibilities including community-based cooperatives, households and other publicly - operated utilities.

(iv) Alongside considerations of NRSE, models on energy policy have been evolved. In particular, the "Less Developed Countries Energy Alternative Planning System" (LEAP) model has been developed in Southern Africa; for organizing energy information and assessing policies for energy planning. LEAP is structured as a family of seven programmes: three core programmes providing detailed national energy accounts and forecasts; a demand, transformation and resource programme. LEAP promises to be more appropriate than other similar models, for the special problems of the rural sector; especially with respect to energy self-sufficiency, land-use patterns and possibilities for NRSE programmes.

(v) In summary, it is noted that too many renewable energy projects in the DC's have suffered from a too narrow, technology-oriented approach; which does not take into account the organisational basis: e.g. strengthening of R & D and planning, technical standardization, technology commercialization, organization of end-users and the public, as well as training and dissemination. Even though gasification using crop residues is often seasonally dependent (at harvest periods), it is still considered wise to utilize the energy if and when it becomes available. Equally important, is the consideration that just as crop residue gasification is a sound and cost-effective energy philosophy; what needs to be done is the development of an **innovative engineering** for the construction of a gasifier that is efficient in terms of both gas cooling and gas cleaning.

## 11.4 Crop Residues and Gasification

### (i) General

What are the options and benefits of utilising gasification technology using agricultural wastes? Perhaps it is pertinent to focus on the most important salient points:

- planning and design of gasification technology projects.
- analysis of socioeconomic aspects of energy consumption, conversion and supply, particularly in the rural areas.
- gasifier technology development and adaptation.
- strengthening of local training and manufacturing capabilities.
- producer gas market organization and coordination.
- workshops, conferences and seminars on exchange of experiences, with regards of crop residues and gasification.

Who benefits from the gasification technology? The choice of the technology should be driven from end-user needs, rather than from supply consderations. Enlightened and sustainable energy options are proving to be reliable and desirable solutions for both the industrialized and the developing countries. The major thrust of a gasifier project should be to promote productivity in the rural agricultural, industrial and commercial sectors; to meet basic needs and enhance the quality of rural lives; especially the alleviation of the drudgery of women. Hence, one can look at a two-fold objective strategy:

*Immediate objective:* to develop an infrastructure for implementing small-scale crop-residue gasifier projects in selected rural areas. The projects would provide a model for replication in other localities.

*Development objective:* to provide reliable gasification energy to rural "off-grid" end-users, from agricultural wastes.

### (ii) The Model

- The most promising gasifier feedstock from crop wastes are maize cobs, groundnut shells and coffee husks/parchment. Although cotton is abundantly grown within the PTA region, its residue has a high ash content, and in addition, cotton wastes are usually burnt into the ground as a means of disease control. Similarly, sugar bagasse is not normally available to non-sugar growers; it is generally used for steam boilers on the sugar estates.
- To select potential "gasifier" sites, the PTA subregion can be conceived in terms of three attributes:
  - areas with adequate and potential crop wastes,
  - areas with scanty crop residue resources,
  - areas in which relevant data and agricultural information are not readily available; hence, the need to maintain timely agricultural statistics database.
- It has also been noted that if political stability is restored in some countries of the sub-region (e.g. Angola, Mozambique, Namibia), crop production will be greatly enhanced, and likewise the availability of crop wastes for gasification. Within the PTA region, areas of high maize productivity (maize production index (MPI) = indicator of gasification potential) have been identified as the most suitable sites for crop-residue gasification plants.

**Assumptions**

- Government, donor - and end-user support for gasification energy using crop wastes (political and institutional problems: need to conscientize the rural community).
- end-user involvement in project implementation from the initial stages.
- existence of reliable databases on agricultural production and crop residue inventory.
- that needy and suitable pilot test centres be identified in the subregion (presence of a technological environment for the transfer and diffusion of energy technology).
- interest among industries to manufacture gasifier hardware (financial constraints and incentives).
- that the generated producer gas is competitive to fossil fuel and grid-power alternatives.

**Target Groups**

The social and environmental impacts of crop-residue gasification extends beyond the individual end-user, and hence decisions should ensure acceptance by the overall target communities. Efforts should be made to develop capabilities at the local level, including selection of the desired technology; within the framework of sustainability.

Energy derived from gasification of crop wastes should provide for cross-sectoral target groups:

- rural domestic households
- small/medium scale farming projects
- water supply/irrigation schemes
- local industries/cooperatives
- health clinics/schools/community centres/institutions.

The end-users and their organizations will have to be actively involved in project implementation; and should be motivated for keeping the systems in continued operation.

**(iii) Renewable Energy (RE) and Energy Efficiency (EE) Programmes**

- Crop residue gasification would operate alongside similar strategies for implementing small-scale energy technologies, so assembled in a "basket." Previous gasification projects have been oriented towards a few field tests and demonstration of different gas generator types. There is NOW need for a shift towards an end-user and application-oriented approach, whereby installation and monitoring of a substantial number of gasifiers in rural areas, can be realized. These installations will create a "critical mass" to justify the establishment of a strong infrastructure; vis-a-vis, encouragement of local industries, service organizations, human resource development, as well as involvement of management and technical expertise from different disciplines.

The criteria for gasifier installation are: skilled personnel, equipment fabrication knowhow, access to feedstock, and need for power generation.

- Crop-residue producer gas energy must be viable in terms of its economic cost (local and foreign) and environmental impacts. Modularity and short gestations are important characteristics of sustainable energy, so that the technology can be adapted to local needs. As regards agricultural wastes, it has been noted that methods of collection (e.g. collect maize before they have dropped to the ground to avoid sandy matter), transportation and storage, can greatly affect the quality and suitability of crop residues as feedstock for gasification. Gasification of crop wastes provides a viable energy technology, if and when the agricultural wastes are available (seasonality); and gasifiers should be installed preferably at agro-processing plants, or at the point of availability of the feedstock.

- To improve designs of "tar-free" producer gas generators, it is highly recommended to research into/ and study combustion properties of various crop wastes (calorific values, C-H analysis, ash characteristics, pyrolysis thermograms, etc.). Encourage the development and use of manually operated briquetting machines, and compare as feedstock; crop wastes which have undergone briquetting or densifying processes, against those which have not.

### (iv) Rural Energy Development (RED)

- Crop residue gasification energy is part of an overall rural development strategy, that can partially offset the rural-to-urban migration drift, which is already creating economic and social problems. But gasification energy alone cannot ensure rural industrialization, although the latter demands energy. Rural energy inputs would need to be suitably packaged with credit, knowhow and training. In addition, it is essential to study rural settlement patterns and agricultural practices to identify which ones maximize procurement of crop wastes.

- Rural and peasant farmers require more than just R + D. They require effective transfer of appropriate technologies; a new innovative approach to energy awareness, information and extension training; especially for women with a generally low resource base. These activities will eventually generate employment, income, self-reliance and secondary industries (repair and maintenance).

- The need to establish a national Rural Energy Centre (REC) has been highlighted; it will be active on crucial fronts:
- development of RE and EE systems;
- provision of consultants to Government, industries and end-users;
- expansion of agro-factories and cottage industries;
- market organization of the energy products;
- dissemination and popularization of rural energy technologies;
- analysis of socioeconomic determinants of energy consumption, conversion and supply;
- acting as a bridge between the needy in energy, and the known expertise.

### Rural Electrification

- Electrification of rural areas has special features:
    - lighting is the first and most popular usage;
    - electrically operated grinding mills are also a viable attraction;
    - other application areas are:
        pumps for domestic water/irrigation systems;
        power tools, agro-industries, rural schools/clinics.
    - incentives (tax relief, credit/loans, subsidies, freehold titles to land).
- Problems faced in implementing rural electrification schemes in the subregion, include: insufficient capacity to meet electrical peak demands, inadequately equipped workshops, insufficient prior planning, poor supply reliability and lack of spare parts. A new strategic approach is therefore necessary, which emphasizes on forward planning, and the thorough training of both technical and financial personnel.

Lastly, the environmental benefits of crop residue gasification energy need not be over-emphasized. The current discussions on environment ("Brundtland" report; UNCED Conference, Brazil, June' 92) are highly supportive to an increased application of both RE and EE. Thus, the project would be a regional contribution to a global strategy for a sustainable energy future.

