OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.

DISCLAIMER

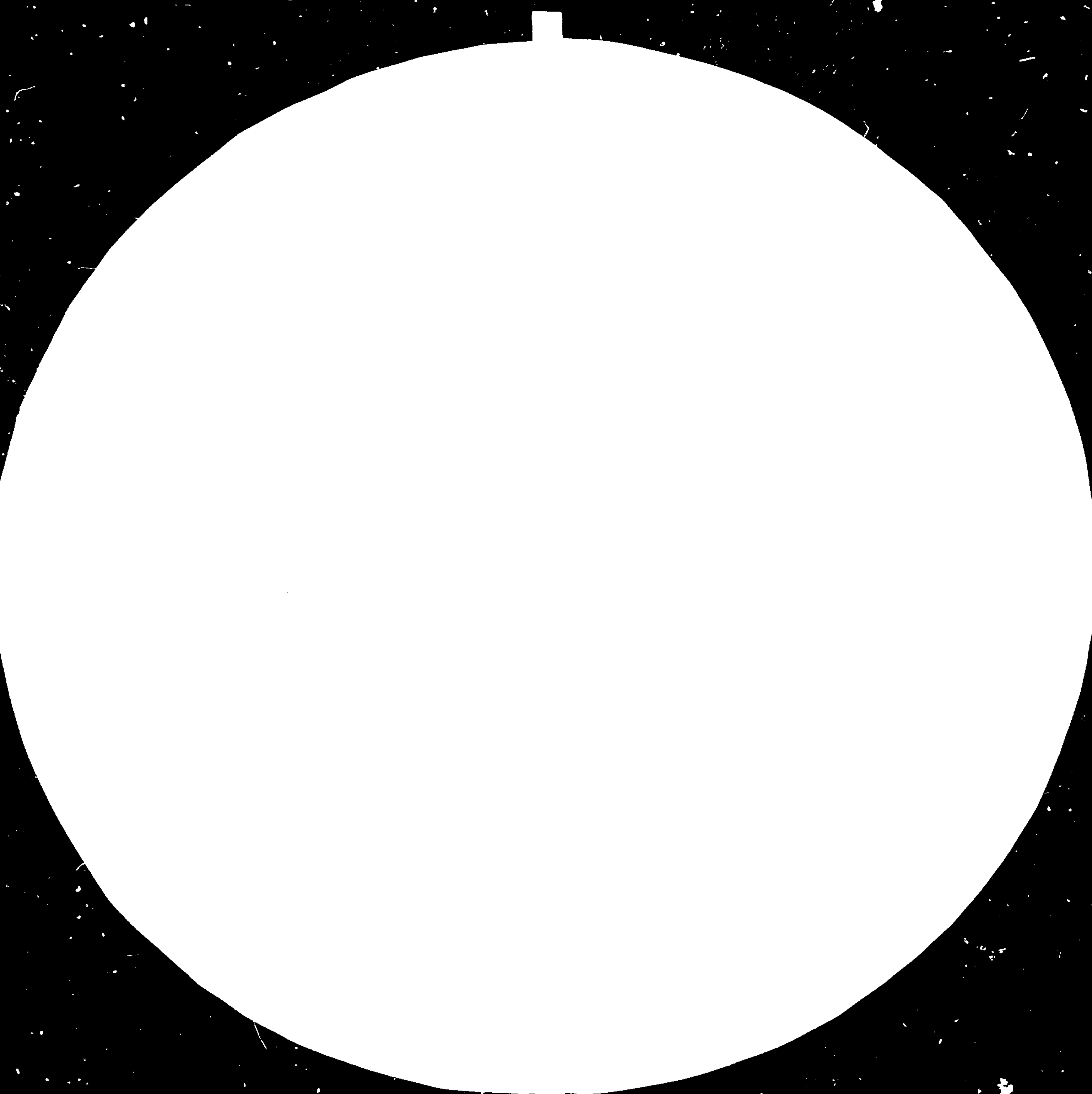
FAIR USE POLICY

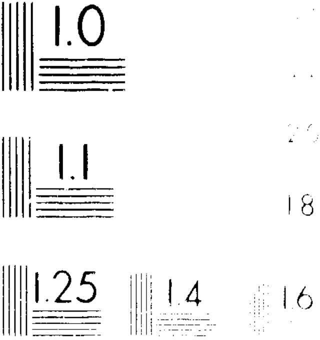
CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org




1.0
1.1
1.25
1.4
1.6
1.8

14030

RESTRICTED

June 1984
ENGLISH

Ethiopia.

THERMOCHEMICAL CONVERSION OF BIOMASS MATERIALS FOR ENERGY PRODUCTION

UC/ETH/82/164

ETHIOPIA

(Biofuels Demonstration Programme)

Technical Report *

Prepared for the Government of Ethiopia
by the United Nations Industrial Development Organization,

Based on the work of Prem D. Grover,
expert in thermochemical conversion technologies

United Nations Industrial Development Organization
Vienna

* This document has been reproduced without formal editing.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF PHOTOGRAPHS

Acknowledgment

The author would like to thank UNIDO for inviting him to undertake this mission. Dr. Myint Maung and Dr. (Ms.) Dagmar Runca-Köberich, Vienna, and Dr. Kadress Vencatachellum and Mr. Arni M. Heineman are acknowledged for their kind assistance during the mission. The author is thankful to Ms. Lucia Kornis for typing and Ms. Tezer Ulusay de Groot for administrative support.

Dr. Eng. Gebru Woldegiorgis, Executive Secretary, ENEC, Mr. Omar Mohammed Geta, and Mr. Yayha Mohammed provided facilities and actively assisted the consultant during his mission in Ethiopia. Their generous co-operation is gratefully acknowledged.

Summary and Recommendations

The major problem in Ethiopia is the acute shortage of domestic fuel. This necessity has led to extensive deforestation with its associated problems. Further large scale burning of animal dung is depriving the land of this fertilizer.

In this report, these issues have been highlighted and agro and forestry biomass residues suitable and available for converting them into efficient domestic fuels have been identified. These are coffee husk, cotton stalk, corn cobs, wheat and barley straw, and logging and milling residues amounting to 320,000 tons of oil equivalent. Considering that the total domestic fuel requirement for Addis Ababa is 168,500 tons of oil equivalent, this represents a substantial source to replace the fire wood presently consumed.

The various thermochemical conversion technologies suitable for Ethiopia have been identified. Only those technologies which have a proven record of commercial operation in other developing countries have been recommended in this programme.

During the present mission, two units, namely biomass gas stove and drum charring unit got fabricated and their performance demonstrated to the minister and top officials of Ministry of Mines and Energy. These simple yet important technologies having been demonstrated to Ethiopian National Energy Committee , steps have been suggested for their wide scale dissemination.

The basic necessity being domestic fuel to replace the conventional usage of fire wood, a number of demonstration plants for charring and briquetting of above mentioned raw materials such as coffee husk, cotton stalk and corn cobs have been incorporated. Being smokeless in combustion characteristics, these briquettes should find ready acceptance as efficient domestic fuel. One unit to make densified logs of wheat and barley straw has been recommended; these logs can be used in industrial furnaces.

There are no gasifiers known to have been working in Ethiopia. To introduce this important technology for conservation of petroleum products, two gasifier demonstration units have been recommended. One charcoal gasifier to operate a 15 HP irrigation pump and one wood gasifier to operate a 40 HP saw mill will serve the requirements for their demonstration and training of manpower.

The financial inputs required for this programme both from UNIDO and Government resources are estimated and included in this report (7.12). The total financial outlays for these demonstration programmes covering a period of 4 years, amounting to US$ 1,354,000 from UNIDO and Birr 1,075,000 per year as recurring expenses from Government of Ethiopia have been estimated. It is anticipated that within a period of 2-3 years, under this project, the Government can recover Birr 1,720,0C0 per year from the sale of fuel products.

Institutional supports for these demonstration projects have been identified. It is also suggested that to monitor these projects and carry out their system analysis and modification of designs etc., a small centre, known as Biomass Energy Development Centre should be set up at Addis Ababa.

1.0 Introduction

Ethiopia is basically agrarian and forestry based country with a land area of 1.22 million square kilometers making it the tenth largest country in Africa. Its gross domestic productivity per capita in terms of energy intensity is lowest compared to many neighbouring countries. GDP* per capita for Ethiopia is 140 compared to 390 for Kenya, 360 for Sudan, 260 for Somalia, and 200 for Uganda.

The most important issue in the energy sector is the supply of household fuel, the related massive deforestation and depletion in agricultural resources. Urgent steps are, therefore, needed to preserve the meagre existing forests, for massive afforestation programme and substitution of conventional fuels with proper utilization of agro and forestry wastes. At present, due to lack of infrastructure and as convenient method of disposal, these residues are being burnt in the fields and forests.

Agro-residues namely coffee husk, cotton stalk, maize residues, wheat and barley straws are available in substantial quantities, in addition to logging and milling wastes. By introducing proven thermochemical technologies and direct briquetting processes, these residues can be converted into convenient fuels for domestic and industrial sectors. These technologies are new to the Ethiopian environments. Therefore, extensive support from international development agencies in terms of finances, technical and managerial inputs, training of personnel and demonstration of technology in Ethiopia are a few steps requiring urgent implementation.

Development of efficient stoves, specially for cooking of "Injera", a local bread, and their wide scale dissemination should be a major activity. The institutional set up to carry out these tasks should be strengthened.

With no proven reserves of either coal or petroleum and with limited resources of foreign exchange, the conservation of petroleum products is another issue worthy of immediate consideration. With the introduction of gasification technologies, petroleum products can be substantially conserved for operating agro and forestry industries, lift irrigation and generation of electricity in remote areas.

During this mission these issues have been discussed. An elaborate programme of setting up demonstration plants has been recommended to introduce these technologies in Ethiopia.

---

* 1980 data from World Bank

2.0 Energy Requirements

The major consumption of energy in Ethiopia is in the household sector amounting to about 93% of total energy consumption. The traditional fuels such as firewood and charcoal still contribute 88.3% of the total domestic fuel demand in Addis Ababa with an estimated population of 1.79 million.

For 82% of the population living in rural areas the entire energy requirement is derived from firewood, charcoal, bark, leaves and animal dung.

Due to this massive requirement of forest products and clearing of forests for food production, the landscape of Ethiopia has changed dramatically with an estimated forest cover of 40% at the beginning of the present century to about 3-4 percent as at present. This has resulted in major ecological problems, threatening the very existence of man and animals.

The Government of Ethiopia (GOE) is well aware of this crisis and brought out an extensive survey and action-oriented report (1). In this report the problems of domestic fuels requirements have been clearly highlighted and measures recommended to solve these both on long and short term basis. In a subsequent report (2), World Bank Mission has brought out data on overall energy consumption pattern in Ethiopia reproduced in Table 2.1.

Table 2.1

Final Energy Consumption, 1982

(1,000 toe)*

	Biomass	Electricity	Petroleum	Total	Share (%)
Industry	30	35	102	167	2.1
Transport	-	-	349	349	4.4
Agriculture	-	1	31	32	0.4
Households	7,402	16	18	7,436	92.8
Commerce/ Government	-	11	21	32	0.4
Total	7,432	63	521	8,016	100
Share (%)	92.7	0.8	6.5	100	-

(1) A study to surmount domestic fuel problems in Ethiopia, June 1981.

(2) World Bank Report No. 4741-ET, Ethiopia - Issues and options in the energy sector, March 1984.

* one ton of oil equivalent (toe) = 10.2×10^6 kcal
= 42.74 thousand mega joules.

2.1 Future Energy Requirements

The future demand and consumption pattern of energy (2) in 1992 are reproduced in Table 2.2.

Table 2.2

(1.000 toe)

	Biomass	Electricity	Petroleum	Total	Share (%)
Industry	104	98	198	400	3.7
Transport	2.3	-	576	599	5.5
Agriculture	-	2	177	179	1.6
Household	9,570	42	73	9,685	88.5
Commerce/ Government	-	13	29	42	0.4
Total	9,697	155	1,053	10,905	100.0
Share (%)	88.9	1.4	9.7	100.0	

The above data clearly indicate that even in future, biomass energy will play a key role in the overall economic development of Ethiopia.

2.2 Domestic Fuel Consumption Pattern

The survey carried out by Ethiopian National Energy Committee (ENEC) and presented in report (1) indicates the predominance of forest products up to 94.8% in the overall consumption of domestic fuel in Addis Ababa. These are reproduced in Table 2.3.

Table 2.3

Domestic Fuel Consumption in Addis Ababa - 1979

Type of fuel	Volume consumption in tons	Energy needs met (%)
Wood	499,789	74.8
Charcoal	44,349	13.5
Butagaz (L.P.G.)	3,390	1.7
Electricity (megawatt hr)	1,980	0.08
Kerosene	55	0.03
Barks	11,120	2.0
Cotton Seeds	10,760	1.95
Dung	7,670	1.14
Leaves	21,605	4.5

It has been estimated (1) that for moderate living, 1 m^3 of firewood or its thermal usage equivalent of 150 kg of charcoal is required per person per year. With 75% contribution from firewood for domestic energy, it implies constant annual availability of $37.3 \times 0.75 = 28 \times 10^6$ m^3 of wood, for an estimated population of 37.3* millions in Ethiopia.

Taking the logging yield of 30 m^3/hectare it would need to clear $28 \times 10^6 \div 30 = 0.93 \times 10^6$ ha of forests every year. This amounts to about 20% of the total forest land in Ethiopia estimated as 4.8×10^6 ha (4% of total land area of 1.2×10^6 $(km)^2$).

As it is neither possible nor desirable to involve the usage of such a magnitude of forest land, alternative resources will have to be developed expeditiously to meet the domestic fuel crisis.

According to FAO/ADB report (3), rationing of domestic fuel had been imposed, which meets only 16% of the requirements. The rest of the requirement is, therefore, being met by private suppliers.

According to the discussions with state-owned "Wood and Charcoal Products Processing and Marketing Enterprise", responsible for procurement and supply of fuels in Addis Ababa, charcoal is being brought to Addis Ababa from as far as 600 km and wood from 250-300 km.

* This estimate is approximate as the census in the country is in progress.

