THE FEASIBILITY STUDY REPORT

ON

THE BRIQUETTES DEVELOPMENT PROJECT

IN

THE REPUBLIC OF ZAMBIA

DECEMBER, 1986

JAPAN INTERNATIONAL COOPERATION AGENCY

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P R E F A C E

In response to the request of the Government of the Republic of Zambia, the Government of Japan decided to conduct a feasibility study on the Briquettes Development Project and entrusted the study to the Japan International Cooperation Agency (JICA). JICA sent to Zambia a survey team headed by Mr. Koji Tanaka, TECHNO CONSULTANTS, INC., from 23 February to 23 March 1986.

The team had discussed on the Project with the officials concerned of the Government of Zambia and conducted a field survey in the project-related areas. After the team returned to Japan, further studies were made and the present report has been prepared.

I hope that this report will serve for the development of the Project and contribute to the promotion of friendly relations between our two countries.

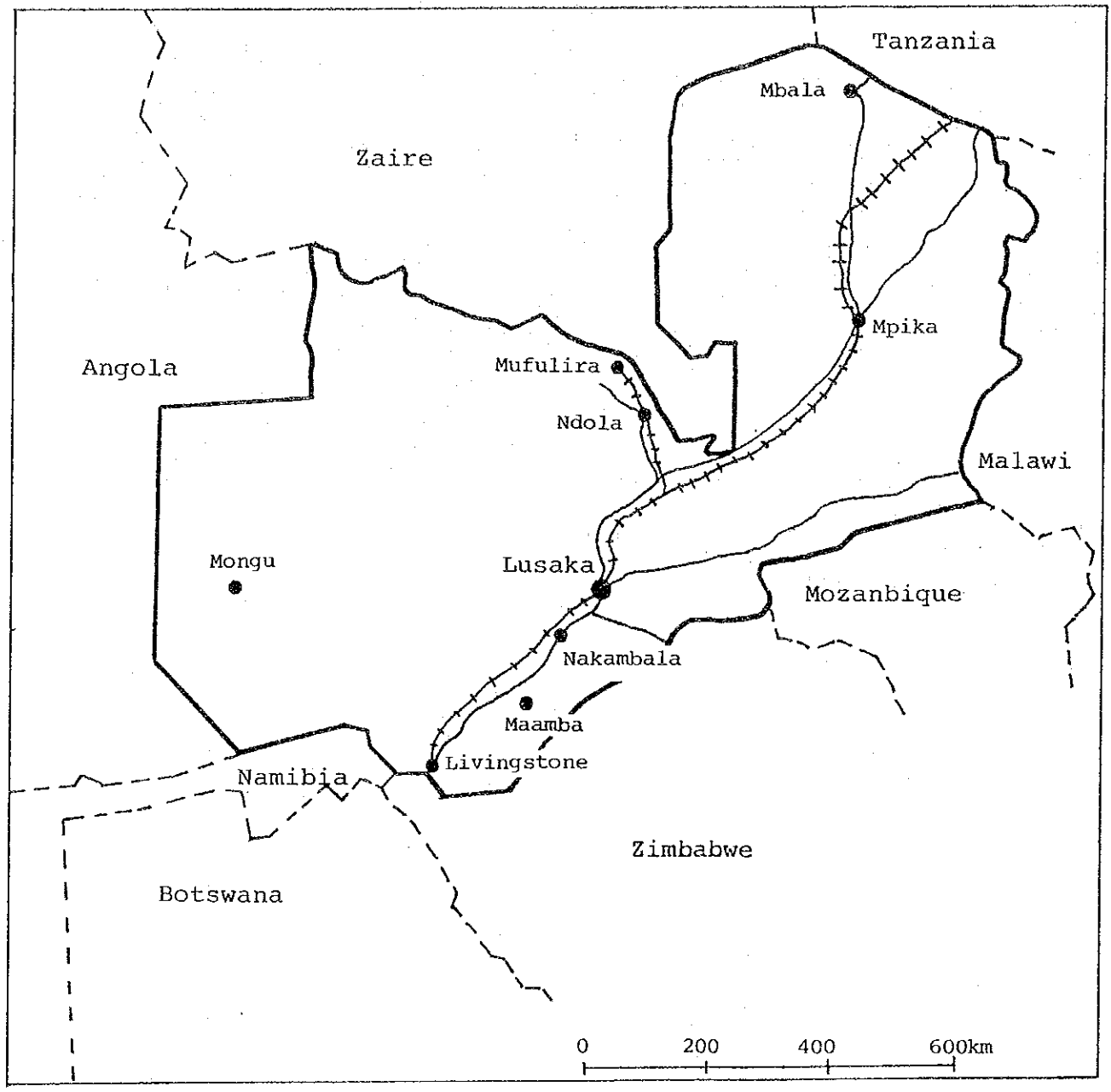
I wish to express my deep appreciation to the officials concerned of the Government of the Republic of Zambia for their close cooperation extended to the team.