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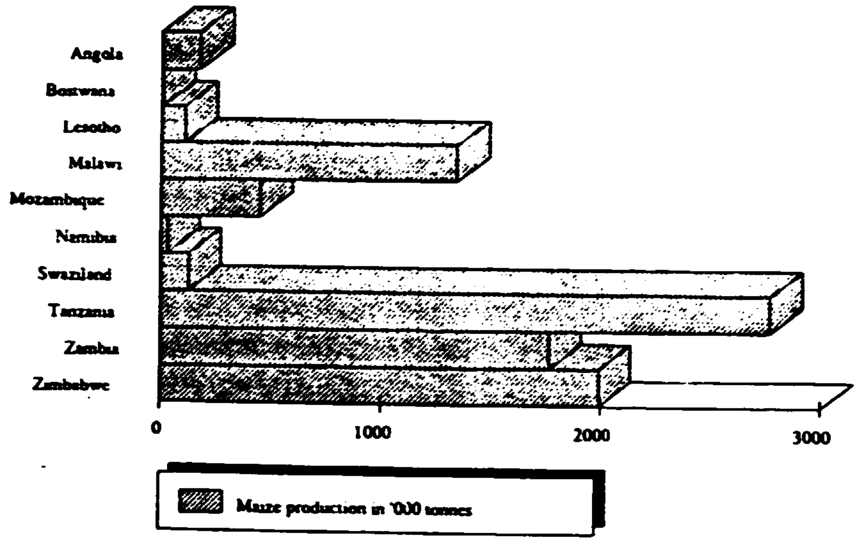
*"When night falls in the tropical forest, one is in a total surround of myriad will-o-the wisp sounds and organic smells. There is a tremendous sense of remoteness but at the same time of being at one with the richest of biological communities." Thomas E. Lovejoy (Smithsonian Institution).*

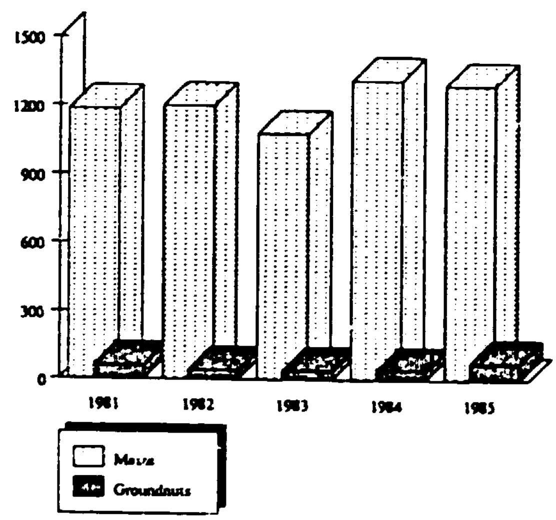
Annex 1.

## Maize Production in Selected Countries 1989/90



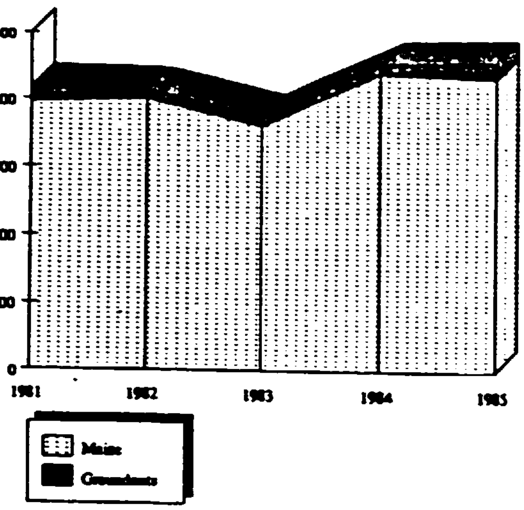

Annex 2a.

## Malawi: Crop Production of Maize and Groundnuts in Smallholder Agricultural Sector

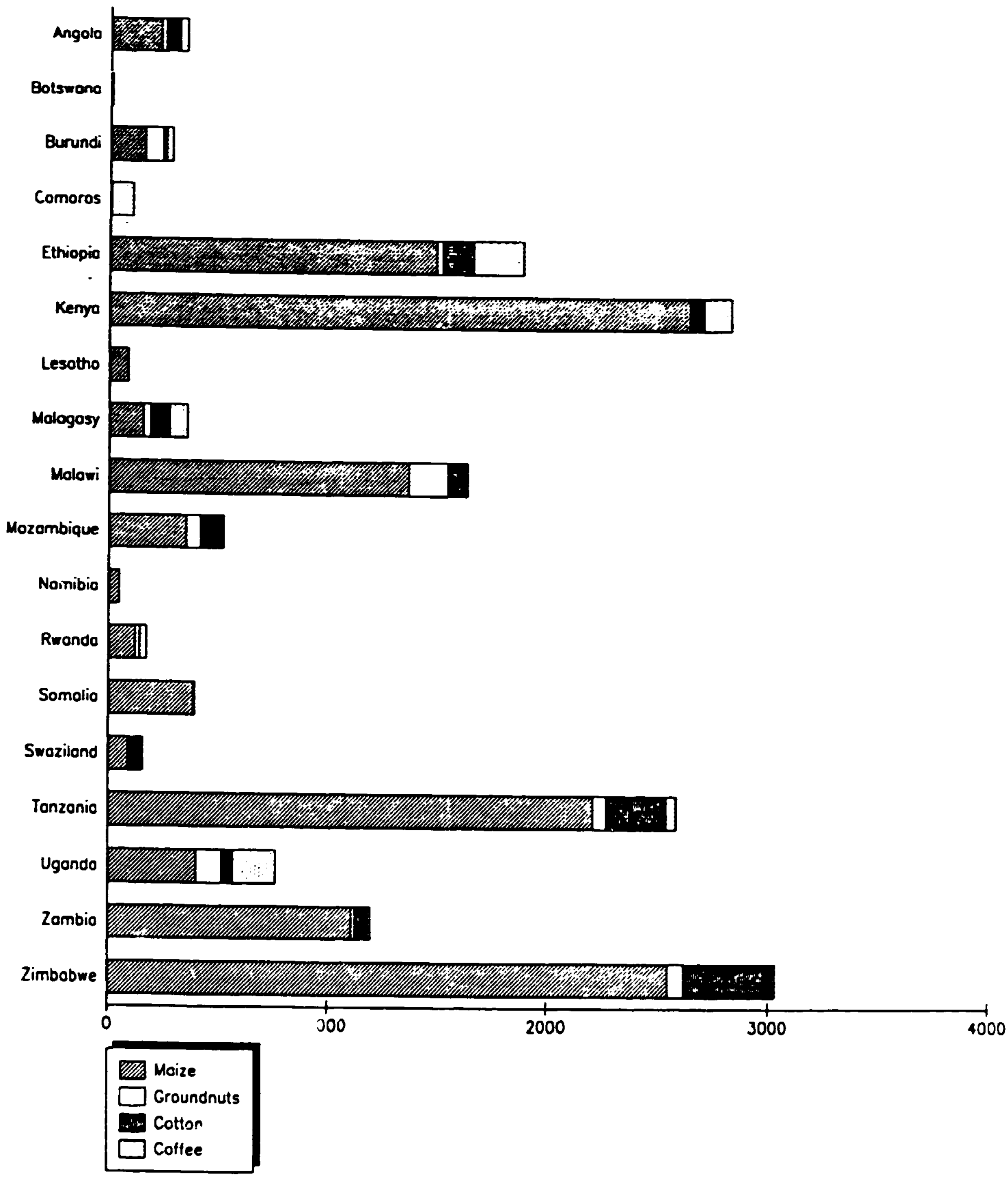


Annex 2b.