(3) Report No. 26/81 of the Ethiopia Addis Ababa Fuel Wood Plantation Project Preparation Mission FAO/ADB.

Inspite of the long distances involved in procurement with associated high transport costs, against the procurement target of 98,078 m^3 of firewood in the nine months period (July 1983 to March 1984), the enterprise could manage to distribute only 32,800 m^3. However, they managed to supply 135,938 sacks of charcoal against the planned target of 46,375 sacks (one sack contains 40-45 kg charcoal). This was made possible as a large amount of forest land is being presently cleared for the increased area required for agricultural production which is definitely a temporary phase. Even with this temporarily increased supply of charcoal, the enterprise could meet less than 60% of the total fuel demand for Addis Ababa.

The short falls are therefore being met by private traders who are selling a sack of charcoal for Birr 30-40 (1US$ = Birr 2.07) against a controlled price of Birr 15.50. Similarly firewood is being sold at 2-4 times the controlled price of Birr 20.40 per stacked volume (13 stacked volume/m^3).

Due to these ever increasing shortages, it is estimated (1) that in Addis Ababa about 20% of the income of an average middle class family is spent on domestic fuel.

Table 2.4 (1) gives the annual fuel demand of cities in Ethiopia with deteriorating supply and estimated volume of firewood available within 100 km of their respective radius (1980).

Table 2.4

Cities	Annual demand	Available wood for cutting (1.000 m^3)	Difference	Percent Short fall
Addis Ababa	1,380	335.8	1,044.2	- 75.6
Asmara	470	28.0	442	- 94.1
Nazareth	93	-	-	-
Gonder	91	62.5	28.5	- 31.3
Assab	28	none	28	- 100%
Harar	79	24.6	54.4	- 68.8
Diredawa	107	-	-	-
Mekele	54	36.5	17.5	- 32.4
Dessie	77	80.7	- 3.7	+ 4.8

The data on the quantities and pattern of energy consumption in rural areas is lacking. Under a collaborative programme with the Government of Italy, data on the consumption of energy and availability of biomass resources are being collected. [Cesen (4) (Finmeccanica - Ansaldo Group), Centro Studi Energia Renzo Tasselli, Via Serra 6 - 16122 (Italy) is involved on behalf of the Italian Government.]

3.0 Biomass Resources

As already described, the major requirement of energy (93%) is in the domestic sector. With extensive deforestation, wood and wood charcoal cannot meet the requirements in this essential and priority sector.

The Government plan to replant 20,000 ha of forests every year is highly inadequate to meet the growing demand of domestic fuels. This implies that the standing forests will have to be cleared to meet the gap between the supply and demand unless immediate measures are taken to substitute firewood and charcoal with other non-conventional sources of energy.

Because of high initial investments, the role of solar and wind energy is going to make only marginal impact in the near future. High costs of appliances used in kitchen for electricity would prevent its large scale usage. However, with large hydroelectric and geothermal potentials its utilization should be encouraged.

With no established sources of fossil fuels like coal, petroleum and natural gas, increasing reliance has to be concentrated on the efficient utilization of other biomass resources. The resources are agro-based residues which are neither fodder nor used for its fibres; logging and lumber wastes and animal dung. Due to shortage of fuels, these residues are being extensively used for cooking with low thermal efficiency of 7-10%.

The strategy, therefore, should be to use animal dung as a source of biogas and improved fertilizer for rural and semi-urban areas and thermochemical conversion technologies of making charcoal briquettes to meet the demand of urban population. Gasification technologies can also be utilized for decentralized integrated industries and also for pumping water for irrigation/drinking and other allied applications.

3.1 Agricultural and Forest Residues

According to Cesen report (4) in 1981, 7×10^6 ha of land was cultivated for agro-products. The cultivation is carried out by private farms, peasants co-operatives and in state farms. 90-95% of land with private farmers is having a land holding averaging 2 ha per family. There are unregistered co-operatives (minimum 3 farmers) and registered co-operatives with 30 farmers. The latter get benefits from the Governments in the form of subsidies and favoured credits.

The species-wise production of agricultural products and associated residues is given in Table 3.1. Though the total residues from agricultural production amounts to 7.3 x 10^6 tons the major portion of these is being used as fuel fodder and construction of rural dwellings.

To supplement traditional domestic fuel, initially, the residues from state farms and coffee processing plants, which are available in bulk quantities should only be considered.

The estimated annual availability of these wastes is given in Table 3.2.

Table 3.1

1981 Annual Production

Species	Product	Area cultivated ha x 1000	Avg. Production ton/ha	Total tons (x 1000)
Teff	Grain	1,366	0.8	1,080
	Straw		1.5	2,096
Barley	Grain	930	0.8	750
	Straw		0.6	560
Maize	Grain	885	1.3	1,200
	Leaves		2.0	1,770
	Stocks		0.4	345
Wheat	Grain	630	1.0	630
	Straw		0.8	500
Sorgum	Grain	900	0.9	810
	Leaves and stock		1.3	1,170
Millets	Grain	260	0.7	190
Horse Beans	Grain	736	0.4	310
	Stock		0.6	440
Chick Peas	Grain	126	0.6	75
Coffee	Grain	710	0.9	115
	Stalks		0.3	213
Beans and	Grain	110	0.6	6[illegible]
Lentils	Stalks		1.9	210

Table 3.2

Yearly availability of collectable residues

Residues	Yearly availability (t)
Coffee husk	150,000 (a)
Cotton Stalk	239,000 (b)
Wheat and Barley Straw	105,000 (b)
Maize residues including cobs	108,000 (b)
Total	602,000

(a) Based on dry processing of coffee.

(b) 1980-81 data based on state farms (2).

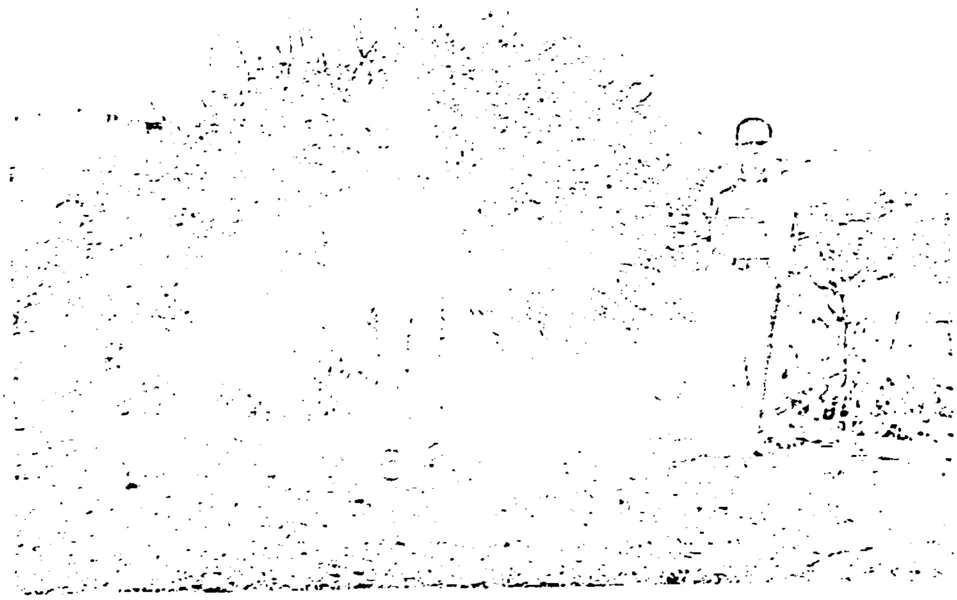
Table 3.3

Forest wastes availability 1982

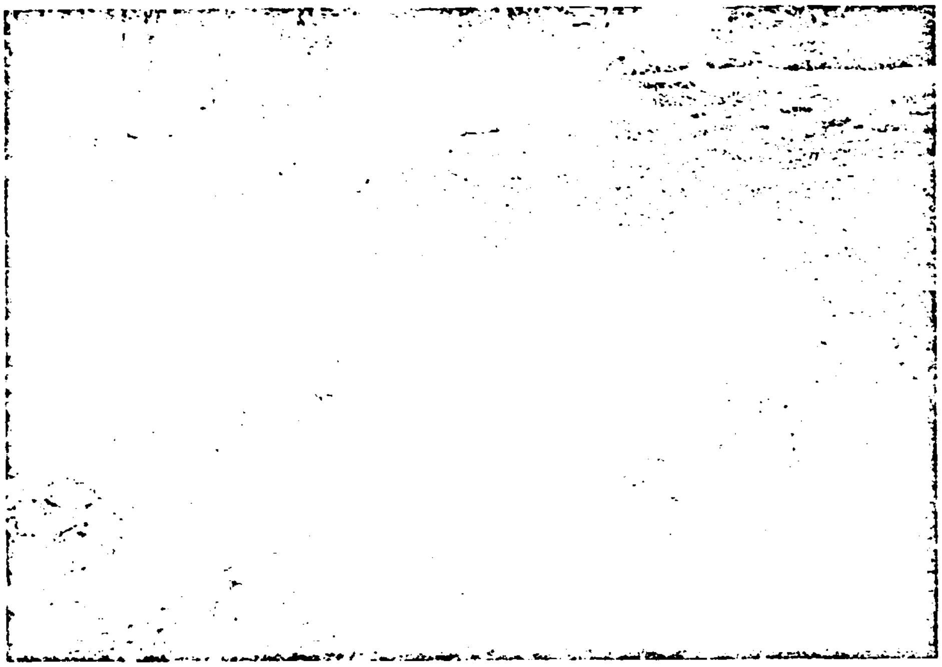
Logging wastes	tons/year
Twigs, leaves, etc.	265,000
Lumber wastes	26,250
Saw dust	17,750
Total	309,000

The quantity of forest residues (Table 3.3) is being obtained by clearing 150,000 - 200,000 ha/year of forest land. This is being carried out to meet the fuel demand and also for retrieving land for farming.

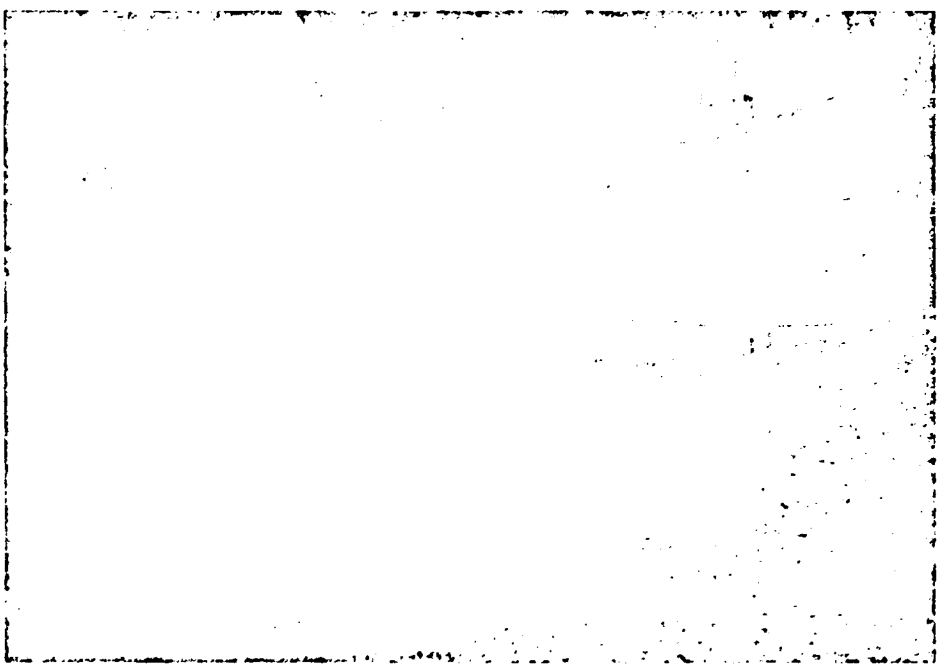
These residues, given in Table 3.2 and Table 3.3 are invariably burnt in the farms and forests mainly as a means of disposal. Only a marginal amount is being utilized as fodder or fuel.

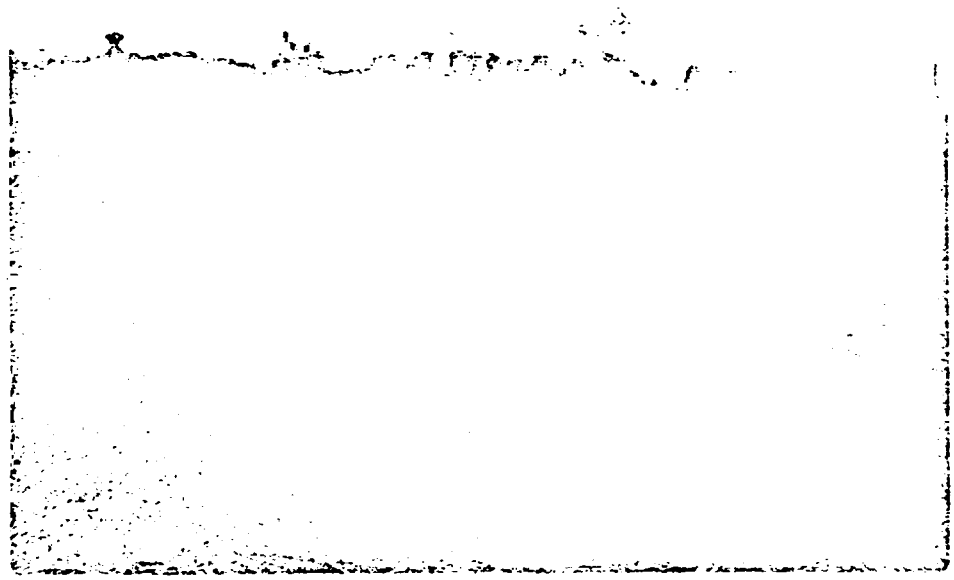


3.0 Dry Cotton Stalk Pile at Awash

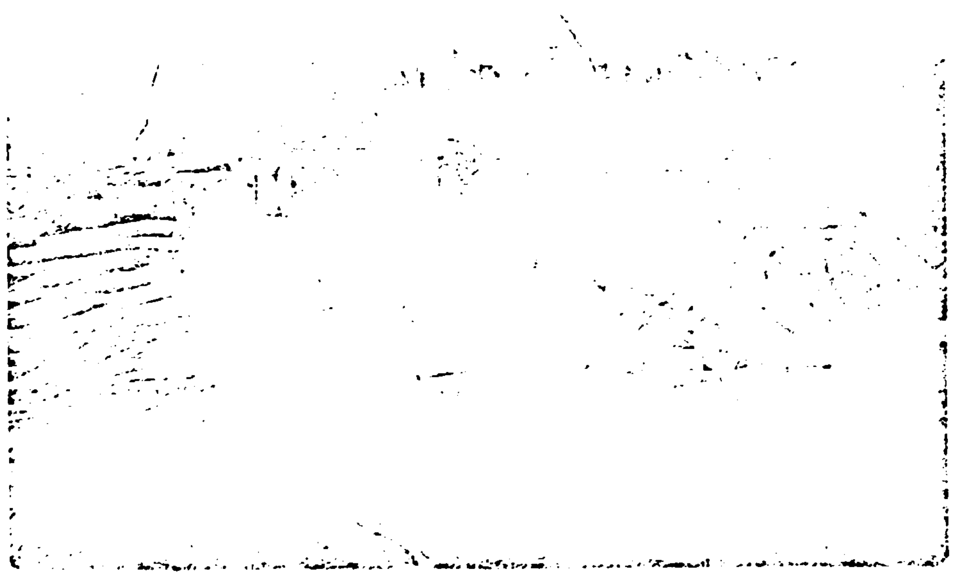


3.1 Coffee Husk Being Burnt at Coffee Processing Plant Yirga - Alem





3.2 Twigs and Logging Residue Being Burnt



3.3 Wood Being Piled for Charcoaling

In terms of energy the collectable agro-wastes from state farms and coffee processing units amount to 206.5 x 10^3 toe, and from forests it is of the order of 113.6 x 10^3 toe.