December, 1986

Keisuke Arita

President

Japan International Cooperation Agency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INTRODUCTION

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.

Immediately following this INTRODUCTION is provided SUMMARY AND CONCLUSION before entering the body of the feasibility study report. SUMMARY AND CONCLUSION is so designed that the reader may have a fairly good understanding of the important conclusions and the contents of this report without reading the body of the 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. This feasibility study report is therefore structured in such a way as to give the reader how all the factors affecting the definition of the project were analyzed, how these factors were put together, weighed, coordinated

and reconciled and how the project was defined. The definition of the project is referred to as PROJECT SCHEME in this report and is discussed in Chapter 10, PROJECT SCHEME. All the factors with few exceptions affecting the definition of the project are discussed before Chapter 10, market and supply/demand study in Chapter 4 and transportation in Chapter 6, for example. A considerable effort has been made to establish right defenition of the project, above all the decision on plant location, capacity of the project and transportation mode.

Once the project is defined the development of the rest of the feasibility study is rather straightforward although there were unwritten trial-and-error endeavors in the experimental productions of coal briquettes and clay stoves to discover the optimum raw material compositions and manufacturing process as elaborated in Chapter 11. Chapter 12, MANUFACTURING PROCESS AND FACILITIES, provedes conceptual designs of the coal briquettes and clay stoves pilot plants developed based on the results of their experimental production. Chapter 13, CONSTRUCTION, analyzes the construction of the plants proposed in Chapter 12 and develops the cost estimates and construction schedule. Chapters 14, 15, 16, 17 and 20 concern evaluation of the project. Chapter 18, ORGANIZATION, presents a recommended organization. Chapter 19, THEME OF FURTHER STUDY, presents what studies should be done using the pilot plant.

Finally, APPENDIX contains materials serving as basis of this study; Scope of Work, minutes, progress reports, etc.

SUMMARY AND CONCLUSION

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. 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. 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.

Since coal briquettes are to replace a portion of charcoal, the best strategy would be 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 would have a distribution channel intimate with people.

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.

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.

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. 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.

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. 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 1,214 tons. 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.

(2) Bagasse

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.

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.

(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) Price

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

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

9. Raw material for 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 tons

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.

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 hydro-electric 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 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 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.

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.

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 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.

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.

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

The financial evaluation was done in three steps as explained previously in 4.6). This project cannot simply pay out the investment. The calculation shows that the project is infeasible unless the project is relieved of the plant construction cost, maintenance cost (spare parts to be exact) and insurance fee by ourside subsidies. On such conditions this project gives the following profit and loss.

Annual income	
Sales of coal briquettes	200,000
Sales of clay stoves	32,000
Total	232,000
Annual expense	
Raw material cost and transportation	87,880
Utility	24,110
Salary and manpower	60,000
Miscellaneous	10,000
Total	181,990

Provided that the above conditions are met, the project can stand on its own feet.

24. Organization

This pilot plant project would be run by NCSR. The Secretary General would assume the overall responsibility of the project. The daily routines of the plants would 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 would 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. 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.

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 viable.
4) Make further studies on clay stoves and develop new versions of clay stoves that could effectively and safely burn coal briquettes of inferior quality, or economically manufactured briquettes.

(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.

CONTENTS

APPENDIX

1. BACKGROUND AND HISTORY OF PROJECT

1.1 Outline of the Project

This project consists essentially in producing coal briquettes using as raw material coal slurry being produced in association with coal washing operation at the Maamba Collieries in the southern part of Zambia. This project also uses bagasse as another carbon source and molasses produced by Nakambala Sugar Estate as well as slaked lime locally available in abundance as desulfurizing agent. The purpose is to establish coal briquettes among middle and lower income brackets as household fuel for heating and cooking as a replacement for firewood and charcoal, particularly charcoal, extensively employed by people of such income groups. In parallel with coal briquettes, this project also produces clay stoves from locally available clay that could replace thermally ineffecient iron-made stoves called "mbaula" now commonly used for burning charcoal.

This project will install one pilot plant each for coal briquettes and clay stoves and necessary associated facilities capable of producing a year 1,000 tons of coal briquettes and 4,000 pieces of clay stoves. Both pilot plants will be located in Namununga Industrial Site of Lusaka.

The reason for being pilot plants instead of full-fledged commercial plants is that, although this feasibility study has established technology for manufacture of coal briquettes and clay stoves, there will be needed firstly to make further researches and developments to adjust to variations of feed properties and, perhaps more importantly, to establish among targeted consumers coal briquettes and clay stoves which are for them entirely new and not tried before.