## Malawi: Crop Production of Maize and Groundnuts in Smallholder Agricultural Sector

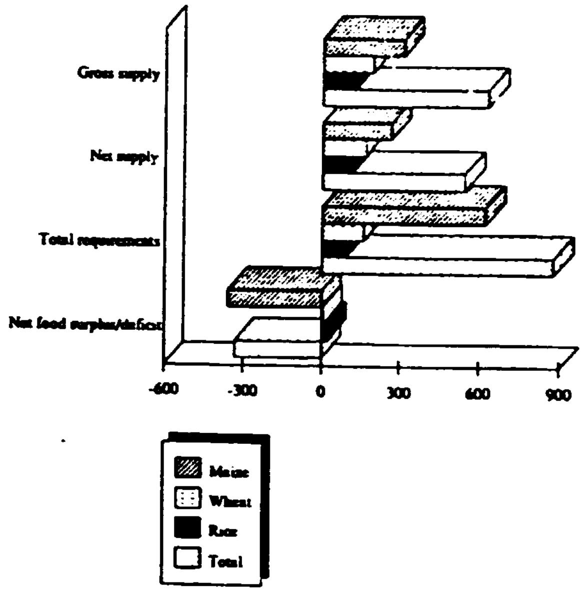


## Crop Production in the PTA (in 1000 metric tonnes)



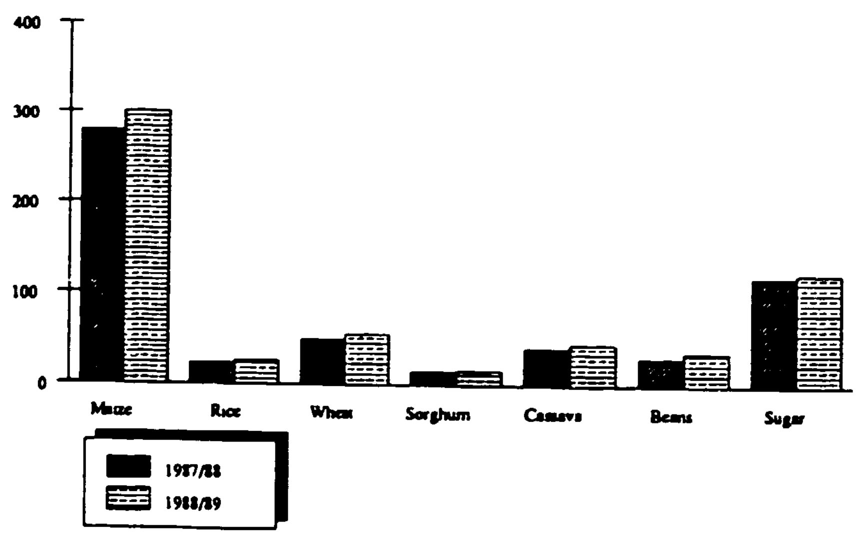
Annex 4.

## Mozambique: Food Balance Sheet (1st May 1987 to 30th April 1988)



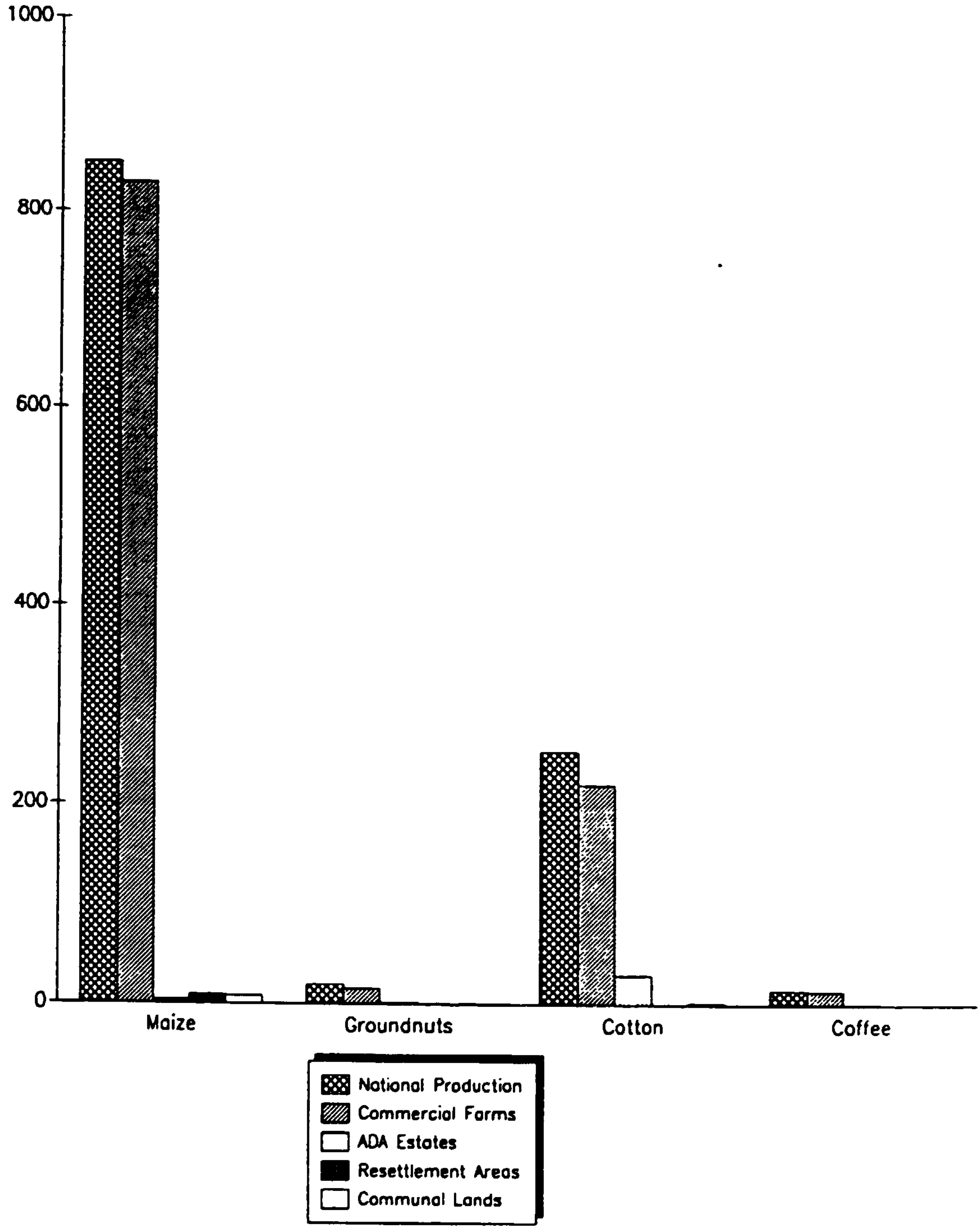

Annex 5.

## Tanzania: Purchases of Food Crops by the National Milling Corporation: 1987/88, 1988/89 (in tonnes)



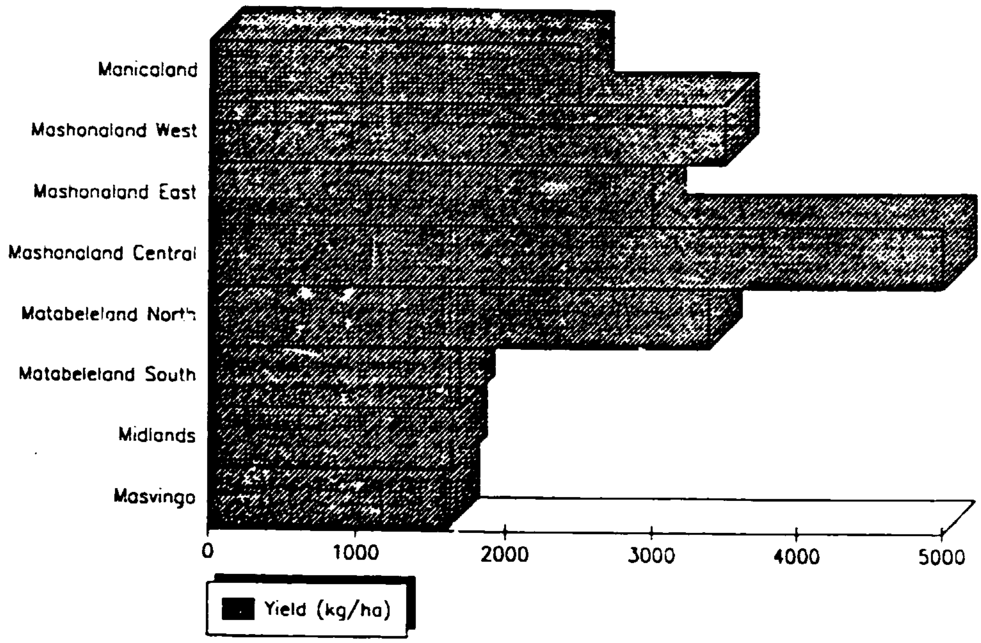
Annex 6.