Considering that the total fuel consumption in Addis Ababa is 168.5 x 10^3 toe (based on per capita consumption of 150 kg charcoal for a population of 1.79 million), these resources are indeed significant and justifiable to use developed biomass technologies to convert them into domestic fuels.

Further that these residues can play an important role in the overall consumption of domestic fuel can be ascertained by comparing their energy content with those derived from various sources given in Table 3.4.

Table 3.4

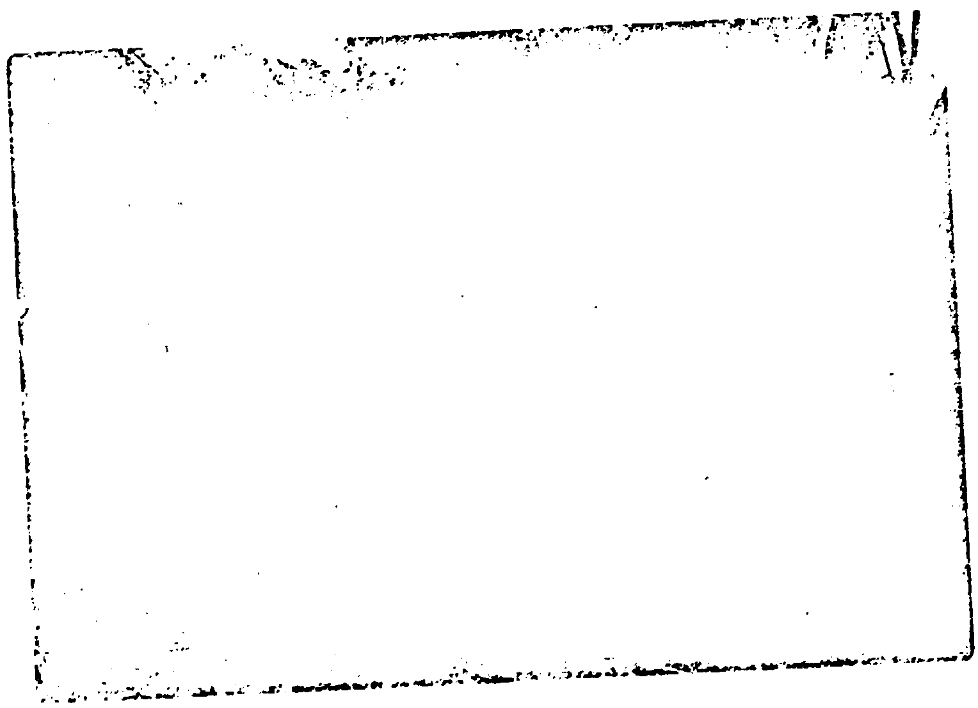
	Quantities as utilized	Tons of oil equivalent (1000 toe)	Fuel Consumption (%)
Firewood (inc. twigs and leaves)	8,829,000 tons	2,958	39.8
Charcoal	150,000 tons	101	1.36
Animal dung	7,864,000 tons	2,539	34.16
Crop residues	5,138,000 tons	1,803	24.26
Electricity	47 GWh	16	0.22
Kerosene	10,200 tons	11	0.15
LPG	4,800 tons	5	0.07
Total		7,433	100.00

World Bank Mission Report (2)

4.0 Appropriate Biomass Conversion Technologies

Over the years a number of thermochemical technologies for pyrolysis and gasification of agro and forest wastes have been developed and commercialized. As the commercial use of any technology is site oriented,therefore,only technologies appropriate to a particular country's requirements and fit into the infrastructure need to be exploited.

3.4 Conventional Charcoal Making in Progress



In this section only those technologies which are most appropriate for Ethiopia and have already been developed and tried in other countries are described. The selection of a particular technology depends upon the type and quantum of raw materials available and on the need for a particular type of end products.

4.1 Thermochemical Technologies

The thermochemical technologies fall under two main areas.

1. Pyrolysis to obtain gases, liquid and char products (briquettes).
2. Gasification of biomass to obtain combustible gases suitable for heating, and for operating engines.

Other related areas are direct liquefaction and also direct combustion.

Pyrolysis also known as carbonization, devolatilization, or destructive distillation, is a complex chemical decomposition reactive process but simply carried out by subjecting the biomass to thermal heating in the absence of air or oxygen. The presence of air during heating will lead to partial or complete combustion.

Depending upon the process conditions such as temperature, rate of heating, residence time and physico-chemical characteristics of the biomass, different yields and quality of three resulting fuels, viz gases, liquids and solids can be obtained. In the traditional method of making charcoal through carbonization from wood, the liquid and gaseous products are either burnt or lost to the atmosphere in the form of vapours.

The gaseous products can be used "in situ" for heating, drying and/or running engines.

The liquid products are obtained in two fractions. Water soluble and water insoluble known as tars. Water soluble fraction is known as pyroligneous acid and is good as preservative of wood especially from the attack of termites.

The water insoluble fraction known as wood tar can be processed to get many chemicals and liquid fuels. The fractionating of tar into pure chemicals needs elaborate processing, but by simple distillation, mixture of liquids and pitch can be separated. The liquids can be used as desinfectant while tar pitch can be converted into black paint with solvents like acetone and methanol. This tar is also useful for protecting the kilns and pyrolysers from corrosion.

The solid char can be either used as such when made from wood or crushed and compacted into charcoal briquettes.

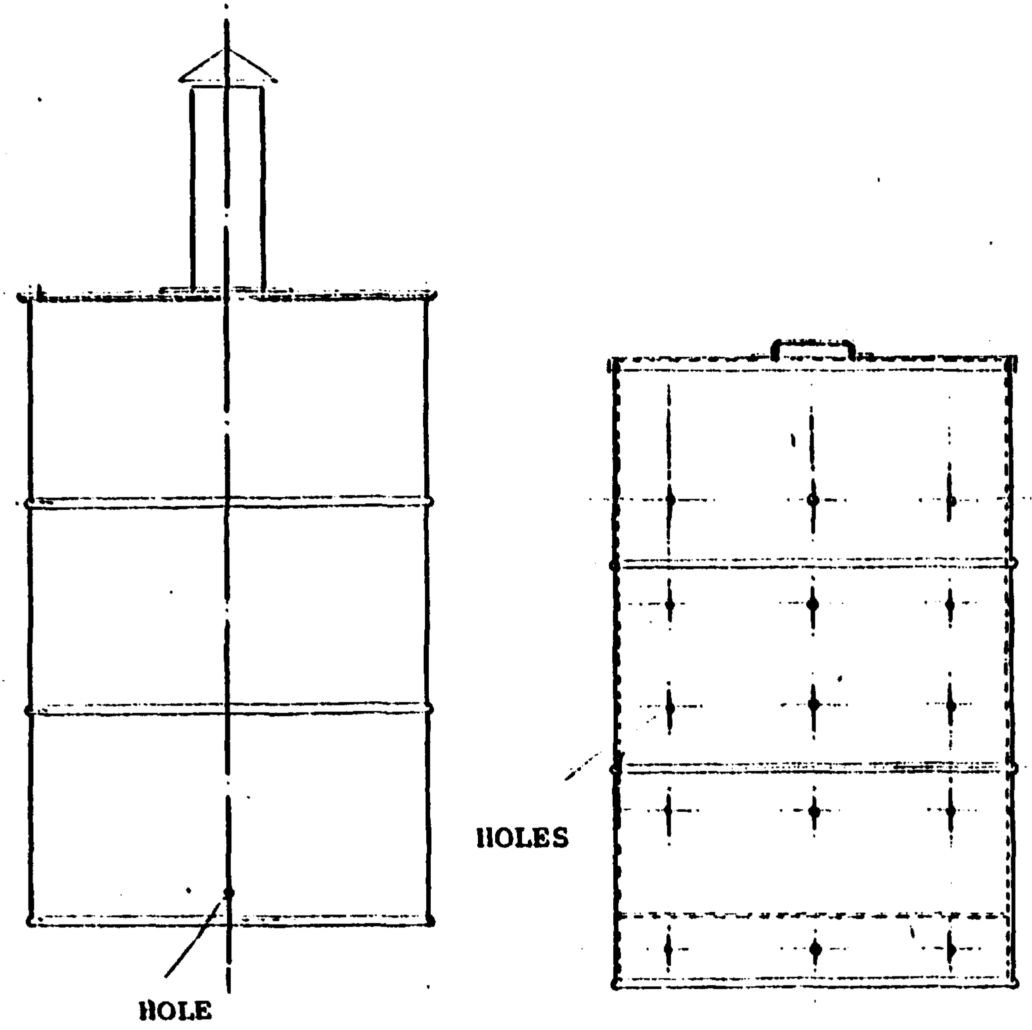
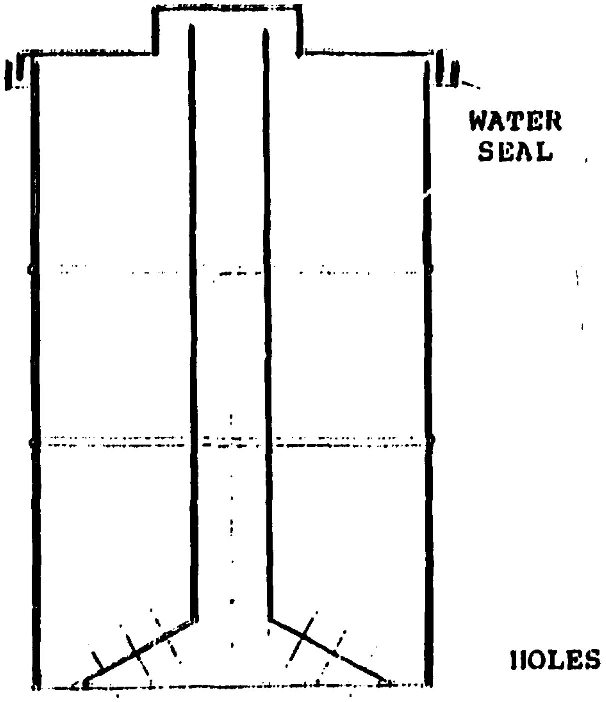


Fig. 4.1 DRUM CHARRING UNITS


WATER
SEAL
HOLES

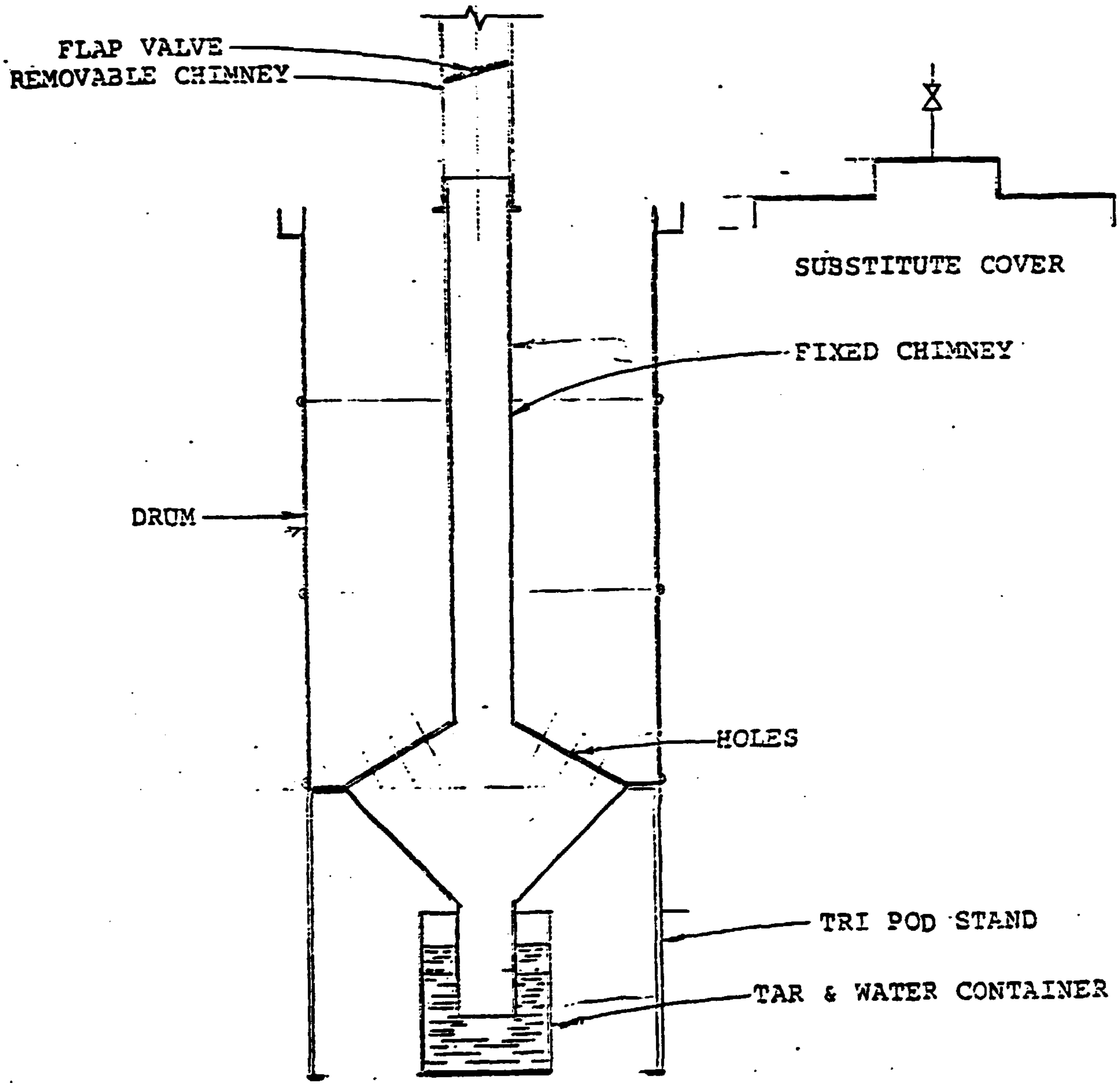


FIG. 4.2 MODIFIED DRUM UNIT

Gasification is normally carried out with restricted amount of air or oxygen or only in the presence of steam. When only steam is used in the gasifier, the heat for gasification has to be supplied indirectly either through an external source or by burning a part of the gas produced in the gasifier.

