THE FEASIBILITY STUDY REPORT
ON
THE BRIQUETTES DEVELOPMENT PROJECT
IN
THE REPUBLIC OF ZAMBIA
(SUMMARY)

DECEMBER, 1986

JAPAN INTERNATIONAL COOPERATION AGENCY

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Tanzania
Mbala
Zaire
Angola
Mpika
Mufulira
Ndola
Malawi
Mongu
Lusaka
Mozanbique
Nakambala
Maamba
Namibia
Livingstone
Zimbabwe
Botswana
0
200
400
600km

CONTENTS

INTRODUCTION

This report is a summary version of FEASIBILITY STUDY REPORT ON BRIQUETTE DEVELOPMENT PROJECT IN THE REPUBLIC OF ZAMBIA. This feasibility study report concerns a pilot plant project in the Republic of Zambia contemplating to produce coal briquettes and clay stoves using unused domestic raw materials. The feasibility study started February 1986 with preparation of Inception Report presented to National Council for Scientific Research (NCSR) on arrival of the field survey team towards the end of February. The field survey was conducted for a period of about one month up to the end of March during which the data and information necessary for the development of this report were collected, samples of the raw materials were collected and sent to Japan. Also a series of studies were conducted with NCSR counterparts to arrive at tentative definitions of the project; most importantly, definitions of the location of the pilot plants and the capacities of the coal briquettes and clay stoves plants. After returning to Japan the study team conducted experiments on the production of coal briquettes and clay stoves using the raw materials collected in Zambia and analyzed the information and data collected during the survey, thus developed this feasibility study report.

When the feasibility study started, the project itself was loosely defined without specifying such important elements of the project as capacity or location. It was therefore up to this feasibility study to analyze, weigh, coordinate and reconcile all the factors that should be considered to arrive at proper definitions of the project.

After the project scheme had been defined, the experimental productions of coal briquettes and clay stoves were conducted. The conceptual designs of the coal briquettes and clay stoves pilot plants were developed based on the results of their experimental production. The construction of the plants are analyzed for the proposed conceptual design and the cost estimates and construction schedule are developed. The study then proceeds with financial and economic analyses, overall evaluation. This report summarizes these results.

1. Outline of project

This project consists in establishing in Zambia a pilot plant for the production of coal briquettes and clay stoves that could replace charcoal and iron-made local stove called mbaula. This project will mainly use locally available unused raw materials; that is, (1) waste washed-out coal slurry lying in waste in Maamba Collieries in the southern part of the country some 350 km from Lusaka, the capital of Zambia, waste bagasse and molasses produced at Nakambala Sugar Estate some 130 km from Lusaka, and a small amount of slaked lime available in Lusaka for coal briquettes, and (2) clay produced in Lusaka area and crushed firebricks for clay stoves. The project will be implemented and operated by NCSR. The production is 1,000 tons/year for coal briquettes and 4,000 pieces/year for clay stoves. The pilot plant will be located in Lusaka.

2. Objective of project

The objectives of this project are to produce coal briquettes and clay stoves on a pilot plant scale and establish them among general consumers as substitutes for charcoal and iron-made local stove called mbaula which is very thermally inefficient. Along with it, further R & D works will be done to search for better combination of raw materials and manufacturing technology.

3. Major items to be studied and confirmed

Even before this feasibility study started, the following questions had been considered important.

1) Technical feasibility to produce coal briquettes from Maamba coal slurry, bagasse and molasses from Nakambala Sugar Estate, and clay stoves from local clays,

2) Design of the quality of coal briquettes and clay stoves best suited to the lifestyles of the local people, and determination of the necessity of carbonization process to produce smokeless and odorless briquettes,

3) Determination of the annual production of coal briquettes and clay stoves,

4) Selection of the best transportation system of raw materials from several possible alternatives and the impact of transportation cost on project feasibility,

5) Selection of the best location for the pilot plant among Maamba, Nakambala and Lusaka and then decision on the site in the selected location,

6) Financial feasibility of the project,

7) Appropriate organization to manage and run the project.

4. Major outcomes of feasibility study

The feasibility study produced the following results, the number corresponding to the major items to be studied given above.

1) The experimental production of the feasibility study established technical feasibility of producing coal briquettes from Maamba coal slurry, bagasse and molasses of Nakambala Sugar Estate, and clay stoves from local clays, both briquettes and stoves of the qualities meeting the requirements below.

2) The lifestyle, particularly the cooking and heating equipment and habit of the local people was intimately surveyed. As a result the following quality standards were set up:

Coal briquettes should be:
1. smokeless and odorless
2. easy to burn
3. not inclined to die down after lighting up

Clay stoves should be:
1. thermally efficient
2. sturdy
3. sized to meet cooking habit.

3) The annual production of coal briquettes and clay stoves has been decided at 1,000 tons and 4,000 pieces, respectively.

4) All conceivable systems of transportation were studied and transportation economics compared. As a result, transportation by own fleet of trucks has been confirmed best.

5) Maamba, Nakambala, Kafue and Lusaka were studied as candidate location for the pilot plant. Lusaka has been proven to be the best from both economic and administration viewpoints.

6) Financial feasibility of the project was first studied by a conventional method of calculating internal rate of return. The calculated rate is negative indicating that the investment will not be paid out. Secondly, financial feasibility was calculated assuming the investment and interest during construction to be zero. This second calculation proved still negative. Finally, the calculation went as far as assuming both the maintenance and insurance to be zero and the result of the calculation naturally became positive.

7) All the works involved in the operation of the pilot plants have been analyzed; and manning and organization chart have been developed. The organization the study team considers best is recommended.

5. Project scheme

The project scheme, or the definition of the project, has been established in two stages; firstly as tentative project scheme at the closing stage of the field survey and finally in the midst of the home-office work when the outcomes of important studies were produced. The project scheme this feasibility study has finally established is:

(1) Coal briquettes pilot plant

plant location: Namununga Industrial Site in Lusaka
annual production: 1,000 tons

raw material:	Coal slurry at Maamba Collieries Ltd., bagasse and molasses of Nakambala Sugar Estate, Slaked lime	
target price:	200 k/ton	
quality:	Smokeless and odorless, easy to burn, not inclined to die down after lighting up	
raw material composition (wt):		
	carbonized coal slurry	90
	carbonized bagasse	10
	molasses	13
	slaked lime	3
transportation		
raw material:	Own truck	
product:	Own pickup	

2) Clay stove pilot plant

plant location:	Namununga Industrial Site in Lusaka	
annual production:	4,000 pieces	
raw material:	Chamba valley clay and grog	
target price:	8 k/piece	
quality:	durable, heat-resistant and heat insulating	
raw material composition (wt%)		
	Chamba Valley clay	80
	Grog	20
types:	3; large, medium and small	
transportation		
raw material:	Own truck	
product:	Own pickup	

6. Market and desired quality of coal briquettes

The strategy is to concentrate on selling in Lusaka. In the absence of reliable statistics, consumption of charcoal, the most important household fuel, in Lusaka alone is estimated to be well in excess of 150,000 tons a year. Table 1 gives estimated household demand of charcoal for 1985. About 4,000 tons for commercial use should be added to obtain total estimated demand. The question is to what extent and how coal briquettes can replace charcoal as household fuel. 1,000 tons of coal briquettes constitute a very small portion of the charcoal market, less than one percent.

Table 2 estimates the demand of coal briquettes by replacing one to five percent of the estimated charcoal demand with coal briquettes. The most important distribution ends of charcoal are what may be termed open markets. There are 35 open markets in Lusaka. There are a total of 167 charcoal shops in these open markets (Refer to Table 3).

Since coal briquettes are to replace a portion of charcoal, the best strategy is to sell coal briquettes on the charcoal channel. NCSR should make arrangements with fuel dealers so that at least one out of ten these shops, or 16 charcoal shops, sell coal briquettes; thus NCSR will have a distribution channel intimate with people. Besides open markets, the charcoal dealers in the housing compounds should be utilized; the distributors mentioned in 4.4.1 of the detailed report would also be effective channels.

The coal briquettes should be smokeless and odorless upon combustion. The houses of low and middle income brackets in Lusaka are mostly of closed type walled on all four side with a small window on a wall if any. Therefore if smoke or odor is emitted it tends to linger in the house. It should also be considered that coal briquettes are to replace smokeless and odorless charcoal. This means that carbonization process to eliminate smoke and odor is necessary. In addition, coal briquettes should be easy to light, burn and not inclined to die down just as charcoal. Figures 1 and 2 show a typical plan of low-cost houses in Lusaka and cooking style.

Table 1 1985 Estimated Household Charcoal Demand in Lusaka by Projected Population

	Share in Total Population*(%)	Projected Population**	Charcoal Consump.Rate*** (Kgs/Year/Capita)	Charcoal Demand (Ton/Year)
Projected Households:	100.00	909,976		
With Electricity				
-High Cost Group:	19.13	174,078	61.30	10,671
-Medium/Low Cost Group:	22.26	202,561	151.90	30,769
Without Electricity				
-Medium/Low Cost Group:	40.18	365,628	194.40	71,078
-Low Cost Group:	18.43	167,709	213.70	35,839
Estimated Charcoal Demand:				148,357

Source: * Prices & Incomes Commission
** 1980 Population and Housing Census of Zambia
*** The Status and Impact of Woodfuel in Urban Zambia

Table 2 Projected Coal Briquettes Demand in Lusaka by Market Penetration of Household Charcoal Market

	1985	1990	1995	2000
Projected Population*:	909,976	1,211,573	1,607,537	2,123,658
Projected Charcoal Demand** (Ton/Year):	148,357	197,528	262,084	346,229
Heating Value (Thousand Million Kcal):	1,038.50	1,382.70	1,834.59	2,423.61
Projected Coal Briquettes Demand (Ton/Year):				
Market Penetration Rate				
1% Case	1,997	2,657	3,528	4,661
2% Case	3,994	5,318	7,056	9,322
3% Case	5,991	7,977	10,584	13,982
4% Case	7,988	10,636	14,112	18,643
5% Case	9,986	13,295	17,640	23,304

Source: * 1980 Population and Housing Census of Zambia
** Table 4-2-6

Note: Heating values of charcoal and briquettes are assumed to be 7,000 Kca./kg and 5,200 Kcal/kg, respectively.