Zimbabwe Agricultural System breakdown (1988)
(Maize, Groundnuts, Cotton, Coffee) ('000 tonnes)



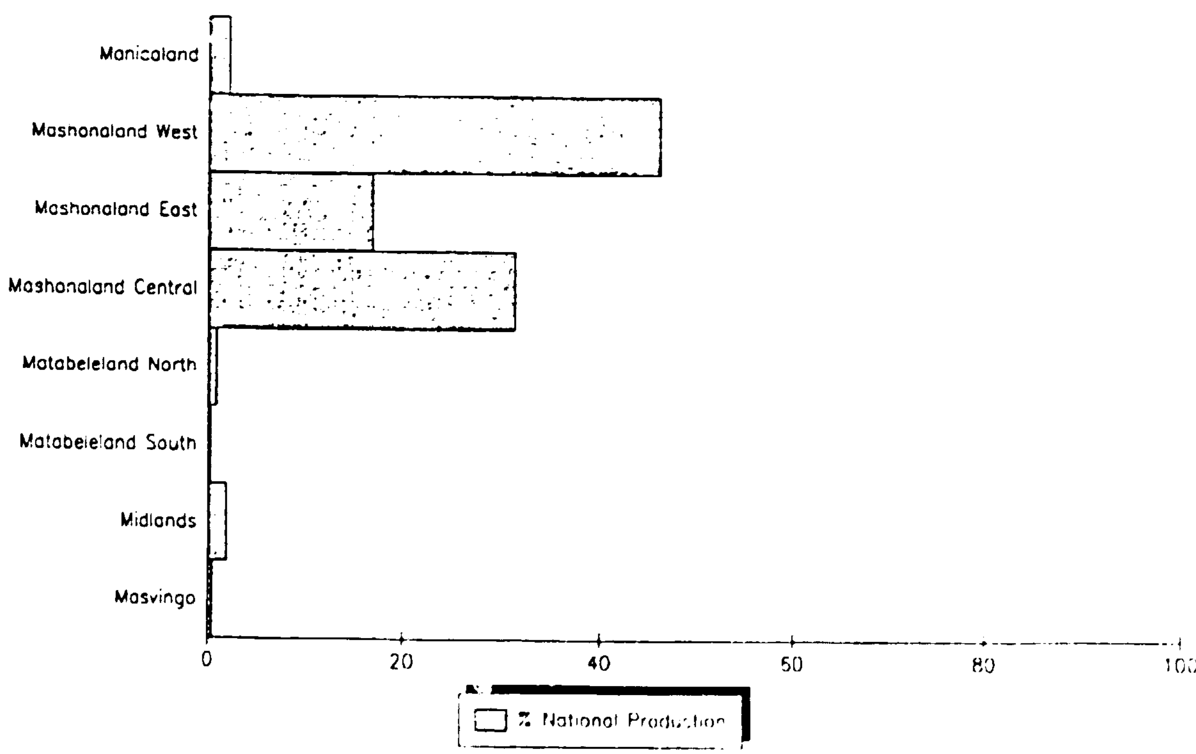
Annex 7a.

## Maize Yield (1989) (Large Scale Commercial Farms)



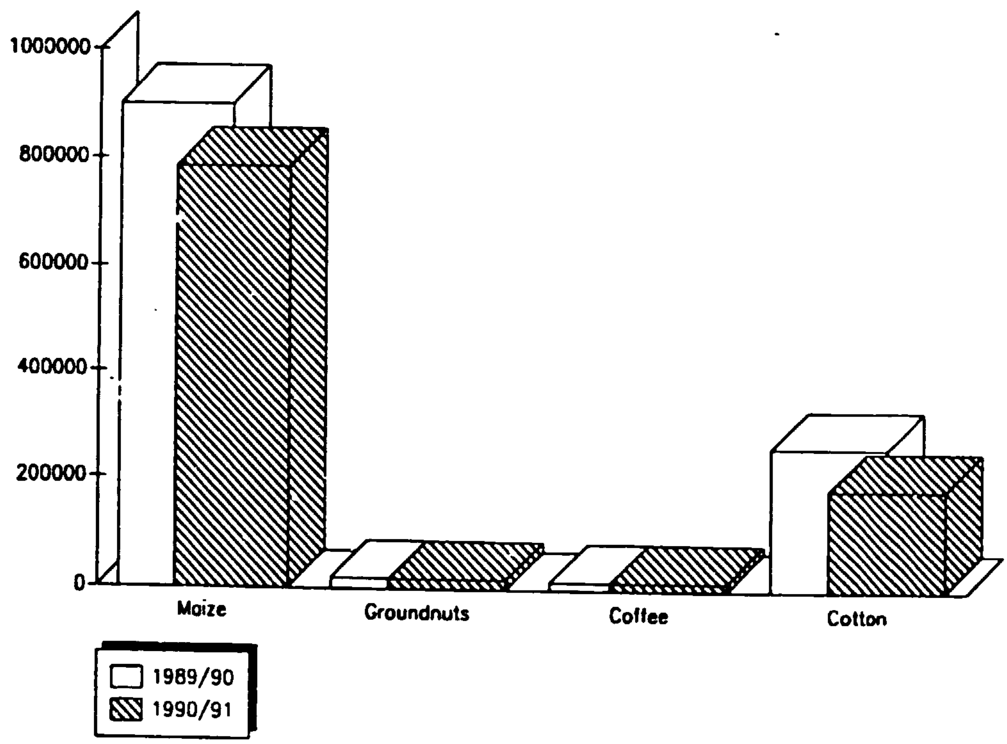

Annex 7b.

## Maize Yield as a percentage of National Production (1989) (Large Scale Commercial Farms



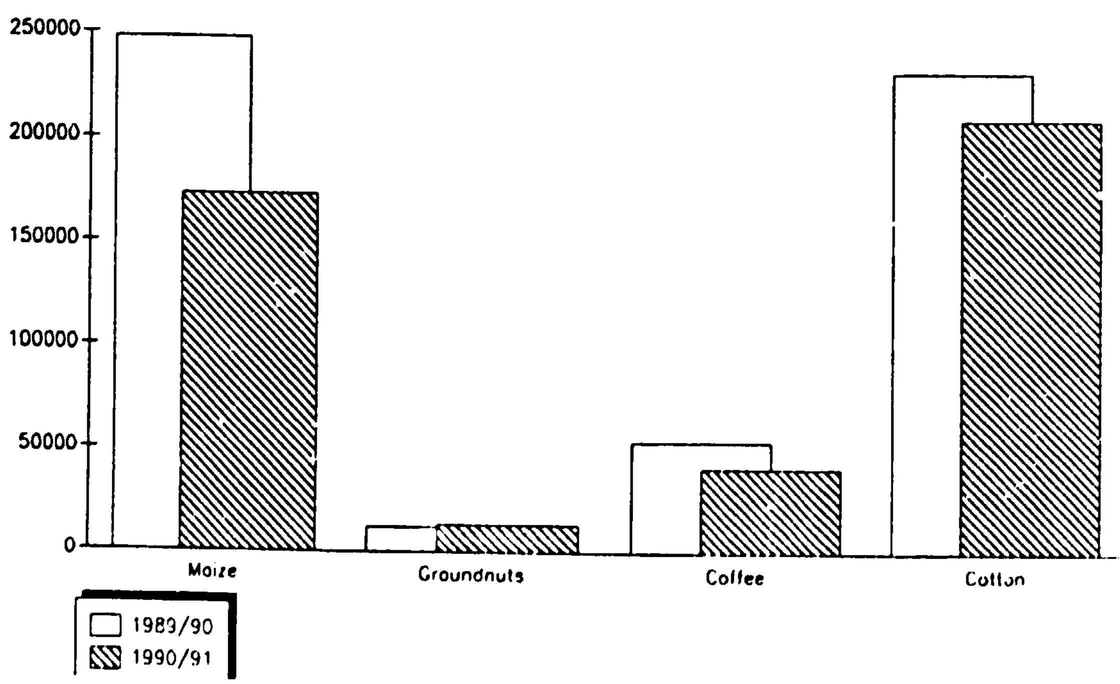
Annex 8a.

## Volume of Principal Crop Sales to Marketing Authorities in tonnes



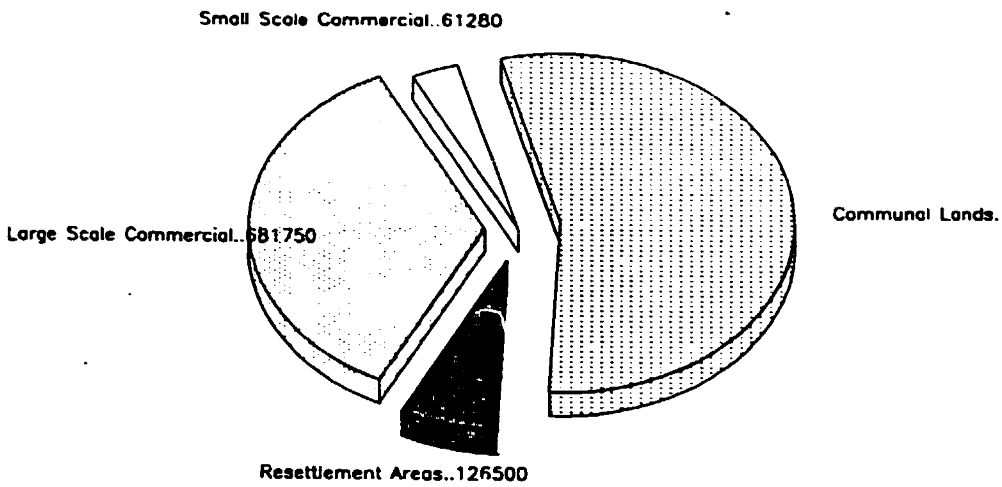

Annex 8b.