Apart from direct combustion, these gases can also be used to run gasoline engines with 100% substitution of oil and for diesel engines up to 75% diesel can be replaced by these gases. Thus gasification technologies can be used to pump water for irrigation, generate power in appropriate remote areas.

4.2 Appropriate Technologies

Considering the resources and the requirements, the appropriate technologies having immediate potentials for their utilization and exploitation in Ethiopia are briefly described. These technologies are already developed in other countries and need trials as demonstration plants in Ethiopia to evaluate their performance and social acceptibility. Some of the low cost/high benefit technologies can be taken as potential candidates for dissemination.

4.2.1 Drum Charring Units

Many simple and successful designs of small charring units manufactured out of 200 liter standard petroleum drums are available. Some of these are shown in Fig. 4.1 and Fig. 4.2.

These are employed to make charcoal on small scale basis from materials such as twigs, lumber wastes and agro-wastes like corn cobs and chopped cotton stalk. Based on wood blocks, 25 kg of charcoal can be obtained from 100 kg of sun dried wood in a period of six hours. The operation is simple and two persons can easily handle 10 drums to produce 250 kg of charcoal in a day.

The char obtained is manually crushed and mixed with moisture and binding clay like potter's clay and/or bentonitic clay and converted into briquettes. The briquettes can be made in the same manner as moulding of bricks from clay. The briquettes are dried in the sun and used as domestic fuel. Alternatively a manually operated briquetting machine can be used to extrude pellets of any desirable size.

4.2.2 Biomass Gas Stove

The gas stove shown in Fig. 4.3 can be used to get smokeless combustion from many types of agro and forestry residues. It is simple in construction having an airtight annular jacket around a conventional charcoal stove. The jacket is filled with biomass and the central portion with charcoal. When charcoal is ignited, the heat is also transmitted to the biomass.

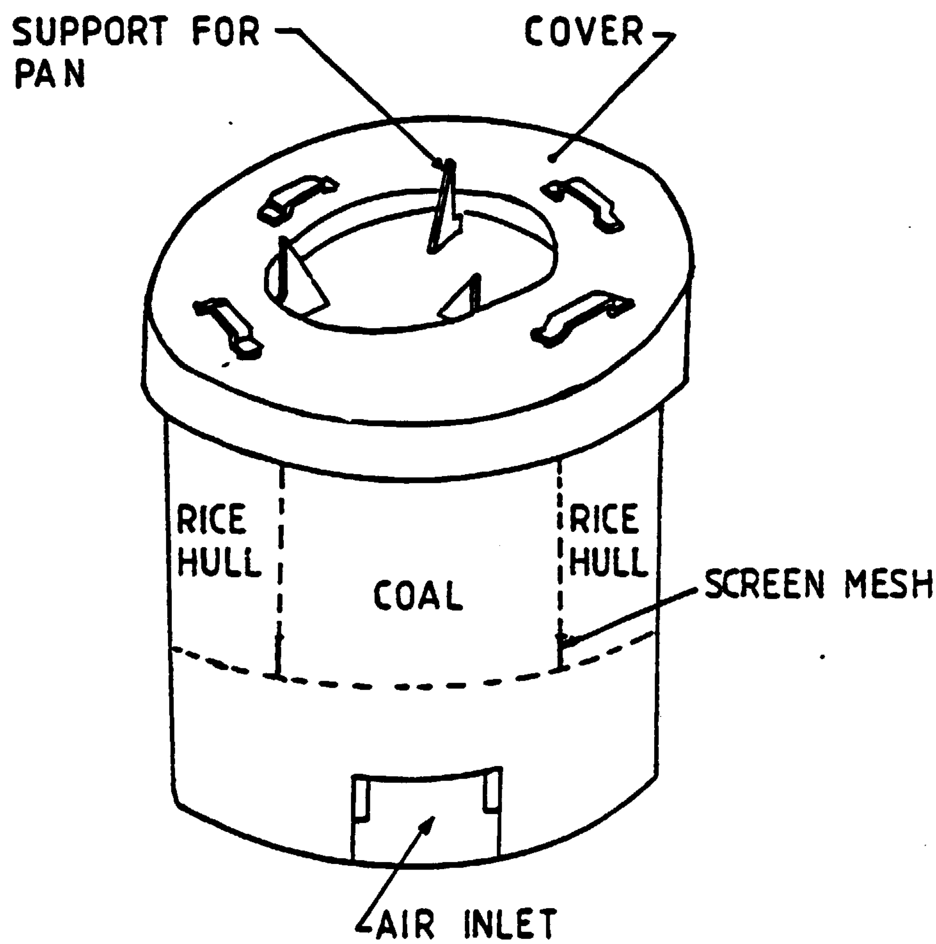


Fig. 4.3 RICE HULL STOVE

The biomass gets progressively carbonized and pyrolysis gases so produced are allowed to escape through the holes provided at the bottom of char coal bed. These gases, while rising through the charcoal bed, get thermally cracked and give smokeless combustion on the top of the stove. Once the carbonization is complete and the stove is extinguished, the char can be taken out, briquetted and reused as fuel in the same stove instead of charcoal.

The prototype unit shown in Fig. 4.3 and Fig. 4.4 would need 4 kg of biomass and 1.5 to 2 kg of charcoal to give intense heat for at least 4 hours. The biomass such as, coffee husk, saw dust, leaves, shredded straw, etc., can be used directly. Such stoves are meant for restaurants and other community kitchen as in police, army and hospital canteens.

The stoves have been developed at the Indian Institute of Technology, New Delhi, and named as "PARU" gas stoves.

4.2.3 Mobile Kilns for Wood

A number of mobile kilns have been developed to make charcoal from wood which give higher production rates, quality products and than better yields those obtained by either pit charcoaling or above the ground clay covered heap methods.

The advantages and disadvantages of charcoal production in steel kiln as compared with a brick work kiln and earthen pit are given in Table 4.1.

Table 4.1

Comparison of Charcoaling Methods

Terms of comparison	Portable steel kiln (oven)	Earthen pit	Brick work kiln
Cost ex. user's site (US$)	5,000	-	1,000 - 2,500
Internal volume (m^3)	6.5	8 - 30	50 - 130
Charcoal cycle (days)	3 - 4	20 - 30	9 - 25
Personnel	skilled	unqualified labour	unqualified labour
Mobility	yes	yes	easy to demolish and rebuilt
Life (years)	1.5 - 4	-	8 - 10
Charcoal quality	good	acceptable	good
Average efficiency	20	15	20
Max. size of wood (cm)	30 x 5 x 5	without limit	200 x 30 x 30
Performance in rainy weather	good	poor	good
Overheating and accident tolerance	poor	fair	good

(5) Unasylva Revue Internationale des Forêts et des Industries Forestières, FAO, vol. 33, No. 131-1981.

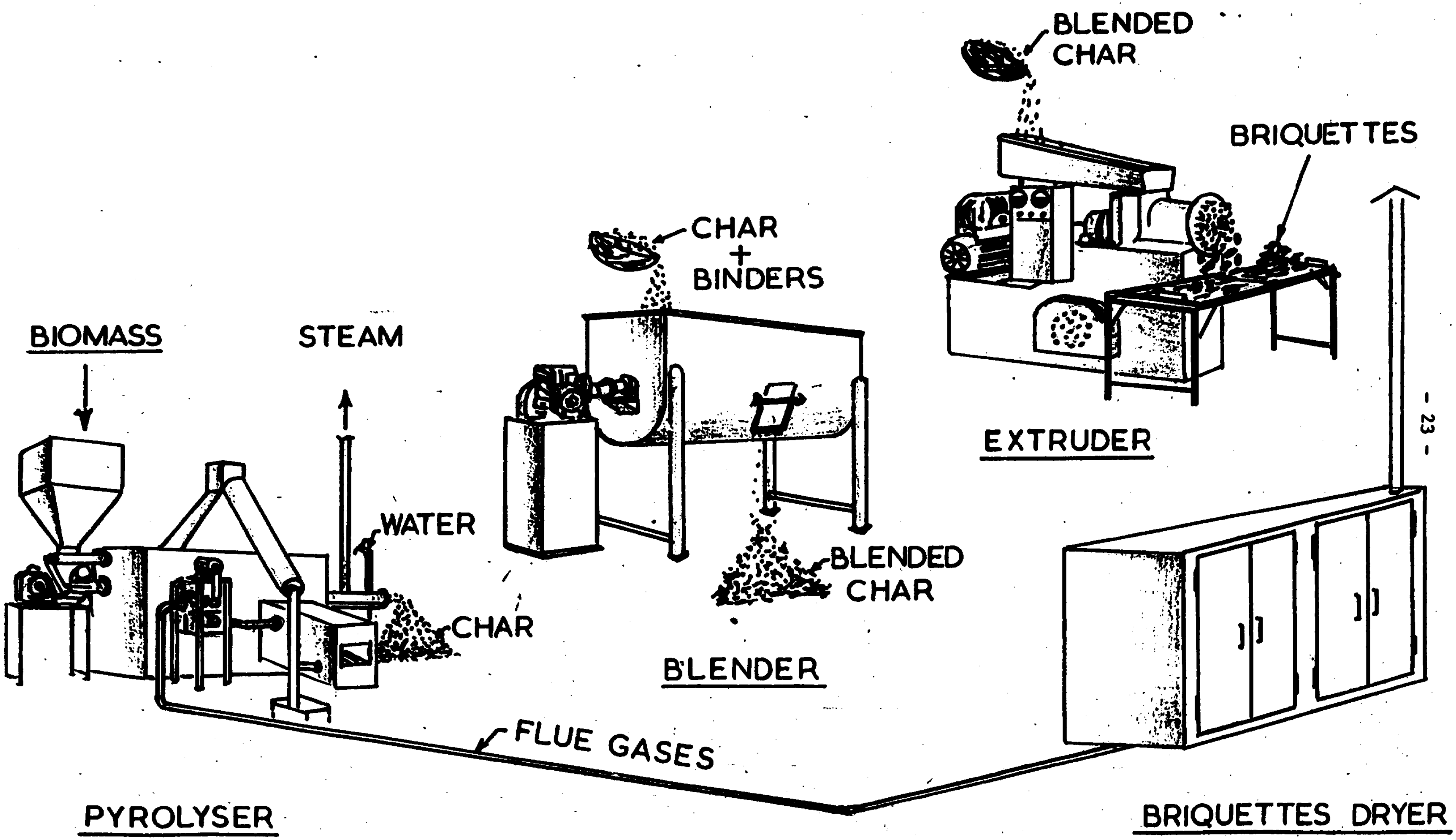


Fig. 4.4 "PARU" - BRIQUETTED FUEL MANUFACTURING PLANT

4.2.4 Mobile Kilns for Forestry and Agro-Wastes

Mobile kilns, which can be easily transported near the sources of biomass materials, have been developed in the Philippines under UNIDO/UNDP project (DP/PHI/78/022). These have been operated for making charcoal from coconut shells. With slight modifications, these can also produce granular/fine charcoal from other residues like cotton stalk, corn cobs, chopped branches and twigs and other such materials.

In construction, it is about 2 meter in height and 0.75 meter in diameter. Once lighted, the material is introduced continuously and charcoal is taken out periodically. Depending on the material, it can process 100 - 250 kg of feed per hour. No electrical power is required to operate these kilns.

In actual practice, a number of kilns can be installed in the farms, and the char obtained from each kiln is brought to a central processing station. During charring some ash will be produced which can be ploughed back into the soil. At this central processing station, the char is crushed, mixed with binder and briquetted in a mechanically operated briquetting plant. The briquettes so formed can be easily transported and used as smokeless domestic fuels in urban areas.