The pilot plants will be managed by National Council for Scientific Research (NCSR), a national research institute under the Ministry of Higher Education.

1.2 Social and Natural Background

Among African countries, Zambia is the one which is blessed with a relatively mild climate and rich forests. In recent years, however, the nation's forests are being increasingly destroyed along with population increase and growth of cities by collection of wood for firewood and charcoal production in such a rapid pace that natural processes alone can no longer restore the loss of forest. Now Lusaka cannot be supplied with firewood or charcoal from its own suburbian areas. The present consumption of charcoal is estimated at some 150,000 tons. About 2 million cubic meters of wood would be needed to produce just this amount of charcoal. A survey on wood consumption and forest conservation jointly conducted in 1985 by the Forest Department of Zambia and UNDP estimates on a provisional basis the wood consumption to be 8,730,000 cubic meters, 80 percent of which being accounted for by firewood and charcoal. Another survey says that wood consumption for fuel purposes alone, including that used for manufacture of charcoal, could wellexceed 10,000,000 cubic meters. The government of Zambia, throughout from the president or prime minister at the top, well recognizes the importance of protecting the nation's forests.

Exploration for oil has been done but has not so far met with success. Coal deposits have been located at a number of locations, among them Maamba Collieries Ltd. has been in operation since 1969. Zambia is blessed with plenty of hydro-electric power resources. Ever since 1974 when Kafue Gorge hydro-electric scheme was completed, Zambia has been a net exporter of electricity. The record for 1984 indicates that the total generation was 9,806 million kwh, of which 6,404 million kwh was domestically consumed and 3,033 million kwh was exported. Inspite of a considerable amount of excess electricity being avaiable, only a small well-to-do bracket of the people can afford to use electricity for heating and cooking, because of the distribution network not well established and appliances being expensive. Petroleum products are supplied by the only refinery in Zambia, Indeni Refinery, which processes crude oil imported by Tazama Pipeline. There is also products importation. The scarcity of foreign currency and the very low purchasing power of general populace inhibits extensive use of petroleum products

as household fuels. It is urgently needed to supply inexpensive and safe fuels that can substitute for firewood and charcoal. If one considers general situations surrounding the energy problem of Zambia, one may easily conclude that such fuels would be ones derived from coal, specifically coal briquettes such as studied in this report.

It would be most practical to extend power supply networks along with coal briquettes to the extent possible within the budgetary limit.

Fortunately, Zambia has all required raw materials for coal birquettes as long as the size of the project is not too ambitious. There is a sufficient amount of coal slurry filling two slurry ponds at the Maamba Collieries which may be regarded as zero-price. In addition, there is also a fresh annual supply of coal slurry which in itself is sufficient to fill the requirement. Quality-wise, the coal slurry is not ideal, having rather high contents of ash and sulfur; and also the slurry produces a considerable amount of smoke upon combustion. However, the experimental production of coal birquettes conducted as part of this feasibility study has successfully produced coal briquettes of the acceptable quality in the Zambian circumstances under which the coal briquettes will be used. Maamba where the coal slurry is, although 350 km apart from Lusaka where the pilot plant will be located, is not prohibitively far in order to make this project viable. Bagasse and molasses are available in sufficient quantities at Nakambala Sugar Estate, about 130 km from Lusaka. Limestone is abundantly deposited in Lusaka area and limestone or slaked lime of good quality may be obtained in Lusaka area.

As for raw materials of clay stoves, there are a number of candidate clay deposits within the economic radius of transportation from Lusaka. Clay from Chamba Valley in a suburb of Lusaka, now used for making bricks, makes a good raw material for clay stoves by baking at around 800°C. As stated above, this pilot plants project has a good combination of raw material supply.

The market for coal briquettes and clay stoves is primarily Lusaka. Lusaka consumes some 150,000 tons of charcoal which may be taken to represent a good potential market for 1,000 tons of coal briquettes. The middle and low income brackets use mainly charcoal for heating and cooking. They mostly live in houses of relatively closed type, walled on all four sides. This is one of the reasons why smokeless and odorless charcoal is used. The distribution of charcoal is mostly in the hands of small-scale individual dealers who purchase charcoal from producers, normally bagged in 16 to 40 kg piece, transport them to consuming areas and store them, wholesale or sometimes retail them. The retail is in a maximum of 40 kg bag down to a small bucketfull lot. Charcoal is retailed in so-called open markets along with other daily necessities and vendors in residential areas. Coal briquettes, in order to penetrate the market, will have to be sold mainly on the present charcoal sales channel and accepted by the people as a good substitute for charcoal. Likewise, clay stoves will have to be sold on the charcoal channel and mbaula channel. Since fuel dealers have complete freedom as to the selection of their sources of supply of charcoal, the coal briquettes, as long as they are acceptable to the consumers from the viewpoints of quality and price, the fuel dealers may well come to NCSR to purchase in wholesale the coal briquettes. The same will hold true with clay stoves.