Table 3 Estimated Charcoal Supply in Lusaka Markets

Name of Markets	No.of Shops (Shops)	Daily Sales Vol. (Bags/Day/Shop)	Ave.Selling Days (Days/Year)	Ann.Sales Vol. (1,000 Bags/Year)
1.Arrakan Barracks	4	3.33	360	4.80
2.Chachacha Road	0	0.00	0	0.00
3.Chainda	2	3.33	360	2.40
4.Chaisa	10	350.00	360	1,260.00
5.Chawama	6	201.50	360	435.24
6.Chelston	7	16.00	365	40.88
7.Chibolya(Soweto)	9	13.50	360	43.74
8.Chifundo	2	45.00	360	32.40
9.Chilenje	5	35.00	360	63.00
10.Chilulu	4	80.00	300	96.00
11.Chingwere	1	62.00	360	22.32
12.Chipata	13	152.00	300	592.80
13.Chitukuko	10	350.00	365	1,277.50
14.Chunga	0	0.00	0	0.00
15.Garden	4	92.50	360	133.20
16.John Howard	6	6.00	365	13.14
17.Kabwata	5	12.50	360	22.50
18.Kalingalinga	6	11.50	300	20.70
19.Kanyama(New)	1	10.50	360	3.78
20.Kaunda Square	10	80.00	300	240.00
21.Kulima Tower	0	0.00	0	0.00
22.Libala	3	155.00	365	169.73
23.Lilanda	3	201.50	300	181.35
24.Longacres	0	0.00	0	0.00
25.Lubuma(Kamwala)	14	11.00	365	56.21
26.Malipole	4	26.00	300	31.20
27.Mandevu	8	3.33	360	9.59
28.Matero	5	176.50	360	317.70
29.Mutambe	6	32.50	365	71.18
30.Mutendere	17	8.00	360	48.96
31.Mwaziona	0	0.00	0	0.00
32.Ngombe	1	25.50	300	7.65
33.Northmead	1	201.50	300	60.45
34.Nyerere	0	0.00	0	0.00
35.Olympia Park	0	0.00	0	0.00
Total	167	-	-	5,258.40

(Source: JICA)

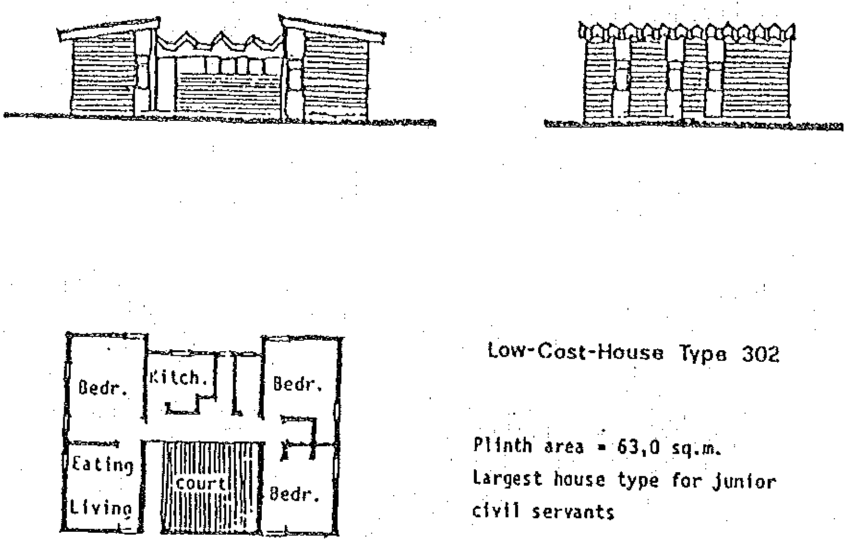

Figure 1 Typical Plan of Low-cost Formal-sector House

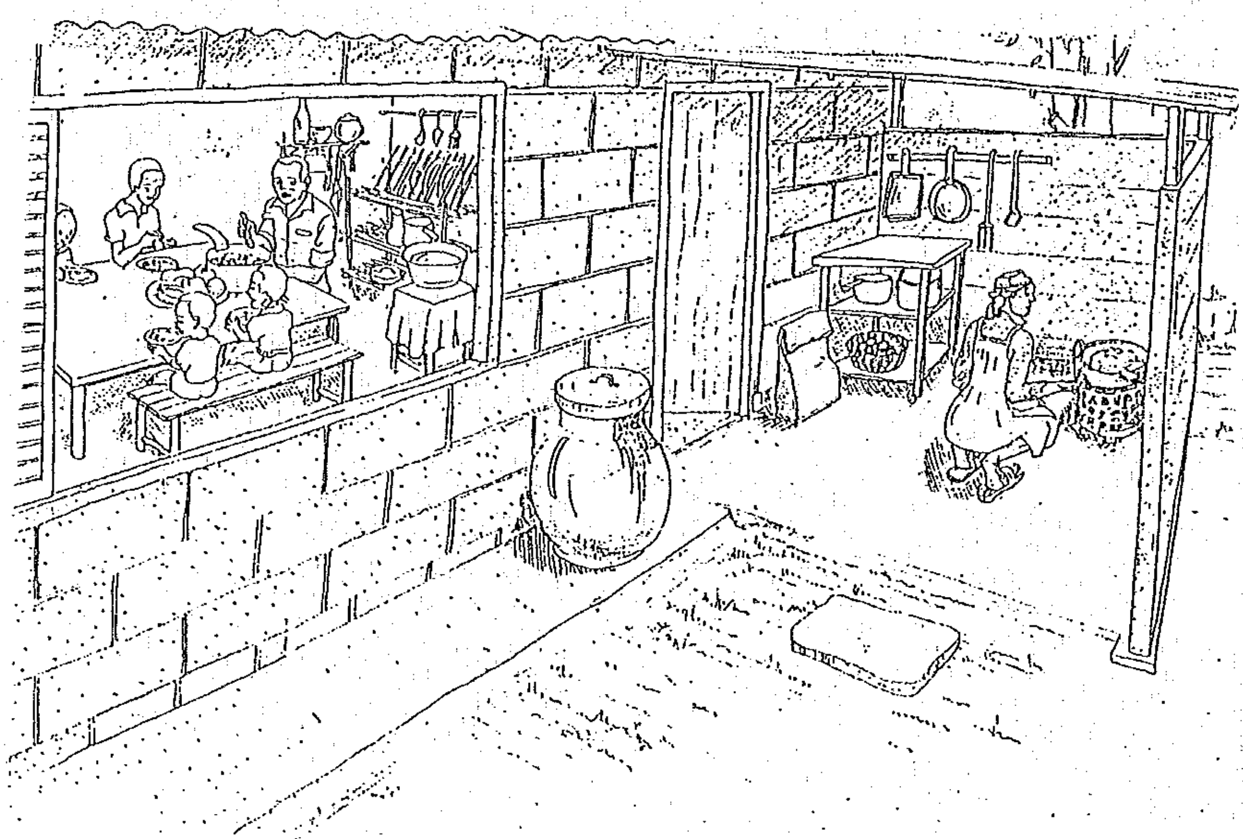

Figure 2 Cooking Style

The target ex-factory price of 200 K/ton is designed to be competitive with charcoal at retail end. During the field survey charcoal was found to be sold at 309 K/ton and 370/380 K/ton at wholesale Lusaka and at an open market, respectively. These correspond to 230 and 275/282 K/ton of coal briquettes, being multiplied by the ratio of heat of combustion of 5,200 and 7,000 Kcal/kg of coal briquettes and charcoal, respectively. Table 4 shows breakdown of the charcoal price per bag, or 25.6kg, in Lusaka for 1978 and March 1986.

Table 4 Structure of Charcoal Pirce in Lusaka

(Kwacha/Bag)

	1978		1986(Mar.)		Growth Rate of	Growth Rate of
	Price	(%)	Price	(%)	Price(%)	Share(%)
Producer Price	2.50	55.6	5.00	41.7	100.0	-25.0
Transportation Fee	1.00	22.2	3.80*	31.7	280.0	42.5
Forest Department Fee	0.10	2.2	0.10	0.8	0.0	-63.6
Trader Profit	0.90	20.0	3.10	25.8	244.4	29.0
Empty Bag Price	0.50	-	3.00	-	500.0	
Total Price Inputs	5.00	-	15.00	-	200.0	
Retail Price (Less Empty Bag)	4.50	100.0	12.00	100.0	166.7	

* Hired truck fee plus cost

7. Market and desired quality of clay stoves

Iron-made local stove called mbaula is in extensive use for burning charcoal for heating and cooking. Mbaulas are hand made and available in greatly varying sizes and makes. Firstly mbaulas are made of iron which is not produced in Zambia. Secondly mbaulas have too many holes on the side and bottom to be thermally efficient by allowing heat to escape. Mbaulas are not adequate for sustaining combustion of coal briquettes.

A Japanese clay stove and a mbaula were compared for thermal efficiency by burning the same amount of charcoal with the result that the Japanese clay stove is three times more thermally efficient than the mbaula. The clay stove is not only good for coal briquettes but also ideal for burning charcoal. The use of clay stove in place of mbaula will result in considerable savings in charcoal consumption.

In Lusaka alone about 87,000 mbaulas are consumed a year. This may be taken to represent a good market of clay stoves. Table 5 shows estimated demand of mbaulas. Table 6 gives estimated demand of clay stoves assuming the degree of replacement of mbaulas by clay stoves to be 5 to 20 percent. The clay stoves are priced at 8 K/piece ex-factory which will give a sufficient incentive for free merchants to come to NCSR to buy wholesale and sell them at open markets with profit. Clay stoves should also be sold at the charcoal shops selected to sell coal briquettes in the open markets. Mbaulas are retailed from 5 to 30 K per piece depending upon the size as of 1986 February/March price.