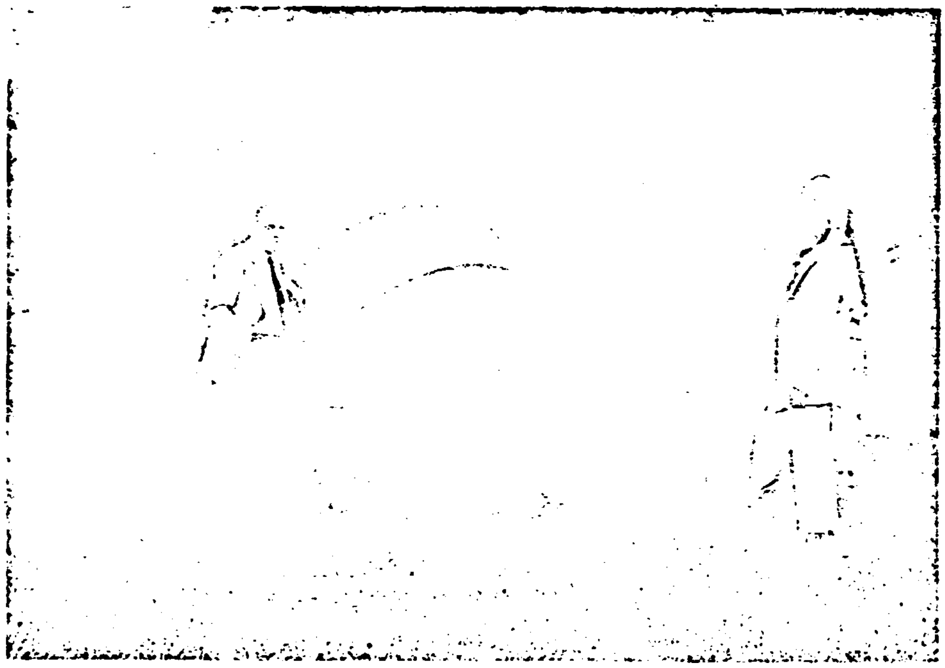
4.2.5 Mechanized "PARU" Charring and Briquetting Plant

Materials having fine and granular structure like coffee husk, saw dust, rice husk, shredded straw and pine needles cannot be carbonized in vertical shaft kilns of the type mentioned in the previous sections. Due to fine structure, these materials tend to pack densely in kilns giving problems of bridging and choking.

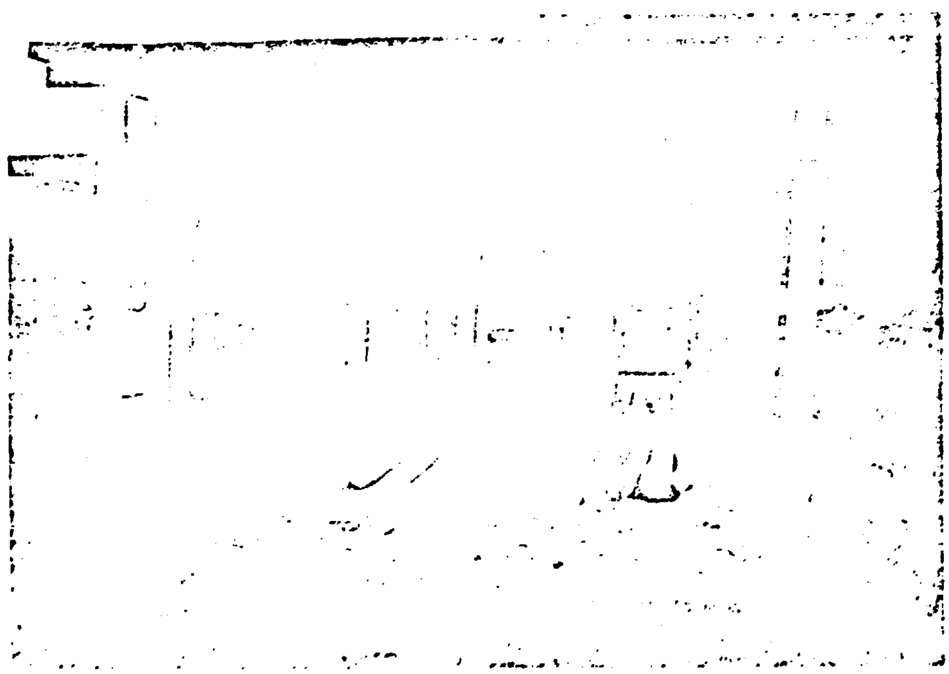
Materials of this type are partially carbonized in systems having mechanical conveyors with agitators as integral part of the pyrolyser. Ribbon mixture, briquette extruders and biquette dryers are commercially available in India. Till today, about 34 plants are installed. This technology has been developed at Indian Institute of Technology, New Delhi, and is termed as "PARU" fuel plants.

In this technology, the biomass is continuously pyrolyzed and pyrolysis gas so produced is recycled and burnt in a furnace to provide indirect heating required for pyrolysis. Further the hot exhaust flue gases are introduced into the briquette drier to provide requisite heat for drying of wet briquettes.

The commercial units of 4 tons briquettes/day capacity have been standardized, which is obtained from 6 tons of dry raw materials having moisture less than 10% by weight. The flow sheet of this unit is given in Fig. 4.4.



4.1 Mobile Kiln at Wendo - Genet



4.2 48 BHP Diesel Engine Operates Saw Mill at Forestry and Wildlife Resources Institute, Wendo - Genet

4.2.6 Wood and Charcoal Gasifiers

Numerous types of wood and charcoal gasifiers are operating in many countries of the world. Amongst the developing countries, Philippines has probably the largest number of charcoal gasifier being used for various applications.

Air gasification of wood/charcoal is obtained when these fuels are burnt under starved amount of air. The gases so evolved are combustible and have CO, H_2 and some hydrocarbon as combustible constituents.

The inert constituents are mainly N_2, CO_2 and water vapours. The mixture of these gases termed as "Producer Gas" has heating values from 1070 to 1426 kcal/m^3 (120 - 160 Btu/ft^3). The heating value depends upon the configuration and type of gasifier, the quality and type of biomass and the operating conditions.
Gasifiers are normally produced in the following configurations:

(1) Vertical shaft gasifier
(a) Updraft (b) Downdraft and (c) Cross flow

(2) Fluidized bed gasifier

(3) Entrained bed gasifier

(4) Rotary gasifier.

Depending upon the capacity, type and shape of biomass feed, and the end use of the gases, any particular configuration can be adopted.

4.2.6.1 Gas Cleaning

The cleaning of the gas forms an important feature of any gasifier. Producer gas is normally contaminated with tars, solid particles and water vapours. The extent of gas cleaning required depends upon its ultimate applications.

For direct combustion, minimal amount of cleaning is required. In case the gas is required as fuel to run engines/turbines, an elaborate cleaning is absolutely essential.

Under many circumstances, gas cleaning operation becomes more complicated and costly than the gasifier itself. To avoid elaborate gas cleaning, specially for mobile and small sized applications, it becomes necessary to use relatively clean fuels like wood charcoal and pyrolyzed agro-forestry residues either as granular char or in the form of briquettes.

The gas cleaning system does vary but essentially consists of (a) solid removal unit, (b) thermal cracker to decompose tars, (c) wet scrubber, (d) condenser to remove water vapours, and (e) demisters to remove final traces of liquid droplets.

In order to simplify the gas cleaning system, normally down draft gasifiers are employed which normally give relatively clean gas. In addition use of clean fuels like char will further reduce the requirements for gas cleaning and may eliminate some of the units mentioned earlier.

It is therefore desirable that for smaller outputs (less than 20 HP), for motive power, down draft gasifiers should be employed and operated on clean fuels.

As mentioned earlier, numerous applications of gasifiers have been identified. Some of these are:

(a) Pumping water for irrigation/drinking,

(b) Generation of electrical power,

(c) Running forest-based industries like saw mills,

(d) Running agro-based industries like rice and coffee processing units,

(e) Grinding of cereals and spices,

(f) Drying and curing agricultural products,

(g) Running mobile units like tractors and other agricultural implements,

(h) Operating concrete mixtures,

(i) Operating road vehicles and small boats.

4.2.7 Direct Briquetting of Biomass

The biomass residues are voluminous and low density materials. Therefore, these are difficult and expensive to transport. Also when used as fuels most of these burn much faster giving very low thermal efficiency in conventional stoves (6-8%) and require large volume of stove/furnace per unit release of heat. To overcome some of these disadvantages, many types of mechanical presses have been developed to densify these materials into logs, briquettes and bales.

The briquettes and to some extent, logs are only suitable as domestic fuels. These are produced by subjecting the crushed biomass to high pressure, of the order of 1500 bar, and temperature above 70°C, normally generated by mechanical friction, produced either by rotary screw extruders or by reciprocating piston press. Under these conditions, the lignin and moisture present in the biomass get reacted and act as binder. The briquettes so formed have a specific density of 1600 kg/m^3. To form such briquettes, it is essential that the material should be in a specific physical form and contain optimum moisture content recommended by the manufacturers of these machines (normally 10-12%).

Alternatively,the briquettes are also manufactured with the use of external binders. These binders are normally lignosulphonates, and briquettes produced by these machines have lower specific density and require lower pressure than that required for binderless briquetting.

Although the high density of briquettes is advantageous for easy bulk handling and transportation, yet this process and briquettes suffer from many serious drawbacks.

(1) The materials need pretreatment and must have optimum moisture content.

(2) Due to high density of briquettes (much more than wood) and devoid of porosity, these have excessive smoke forming characteristics and hence poor social acceptability as domestic fuel.

(3) The compacting machine is normally capable of handling only one type of biomass or even the same type (like sawdust) from one species. Due to this inflexibility, it is essential that the extensive trials of a particular raw material should be made on a specific machine before it is purchased from the manufacturers. Due to this very factor, many buyers and suppliers of machinery have incurred heavy financial losses.

(4) Due to low porosity, the gases produced inside the briquettes due to heat during combustion, carbonization and gasification cannot escape. The pressure generated by these gases tends to disintegrate these briquettes. To avoid this, it is desirable that the briquettes should be as small as possible which can be easily handled in a particular process.

(5) Due to the abrasive nature of biomass and the requisite high pressure for briquetting, the wearing of machine parts is excessive and expensive in maintenance.

Due to excessive smoke formation, these briquettes have very poor acceptibility as domestic fuel. It is therefore, desirable to use them in industrial furnaces to replace fire wood. In Ethiopia, most of the industrial boilers are using wood as the primary fuel.

For domestic fuel, it is more advantageous to partially carbonize the biomass and then form briquettes. The advantages of this process are:

(a) The briquettes give smokeless combustion.

(b) With the use of binders and moisture, the char is lubricated and wearing of the machine parts is much reduced.

(c) Being similar in appearance to charcoal, it has good social acceptability.

(d) With the carbonization carried to the extent of degrading the structure (150-200°C), 75% of original energy can be retained in the briquettes.

5.0 Technologies - Demonstrated - Transferred

During the present mission, two prototype units one each of "PARU" biomass gas stove (4.2.2) and drum charring unit (4.2.1) got fabricated and their performance were demonstrated to the Government officials of Ministry of Mines and Energy.

The designs and working drawings were supplied to ENEC and Mr. Hunde Kekeba and his partner of m/s Ethio Briquette Factory, P.O. Box 41509 Addis Ababa. Mr. Kekeba is negotiating with ECO briquettes, a Danish firm, to set up a briquetting plant at Addis Ababa.

Mr. Kekeba arranged to get these units fabricated by Mr. Costantino Gliptis, proprietor of fabrication workshop, Iron Industrial Installation, P.O. Box 40050 Addis Ababa.

The demonstration was arranged in the premises of m/s Iron Industrial Installation, on 28 and 29 May 1984.

The gas stove was operated on coffee husk and charcoaling of small wood blocks was demonstrated in the drum charring system.

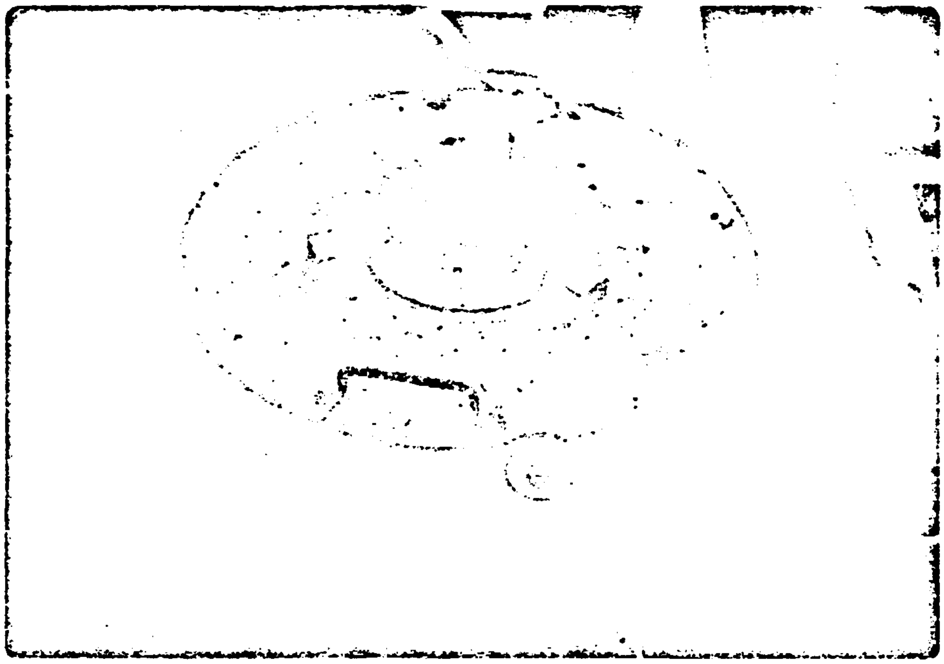
5.1 Officials attending the demonstration

On 28 May 1984 the demonstrations were performed in the presence of Dr. Eng. Gebru Woldegiorgis from ENEC and Mr. Arni M. Heineman from UNIDO.