This feasibility study has confirmed by experiment possibility of producing coal briquettes that can substitute for charcoal and clay stoves that can substitute for mbaulas at acceptable prices. The real problem here, however, is the fact that coal briquettes and clay stoves are both entirely new products never tried out before by general consumers; therefore, both will take time to penetrate the market, even for years. Effective promotion efforts appear indispensable to quicker market penetration. In a society where mass media like radio or television sets are not very common among low and medium income brackets, where even newspaper circulation is not very high, person-to-person communication like that through housewive's talks must be counted on. It would, therefore, be prudent not to expect ready and positive responses immediately upon introduction to the market of coal briquettes and clay stoves.

To sum up socio-natural circumstances surrounding this project, except that both coal briquettes and clay stoves would have to take some time before they are established in the Zambian society, the energy situation, raw material situation, market situation, the government policy all may be considered very favorable to this project.

1.3 History of the Project

Prompted by the need to arrest further advance of deforestation caused mainly as a result of producing household fuels, firewood and charcoal, NCSR has been doing a research and development activity on the production of coal briquettes utilizing waste coal slurry in the Maamba Collieries. In 1985 the government of Zambia made a formal request with the Japanese govermnent in summary to: (1) conduct a technoeconomic study to determine techno-economic viability of a pilot plant project to produce coal briquettes and clay stoves, (2) extend financial assistance in the form of grant to the construction of the pilot plants, and (3) assist in transfer of technology for the operation of the pilot plants, production of coal briquettes and clay stoves.

In accordance with this request, the Japanese government discussed the content of cooperation with the government of Zambia and sent a preliminary study team of Japan International Cooperation Agency (JICA) from December 9, 1985 to December 25 and agreed with NCSR on the Scope of Work attached.

1.4 Brief Account of Feasibility Study

As per thus agreed between the both governments JICA sent to Zambia a study team consisting of nine experts from February 23, 1986 to March 23. During this period the study team, in close cooperation with NCSR and other concerned organizations, conducted a field survey of which the main objectives are to: (1) collect information and data necessary for the subsequent home-office work (2) collect raw material samples for coal briquettes and clay stoves and send them by air to Japan, (3) establish and agree with NCSR on the tentative project scheme which defines the project by specifying capacities and site, etc. and (4) prepare and submit to NCSR a progress report which

describes the results of the field survey, the project scheme and its rationale, basis for the home-office work, and finally prepare and agree with NCSR on a minutes of meeting (attached) on important items. All the above objectives were successfully achieved.

The study team was able to collect information and data necessary for the home-office work; worth particular mention are:

1) Information on the transportation modes of raw materials -- coal slurry, bagasse, molasses, etc. -- and their costs

2) Market size, distribution scheme and prices at major stages of distribution of charcoal in Luska

3) Information on intrastructure, site, cost data for the construction of the pilot plants, and

4) Required quality of coal briquettes, particularly smokelessness and odorlessness and thereby necessity of carbonization process to eliminate smoke and odor, in view of the lifestyle in Lusaka area.

The following amounts of raw material samples were collected and sent to Japan by air and used for experimental production of coal briquettes and stoves:

	kg
Coal slurry	833.9
Bagasse	1,118.7
Molasses	118.3
Slaked lime	100.0
Clay	200.0
Total	2,370.9

The tentative project scheme established during the field survey consists of the followings leaving to the home-office work development of details of the project:

1) Annual production

Coal briquettes, tons/year	1,000
Clay stoves, pieces/year	4,000

2) Plant site

Namununga industrial site of Lusaka

3) Target price (March 1986 price)

Coal briquettes, k/ton	200
Clay stoves, k/piece	8

The home-office work commenced in April 1986. The main items of study are to: (1) produce by experiment coal briquettes and clay stoves from the raw material samples sent from Zambia, (2) compile, organize and study the information and data collected during the field survey and develop analyses of market, infrastructure, transportation, raw materials, policy and inputs to financial/economic study, (3) review, modify, as necessary in the light of the result of the home-office work, and finalize the tentative project scheme, (4) develop a conceptual design of the pilot plants and associated facilities, (5) estimate investment costs, operation costs and total capital requirements (6) conduct financial and economic evaluations, and (7) present overall evaluation of the project and necessary recommendations.

Of the outcomes of the home-office work the followings are worth particular mention:

1) Possibility is established to produce coal briquettes and clay stoves from locally available raw materials that would match the lifestyle of the local people
2) The preliminary project scheme set up during the field survey has been finalized without major modifications
3) The total capital requirement consists of 1,522.8 million yen for foreign currency portion and 6,329.8 thousand K for domestic currency portion. It has been confirmed that if the project is relieved of the burden of capital investment, interest during construction, annual maintenance, and insurance, the project is financially feasible.