## Value of Principal Crop Sales to Marketing Authorities, Z$ '000



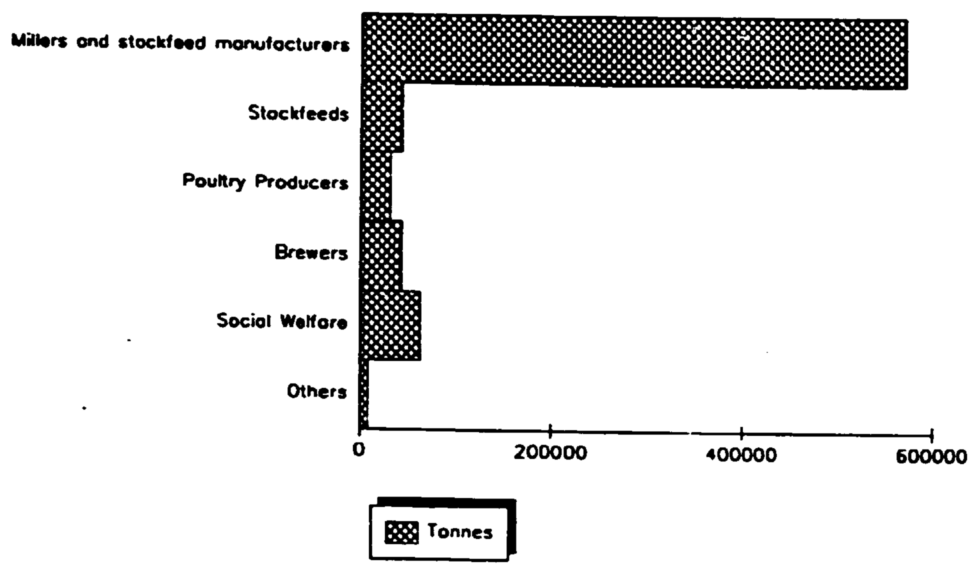
Annex 8c.

## Maize Production Estimates (1990)



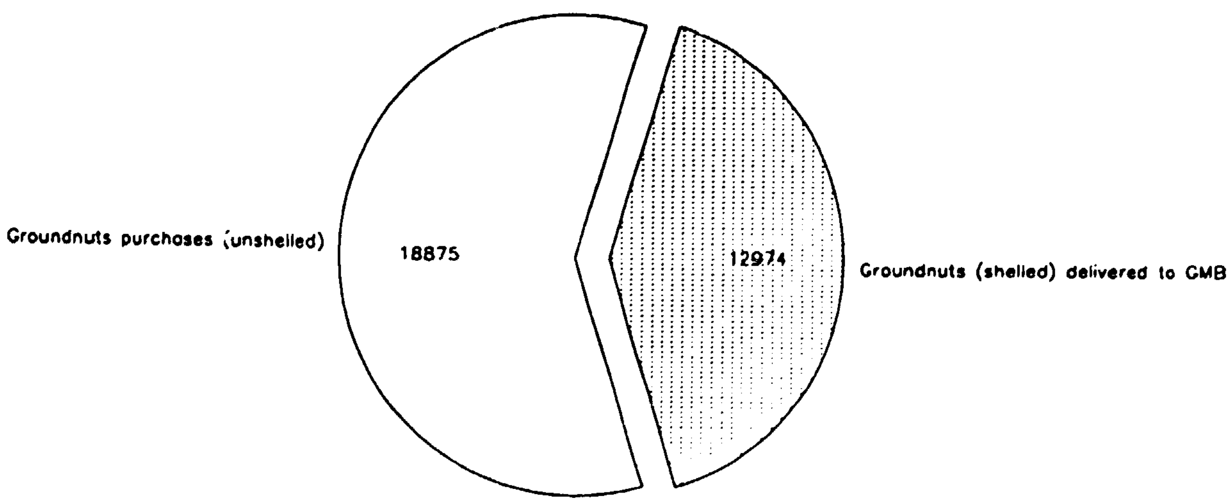
Annex 9.

## Maize Sales by Customer 1989/90



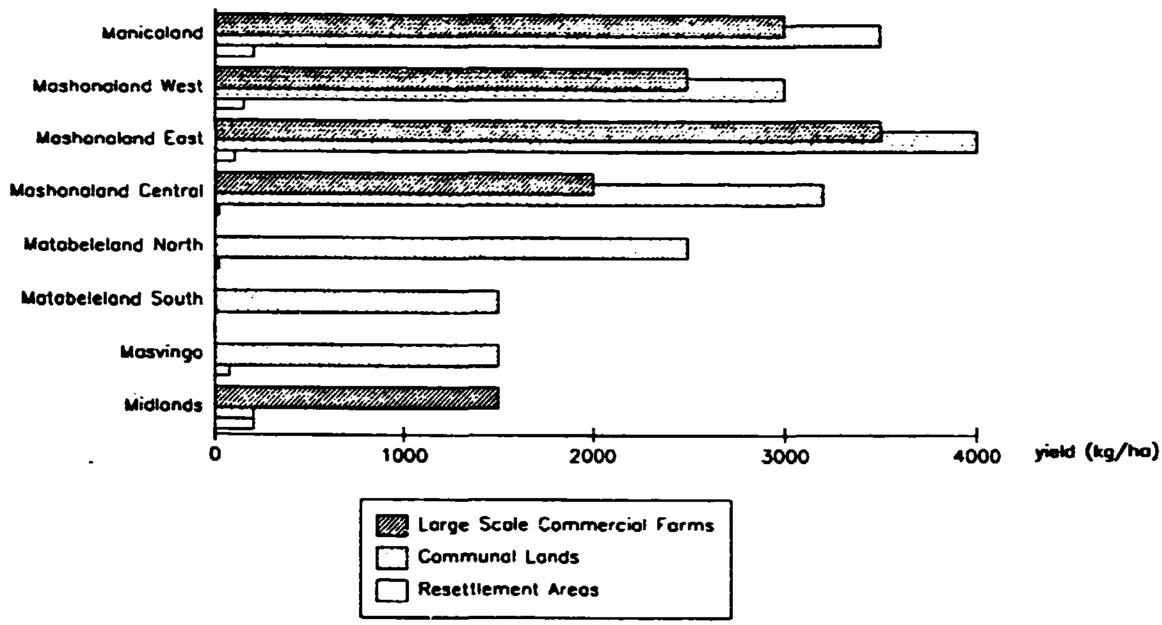

Annex 10.

## Groundnuts Deliveries to the GMB (1989/90), in tonnes



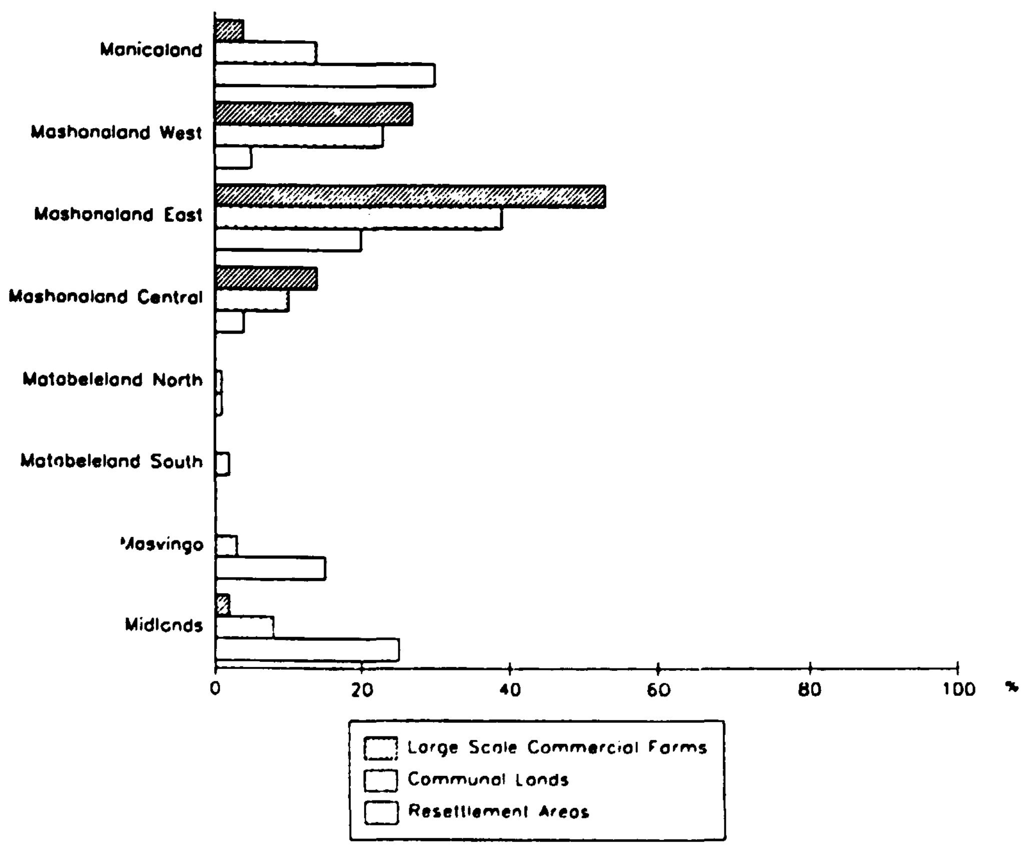
Annex 11a.