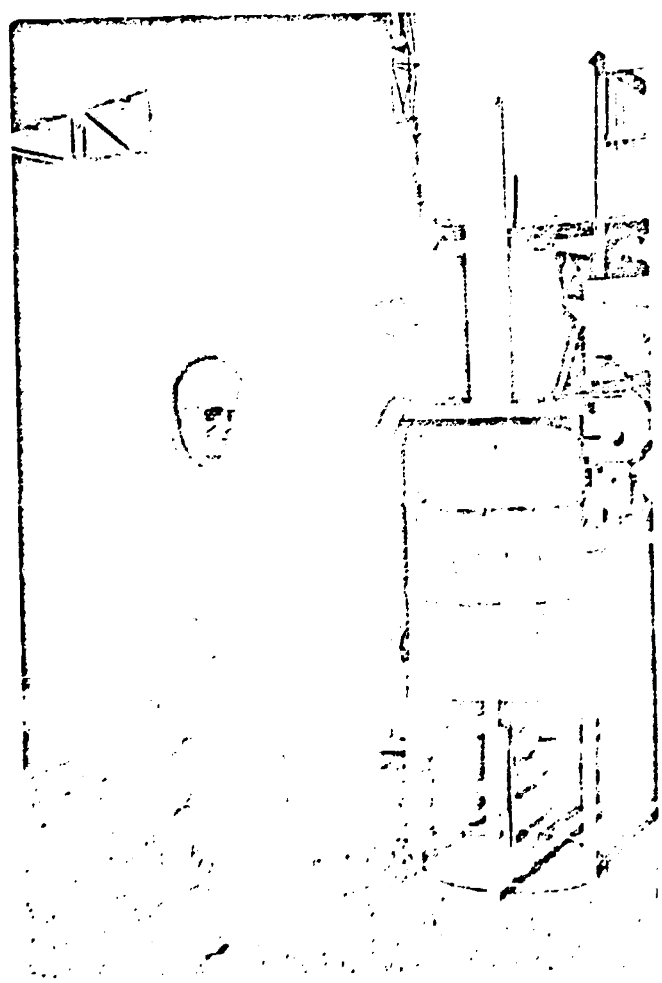
In addition to a number of engineers, the demonstrations on 29 May 1984 were attended by the following officials:

1. Eng. Tekazashoa Aitefisu
   Minister for Mines and Energy
2. Mr. Asafea Tiluahu
   Permanent Secretary
   Ministry of Mines and Energy (M.M.E.)
3. Dr. Eng. Gebru Woldegiorgis
   Executive Secretary
   Ethiopian National Energy Committee (ENEC),
   M.M.E.
4. Dr. Kaaress Vencatachellum
   SIDFA, UNIDO
5. Mr. Arni M. Heineman
   JPO, UNIDO
6. Mr. Enrico Pimpinelli
   Director of Irrigated Agricultural Division
   C. Lotti and Associates SPA.
   Consulting Engineer
   I-00186 Roma, Italy
   Via del Fuime - 14
   (on a visit to Ethiopia)

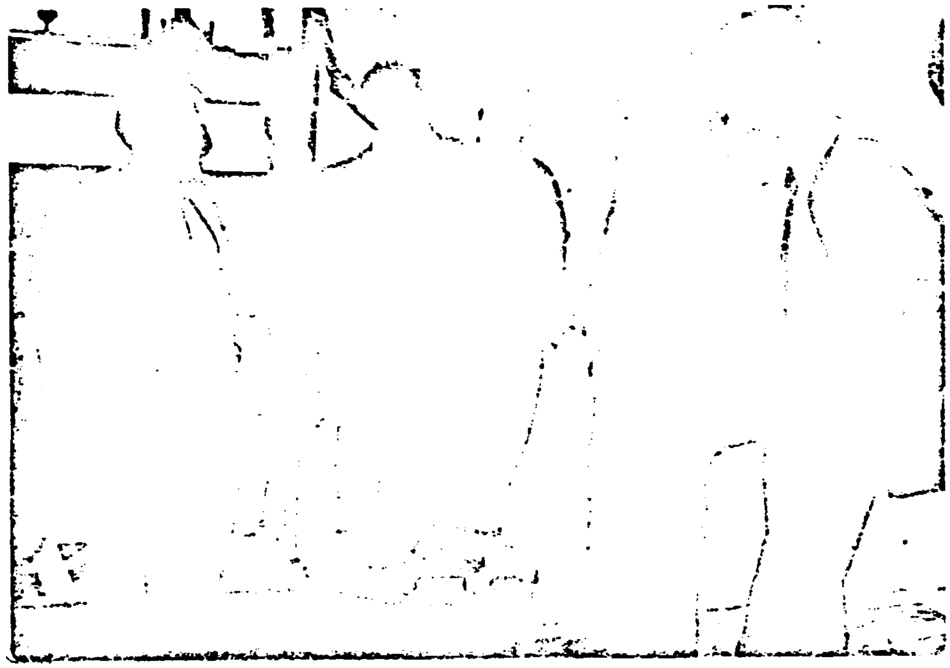
Technologies Demonstrated



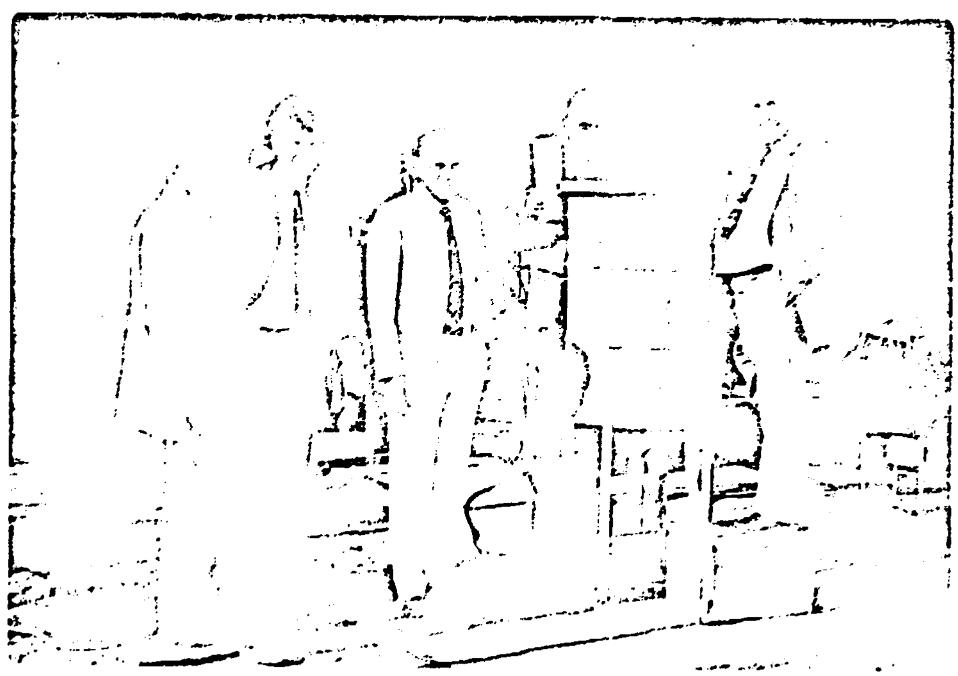
5.1 Biomass Gas Stove in Use



5.2 Drum Charring Unit



5.3 The Minister of Mines and Energy (second from left) witnessing the Performance of Biomass Gas Stove



5.4 Executive Secretary ENEC (extreme right) inspecting the drum charring unit

7. Mr. Debesai Tesfoin
   Head of Engineering Development
   Arsi Rural Development Unit
   Asela, Ethiopia

8. Mr. Yahya Mohamad *
   Mechanical Engineer, ENEC

These technologies having been demonstrated and appreciated by the top rank officials of Ministry of Mines and Energy, it was emphasized that immediate steps should be taken by ENEC for their dissemination. The designs for scale-down and scale-up models with two hearths of the prototype gas stoves were also provided. Extensive proliferation of these simple yet important technologies for Ethiopia, especially gas stove and their usage in such organized sectors as Army and Police kitchens and other community kitchen would result in substantial saving of fire wood.

6.0 Visits - Institutional Support - Priorities

In the course of present mission, extensive discussions were held with the officials of ENEC to identify the fuel problems and highlight the role of thermochemical conversion technologies in reducing the consumption of fire wood.

The opportunities and facilities were also provided by ENEC to visit many allied ministries, organizations and institutes who could be involved to support the demonstration programme envisaged in this project.

Some of these are:

1. Mr. Tesfaye Tadele
   Senior Planning Officer
   Ministry of State Farms Development, Addis Ababa (A.A.)

2. Mr. Tesfaye Asfaw
   Project Manager
   Ministry of Coffee and Tea Development, A.A.

3. Mr. Getachew Makuria
   Head, Basic Education Panel
   Ministry of Education, A.A.

4. Col. Tesfaye Legesse
   Secretary, Ethiopian Science and Technology Commission, A.A.

5. Mr. Bekele Damte
   Washed Coffee Processing Plant, A.A.

6. Mr. Aklog Laike
   Head, Production
   Wood and Charcoal Products Processing
   and Marketing Enterprise, A.A.

---

* Mr. Mohamad was consistantly associated with the present mission and responsible for biomass conversion technologies in ENEC.

7. Mr. Philipini
   Burayo Basic Technology Centre
   Burayo near A.A.

8. Mr. Mulugata Ayalew
   Secretary, Forestry and Wildlife
   Conservation and Development Authority, A.A.

9. a) Dr. Wolfgang Scheer, Professor (Mech. Eng.)

   b) Dr. Wolde Ghorgis, Woldemariam
      Assoc. Professor (Elec. Eng.)

   c) Chairman, Dept. of Mechanical Engineering
      University of Addis Ababa (Faculty of Engineering)

10. a) Mr. Kinpe Abebe, Principal

    b) Mr. Hans von Schoultz, Head of Academic Affairs
       Forestry and Wildlife Resources Institute
       Wendo - Genet (Near Awassa)

11. Mr. Kassaye Goshu
    Assistant Dean
    Awassa Junior College of Agriculture

12. Mr. Mulugeta Abera, Administrator
    Coffee Marketing Corporation Sidama
    Yirga - Alem

13. Monesa Charcoaling area Monesa

14. a) Mr. Amsalu Negussie, Head of
       Water Development and Soil Conservation

    b) Mr. Debesai Tesfoin, Head of
       Engineering Development
       Arsi Rural Development Unit Asela

15. a) Mr. Tazera Agegnehu, Head

    b) Mr. Mesfin Endezinaw
       Arsi Agricultural Development Corporation

16. The Manager, Lole State Farms

17. The Manager, State Cotton Farms
    Melka Sedi (Awash)

18. Mr. Moges Abrha, Manager
    MAAE - Enterprise
    Malka Saoj (Awash)

19. Mr. Zeratzion Woldehul
    Institute of Agricultural Research
    Melka Werer (Awash)

6.1 Institutional Support

The demonstration plants identified in the proceeding section (7.0)will be co-ordinated and executed by the Ethiopian National Energy Committee. The installation, testing and normal operation shall be the responsibility of a specific ministry/agency or organization. These will also be responsible for the availability of raw materials providing infrastructure, space, labour utilities and sale of the products.

The plants will require support from technical institutes not limited to but including the following activities:

(i) Performance analysis,

(ii) Material and energy balance calculations,

(iii) Chemical analysis of raw materials and the finished products,

(iv) Shattering and other physical tests of the briquettes,

(v) Testing the combustion characteristics of the briquettes in actual stoves,

(vi) Recommend modifications to improve the performance and quality of briquettes.

The above-mentioned data shall be periodically supplied to ENEC to enable them to carry out feasibility and socio-economic studies of these plants.

To enable the institutes to perform the assigned task requisite instruments, manpower and financial assistance have to be provided by ENEC. As far as possible, these should be met from the internal resources of these institutes.

6.1.1 Institutes identified

The institutes identified to carry out the above task are based on the criteria that these have the requisite infrastructures such as laboratories/workshops, technical expertise and above all the close proximity to the sites of these plants.

(a) Forestry and Wildlife Resources Institute, Wendo - Genet

The institute started in 1978 with active collaboration and financial inputs from SIDA. It has requisite expertise, both Ethiopian and foreign faculty members and recently acquired a spacious academic block with adequate laboratory space. The collaborative agreement with SIDA shall continue at least for the next five years. Meant to train 70 students in forestry science, engineering and management, as forest rangers per year, the institute has its own forests, agricultural and dairy farms, workshop and 48.5 BHP diesel engine operated saw mill in an enclosed area of 540 hectares.

Demonstration plant for wood gasification , and retrofitting the saw mill diesel engine should be done in the institute. Laboratory testing instruments, "PARU" gas stove and drum charring system should also be provided. The stoves, apart from training the foresters, can be used in the students' canteen.

(b) Awassa Junior College for Agriculture, Awassa

The institute has its own well equipped campus capable of imparting theoretical and practical training to about 300 students per year in the areas of home science, agricultural engineering, animal and plant sciences and technology. With its own dairy and vegetable farms, three biogas plants have already been installed. Home Science Department is also active in developing cheap and reliable cook stoves made from local materials. The agricultural Engineering Department has well equipped workshops, laboratories and drafting section: Many new agricultural implements are being developed.

Apart from fuel testing laboratory instruments for the institute, the Home Science Department should be provided with PARU gas stove and drum charcoaling units.

Agricultural Engineering Department should be entrusted with the responsibility of providing technical inputs to coffee husk charring and briquetting demonstration unit proposed to be put up at Aleta Wendo in Awassa district.

(c) Arsi Rural Development Unit, Asela

This institute situated in Asela about 160 km south of Addis Ababa is basically responsible for integrated development of rural areas in Arusi administrative region. Activities include imparting training to peasant associations and small farmers in the use of agricultural implements, and providing infrastructure such as feeder roads, irrigation systems and incentives for rural industries. Area covered by this institute has fertile land for growing wheat,barley, rapeseed and some maize and other crops in irrigated areas near Lake Ziway.

The institute has necessary infrastructure with well equipped workshops and technical expertise. Maintenance of agricultural implements like tractors including overhauling of engines and irrigation pumps are regular activities of this institute.

As proposed in the proceeding section, the Engineering Department of this institute can be entrusted with the responsibility of providing technical support for two demonstration projects:

(1) Charcoal gasifier for 15 HP engine pump for irrigation;

(2) Direct briquetting of wheat straw proposed to be set up at 12,000 hectare state farm at Gardela about 100 km away from Asela.

Requisite instruments and other associated inputs as envisaged for other institutes should be provided to monitor the performance of these demonstration plants.

Two sets, each of gas stoves and drum charcoaling system should be provided to the institute to carry out training and dissemination of these technologies in this area.

(d) Institute of Agricultural Research, Melka Werer Research Station

This agricultural research station is engaged in providing scientific and engineering inputs for the development of agricultural production in middle Awash area. This region is basically a cotton and banana production centre and well irrigated with water from Awash, one of the major rivers in the country.

Though, not as well equipped as other above-mentioned institutes, yet it has basic facilities and infrastructure including laboratories and workshops. The institute has ability to provide technical inputs for a demonstration project on charcoaling and briquetting of cotton stalks, proposed to be installed in this region.