1.5 Research and Development by NCSR

NCSR has been doing a development work of coal briquettes of their own. NCSR had been able to produce their own coal briquettes by the time of field survey, or February/March of 1986, although the production was on a hand-made scale.

The study team conducted burning tests of NCSR's briquettes. The briquettes were made from whole slurry, or slurry without pretreatment for the removal of mud and sand or carbonization for the removal of smoke, odor and sulfur. The pretreatment was suspended because of them being considered to be expensive. The coal briquettes looked good and rigid enough. But they produced a volume of smoke on burning, particularly during the intial period of combustion when fire was not still strong, enough to regard them not entirely of adequate quality for Zambia, especially Lusaka area where houses are of closed type. The briquettes also exhibited some tendency to die down after they started burning. The Japanese briquettes the study team brought along did not produce smoke, odor, or show any tendency to die down.

Industrial Mineral Research of NCSR is well equipped humanly and materially but was not doing developmental works on clay stoves. They have crushers, mills, shieves, classifiers, ovens, X-ray flourimetry analyzers, etc. They have information on Zambian clays.

NCSR has been doing very well but injection of an appropriate foreign technology and assistance would enhance the already strong NCSR's capability.

2. PROFILE AND POLICY OF ZAMBIA

2.1 Natural Conditions and Population

The Republic of Zambia is a landlocked country with an area of 750,000 km^2 in South Central Africa at 9 to 18 degrees south latitude and at 23 to 42 degrees east longtitude. Zambia shares borders on the north with Tanzania, Zaire; on the south with Zimbabwe, Botswana; on the east with Malawi, Mozanbique; and on the west with Angola, Namibia. Geographically, Zambia is mostly a flat plateau averaging 900 to 1,500m above the sea level except for the northern mountains bordering Tanzania exceeding 2,000m above the sea level and a number of valleys along rivers such as Kafue or Luwangwa Rivers less than 600m above the sea level. Although Zambia is close to the equator, the climate is moderate because of the altitude. The temperature seldom exceeds 30°C except in some valleys.

The population is about 6.4 million (mid-1984), and is rapidly growing at a rate of 3.1% a year (See Table 2-2-1). Most people live in the area along the railway running from the Copperbelt in the north through Lusaka to Livingstone in the south. Although Lusaka only has a population of more than 500,000, the increase in urban population, a phenomenon common in many developing countries, has been remarkable in Zambia too. Especially in such large cities as Kitwe, Ndola, Mufulira and Lusaka, the population has been increasing so fast with the advance of economic activities, that a variety of social problems such as unemployment, housing shortage, lack of educational or medical facilities ensued.

2.2 Economy and Policy of Zambia

2.2.1 Zambian economy in perspective

Since independence, the rise and fall of the Zambian economy has been closely linked with the mining industry, or copper mining; more specifically, the following three factors have had a great impact upon the economy of Zambia:

1) LME (London Metal Exchange) copper price
2) Transport routes from Zambia to coast
3) Diplomatic relations with neighbouring countries

Since independence, the Zambian government has been consistently keen on diversifying its economy and thereby reducing the country's excessive dependence on copper mining industry, also on promoting import substitution industries and thus creating new employment opportunities and reducing the import of consumers' goods and ultimately to improve the balance of payments. In addition, under the slogan of Zambianization, the government has nationalized some of the important industries to hold control of the economy.

The first national development plan (1966-70) emphasized the diversification of economy, improvement of agriculture, extention of educational system, and development of transport infrastructure. During this period, the annual GDP growth rate of 10.6% was achieved. During this period, booming copper price prevailed. However, the development in mining and agriculture sector fell short of the target on account of disruption of the trade route by the deterioration of relations with Rhodesia (now Zimbabwe). The second plan (1972-1976) emphasized investment in the manufacturing sector. The projected GDP annual growth rate was 15 and 6.8% for manufacturing sector and nation as a whole, respectively. However, the achievement has been below the target because of disruption of trade routes, the sharp fall in copper price during 1975, and the price increase of imported commodities affected by the world-wide inflation. The third plan (1980-84) had to set lower targets of economic development plans, due to the difficult financial conditions. The GDP growth rate was projected to 4.8% a year. This target could not be achieved mainly because of the shortage of foreign exchange and the failure of agricultural productions.

2.2.2 Current economic situation

Tables 2-2-1 to 2-2-3 below show basic economic indicators, GDP by industry and balance of payments situation.