Table 5 Projected Mbaulas Demand in Lusaka by Projected Households

	Share in Total Households*(%)	Mbaulas Consump. Rate*** (Pieces/ Year/Household)	1985 No. of Households (1,000 Households)	1985 Mbaulas Demand (1,000 Pieces/Year)	1990 No. of Households (1,000 Households)	1990 Mbaulas Demand (1,000 Pieces/Year)	1995 No. of Households (1,000 Households)	1995 Mbaulas Demand (1,000 Pieces/Year)	2000 No. of Households (1,000 Households)	2000 Mbaulas Demand (1,000 Pieces/Year)
Projected Households**:	100.00	-	182.80	-	242.70	-	321.80	-	411.40	-
With Electricity										
- High Cost Group:	19.13	0.250	34.97	8.74	46.43	11.61	61.56	15.39	78.70	19.68
- Medium/Low Cost Group:	22.26	0.333	40.69	13.55	54.03	17.99	71.63	23.85	91.58	30.50
Without Electricity										
- Medium/Low Cost Group:	40.18	0.400	73.45	29.38	97.52	39.01	129.30	51.72	165.30	66.12
- Low Cost Group:	18.43	1.000	33.69	33.69	44.73	44.73	59.31	59.31	75.82	75.82
Projected Mbaulas Demand:	-	-	-	85.36	-	113.33	-	150.27	-	192.11

Source: * Prices & Incomes Commission
** 1980 Population and Housing Census of Zambia
*** National Council for Scientific Research

Table 6 Projected Clay Stoves Demand in Lusaka by Market Penetration of Mbaulas Market

	1985	1990	1995	2000
Projected Households* (1000 Households/Year):	182.80	242.70	321.80	411.40
Projected Mbaulas Demand** (1000 Pieces/Year):	85.36	113.33	150.27	192.11
Projected Clay Stoves Demand (Pieces/Year): Market Penetration Rate				
5% Case	4,268	5,667	7,514	9,606
6% Case	5,122	6,800	9,016	11,527
7% Case	5,975	7,933	10,519	13,448
8% Case	6,829	9,066	12,022	15,369
9% Case	7,682	10,200	13,524	17,290
10% Case	8,536	11,333	15,027	19,211
11% Case	9,390	12,466	16,530	21,132
12% Case	10,243	13,600	18,032	23,053
13% Case	11,097	14,733	19,535	24,974
14% Case	11,950	15,866	21,038	26,895
15% Case	12,804	17,000	22,541	28,817
16% Case	13,658	18,133	24,043	30,738
17% Case	14,511	19,266	25,546	32,659
18% Case	15,365	20,399	27,049	34,580
19% Case	16,218	21,533	28,551	36,501
20% Case	17,072	22,666	30,054	38,422

Source: * 1980 Population and Housing of Zambia
** Table 4-3-3

8. Raw material for coal briquettes

1) Waste coal slurry

The raw materials for coal briquettes are principally wash-out coal slurry of Maamba Collieries Ltd. The coal slurry is now lying in waste filling two slurry ponds. The older pond is completely full and well drained; the newer is half-full and still swampy. A large number of samples were taken from the dry older pond and analyzed. As a result the accumulated slurry in the downstream half of the older pond is found to be adequate as feed to the depth of about 2 meters. Figure 3 is a rough sketch of the older pond on which are indicated where samples were taken. Tables 7 and 8 give sieve analysis and proximate analysis of the samples. The sample taken at C point has high contents of ash and sulfur. The raw material slurry should be taken downstream of D point. This portion of slurry amounts to about 12,000 tons of pure coal fines and corresponds to about 10 years feed, since the annual requirement is 1,241 tons. The slurry may be transported by 120 trips of a 10 ton truck. In addition, there will be fresh supply of 28,000 tons per year of coal fines assuming coal production to be at 700,000 tons and yield on coal to be 4 percent.

Figure 3

COAL SLURRIES SAMPLING LOCATION (SCALE: 1/1000)

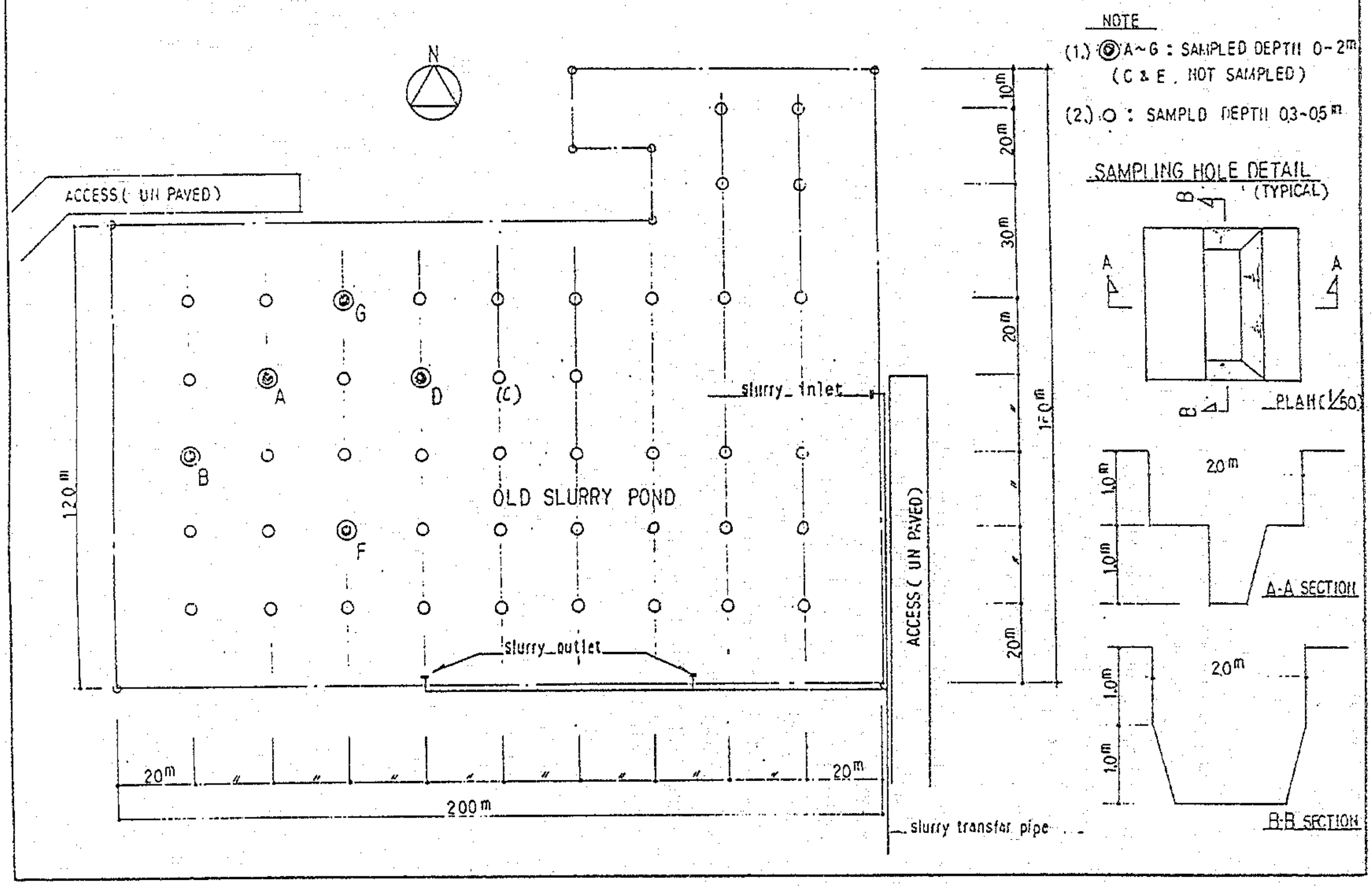

Table 7 Sieve Analysis of Slurries

Mesh	mm	A-Bottom %	A-mix. %	B-mix %	C-mix. %	D-mix. %	F-mix. %	G-mix. %
10	1.65	0.9	3.2	0.4	4.0	5.5	3.0	7.
20	0.84	5.2	10.5	2.8	11.0	11.2		
30	0.59	19.8	18.5	6.0	19.9	19.0	22.9	25.8
40	0.42	16.5	11.2	6.0	13.0	11.0		
50	0.30	18.5	9.9	7.1	11.8	10.2		
60	0.25	11.8	8.1	10.7	8.9	7.8	29.8	23.5
100	0.15	13.6	12.6	16.9	12.8	11.7	17.6	11.6
-100		12.7	25.0	46.2	17.9	20.9	26.7	31.8
Loss		1.0	1.0	3.9	0.7	.2.7		
Total		100.0	100.0	100.0	100.0	100.0	100.0	100.0
Moisture %		10.8	16.1	21.6	12.1	14.3	13.4	16.0
Bulk density			0.7-0.8 0.9(wet)					

Table 8 Proximate Analysis of Slurries

	A-Bottom	A-mix.	B-mix	C-mix	D-mix.	F-mix.	G-mix.
Inherent moisture	2.31%	2.28	2.51	1.75	2.24	2.50	2.30
Ash	22.64	22.39	22.14	33.06	25.10	25.10	22.30
Volatile matter	17.78	18.95	19.93	19.93	19.44	19.90	18.96
Fixed carbon	57.27	56.38	54.42	45.25	53.22	52.50	56.44
Heating value	5,891	5,894	5,863	4,899	5,657	5,704	5,922
Total sulfur	1.07	1.29	1.00	2.43	1.44	1.47	1.40

2) Bagasse

The bagasse is carbonized to produce a soft char which is blended into briquettes to improve burning quality. Bagasse, or squeezed canes, is produced as a byproduct of sugar production at Nakambala Sugar Estate about 130 km from Lusaka on the way to Maamba. Normally about 400,000 tons are produced a year, of which 350,000 tons are burnt as own fuel giving rise to a surplus of 50,000 tons.
At the outlet of the plant the bagasse contains 48 to 52 percent moisture. Canes are grown during the rainy season which lasts from the middle of April to November when the dry season sets in. Canes are harvested during the dry season; that is to say, bagasse is produced only during the dry season. During the rainy season, bagasse is not fresh; the raw material bagasse must be taken from the outdoor pile weathered to the rain. The experimental production of coal briquettes confirmed that the weathered bagasse can be used, although fresh drier bagasse is better. As long as Nakambala Sugar Estate has a stockpile this project can rely on Nakambala Sugar Estate for stable supply. Tables 9, 10 and 11 show sieve analysis, proximate analysis and ultimate analysis of bagasse compared with similar materials.

Carbon from bagasse is blended to a ratio of 9.4% to the briquettes; that is, 94 tons of carbon from bagasse is required to produce 1,000 tons of coal briquettes. To obtain 94 tons of carbon, 940 tons of bagasse must be carbonized. This amount of bagasse constitutes a very small fraction of excess bagasse available at Nakambala Sugar Estate, or 50,000 tons a year. Bagasse will be transported by truck from Nakambala to the plant site at Lusaka. About 100 trips by a truck will be necessary, each carrying 10 tons.