## Groundnuts Yield by Province



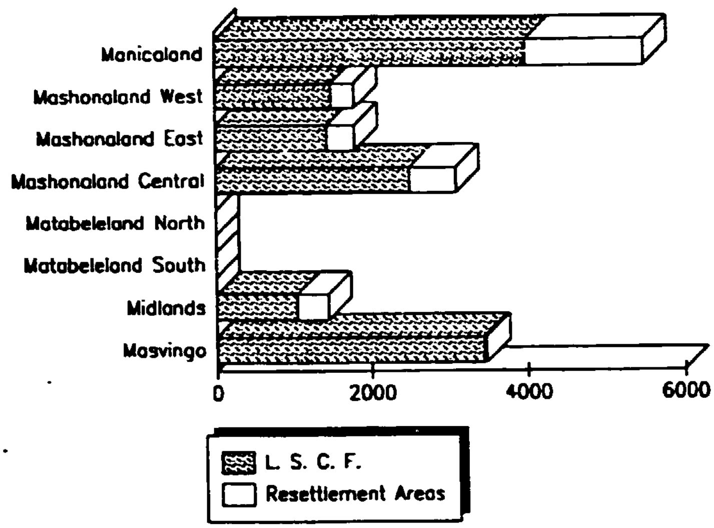

Annex 11b.

## Groundnuts Production by Province (1989)



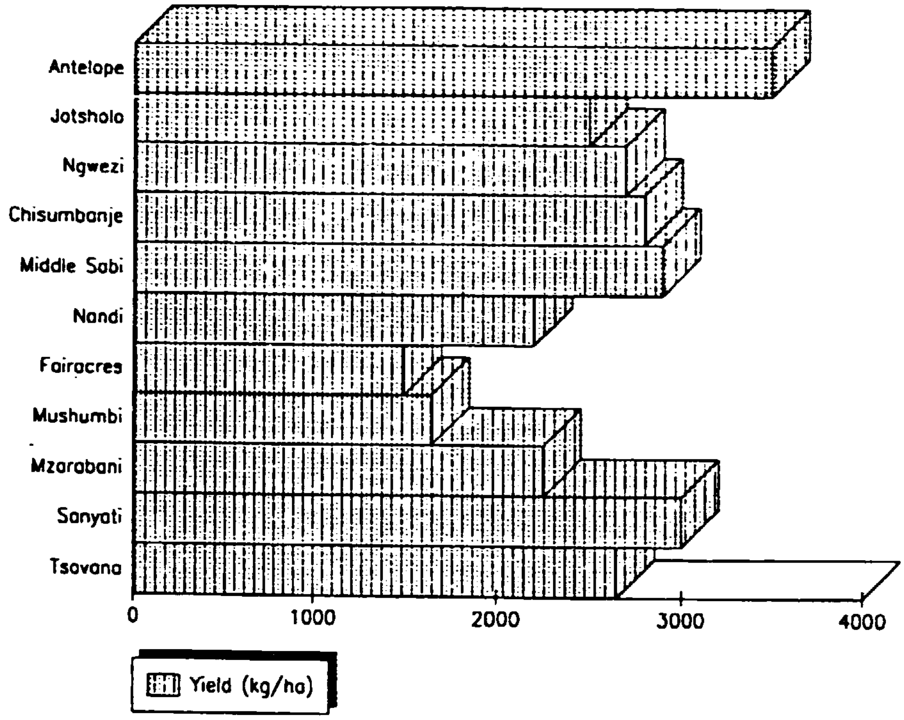
Annex 12.

## Cotton Yield (1989)

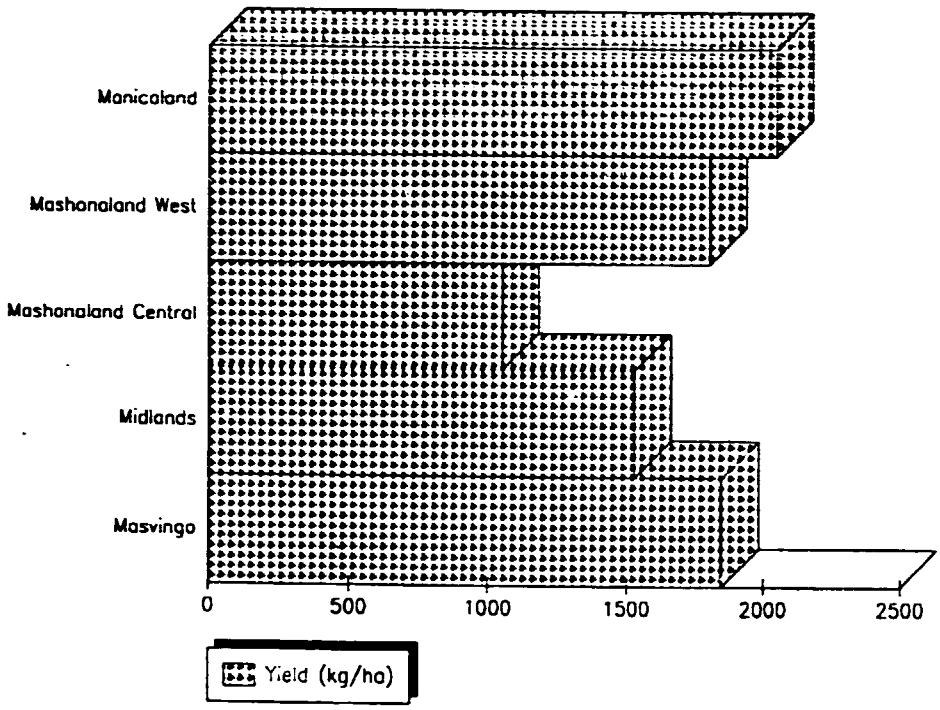


Annex 13.

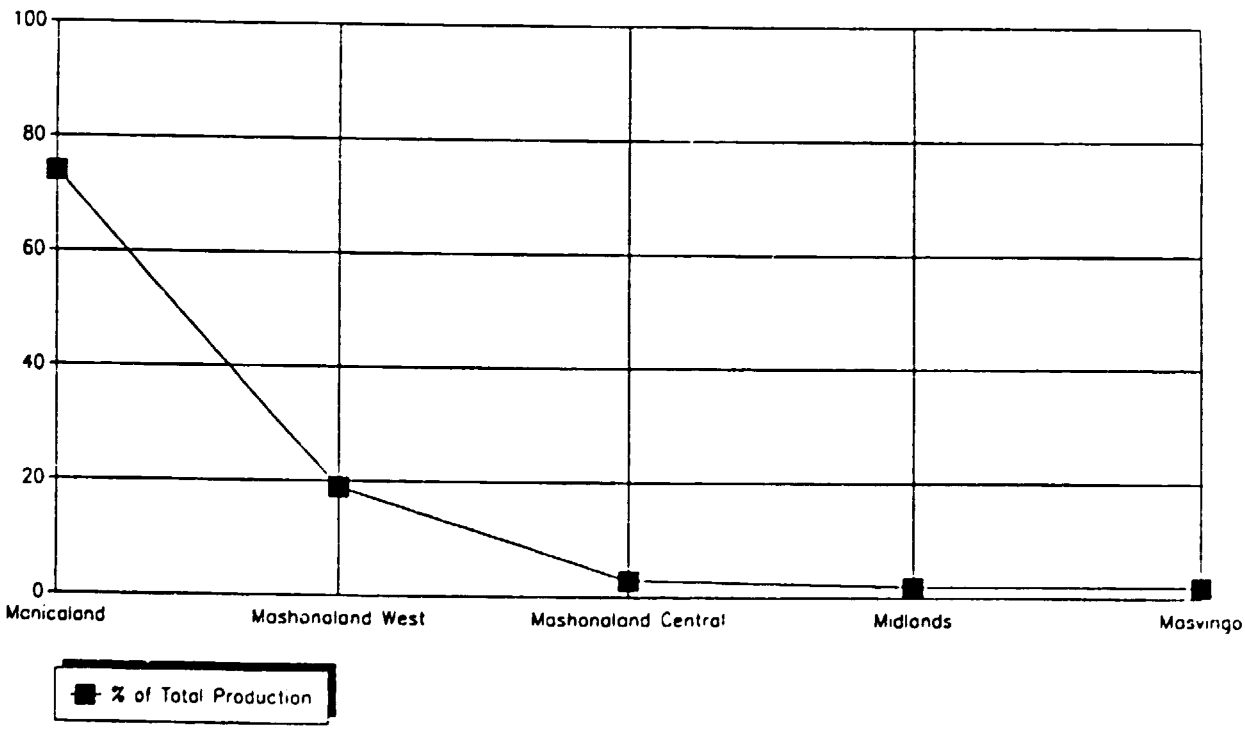
# ADA Estates Cotton Production (1989)