Similar inputs as envisaged for other institutes should also be provided to this institute. In addition, a mechanical/chemical engineer should be specially hired for this institute to look after this programme.

Institutional Support for Corn-Cobs Project

The maize is extensively produced in the western part of Ethiopia. Due to limitation of time, the visit to this part of the country could not be arranged. However, based on criteria used for identification of above institutes, for technical support, a technical institute at Nejo about 100 km west of maize growing farms at Dedessa/Wollega is suggested.

This institute should be able to provide support for field charcoaling of corn cobs and central briquetting of char into smokeless briquettes. In consultation with the Ministry of State Farms Development, Maize Growing State Farm at Anger Didesa about 300 km from Addis Ababa has been recommended as the suitable site for this demonstration plant.

6.2 Issues and Priorities

Like many other developing countries, Ethiopia has many problems. The major issue is to provide basic necessities of life for a moderate living to the majority of its population. Keen to ameliorate the sufferings of the poor section of the population yet with limited resources, this gigantic task makes it imperative for the Government to identify priorities.

The prime issues are to provide food and supply enough domestic fuel to cook the food. While extensive efforts are being made to enhance the food production, the availability of domestic fuel has not been given the same priority. This is, therefore, resulting in clandorous devastation of forests at rapid rates. While on one side there is acute shortage of domestic fuel, on the other end, a large amount of forest and agricultural residues are being burnt "in situ" mainly as a convenient method of disposal and secondly due to lack of transport and utilization facilities. In this context the exploitation of these wastes through the application of thermochemical conversion technologies for domestic fuels assumes special importance.

The issues and options in the energy sectors have been identified and elaborated in the World Bank (2) and Domestic Fuel Reports (1). However, some of the major issues and priorities are described to highlight their importance and dire need to implement these expeditiously.

1. Rapid reforestation of unused land areas. Some of the steps envisaged are:

(a) Social awakening of the population and active participation of students and youth organizations in plantation programme specially near the schools, villages and along the roads.

(b) Commercial timber and energy plantation with loans and grants from international organizations. There are unlimited potentials for Ethiopia to export timber to neighbouring oil producing countries in Africa and middle east countries of Asia.

(c) Planting trees and forests as the integral part of all the state farms activities.

(d) Set up separate organization and build up infrastructure to provide incentives and inputs for extensive tree plantation.

2. Development of efficient domestic stoves

The present practices of cooking are indeed very wasteful in energy. The leaves and small twigs being used for cooking in open fires give only 6-10% of thermal efficiencies. With simple modifications these could be enhanced by a factor of two.

Cooking of "Injera", a local bread, consume nearly half of domestic energy budget for the average Ethiopian family. Development of stove similar to "PARU" gas stoves can substantially reduce the consumption of fire wood.

3. Conversion of agro-forestry residues into fuels

Extensive dissemination of thermochemical technologies, at cottage, small scale sector and at mechanized commercial levels can play an important role in the conservation of forests.

The basic and potential raw materials identified are logging and milling residues, coffee husk, cotton stalk, maize cobs and wheat and barley straws, which are being burnt at present in the fields.

Sugarcane bagasse is not considered as a potential source for domestic fuels for the following reasons:

(a) At present, it is being used as a main fuel for sugar mills.

(b) It is a potential raw material for making quality paper.

(c) Digestion with steam and mixed with molasses, a by-product of sugar industries, it can make an excellent fodder for cattle.

(d) Milled bagasse contain 50% moisture. Drying of bagasse is difficult and highly energy intensive process.

4. Utilization of efficient charcoaling methods

Portable metal kilns are far superior to the conventional method of making charcoal from wood. This fact has been recognized by the Government, and steps have already been initiated to implement their usage on a pilot scale. FAWCDA has already ordered these units for dissemination. Since the Government already initiated a programme for the development of these kilns, a similar programme under the present project has been omitted.

7.0 Recommendations for a Demonstration Programme

In the area of thermochemical conversion and also direct compaction of biomass, the following demonstration units are recommended for immediate adoption. An estimation on financial inputs and outputs is represented in Tab. 7.1.

7.1 Drum Charring Units and Biomass Gas Stoves "PARU" (Step No.4 - Fig. 7.1)

During the present mission, based on designs supplied by the consultant, these units got fabricated in Addis Ababa and were demonstrated. These are in fact ready for dissemination. Further demonstrations should be arranged specially for organized sectors such as for Army and Police canteens and also popularized through mass media network.

It is also recommended that two of each unit should be supplied to the following institutes. These are basically training institutes where the students and peasants can learn these simple techniques, and, when these trainees go to the field, they could help in further dissemination of these technologies.

The institutes are:

(a) Forestry and Wild Life Resources Institute, Wendo - Genet

(b) Awassa Junior College of Agriculture, Awassa (Home Science Department)

(c) Arsi Rural Development Unit (ARDU), Asela

(d) Peasants Training School, Agarfa

(e) Institute of Agriculture Research, Malka Werer (Awash)

(f) Burayo Basic Technology Centre, Burayo (Ministry of Education).

To test the performance of these units on various biomass residues, it is also recommended that institutes (a), (b), (c) and (e) above should be provided with basic necessary laboratory equipment. These instruments will be useful to analyze the fuels and the briquettes made from biomass for which budgetory provisions have been made.

Co-ordinating and Executive Agency: Ethiopian National Energy Committee (ENEC)

Estimated Financial Inputs:

UNIDO:	Laboratory equipment and instruments for above-mentioned institutes.	US$ 20,000
Government:	Mainly for stoves and drums.	Birr* 20,000

7.2 Demonstration Plant for Charring and Briquetting Cottonstalks

Capacity: 6 tons/day (Step 5, Fig. 7.1)

Cotton stalk grown in state farms are being burnt in the fields. It is recommended that these stalk should be carbonized in mobile kilns in the fields itself. The granular char after screening to remove the ash, should be brought to a central mixing and briquetting plant. A roller briquetting unit is recommended for making briquettes. The kiln already developed in the Philippines under project DP/PHI/78/022 for coconut shells can be modified to carbonize cotton stalk. The modifications and testing could be carried out in India having similar biomass (cotton stalk) and the improved model can then be transferred to Ethiopia along with the roller-briquetting machine and auxiliary equipment. 8-10 kilns will be required to feed one briquetting plant having a capacity of 750 kg of briquettes per hour.

* 1 US$ = Birr 2.07

This plant should be located in one of the state farms either at Amibara or Malka Sedi in middle Awash area.

The technical inputs required for testing of raw materials and briquettes can be provided by Institute of Agricultural Research, Malka Werer (Awash), located in the same area.

Co-ordinating Executing Agency: ENEC

Collaborating Agency: Ministry of State Farms Development

Estimated Financial Inputs:

UNIDO:	For plant and machinery, including the development of kilns in India.	US$ 100,000
Government:	For infrastructure: fixed amount	Birr 60,000
	operating amount	Birr 100,000/year

Estimated Financial Outputs:

For the sale of carbonized briquettes 6 tons/day, 200 days per year. Selling rate = Birr 250 per ton 6 x 200 x 250	Birr 300,000/year

7.3 Demonstration Plant for Charring and Briquetting of Coffee Husk (Step 7, Fig. 7.1.)

The coffee husk is available at the coffee dehusking plants. Coffee husk can be easily carbonized and the char obtained is then mixed with binders such as clay, etc., and then briquetted. These briquettes after drying make excellent smokeless domestic fuel.

The plants installed on turn-key basis are operating on commercial basis in India by private small scale industries using coffee husk as the basic raw material.

It is recommended that a similar plant with capacity 4 tons/day should be installed in coffee processing area.

Site recommended is: Coffee Marketing Corporation
Yirga Alem, Awasa,
at or near Aleta.
Wendo dehusking units.

This sub-centre has four dehusking units in one compound. Enough material to feed this plant is available. In case of any shortfall, it could be conveniently collected from other dehusking units located in close proximity.

The technical inputs can be provided by Agricultural Engineering Department of Awash Junior Agricultural College.

Co-ordinating and Executing Agency: ENEC

Collaborating Agency: Ministry of Coffee and Tea Development

Estimated Financial Inputs:

UNIDO:	For plant and machinery		US$ 130,000
Government:	For infrastructure:	fixed amount	Birr 60,000
		operating amount	Birr 200,000/year

Estimated Financial Output:

For the sale of the carbonized briquettes
4 tons per day x 250 days per year.
Sale price = Birr 250 per ton.
4 x 250 x 250 Birr 250,000

7.4 Demonstration Plant for Charring and Briquetting of Corn Cobs (Step 7, Fig. 7.1)

The scheme proposed for making briquetted fuel is similar to the one recommended for charring and briquetting of cotton stalk. The handling of corn cobs being much easier that that of cotton stalk, the same kiln should give higher production rates. However, like mobile kiln for charring of cotton stalk, the kiln for corn cobs shall have to be modified. This could be accomplished either in the Philippines or in India and then the complete unit on turn-key basis can be transferred to Ethiopia.

The location of this unit should be in one of the maize growing state farms at Dedessa/Wollega, about 330 km away from Addis Ababa.

The technical inputs for the analysis of corn cobs and briquetted fuel can be provided by a technical institute located at Nejo, 100 km west of Dedessa/Wollega farms area.

Co-ordinating and Executing Agency: ENEC

Collaborating Agency: Ministry of State Farms and Development

Estimated Financial Inputs:

UNIDO:	For plant and machinery		US$ 100,000
Government:	For infrastructure:	fixed amount	Birr 60,000
		operating amount for three years	Birr 100,000/year

Estimated Financial Outputs:

For sale of carbonized briquettes
6 tons per day, 250 days per year.
Selling price = Birr 250 per ton.
6 x 250 x 250 Birr 375,000/year

7.5 Charcoal Gasifier for Irrigation Pump (Step 8, Fig. 7.1)

There is no known gasifier in use in Ethiopia. In order to introduce this technology and train personnel the procurement and installation of a charcoal gasifier will be most appropriate. Charcoal gasifiers are simple in construction, easy to operate and maintain and give relatively clean gas.

Many irrigation pumps of 15 HP operating with diesel engines are being used in the country. It is therefore recommended to procure one gasifier fitted with spark ignition engine and pump as composite unit and instal the same near Zwai Lake near Asela, under the direct supervision of Arsi Rural Development Unit Asela (ARDU).

The spark ignition engine (gasoline engine) is recommended because it can run with 100% substitution by producer gas compared to 70-75% substitution for diesel engine.

This unit should be initially installed at ARDU for testing and training of operators and later transferred to the field for extensive testing under local conditions.

In the later stages, tests can be carried out to substitute wood charcoal by carbonized briquettes made from corn cobs available in this area.

Co-ordinating and Executing Agency: ENEC

Collaborating Agency: Ministry of Agriculture

Estimated Financial Inputs:

UNDIO:	For composite unit	US$ 30,000
Government:	For installation and testing	Birr 10,000

7.6 Wood Gasifier for Saw Mill (Step 9, Fig.7.1)

Forestry and Wild Life Resources Institute at Wendo Genet is one of the well established forest institutes in Ethiopia training 70 forest rangers every year. It has a workshop and testing laboratories are being equipped. Having active collaboration with SIDA both foreign and Ethiopian technical and engineering expertise is available. The collaborative contract with SIDA is now being extended for another five years upto 1989.

The institute has a modern saw mill being operated with 48.5 B.H.P. "Caterpillar" diesel engine. To demonstrate the advantages and importance of using wood gasifier for running saw mills instead of on diesel fuel, it is desirable that a wood gasifier with gas clean up system should be installed at the institute. Once operational it can be demonstrated to the managements of other saw mills in the country. Special programmes can be arranged to train workers in operation and maintenance of the gasifier.

Subsequently, raw materials such as corn cobs and briquetted agricultural residues can substitute wood block as the basic raw materials for the gasifier.

Co-ordinating and Executing Agency: ENEC

Collaborating Agency: Forestry and Wild Life Conservation Development Authority (FAWCDA)

Estimated Financial Inputs:

UNIDO:	For wood gasifier clean up system and auxiliary burner	US$ 50,000
Government:	fixed for infrastructure	Birr 50,000

7.7 Demonstration Plant of Direct Briquetting of Wheat/Barely Stalk (Step. 10, Fig. 7.1)

The briquettes produced by direct compaction/pelletization of agro-wastes and saw dust, with or without binders, but without prior carbonization, are difficult to burn in domestic stoves. Because of high basic density ranging from 1000-1600 kg/m^3 (wood = 750 kg/m^3) and consequently low porosity, these briquettes have excessive smoke forming characteristics and hence poor social acceptability. However, these briquettes in the form of logs can be used in industrial boilers and furnaces which are already using wood as the main fuel.

The strategy therefore should be to supply these briquettes to the industrial sector and the fire wood so saved can be directed to meet the acute shortages in the domestic sector.

Because of high maintenance costs, plants of smaller capacity are not feasible. It is therefore recommended that a demonstration plant with 1 ton/hr capacity should be installed at one of the state farms under the Southern Agricultural Development Corporation. The appropriate site shall be Gardela farm in Arsi area, where wheat/barley is cultivated in 12,000 hectare and the straw and other residues are burnt.

Co-ordinating and Executing Agency: ENEC

Collaborating Agency: Ministry of State Farms Development

Estimated Financial Inputs:

UNIDO:	For plant and machinery on turn-key basis	US$ 250,000
Government:	Fixed costs for infrastructure	Birr 80,000
	operating amount	Birr 250,000

Estimated Financial Outputs:

Capacity: 1 ton/hr
2 shifts per day = 16 hours
200 days in a year

Production: 1 x 16 x 200 = 3,200 tons/year

Sale price = Birr 200 per ton
200 x 3,200 = 640,000 Birr 640,000

7.8 Establishment of Biomass Energy Development Centre (Step II, Fig. 7.1)

Presently there is no known institute in the country doing work on biomass energy, either through thermochemical conversion route or biogas generation. Isolated biogas plants have been set up and also some isolated work is being carried out on the measurement of thermal efficiencies of domestic stoves.

The success of the afore-mentioned demonstration units and biogas programme depends upon the execution of the following activities:

(a) Continuous performance monitoring by the co-ordinating agency.

(b) System analysis and system engineering of these technologies.