Table 9 Sieve Analysis of Bagasse

mm	%
Longer fibrous materials	38.8
1.8	31.9
0.59	22.9
0.25	4.9
0.1	1.5
0.1	0.0
Total	100.0

Max. long piece (Unit mm) Length: 120
Width: 10 to 15
Thickness: 6

Table 10 Proximate Analysis of Bagasse and Sawdust

	Bagasse	Sawdust
Inherent moisture	5.7%	
Ash	2.4	0.4%
Volatile matter	80.5	83.6
Fixed carbon	11.4	16.0
Heating value	3770.0	4700.0
Total sulfur	0.06	0.0

Table 11 Ultimate Analysis of Bagasse and Other Vegetable Materials

	Bagasse	Sawdust	Cellulose	Wood
Carbon %	47.3	51.0	44.4	49.7
Hydrogen %	5.4	6.1	6.2	6.1
Oxygen %	41.7	42.1	49.4	44.1
Nitrogen %	0.4	0.1	-	0.1
Sulfur % combustible	0.00	0.0		
Ash %	5.2	0.4		
		100.0		

3) Molasses

Molasses is also available at Nakambala Sugar Estate. Molasses is used as binder. The annual production is about 50,000 tons which is sold as fermentation raw material or animal feed. This project requires about 120 tons.

Molasses is transported by truck with bagasse. This amount of molasses can be obtained from the estate.

4) Slaked lime

Slaked lime is purchasable at Crush Stone Sales, a limestone burner in Lusaka selling limestone, quick lime and slaked lime. Slaked lime is sold in 25 kg bag. Slaked lime will be transported by truck. Annual requirement is about 30 tons and is easily purchased from this dealer.

5) Carbonaceous fly ash at Nitrogen Chemicals of Zambia

Nitorogen Chemicals of Zambia in Kafue gasifies the Maamba coal by the Koppers-Totzek gasifier to produce fertilizers and explosives such as ammonium nirtate. Their carbonaceous fly ash produced from this gasifying plant was investigated during the field survey and was found unsuitable as raw material for coal briquettes. The carbonaceous fly ash contains only 25% carbon which is sooty dust carbon produced as a residue of gasification of coal fines. The material is in the form of a suspension in water at the plant and in a mixture with pyrite cinder in the sedimentation basin.

6) Price

The prices of the raw materials as of Feburary/March 1986 are set as follows:

	K/ton
Coal slurry	0
Bagasse	0
Molasses	40
Slaked lime	440

9. Raw material for clay stoves

Maamba and Nakambala were considered as candidate location in addition to Lusaka; therefore, Maamba and Nakambala were surveyed in search for good clay. No suitable clay was identified in Maamba. One promising clay was found in Nakambala. Four clays in Lusaka area and one in Nakambala were sent to Japan for analysis and experimantal production of clay stoves. The experimental production of the present feasibility study confirmed the following composition as desirable from the standpoints of raw materials availability, ease of procurement, product quality and manufacturing operation.

Chamba Valley clay	80 (wt%)
Grog	20

Grog is crushed firebricks which are made available as a result of turnarounds of the oil refinery, cement factory and fertilizer plant. Chamba Vallay clay is produced in the suburbs of Lusaka and is used for production of bricks. The reserves are large. The transportation is by truck.

10. Experimental production of coal briquettes

The experimental production of coal briquettes successfully confirmed that it is possible to produce from the four raw materials coal briquettes of the required quality under the Zambian circumstances; smokeless and odorless, easy to burn, not inclined to die down after lighting up. The experimental production established composition of the raw materials and processing conditions which have beeen reflected in the conceptual design. As basis for conceptual design, the following amounts of raw materials are found needed to produce 1,000 tons of coal briquettes:

Coal slurry	1,214	tons
Bagasse	940	
Molasses	123	
Slaked lime	28	
Total	2,305	

11. Experimental production of clay stoves

Clay stoves of satisfactory quality are produced by experiment using the samples of Zambian clays collected and sent to Japan by the field survey team. The compositions of raw materials for outer and inner frames are given in 9, Raw material for clay stoves, above. The clay stoves are baked at 800°C. The experimental procedures that led to the successful production of clay stoves can be simulated by the actual production process of the pilot plant. The conceptual design of the pilot plant is based on the satisfactory results of the experimental production. The clay stoves are designed to be of double frame type for the sake of safety and enhanced thermal efficiency. The structure of the experimentally produced stove is illustrated in Figure 4.

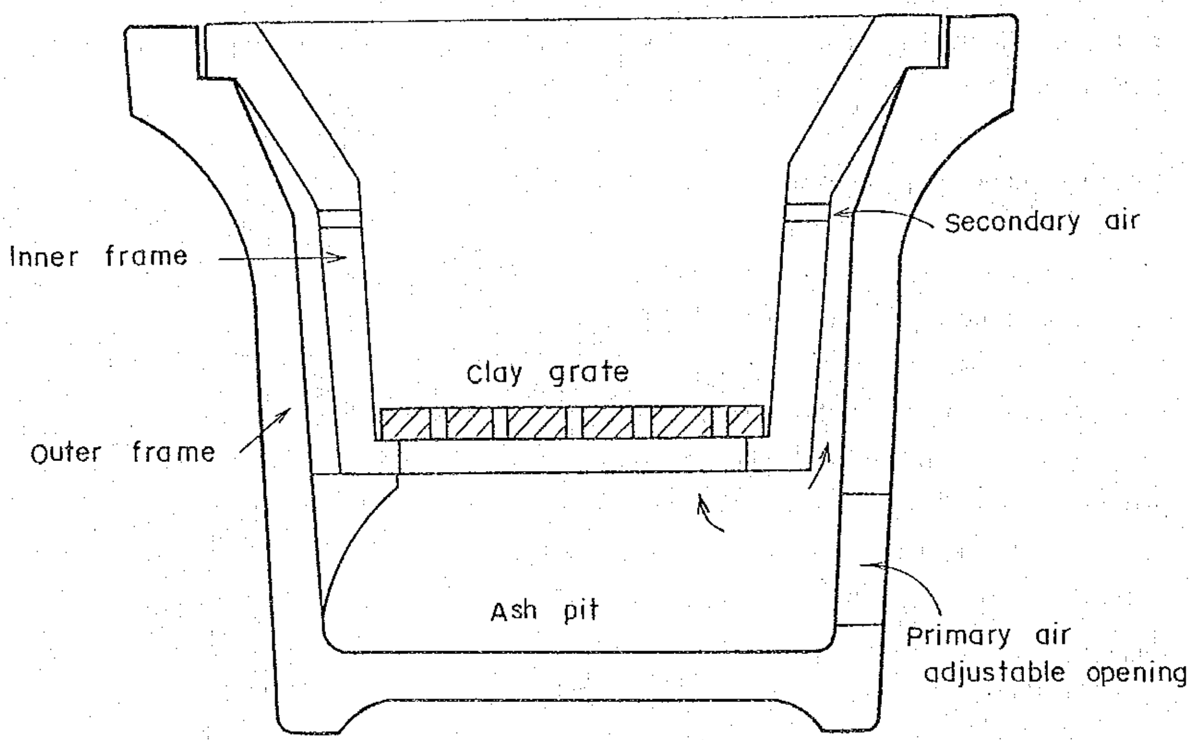

Figure 4 Double - Frame Clay Stove

12. Energy situation of Zambia

The total commercial energy production that appears in official statistics is as follows:

	1978		1983	
	Production	%	Production	%
Electricity, Gwh	7,833		10,072	
PJ	28.4	38.3	36.3	49.4
Petroleum, 1,000 MT	734.7		606.9	
Products PJ	31.2	42.0	25.8	35.1
Coal, 1,000 MT	582.0		453.6	
PJ	14.6	19.7	11.4	15.5
Total PJ	74.2	100.0	73.5	100.0

Charcoal and firewood do not appear in the above statistics inspite of their overriding importance as household fuel. Zambia is gifted with generous and cheap supply of hydroelectric power which explains an extensive use of electricity as household energy for cooking and heating among high-income families.

Zambia has an excess power generation which is exported as shown below:

(Gwh)

	Domestic Consumption	Domestic Production	Net Export
1983	6,444	10,072	3,760
1984	6,404	9,806	3,033

As of January 1982, the nation's total capacity was 1,798 MW of which 1,667 MW is hydroelectric and 129 MW is by diesel engine. Zambia does not produce a drop of oil. There have been some exploratory surveys for oil but without success so far. Zambia does not have natural gas either. Crude oil is imported by Tazama Pipeline which runs through Tanzania to Dar es Salaam and processed by the only refinery, Indeni Refinery Company. There is also importation of petroleum products. The geographical condition of being landlocked and its financial conditions make oil import rather difficult.

Charcoal and firewood, notably the former, are by far the most important household fuels among middle and low income brackets, particulary in the urban areas. The amount of consumption significantly varies with the source of information. The present consumption of charcoal in Lusaka, the market of major interest as far as this feasibility study is concerned, ranges from the order of 50,000 tons to 150,000 tons per year depending upon the sources of information. The present feasibility study investigated of its own the consumption and concludes that the higher number, 150,000 tons per year should be adopted, as explained in the detailed report.

13. Process flow, arrangement of facilities

The process of producing coal briquettes consists in series of carbonization of the slurry and bagasse; blend of powdered carbonized slurry, carbonized bagasse, molasses and slaked lime; briquetting; drying and desmoking. The process of producing clay stoves consists in refining of raw material, shaping, finishing and baking. Figures 5 and 6 illustrate production processes of coal briquettes and clay stoves.