## Coffee Yield (1989)

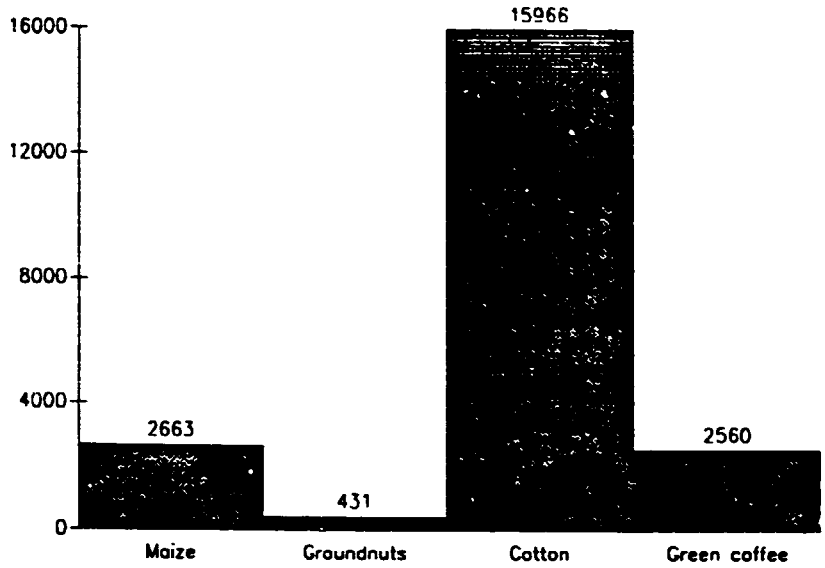



## Coffee Yield as a percentage of Total Production



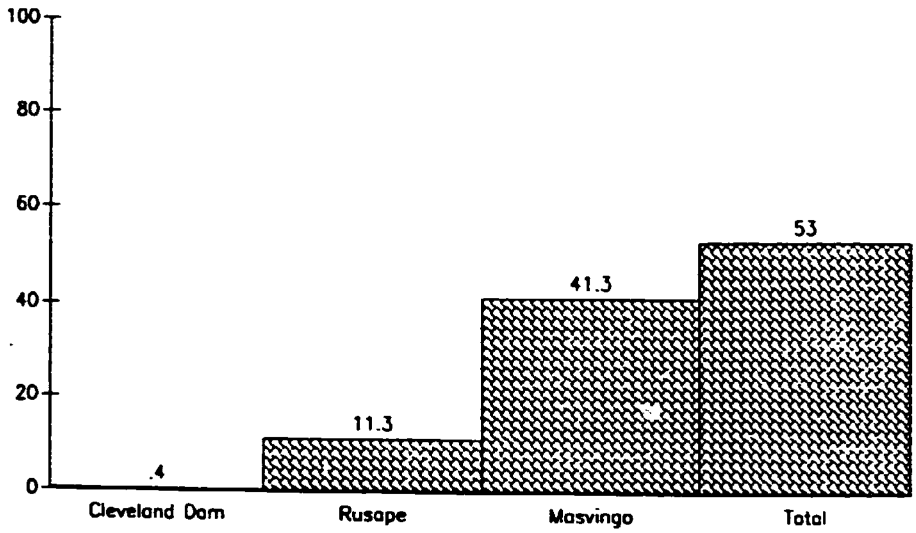
Annex 15.

# ADA : Principal Crop Production, 1989 (000' kg)



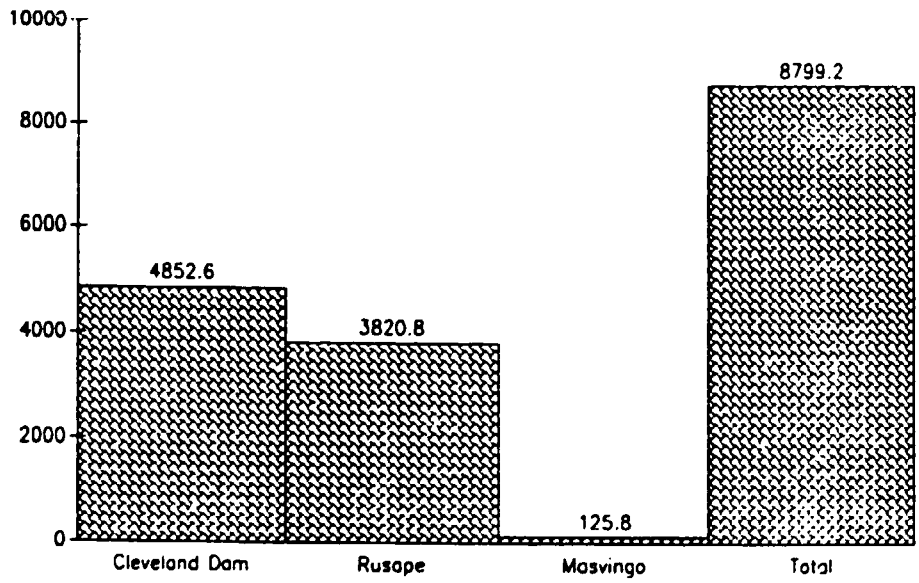
Annex 16a.