Table 2-2-1 Basic Economic Indicators (1977 -1984)

	Unit	1977	1978	1979	1980	1981	1982	1983	1984
1. Population (Mid-year)	million	5.2	5.36	5.52	5.63	5.87	6.05	6.22	6.42
2. Gross Demestic Product									
at current prices	K.million	1996.4	2250.7	2660.4	3063.6	3485.4	3595.3	4181.2	4733.3
at 1977 prices	K.million	1996.4	1997.8	1937.0	1995.8	2118.5	2059.3	2018.2	1992.1
3. GDP Growth Rate									
at current prices	percent	--	12.7	18.2	15.2	13.8	3.2	16.3	13.2
at 1977 prices	percent	--	0.1	-3.0	3.0	6.1	-2.8	-2.0	-1.3
4. Per Capita GDP									
at current prices	Kwacha	383.9	419.9	482.0	544.2	593.8	594.3	672.2	737.3
at 1977 prices	Kwacha	383.9	372.7	350.9	354.5	360.9	340.4	324.5	310.3
5. National Income									
at current prices	K.million	1607.4	1809.8	2124.3	2495.9	3004.1	2870.3	3508.3	3910.3
at 1977 prices	K.million	1607.4	1616.9	1575.5	1671.2	1856.6	1773.2	1773.2	1770.1

Source: Monthly Digest of Statisitics: Central Statistical Office

Table 2-2-2 GDP by Industry Origin at Constant (1977) Prices

(Unit: K.million)

	1980	1981	1982	1983	1984	1984(%)
Primary sector						
Agriculture foresty & fishing	304	329	290	315	345	17.3
Mining & quarrying	205	215	215	222	204	10.3
Secondary sector						
Manufacturing	384	430	415	385	378	19.0
Electricity, gas & water	66	71	76	72	72	3.6
Construction	103	79	84	89	88	4.4
Tertiary sector						
Commerce	196	195	179	172	155	7.8
Hotels & restaurants	40	53	53	56	55	2.8
Transport & communication	118	118	119	119	113	5.7
Financial institutions & insurance	67	65	71	66	56	2.8
Real estate & business services	145	153	156	168	169	8.5
Community social & personal services	346	394	394	356	356	17.9
Import duties	42	36	28	19	15	0.8
Sub-total	2,016	2,138	2,080	2,039	2,006	100.8
Less: imputed bank charges	-19	-18	-20	-19	-16	-0.8
GDP at producer's values	1,997	2,120	2,060	2,020	1,990	100.0

Source: Economic Report: IMF

Table 2-2-3 Balance of Payments

($ mn)

	1979	1980	1981	1982	1983
Merchandise exports, fob	1,408	1,457	996	948	982
Merchandise imports fob	-756	-1,114	-1,065	-1,004	-771
Trade balance	652	343	-69	-56	271
Exports of services	127	152	163	137	106
Imports of services	-637	-946	-788	-657	-543
Net private transfers	-137	-183	-157	-66	-42
Net official transfers	32	7	25	26	39
Balance on current account	37	-627	-826	-616	-169
Direct investment	35	57	34	-	-
Other long term capital	183	115	415	261	67
Short term capital	-88	62	-105	99	-43
Balance on capital account	130	234	344	360	24
Errors & omissions	-87	170	21	-81	-207
Counterpart items	37	32	52	35	-78
Exceptional financing	-187	219	52	399	396
Liabilities constituting foreign authorities' reserves	-1	-2	-3	-	-
Change in reserves (- indicates increse)	72	-27	360	-98	34

Source: IMF, International Financial Statistics

The Zambian economy is suffering from low prices of copper, the resultant reduction in foreign currency earnings, budgetary deficit and negative economic growth. Above all, the decreasing foreign currency earnings have made it increasingly difficult to obtain raw materials, spare parts; which, in trun, resulted in unsatisfactory maintenance and low running rates of facilities and equipment. The reduction in foreign currency gaining also makes it difficult to meet foreign debt obligations. The Zambian government has drastically cut imports and negotiated rescheduling of debt services and refinancing. Concurrently, the government has implemented the following measures in line with IMF's suggestions.

1) Introduction of market principle in price setting of commodities
2) Tighter government budget, decrease of government subsidy, suspension of wage hikes
3) Devaluation of Kwacha

With all those measures, the economic conditions did not improve as had been expected again mainly because of inactive copper export. On October 4, 1985, the government decided to introduce a foreign exchange auction system similar to that Uganda tried before with some effects. Under this new system, all the uses of foreign exchange except for a few needed for payments by Zambia Airways or ZCCM (Zambia Consolidated Copper Mines) have to be bid in auction by the banks representing the buyers. The auction is normally held once a week.

The impact of the introduction of the auction system on the exchange rate is very significant as might be expected. After the first auction the value of Kwacha against US dollar dropped from 2.17 to 5.01. Ever since Kwacha has continued to fall reflecting difficult financial conditions. As of the field survey the exchange rate was 6.65 k/US$.