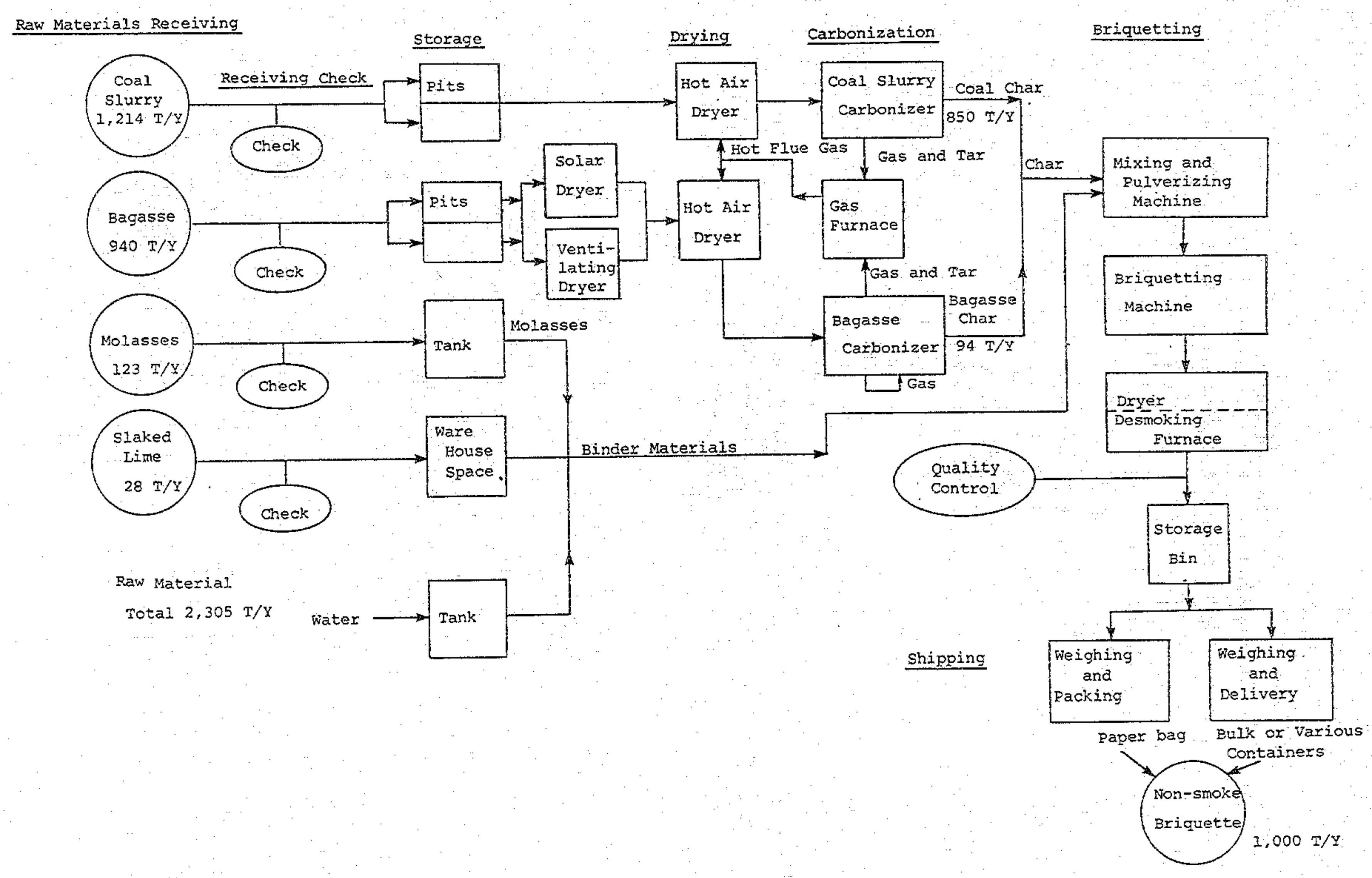

Figure 5 Flow Sheet of Non-Smoking Briquette Process

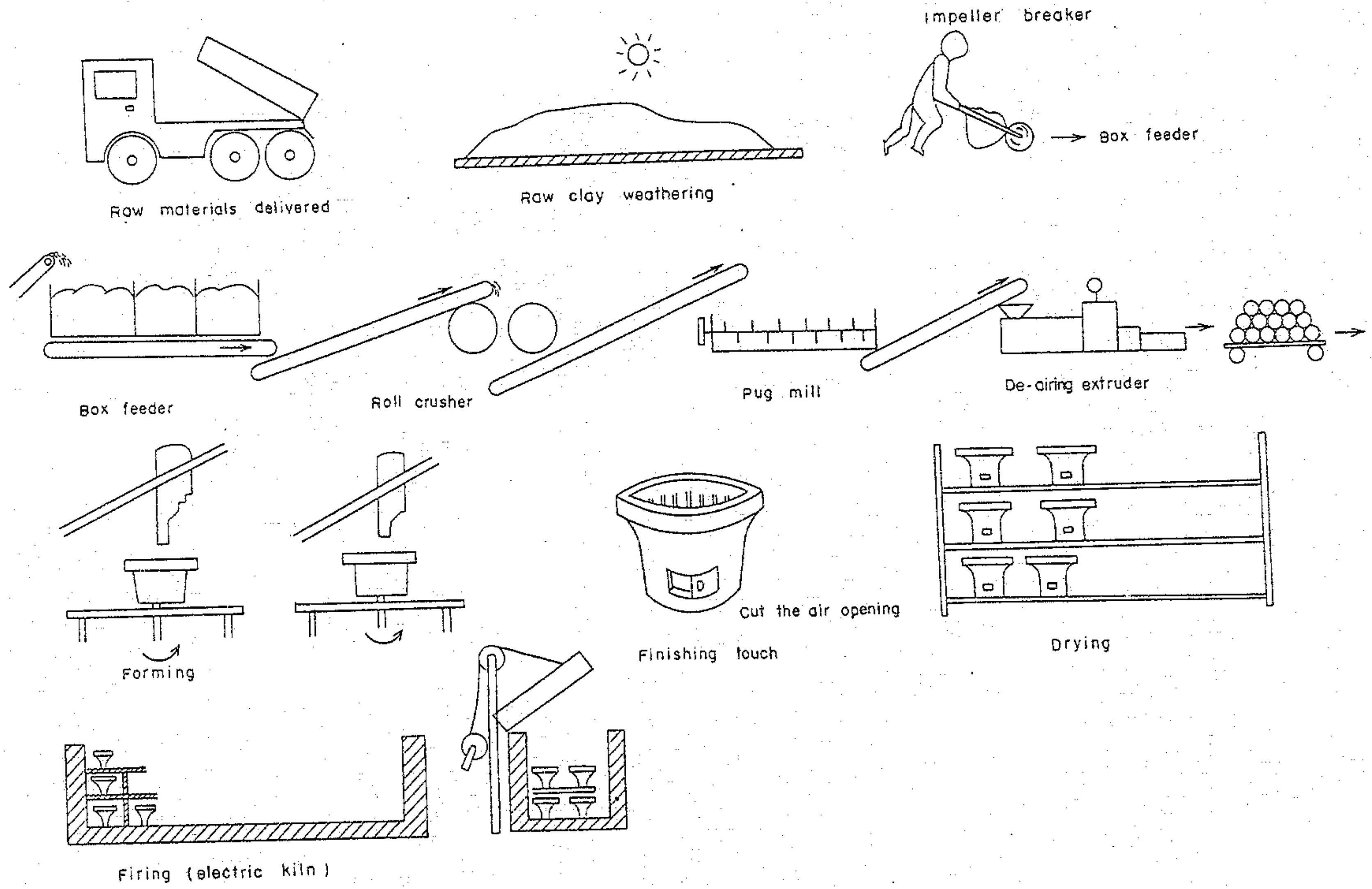

Figure 6 Clay Stove Production Flow

14. Auxiliary and ancillary facilities

There is not very much of auxiliary operation for this project. Power generation, steam generation, water purification are not needed. For transportation of the raw materials and products three 10 ton dump trucks and one pickup are needed.

15. Plot plan

The whole pilot plant project is comfortably laid out in the 12,000 m2 Namununga site. Figure 7 shows the plot plan for the project.

16. Plant location and site

Maamba, Nakambala, Kafue and Lusaka were studied. Kafue was dropped because there is no raw material there. The most important factors affecting the location are transportation economics, investment cost and administration. To produce one ton of coal briquettes, about 2.3 tons of raw materials are required. Transportation economics favors Nakambala best, Maamba and Lusaka are about even.

The investment cost for plant construction increases in the order of Lusaka, Nakambala and Maamba. The incremental capital-related cost associated with locating the plant in Nakambala far exceeds the savings in transportation cost as compared with locating the plant in Lusaka. Thus, economic consideration favors Lusaka as most advantageous. The economic comparison among Lusaka, Nakambala and Maamba is quantitatively analyzed in Chapter 10 PROJECT SCHEME, 10.2.1, Economic factors affecting location, of the detailed report. The administration cost, small as it is compared with the transportation cost and capital-related cost, is of course lowest at Lusaka and highest in Maamba, and perhaps between the two at Nakambala as long as the pilot plant is managed by NCSR. Hence, Lusaka is selected.

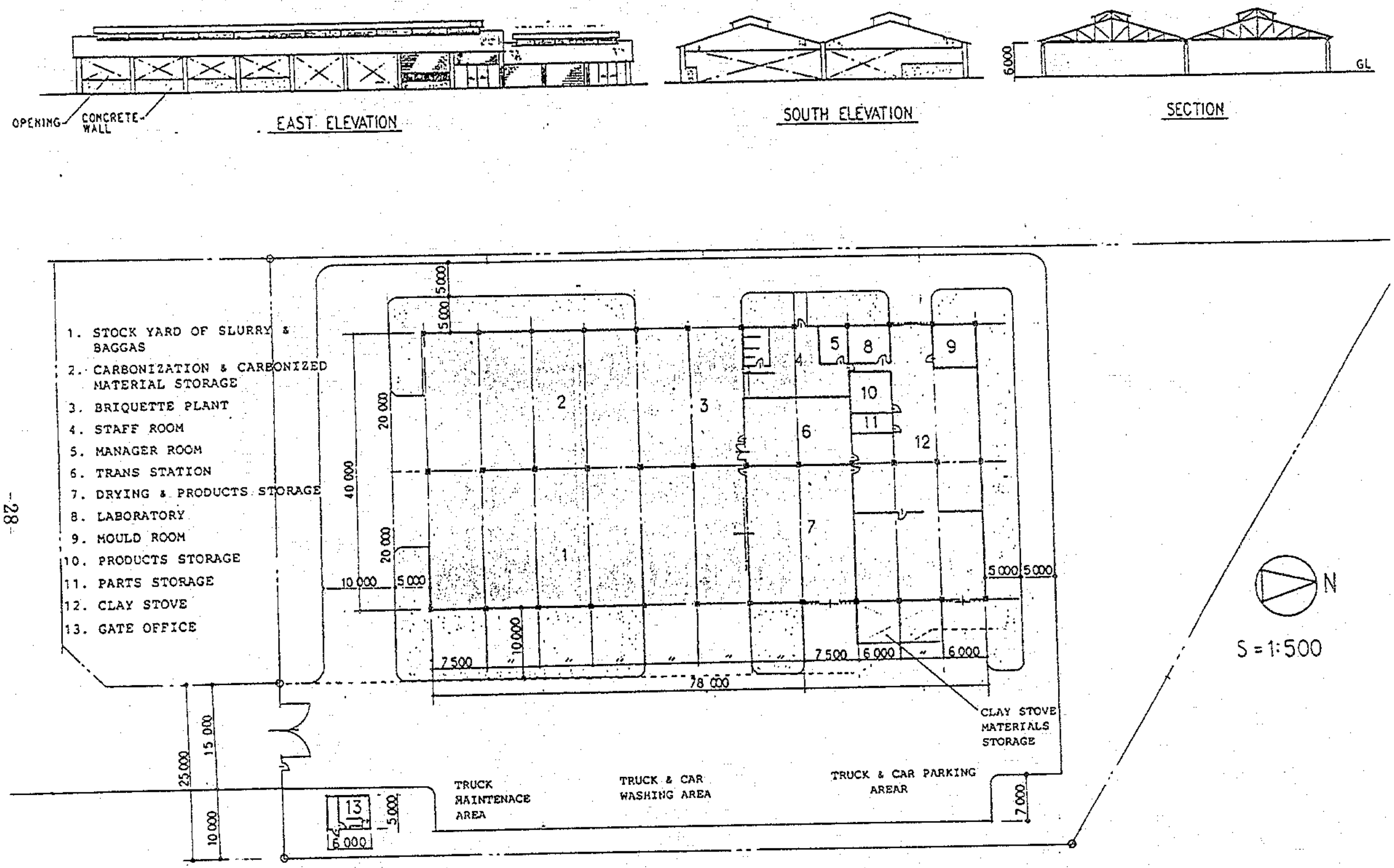

Figure 7 Plot Plan

ZAMBIA COAL BRIQUETTES FACTORY PROJECT
(PRELIMINARY)

Three candidate sites were studied in Lusaka. One is a site NCSR has already taken possession of, another is NCSR's premises, and the third is Namununga Industrial Area. The first site is not recommendable for technical reasons. NCSR's premises is not recommendable for environmental reasons. Namununga Industrial Area is recommendable for every reason except that the untaken land left for this project is a little too small. However, the land next to the contemplated site taken by Zambia Railways Limited is not used and could be lent or purchased as needed. Namununga Industrial Area is the best candidate available and is chosen for the site in this study.