(c) Modification of engineering designs to meet local conditions of materials and manpower.

(d) Data analysis and documentation of resources.

(e) Analysis and testing of biomass fuels and the products such as briquettes and biogas.

(f) Testing and development of biogas utilization appliances and domestic stoves.

(g) Studies on feasibility of biomass projects and socio-economics/cost benefits.

(h) Continuous publicity to disseminate usage of simple technologies and products and efficient cook stoves.

(i) Organizing educational and training programmes for rural masses in collaboration with other agencies.

It is envisaged that the proposed institute under ENEC shall perform these activities.

The Government of Ethiopia is considering a proposal to set up a National Institute for Energy Development with aid from other Governments. According to the authorities, this being a large project, covering all forms of energy both fossils and renewables, it will be subjected to considerable delays before it is established.

Considering these factors, it is recommended that a small centre, known as "Biomass Energy Development Centre" should be started at Addis Ababa in a small building. Later, when the National Institute gets established in its new premises, this centre could form an important integral section of this institute.

Estimated Financial Inputs:

UNIDO:	(a)	Mainly for testing equipment and analytical instruments	US$ 100,000
	(b)	Auxiliary infrastructure for field operations and documentation (only imported components)	US$ 40,000
Government:	(a)	Furnished building and appropriate infrastructure (fixed amount)	Birr 100,000
	(b)	Recurring expenses including staff salaries and materials	Birr 200,000/year

7.9 Training for Ethiopian Staff (Step 2, Fig. 7.1)

In consultation with ENEC, it has been recommended to have 11 man-months of training component for the successful execution of this programme.

Six man-months (3 persons for 2 months each) could be deputed to developing countries like India and Philippines which are quite advancedin pyrolysis-gasification technologies and their commercialization.

Five man-months (1 person for 3 months and 1 person for 2 months) could be assigned to appropriate European countries. In this manner, the inputs both from developing and developed countries can be assimilated in this programme.

Estimated Financial Inputs:

UNIDO: For travel and DSA as per norms US$ 40,000

7.10 Study Tour

It is essential that the National Leader of this programme, appointed by the Government, should get independent knowledge of technologies being exploited and/or developed on biomass utilization area, specially in the developing countries.

This tour will enable him to assess these technologies in the context of their exploitation in Ethiopia and equip him to guide development in these important areas of biomass conversion systems.

To meet these objectives, a study tour of 2 man-months in countries like China, Brazil, Philippines, India and other neighbouring countries has been proposed.

Estimated Financial Inputs:

UNIDO: For travel and DSA as per norms US$ 10,000

7.11 Consultants/Experts from Overseas

In consultation with ENEC, and considering the large scale and diversity of this programme, it is recommended that a total of 24 man-months of outside consultancy component should be incorporated in this programme. These demonstration projects require constant assessment/monitoring, technical and managerial inputs. Training of Ethiopian engineers and technicians should be considered an important input by the visiting experts.

Although a consultant/expert may be assigned a major task, he is also expected to assess and provide technical inputs to all the sub-projects identified in this programme of four years duration.

Estimated Financial Inputs:

UNIDO: 24 man-months
rate envisaged as US$ 8,000 per man-month
total 24 x 8,000 = 192,000
US$ 200,000

These could be changed as per UNIDO norms.

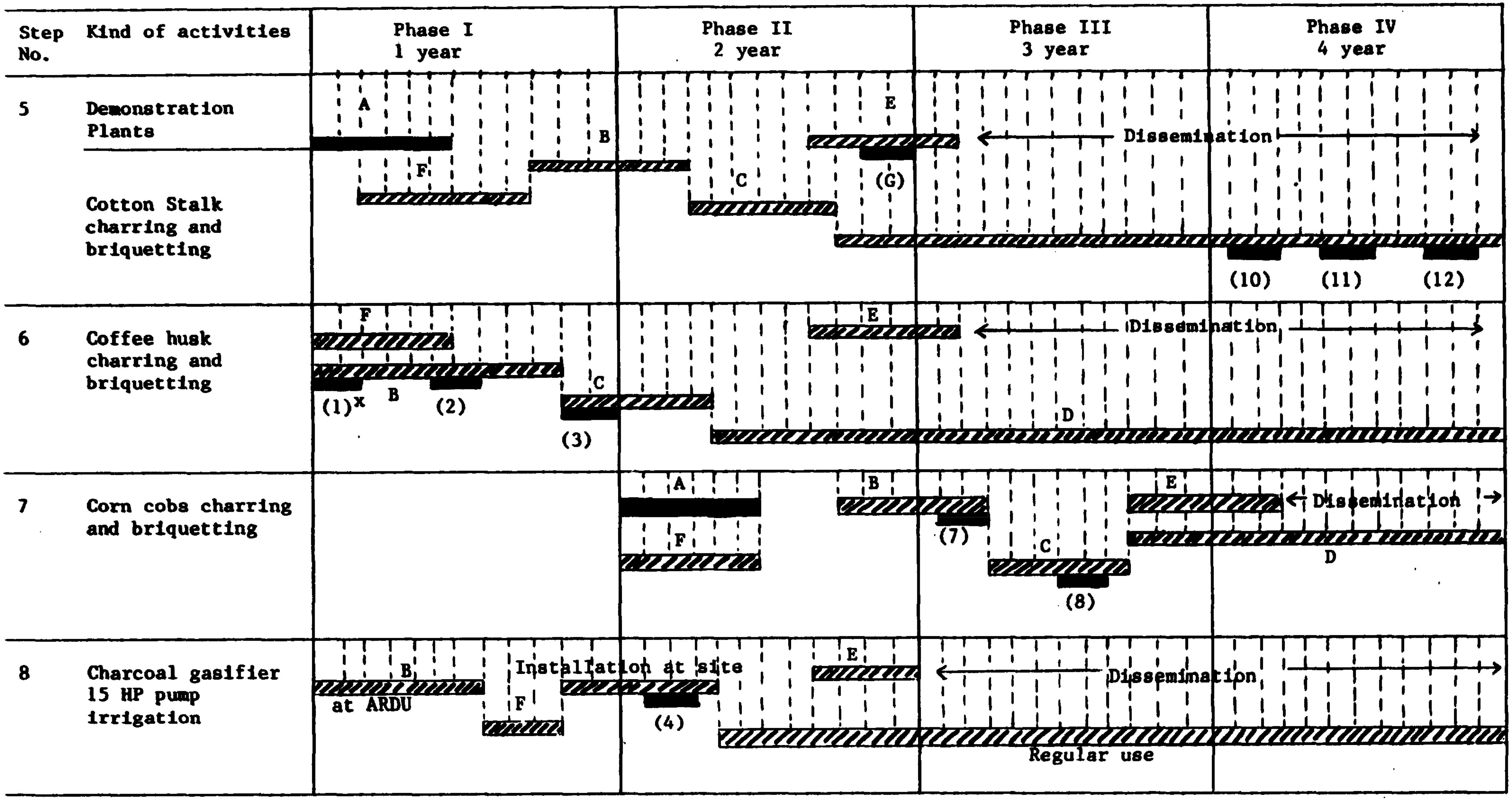
7.12 <u>Summary of Estimated Financial Outlays, Inputs and Outputs</u>

No.	PROJECT	INPUTS	INPUTS in thousands		OUTPUTS
		UNIDO/UNDP	Government of Ethiopia		
		US Dollars in thousands	Birr per year	Birr fixed	Birr per year
1.	Drum charring and biomass gas stove	20	-	20	-
2.	Cotton stalk charring and briquetting	100	100	60	300
3.	Coffee husk charring and briquetting	130	200	60	250
4.	Corn cobs charring and briquetting	100	100	60	375
5.	Charcoal gasifier	30	-	10	-
6.	Wood gasifier	50	-	50	-
7.	Direct briquetting of wheat and barley straw	250	250	80	640
8.	Setting up biomass centre	140	200	100	-
9.	Training component	40	-	-	-
10.	Expert/Consultants	200	-	-	-
	Sub-total	1,070	850	340	1,565
	Contingency 10%	107	85	34	-
	TOTAL	1,177	935	347	1,565
	Inflation 5% per year for 3 years	177	140	56	156 *
	TOTAL	1,354	1,075	430	1,721

* For 2 years

Fig. 7.1 SCHEDULE OF ACTIVITIES - Biomass Thermochemical Conversion Programme in Ethiopia

Step No.	Kind of activities	Phase I 1 year	Phase II 2 year	Phase III 3 year	Phase IV 4 year
1	Training for Ethiopian staff (a) mech. engg. (b) chem. engg. (c) ag. engg. (d) data analyst (e) chemist 5 trainees	(a) Ind-Phi. (b) Ind-Phi. (e) Ind-Phi (d) Europe (c) Europe	Ind. India Phi. Philippines Training (a) briquetting, gasification - engines (b) briquetting - gasification (c) charcoaling (d) computers (e) analysis		
2	Study tour for Chief Executive (National Leader)	Ind., Phi., China, Brazil, both for biomass and biogas			
3	Ordering and installation of equipment for field laboratories	(1)			
4	Biomass gas stoves and drum charring units installation and training testing		← Dissemination →		



* Oversea's consultant total 12
24 man-months

A Development of kilns in Ind. or Phi.

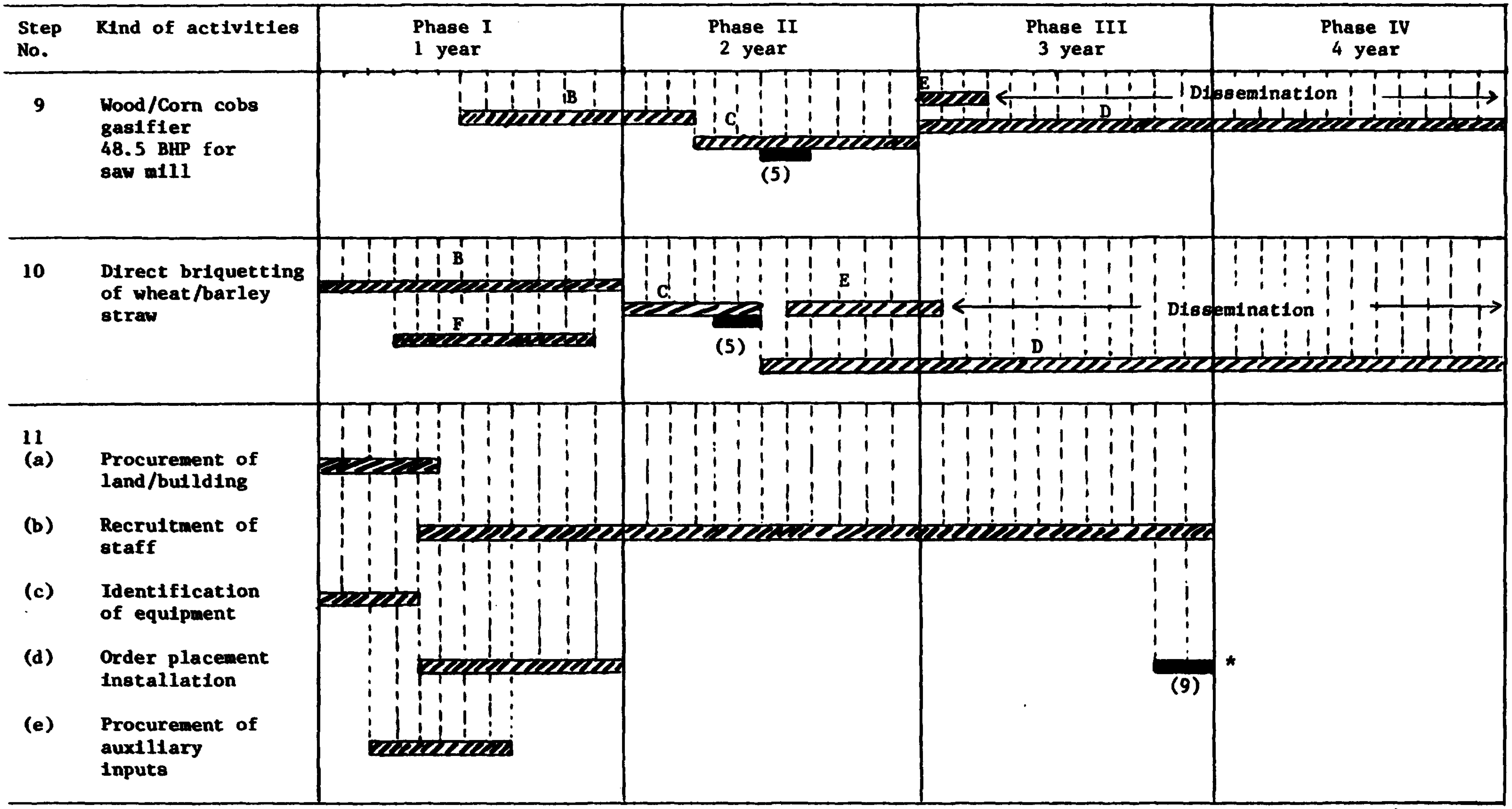
B Procurement and installation

C Trial production/modifications

D Regular production (commercial)

E Feasibility studies and evaluation

F Site selection - preparation



Activities of consultant staff members

Activities of Ethiopian staff members or officials

* (x) Consultant - need not be attached to one activity. In addition to one major assignment should look after entire biomass conversion project.

References

(1) A study to surmount domestic fuel problems in Ethiopia, June 1981

(2) World Bank Report No. 4741-ET, Ethiopia - Issues and Options in the energy sector, March 1984

(3) Report No. 26/81 Ethiopia,Addis Ababa, Ind. Wood Plantation project (FAO/ADB)

(4) Report from Cesen/Finmeccanica - Ansaldo group, Italy, personal communication

(5) UNASYLVA - Revue Internationale des Forêts et des Industries Forestières, FAO, vol 33, No 131/1981

Units

tons = metric tons

1 ton of oil equivalent (toe) = 10.2 10^6 kcal

= 42.7 10^3 mega Joule

Abbreviations

ADB	African Development Bank
ENEC	Ethiopian National Energy Committee
FAO	Food and Agriculture Organization
FAWCDA	Forestry and Wildlife Conservation Development Authority

Currency conversion rate

1 $ = 2.07 Birr as of June 1984