2.2.3 Economic development policy

At present, it is most important for the Zambian economy to restore stability by improving the balance of payments, and to promote agriculture in order to reduce the country's dependence on copper which is considered to have 15 to 20 more years of reserves; or in other words, which will be virtually exhausted by the end of the century.

(1) Short-term policies

Zambia depends for the supply of consumers goods, raw-materials and spare parts basically on importation. The chronic shortage of foreign exchange, in turn, causes shortage of essential goods, and this shortage has led to a rapid acceleration in the inflation rate. The Zambian government's basic policy to curb this inflation is the attainment of balance between supply and demand by increasing supply of goods and services on one hand in parallel with judicious allocation of goods and other resources on the other.

In the manufacturing sector, the government has changed the development priority from capital intensive industry to labor intensive industry. Under this policy public corporations with unsatisfactory performance records would be more scrutinously controlled by the government through ZIMCO. In addition, the government embarked on the streamlining of export procedures and the reorganization of export promotion council to intensify export competitiveness of manufactured goods.

In the mining sector, the government has been emphasizing increase in production and reduction in cost by rehabilitation of existing facilities. In the energy sector, the government seeks to diversify and make the best of domestic energy such as electricity and coal and reduce uses of imported oil, thus reduce foreign exchange expenditure. In its relations with foreign countris, the stand-by arrangement by IMF and debt rescheduling are essential for Zambia.

Zambia therefore attaches great importance to maintaining good relations with IMF and foreign creditor countries. As for the domestic financial policy, the government has decided to greatly limit investment to foreign exchange earning or import substitution projects under the retrenchment polocy. With respect to debt services, rescheduling and injection of additional finances would be necessary; and for this purpose, recommendations by IMF would be implemented. The budgetary expenditure would be curtailed. Investments in new projects would be postponed unless they could generate foreign currency income or produce import substitutes. The interest rates are expected to rise. The subsidy will be drastically cut. The wage hike will be controlled.

(2) Long-term policies

In the process of restructuring the economy away from dependence on copper, the Zambian government has been emphasizing the rural development by promotion of agriculture. Zambia has considerable agricultural potential, with about 9 million ha of good to arable land. Despite this potential, however, only 20% of arable land is currently utilized, due largely to the unattractive producer prices in the 1960s and 1970s, the lack of skilled manpower in agricultural sector, inadequate marketing and transport facilities.

The basic policy for the agricultural development aims to achieve food self-sufficiency and boost agricultural export. The ultimate purposes of the agricultural development are to promote rural development, create new employment and income opportunities in the rural area, and reduce the disparities in the level of income between rural and urban areas.

The government, in order to achieve the above purposes, has decided to raise agricultural producer price. Non-price incentives including farmers' tax reduction and foreign exchange incentives are also introduced. In addition, the government has been encouraging the irrigation works, construction of storage facilities, and improvement of distribution system with assistance from foreign countries.

2.3 Government Policy and the Project

A new project should conform to the policy of the host country government in its plan in order to be successful. This section presents a brief introduction of the energy policy and industrial policy of the government of Zambia which naturally affect the course of this project.

2.3.1 Energy policy

The domestic sources of energy are hydroelectricity, coal, and woodfuel. The hydroelectricity and coal are used mainly for industrial purposes and woodfuel for household use.. Petroleum products and crude oil are imported. The government has consistently taken the policy of reducing the import of petroleum while encouraging increased utilization of the domestic energy. The importation of petroleum peaked in 1976 and has been on the decline ever since; however, in terms of Kwacha, it has been steadily increasing owing to the rise in the price of oil and devaluation of Kwacha. (Refer to 3.1 Current Energy Use.)

Zambia has excess electricity to export. The production of coal falls short of the demand obliging a portion of the demand to be met by import. The consumption of woodfuel, particularly that of charcoal, has been sharply increasing keeping pace with the increase in urban population which is causing a rapid destruction of the nation's forest resources. Against such a background the government of Zambia has established and been promoting the following policies:

1) Restrain the importation of petroleum and promote and encourage extensive utilization of local energy resources like hydroelectricity or coal

2) Promote the substitution of such local energy for petroleum

3) Rehabilitate old facilities, or install new equipment if necessary, to achieve energy savings, and

4) Investigate the possibility of developing new energy sources such as solar energy or ethanol.

More practically, the followings are under study:

1) Rehabilitation of Indeni Refinery
2) Rehabilitation of Tazama Oil Pipeline
3) Rehabilitation of the Maamba Collieries, Ltd.
4) Improvement of power supply grid and maintenance and rehabilitation of the existing system
5) Improvement in efficiency of production and utilization of charcoal, and

6) Replacement of woodfuel by coal briquettes, wood pellets or other substitute fuels.