17. Infrastructure

The infrastructure which concerns the implementation and operation of this pilot plant project was studied. The means of transportation; e.g., rails, roads, bridges, carriers and vehicles, and means of communication were studied and found, though not necessarily well developed, not to prevent the smooth implementation and operation of the project. Table 12 summarizes assessments of infrastructure relevant to raw material transtortation.

Table 12 Infrastructure related to Transportation

	Route & Distance (km)	Availability Width (m)	Condition of Surface	Condition of Bridge	Flooded Place	Maintenance	Route & Distance (km)	Available Station	Available Stockyard
1. Maamba-Batoka	66	Yes 7	Paved good	4 (concrete)	1 35 km from Maamba	Soil sand filling	-	-	-
2. Maamba-Masuku	28	Yes 3.5	Not paved Bad	0	2	Cutting & filling	11.7 (ropeway)	Yes	Open air
3. Masuku-Batoka	89	Yes 6	Not baved Not good	3 Not good	2	Soil filling	95	Yes	Open air
4. Batoka-Mazabuka	128	Yes 7	Paved Good	3 Good	0	Soil & sand filling	130	-	Warehouse
5. Mazabuka-Kafue	81	Yes 7	Paved Good	3	0	ditto	48	Yes	Open air
6. Kafue-Lusaka	44	Yes 7	Paved Good	1 (steel truss) Good	0	complete	48	Yes	Open air
7. Neganega Clay Depo.-Kafue	rural 1 connect 20 main 12	No Yes Yes	Bush Not paved Paved	0 1 Not good	1	Soil filling	0	Yes	Open air
8. Kasisi Clay Depo.-NCSR	rural 3 connect 5 main 4	No Yes Yes	Bush Not paved Paved	0	-	No soil filling complete	-	-	-
9. Venter & Chamba Valley clay Depo.	in the city	Yes 7	Paved Good	0	0	complete	-	-	-

18. Transportation

All conceivable systems of transporting raw materials and products and also equipment and machinery for construction were studied. Given that coal slurry is at Maamba, bagasse and molasses at Nakambala and the market of coal briquettes and clay stoves mainly at Lusaka, there are following three patterns of flow of materials for the production of coal briquettes.

Plant location	Maamba	Nakambala	Lusaka
Maamba			
bagasses, molasses	←————	————	
slaked lime	←————	————	————
coal briquettes	————	————	————→
Nakambala			
coal slurry	————	————→	
slaked lime		←————	————
coal briquettes		————	————→
Lusaka			
coal slurry	————	————	————→
bagasse, molasses		————	————→

There are alternatives for means of transportation; namely, by rail, by road, the latter may be contracted transportation or by own fleet of trucks. In terms of total ton-km, the case where the plant is located at Nakambala turns out to be the least; the other two cases being about even. From the viewpoint of total economics which considers capital related cost and also from the viewpoint of administration, Lusaka has been chosen as the plant location.

Once Lusaka has been selected, again there are a number of possible transportation systems, of which the followings are practical:

Coal slurry, Maamba to Lusaka	rail
	truck, contract
	truck, own
Bagasse/Molasses, Nakambala to Lusaka	rail
	truck, contract
	truck, own
Product/within Lusaka	pickup, own
Slaked lime/within Lusaka	Truck, contract
	Truck, own
Clay/within Lusaka	Truck, contract
	Truck, own
Clay stoves/within Lusaka	pickup, own

The most economical is transportation by own truck and pickup. The road conditions and maintenance of the vehicles are major concerns. The roads along the corridor between Lusaka and Maamba via Nakambala are among the best in Zambia although there are sporadic holes but not to prevent vehicles from running. The maintenance of the vehicles can be managed by NCSR and local maintenance garages operated by motor companies or their affiliates provided that the necessary spare parts could be secured.

The cost of transportation of raw materials per ton of coal briquettes turned out to be: The depreciation represents the purchase cost of the vehicles.

	K/ton coal briquettes	
	with Depreciation	without Depreciation
rail	119	
truck, contract	297	
truck, own	109	70

19. Pollution, environmental impact

The operation of both pilot plants is rather clean by nature. The carbonization of coal slurry produces volatile gases and sulfur compounds which will be burnt before emission to atmosphere. The amount of sulfur dioxide contained in the exhaust gas is small and would be tolerable in view of the site being in the industrial area.

Dust produced at various processes can be a health threat to the operators if left unattended. The building to house the machine is so designed as to allow maximum ventilation. Forced ventilation is provided to closed portions. In case of working in a particulary dusty environment, operators should wear masks. Waste water can be discharged to the municipal sewage. Waste materials produced like sand and muds may be safely dumped in the dumping area designated by the city.

20. Construction work

All the machines and equipment composing the pilot plants will be imported via Dar es Salaam. Cement, aggregates, asbestos cement sheets, concrete blocks and similars are locally produced. The official standards applicable to construction works mostly include in themselves British Standards and; therefore they would not hinder international procurement and tendering. The construction works will mostly be done by local people. There are a couple of local constructors of experience. For supervision and engineering two to three expatriate engineers will be necessary. The construction would take about 15 months from coming into effect of the contract to completion.

Before that seven months are required for preparation of tender documents, tendering, evaluation and contract. The construction camp may be set up on the site where water and electricity can be easily tapped. Electricity for construction can also be taken at the site.

21. Schedule

The overall schedule from the completion of this feasibility study may be considered as shown below assuming all the procedures go smoothly.

	Months	
	Duration	Cumulative
Evaluation of feasibility study	3	3
Arrangement for basic design study	3	6
Basic design study	6	12
Procurement of funds	3	15
Selection of owner's consultant	2	17
Tender documents, tender, contract	7	24
Construction	15	39

According to this schedule, the construction starts at the beginning of the 25th month and completes at the end of the 39th month.

22. Investment cost, total capital requirement

The investment cost -- broken down into plant construction cost, interest during construciton, initial working capital --, and preoperation cost are estimated as follows:

(Unit Thousand Kwacha)

	1st Year	2nd Year	Total
Plant construction cost	12,593.2	50,372.6	62,965.8
Interest during construction	0.0	597.4	597.4
Initial working capital	0.0	5.0	5.0
Preoperation cost	0.0	9.4	9.4
Total	12,593.2	50,984.4	63,577.6

Note: One Kwacha is equivalent to 26.6 Japanese yen.

23. Financial analysis

(1) Methodology of financial analysis

Financial analysis is conducted in three steps. Firstly, based on the sales revenue and such costs as total capital requirement and operating cost, financial statements are developed and subsequently financial internal rate of return (FIRR) is calculated for the financial evaluation of this project (Case-1).

In case that the result of financial analysis thus conducted is infeasible, which actually is the case of this project, financial evaluation is repeated but by excluding the plant construction cost and interest during construction from the total capital requirement (Case-2). If Case 2 evaluation proves negative, again which is the case with this project, financial evaluation is done excluding spare parts cost and insurance on top of construction cost and interest during construction (Case-3).

(2) Major Premises for financial analysis

Project life

. Construction period: 15 months
. Operation period: 10 years

Price base

All prices and costs such as investment cost, production costs and sale price are calculated at the fixed pirce in March 1986, and the price escalation is not incorporated. The calculation is made on local currency, and the foreign currency portion is converted to the local currency by using the following exchange rate.

US$ 1 = 6.76 Kwachas
Kwacha 1 = 26.6 Japanese Yen

Operation rate

. First year: 50%
. Second year: 70%
. Third year and after: 100%

Financing plan

(a) Financial sources

. Local currency portion:
NCSR's own funds or grants from the Zambian governmental organizations such as Ministry of Higher Education

. Foreign currency portion: Long-term loan

(b) Conditions for long-term loan

. Interest rate: 3.0% p.a.
. Repayment: 20 times/10 years, constant amount of principal

(c) Conditions for short-term loan

Interest rate: 26% p.a.
Repayment: All debt are repaid in the year following the introduction of the loan.

Depreciation

The basis for depreciation are as follows:

Item	Method of Depreciation	Salvage Value (%)
Machinery & equipment	Declining balance method 30%	-
Civil works & buildings	Straight line method in 20 years	0
Pre-operation cost	Straight line method in 20 years	0
Interest during construction	Not depreciable	-

Taxes

This project is a national project; and all taxes such as import duty, sales tax and corporate income tax are exempted.

(3) Result of financial analysis

The result of Case 1 financial analysis is that although extremely favorable conditions are applied to the long-term loan, the shortage of funds occurs throughout the operation period. In addition, the interest on the short-term loan introduced to compensate for the shortage of fund worsens the financial situations.

The annual cash flows are all negative throughout; and calculation of IRR is impossible. As is obvious from the above discussion, Case 1 of this project is not viable.

The total capital requirement for Case 2 is calculated to be 14,410 Kwachas as the sum of pre-operation expense (9,410K) and initial working capital (5,000K). The calculation shows that this project is infeasible even if plant construction cost and interest during construction are exempted. The operation expenses exceed the sales revenue in every year, and annual cash flows are all negative. Especially, maintenance cost and cost for insurance are equivalent to about 5 times and 68% of the sales revenue. However, the production cost excluding the above two costs is lower than sales revenue. In other words, the project is financially infeasible unless the project is relieved of the maintenance and insurance costs by outside subsidies (Case 3). The conditions for making this project feasible are the outside subsidies for the plant construction cost, maintenance (spare parts) and insurance, the required amounts of the latter two throughout the operation period are 10 million and 1,570 thousand Kwachas, respectively.