## Groundnuts : Shelled (Tonnes)

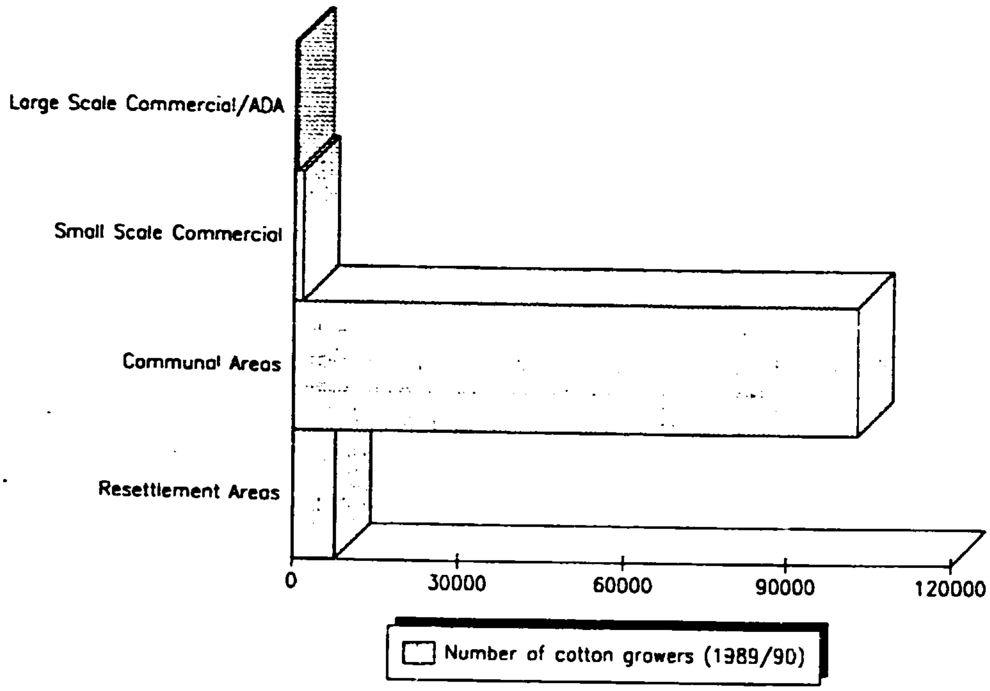


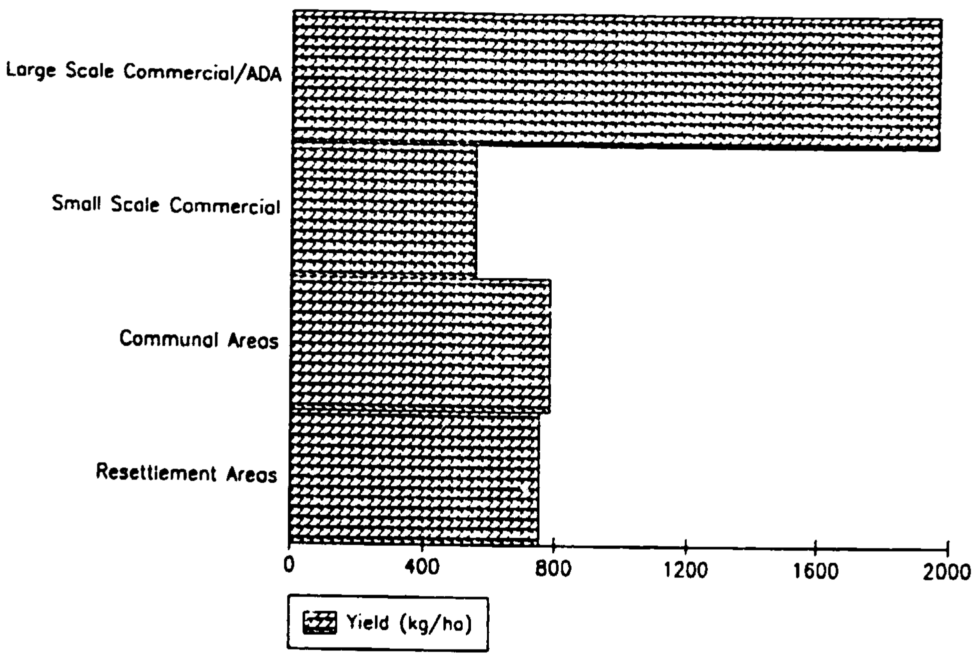

Annex 16b.

## Groundnuts : Unshelled

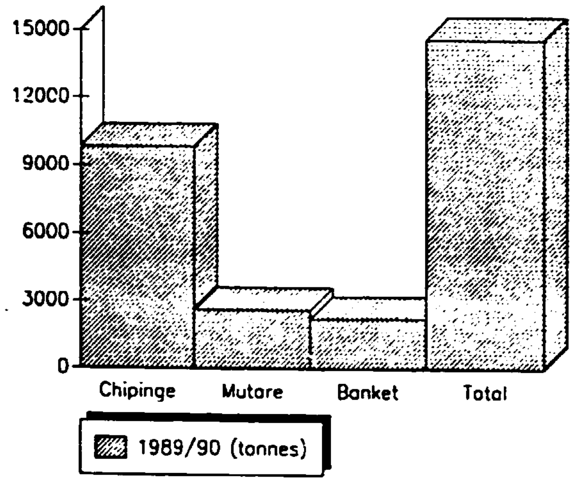


# Cotton Production in Zimbabwe (1990)



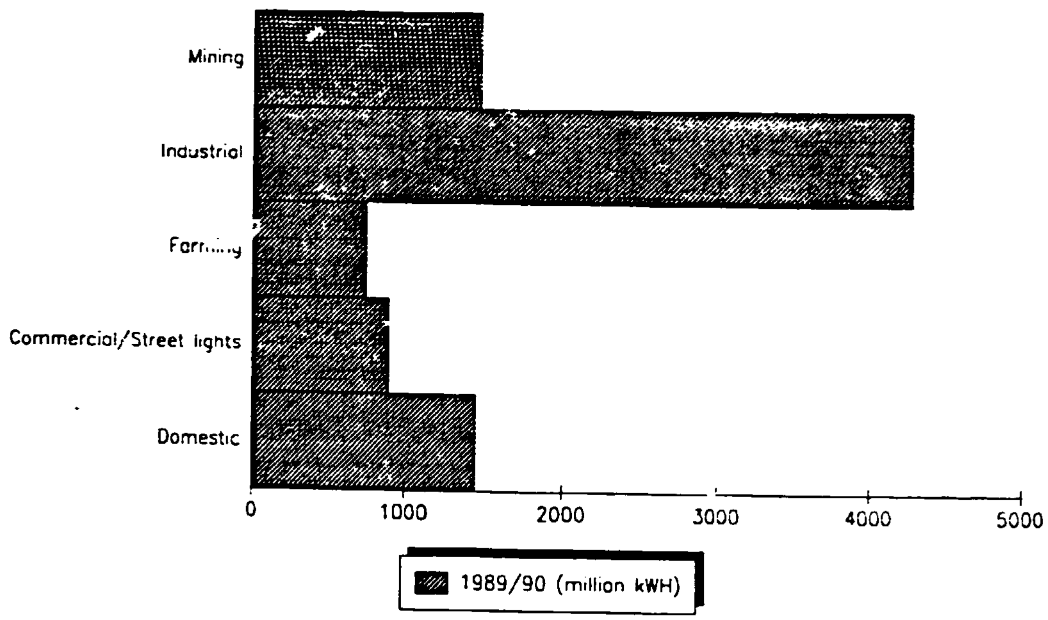



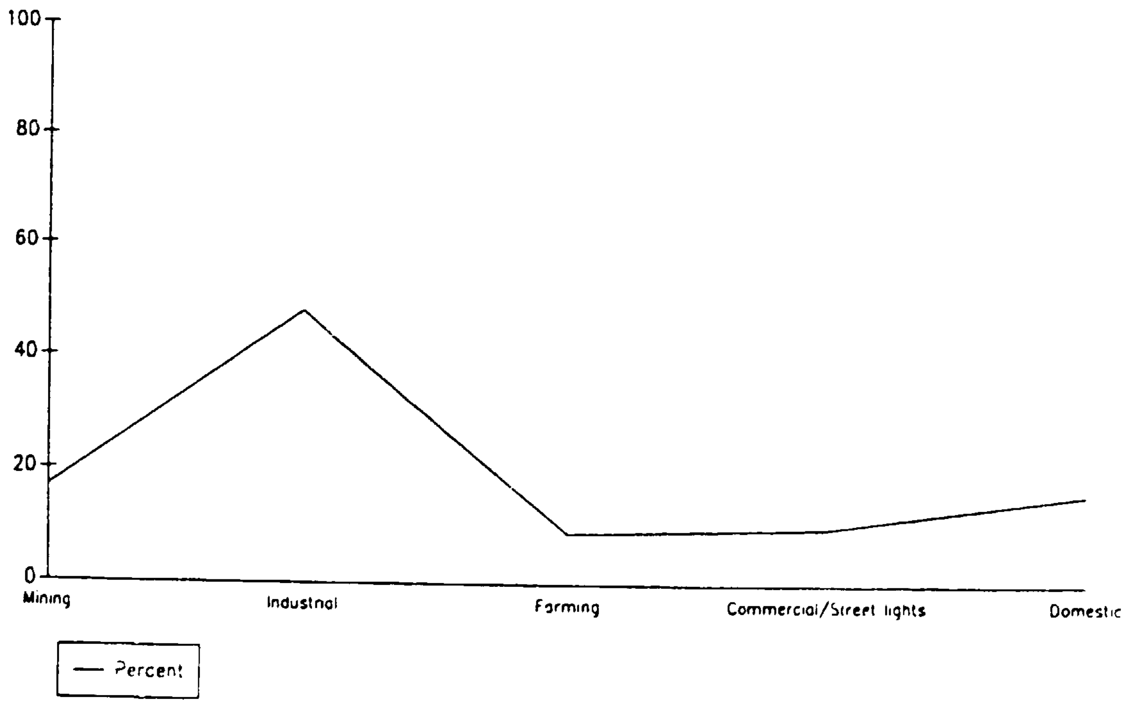
# Coffee intake at its Principal Depots



Annex 19.

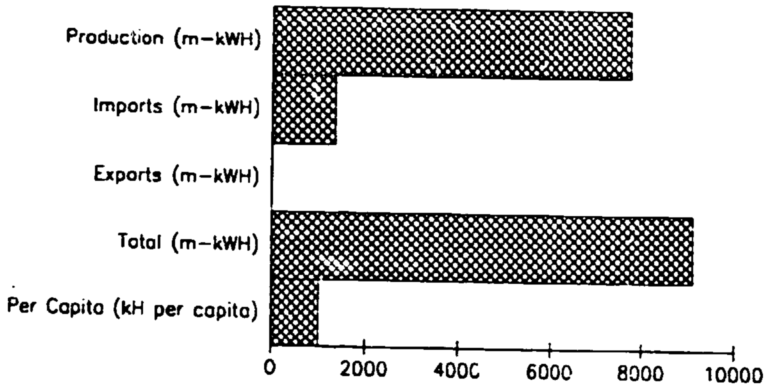
# Energy Sales by Sector



Annex 20.

# Production, Trade and Consumption of Electricity (1988)



## 13. Selected Reading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