The results of the Case 3 financial analysis are good throughout the operation period as summarized in the following tables:

. Production Cost Accounting Table (Table 13)
. Profit and Loss Statement (Table 14)
. Fund Flow Statement (Table 15)
. Balance Sheet (Table 16)
. Cash Flow Statement (Table 17)

The average production costs of coal briquettes and clay stoves are 162 K/ton and 7.9 k/piece. The sale of the products at the previously targeted selling prices, coal briquettes 200 K/ton, clay stoves 8.0 K/piece, is possible.

Table 13 Production Cost Accounting Table (Case-3)

(Unit:'000 Kvachas)

Project Year	-2	-1	1	2	3	4	5	6	7	8	9	10	Total
<< Coal Briquettes >>													
Production Volume (tons/year)	--	--	500	700	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	9,200
Variable Operating Expenses													
Coal Slurry	--	--	33.09	39.52	49.17	49.17	49.17	49.17	49.17	49.17	49.17	49.17	465.97
Bagasse	--	--	14.08	15.76	18.27	18.27	18.27	18.27	18.27	18.27	18.27	18.27	175.97
Molasses	--	--	3.62	4.63	6.14	6.14	6.14	6.14	6.14	6.14	6.14	6.14	57.39
Slaked Lime	--	--	6.16	8.62	12.34	12.34	12.34	12.34	12.34	12.34	12.34	12.34	113.48
Electricity	--	--	9.54	13.36	19.09	19.09	19.09	19.09	19.09	19.09	19.09	19.09	175.59
Water	--	--	0.38	0.57	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	7.79
Sub-total	--	--	66.87	82.46	105.86	105.86	105.86	105.86	105.86	105.86	105.86	105.86	996.19
Fixed Operating Expenses													
Direct Labor	--	--	40.00	40.00	40.00	40.00	40.00	40.00	40.00	40.00	40.00	40.00	400.00
Maintenance	--	--	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Insurance	--	--	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Miscellaneouse	--	--	6.67	6.67	6.67	6.67	6.67	6.67	6.67	6.67	6.67	6.67	66.67
Sub-total	--	--	46.67	46.67	46.67	46.67	46.67	46.67	46.67	46.67	46.67	46.67	466.67
Depreciation	--	--	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	6.84
Interest on Long-term Loan	--	--	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Interest on Short-term Loan	--	--	0.00	8.16	9.79	1.33	0.00	0.00	0.00	0.00	0.00	0.00	19.29
Total Production Cost	--	--	114.22	137.97	163.00	154.54	153.21	153.21	153.21	153.21	153.21	153.21	1,488.99
Unit Production Cost (K/ton)	--	--	228.45	197.10	163.00	154.54	153.21	153.21	153.21	153.21	153.21	153.21	--
<< Clay Stoves >>													
Production Volume (pieces/year)	--	--	2,000	2,800	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	36,800
Variable Operating Expenses													
Clay	--	--	0.78	1.09	1.56	1.56	1.56	1.56	1.56	1.56	1.56	1.56	14.37
Grog	--	--	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04
Gypsum	--	--	0.20	0.28	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	3.68
Electricity	--	--	1.94	2.71	3.87	3.87	3.87	3.87	3.87	3.87	3.87	3.87	35.65
Water	--	--	0.13	0.19	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	2.60
Sub-total	--	--	3.05	4.28	6.13	6.13	6.13	6.13	6.13	6.13	6.13	6.13	56.33
Fixed Operating Expenses													
Direct Labor	--	--	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	200.00
Maintenance	--	--	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Insurance	--	--	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Miscellaneouse	--	--	3.33	3.33	3.33	3.33	3.33	3.33	3.33	3.33	3.33	3.33	33.33
Sub-total	--	--	23.33	23.33	23.33	23.33	23.33	23.33	23.33	23.33	23.33	23.33	233.33
Depreciation	--	--	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.36
Interest on Long-term Loan	--	--	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Interest on Short-term Loan	--	--	0.00	0.43	0.52	0.07	0.00	0.00	0.00	0.00	0.00	0.00	1.02
Total Production Cost	--	--	26.42	28.08	30.01	29.56	29.49	29.49	29.49	29.49	29.49	29.49	291.03
Unit Production Cost (K/piece)	--	--	13.21	10.03	7.50	7.39	7.37	7.37	7.37	7.37	7.37	7.37	--

Table 14 Profit and Loss Statement (Case-3)

(Unit:'000 Kvachas)

Project Year	-2	-1	1	2	3	4	5	6	7	8	9	10	Total
Sales Revenue													
Coal Briquettes	--	--	100.00	140.00	200.00	200.00	200.00	200.00	200.00	200.00	200.00	200.00	1,840.00
Clay Stoves	--	--	16.00	22.40	32.00	32.00	32.00	32.00	32.00	32.00	32.00	32.00	294.40
Total	--	--	116.00	162.40	232.00	232.00	232.00	232.00	232.00	232.00	232.00	232.00	2,134.40
Costs & Expenses													
*Variable Operating Expenses													
Coal Slurry	--	--	33.09	39.52	49.17	49.17	49.17	49.17	49.17	49.17	49.17	49.17	465.97
Bagasse	--	--	14.08	15.76	18.27	18.27	18.27	18.27	18.27	18.27	18.27	18.27	175.97
Molasses	--	--	3.62	4.63	6.14	6.14	6.14	6.14	6.14	6.14	6.14	6.14	57.39
Slaked Lime	--	--	6.16	8.62	12.34	12.34	12.34	12.34	12.34	12.34	12.34	12.34	113.48
Clay	--	--	0.78	1.09	1.56	1.56	1.56	1.56	1.56	1.56	1.56	1.56	14.37
Grog	--	--	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04
Gypsum	--	--	0.20	0.28	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	3.68
Electricity	--	--	11.48	16.07	22.96	22.96	22.96	22.96	22.96	22.96	22.96	22.96	211.23
Water	--	--	0.51	0.76	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	10.39
Sub-total	--	--	69.92	86.73	111.98	111.98	111.98	111.98	111.98	111.98	111.98	111.98	1,052.52
*Fixed Operating Expenses													
Direct Labor	--	--	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	600.00
Maintenance	--	--	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Insurance	--	--	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Miscellaneouse	--	--	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	100.00
Sub-total	--	--	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	700.00
Total	--	--	139.92	156.73	181.98	181.98	181.98	181.98	181.98	181.98	181.98	181.98	1,752.52
Depreciation	--	--	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	7.21
Interest on Long-term Loan	--	--	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Interest on Short-term Loan	--	--	0.00	8.59	10.31	1.40	0.00	0.00	0.00	0.00	0.00	0.00	20.30
Profit before Tax	--	--	-24.64	-3.65	38.99	47.89	49.30	49.30	49.30	49.30	49.30	49.30	354.37
Income Tax	--	--	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Profit after Tax	--	--	-24.64	-3.65	38.99	47.89	49.30	49.30	49.30	49.30	49.30	49.30	354.37

Table 15 Fund Flow Table (Case-3)

(Unit; '000 Kwachas)

Project Year	-2	-1	1	2	3	4	5	6	7	8	9	10	Total
Sources of Fund													
Profit after Tax	0.00	0.00	-24.64	-3.65	38.99	47.89	49.30	49.30	49.30	49.30	49.30	49.30	354.37
Depreciation	0.00	0.00	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	7.21
Equity	0.00	14.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.41
Long-term Loan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	78.09
Short-term Loan	0.00	0.00	33.06	39.64	5.40	0.00	0.00	0.00	0.00	0.00	0.00	-9.33	0.00
Increase in Account Payable	0.00	0.00	5.83	1.40	2.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	454.08
Sub-total	0.00	14.41	14.96	38.11	47.22	48.61	50.02	50.02	50.02	50.02	50.02	40.69	
Applications of Fund													
Plant Construction	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pre-operation Expense	0.00	9.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.41
Initial Working Capital	0.00	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.00
Interest during Construction	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Increase in Account Recievable	0.00	0.00	9.67	3.87	5.80	0.00	0.00	0.00	0.00	0.00	0.00	-19.33	0.00
Increase in Inventory													
Raw Materials	0.00	0.00	2.38	0.49	0.73	0.00	0.00	0.00	0.00	0.00	0.00	-3.60	0.00
Products	0.00	0.00	2.91	0.70	1.05	0.00	0.00	0.00	0.00	0.00	0.00	-4.67	0.00
Repayment on Long-term Loan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Repayment on Short-term Loan	0.00	0.00	0.00	33.06	39.64	5.40	0.00	0.00	0.00	0.00	0.00	0.00	78.09
Sub-total	0.00	14.41	14.96	38.11	47.22	5.40	0.00	0.00	0.00	0.00	0.00	-27.60	92.50
Surplus Funds	0.00	0.00	0.00	0.00	0.00	43.21	50.02	50.02	50.02	50.02	50.02	68.28	361.58
Accumlated Surplus Funds	0.00	0.00	0.00	0.00	0.00	43.21	93.23	143.25	193.26	243.28	293.30	361.58	361.58

Table 16 Balance Sheet (Case-3)

(Unit:'000 Kwachas)

Project Year	-2	-1	1	2	3	4	5	6	7	8	9	10
Current Assets												
Cash on Hand & Bank	0.00	5.00	5.00	5.00	5.00	48.21	98.23	148.25	198.26	248.28	298.30	366.58
Account Recievable	0.00	0.00	9.67	13.53	19.33	19.33	19.33	19.33	19.33	19.33	19.33	0.00
Inventory												
Raw Materials	0.00	0.00	2.38	2.87	3.60	3.60	3.60	3.60	3.60	3.60	3.60	0.00
Products	0.00	0.00	2.91	3.61	4.67	4.67	4.67	4.67	4.67	4.67	4.67	0.00
Others	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Current Assets	0.00	5.00	19.96	25.01	32.60	75.81	125.82	175.84	225.86	275.88	325.89	366.58
Fixed Assets												
Plant	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Intangible Assets	0.00	9.41	9.41	9.41	9.41	9.41	9.41	9.41	9.41	9.41	9.41	9.41
Accumlated Depreciation	0.00	0.00	0.72	1.44	2.16	2.88	3.60	4.32	5.04	5.76	6.48	7.21
Book Value	0.00	9.41	8.69	7.97	7.25	6.53	5.81	5.09	4.37	3.65	2.93	2.21
Others	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Toatl Fixed Assets	0.00	9.41	8.69	7.97	7.25	6.53	5.81	5.09	4.37	3.65	2.93	2.21
Total Assets	0.00	14.41	28.65	32.98	39.84	82.33	131.63	180.93	230.23	279.52	328.82	368.78
Current Liabilities												
Account Payable	0.00	0.00	5.83	7.23	9.33	9.33	9.33	9.33	9.33	9.33	9.33	0.00
Short-term Loan	0.00	0.00	33.06	39.64	5.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Others	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Current Liabilities	0.00	0.00	38.88	46.86	14.73	9.33	9.33	9.33	9.33	9.33	9.33	0.00
Long-term Liabilities												
Long-term Loan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Stockholders Equity												
Capital	0.00	14.41	14.41	14.41	14.41	14.41	14.41	14.41	14.41	14.41	14.41	14.41
Retained Earning	0.00	0.00	-24.64	-28.29	10.70	58.59	107.89	157.19	206.48	255.78	305.08	354.37
Total Equity	0.00	14.41	-10.23	-13.88	25.11	73.00	122.30	171.60	220.89	270.19	319.49	368.78
Total Equity & Liabilities	0.00	14.41	28.65	32.98	39.84	82.33	131.63	180.93	230.23	279.52	328.82	368.78

Table 17 Cash Flow Table (Case-3)

(Unit:'000 Kwachas)

Project Year	-2	-1	1	2	3	4	5	6	7	8	9	10	Total
Cash Inflow													
*Sales Revenue													
Coal Briquettes	0.00	0.00	100.00	140.00	200.00	200.00	200.00	200.00	200.00	200.00	200.00	200.00	1,840.00
Clay Stoves	0.00	0.00	16.00	22.40	32.00	32.00	32.00	32.00	32.00	32.00	32.00	32.00	294.40
Total Cash Inflow	0.00	0.00	116.00	162.40	232.00	232.00	232.00	232.00	232.00	232.00	232.00	232.00	2,134.40
Cash Outflow													
*Investment	0.00	14.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.41
*Variable Opreating Expenses													
Coal Slurry	0.00	0.00	33.09	39.52	49.17	49.17	49.17	49.17	49.17	49.17	49.17	49.17	465.97
Bagasse	0.00	0.00	14.08	15.76	18.27	18.27	18.27	18.27	18.27	18.27	18.27	18.27	175.97
Molasses	0.00	0.00	3.62	4.63	6.14	6.14	6.14	6.14	6.14	6.14	6.14	6.14	57.39
Slaked Lime	0.00	0.00	6.16	8.62	12.34	12.34	12.34	12.34	12.34	12.34	12.34	12.34	113.48
Clay	0.00	0.00	0.78	1.09	1.56	1.56	1.56	1.56	1.56	1.56	1.56	1.56	14.37
Grog	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04
Gypsum	0.00	0.00	0.20	0.28	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	3.68
Electricity	0.00	0.00	11.48	16.07	22.96	22.96	22.96	22.96	22.96	22.96	22.96	22.96	211.23
Water	0.00	0.00	0.51	0.76	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	10.39
Sub-total	0.00	0.00	69.92	86.73	111.98	111.98	111.98	111.98	111.98	111.98	111.98	111.98	1,052.52
*Fixed Operating Expenses													
Direct Labor	0.00	0.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	600.00
Maintenance	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Insurance	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Miscellaneouse	0.00	0.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	100.00
Sub-Total	0.00	0.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	700.00
*Working Capital Increase	0.00	0.00	9.13	3.65	5.48	0.00	0.00	0.00	0.00	0.00	0.00	-18.26	0.00
Total Cash Outflow	0.00	14.41	149.06	160.39	187.46	181.98	181.98	181.98	181.98	181.98	181.98	163.72	1,766.93
Net Cash Flow	0.00	-14.41	-33.06	2.01	44.54	50.02	50.02	50.02	50.02	50.02	50.02	68.28	367.47
Cumlative Cash Flow	0.00	-14.41	-47.47	-45.45	-0.91	49.11	99.12	149.14	199.16	249.18	299.19	367.47	--
Discounted Cash Flow	0.00	-9.26	-13.65	0.53	7.59	5.48	3.52	2.26	1.45	0.93	0.60	0.53	0.00

24. Organization

This pilot plant project will be run by NCSR. The Secretary General will assume the overall responsibility of the project. The daily routines of the plants will be taken care of by six technicians: four for coal briquettes and two for clay stoves. One of the four technicians for coal briquettes manufacturing will be the local manager of the pilot plants. Provided that the right technology is transferred to NCSR, NCSR is capable of meeting the administration and management requirements for operating the pilot plant project. However, this project should have a government-wide support for which the organization shown in Figure 8 is recommended. And two or more expatriate engineers, one for coal briquettes and one for clay stoves, should be invited to transfer the technology and skill of operation and management to the local staff.

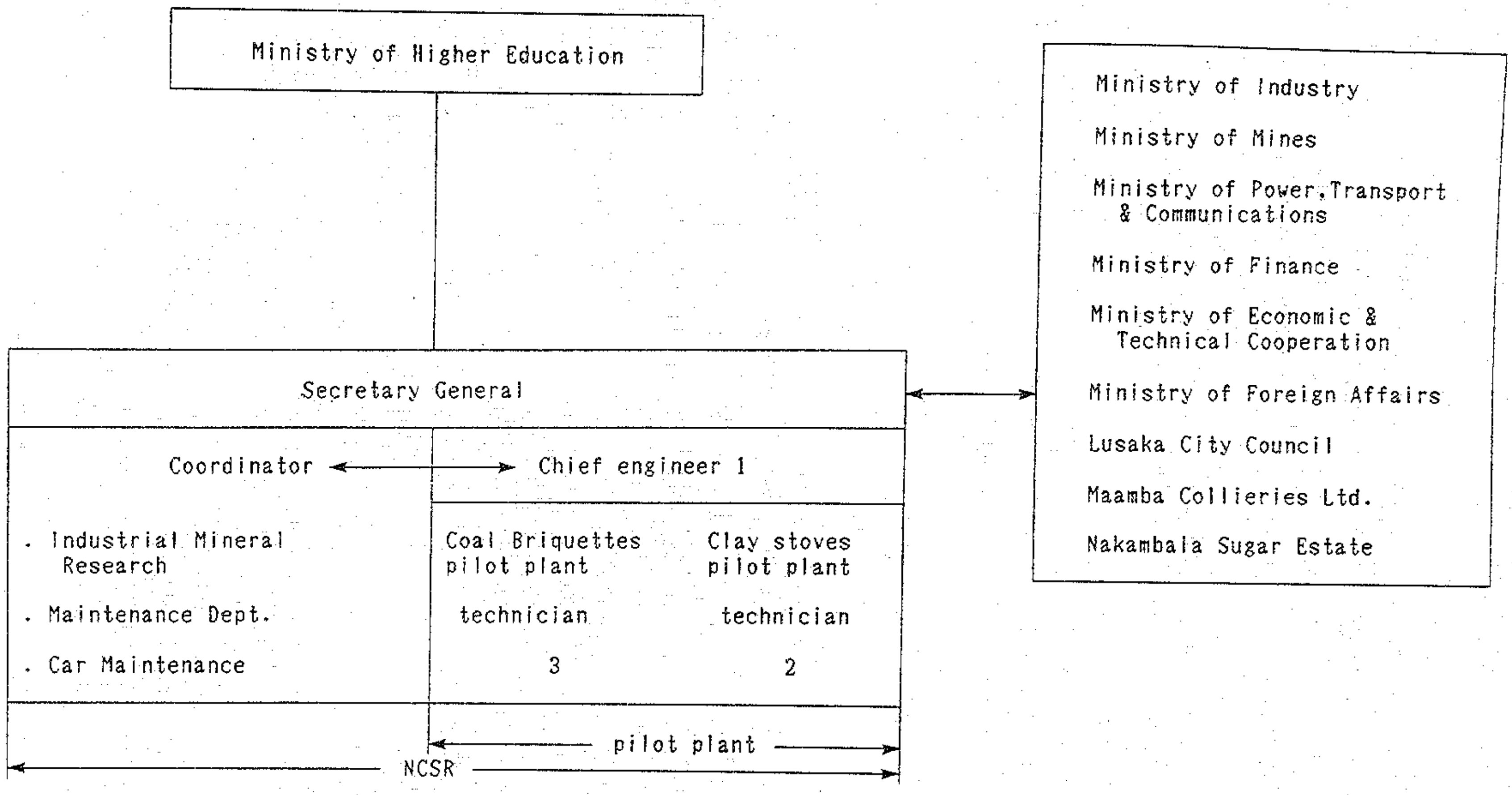

Figure 8 Organization

25. Theme of further study

In case this project is materialized, the pilot plant should be operated, at least during some initial years, to realize the design conditions of operation and quality of the products. After the plant has been thoroughly broken in the following studies should be done by effectively utilizing the pilot plant:

(1) Technical and economic subjects

1) Study possible ways to reduce or eliminate use of expensive components.
2) Study the possiblity of simplifying the manufacturing process.
3) Find a practical and reasonable compromise between the desired quality and manufacturing economy that could make production economically.

(2) Social subjects

1) What kinds of organization are effective to promote and operate a project of this nature.
2) What kinds of incentives should be prepared to stimulate use of coal briquettes in place of traditional woodfuel.
3) What distribution channels would be effective for coal briquettes to reach general consumers.
4) What typical behavioral reactions of general consumers would be to an entirely new commodity and what actions should be taken to the reactions.
5) What kinds of PR, or promotion activities would be effective and under what conditions.

This feasibility study has already investigated these themes and made the results of the study reflected in the report. Once the project is realized the organization in charge of running the project should be able to rightly respond to any challenges no matter how unexpected they may be.

26. Overall evaluation

As explained in 23 "Financial analysis" this project could not make both ends meet without introduction of a subsidy to relieve the project of the burden of spare parts and insurance fee on top of the construction cost. Technically it was confirmed that coal briquettes and clay stoves of the desired quality may be produced from the intended domestic raw materials; also the market analysis indicates good possibility of marketing the products.

The overall evaluation of this project consists in the tradeoff between the financial burden to be incurred in the project and such benefits as utilization of unused resources and a practical step towards making a substitute fuel for woodfuel available. If there is an outside subsidy to cover the cost of spare parts and insurance fee, the research and development activities into the technical economic and social subjects mentioned in 25 "Theme of further study" would be made possible.

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