2.3.2 Industrial policy

Against a background of deteriorating foreign currency situations, the Zambian government places emphasis upon development of medium- and small-scale industries that could earn foreign currencies or produce commodities replaceable imported goods. At the same time development of agro-based industries is encouraged. The Small Industry Development Organization, or SIDO, plays a leading role in the development of medium- and small-scale industries. During the period from 1983 to 1985 SIDO had transferred the following technologies to the private sector in cooperation with NCSR and the University of Zambia.

1) Development of industrial salt
2) Manufacture of gypsum
3) Production of honey and beeswax
4) Production of cashew nuts
5) Improvement in charcoal burning technique

Listed in Table 2-3-1 are high-priority projects of which research and development activities are contemplated.

Table 2-3-1 Summary of New R&D Projects

Product Line	No. of Enterprises
Food Processing	8
Textiles	8
Wood based	5
Engineering	5
Chemical	4
Leather based	3
Construction	1
Ceramics	1

Source: SIDO, Annual Report (1984/85)

2.3.3 Coal briquettes and clay stoves against policy background

Production of coal briquettes drawing upon waste domestic resources would contribute to the savings of charcoal consumption. Promotion of extensive use of clay stoves in place of iron-made local stoves, mbaulas, would also contribute to the savings of charcoals because of their by far the superior thermal efficiency compared with mbaulas. They also saves iron consumption which is an imported commodity. Thus, this pilot plant project undoubtedly agrees with the government policy.

3. ENERGY SITUATION

3.1 Current Energy Use

Zambia is not endowed with rich energy resources, although hydroelectric power, coal, and wood fuel have potentials more than to meet the present requirements. Hydroelectric power and coal are used chiefly for commercial purposes and wood and charcoal for household consumption. The demand for woodfuel differs by survey sources. According to slightly outdated 1983 data (Zambia: Issues and Options in the Energy Sector January 1983, Report No. 411-ZA), total energy consumption in 1981 including traditional fuel forms was equivalent to 4.5 million tons of oil. Of these, hydroelectric power constituted 31% and coal 6%. In contrast, traditional forms of energy represented by firewood, charcoal, and bagasse made up 45%, or 2.03 million tons of oil equivalent. Other sources of energy, oil and coke, were imported accounting for 16.5% and 1.3% respectively.

Hydroelectric power is Zambia's most vital energy resource and the reserve is estimated at 4,000 MW. At the time of independence, the nation relied totally upon outside electricity resources but with the Second National Development Plan (SNDP) from 1972 to 1977, the nation achieved self-sufficiency. Since then, the nation has become a net exporter of electricity.

Zambia is fortunate in having substantial deposits of coal although only a small amount of resource is exploited at present at the Maamba Collieries. However, the obsoletion of the facilities at the collieries restricts production and; therefore, Zambia has had to import limited amounts of coal recently. As mentioned above, woodfuel may be considered to constitute nearly half of Zambia's total energy consumption, although the figures have not been accurately substantiated. The supply and consumption of woodfuel, used chiefly as household fuel, are hardly traceable making estimates at any degree of accuracy very difficult because of the collection and distribution channels not well organized.

Zambia does not have producing nor proven petroleum deposits; accordingly, the nation depends entirely on imports for the supply of petroleum. Indeni Refinery, the only refinery of Zambia at Ndola, being not equipped with facilities to convert heavy oil into light oils, oil is imported in the form of spiked crude, or crude oil enriched with light oils, via Dar es Salaam, Tanzania, through Tazama Oil pipeline.

Petroleum imports peaked at 908,000 tons in 1976 and is on the decrease, with 774,000 tons in 1983. However, the import value has grown from 49.2 million kwachas in 1975, or 13.2% of total imports, to 232 million kwachas, or 26.0% in 1983. This gave a significant impact upon the financial conditions of the country.

The major commercial energy sources have been and will be hydroelectricity, petroleum, and coal, whose production in 1978 and 1983 are shown in Table 3-1-1. It is evident from this table that dependence on imported petroleum was reduced and consumption of local energy was increased.

Table 3-1-1 Energy Production

Energy Type		1978	(Percentage)	1983	(Percentage)
Electricity	(Gwh)	7,883	-	10,072	-
	(PJ)	28.4	(38.3)	36.3	(49.4)
Refined Petroleum	('000MT)	734.7	-	606.9	-
Products	(PJ)	31.2	(42.0)	25.8	(35.1)
Coal	('000MT)	582.0	-	453.6	-
	(PJ)	14.6	(19.7)	11.4	(15.5)
Total	(PJ)	74.2	(100.0)	73.5	(100.0)

Source: Energy Production & Consumption in Zambia 1978-1983
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Note: PJ (peta joule) = 10^{15}J = 23,900 TOE (1 ton of oil equivalent)
1 Gwh corresponds to 3,600 GJ or 3.6 TJ.
1 ton of the Zambian mix oil products corresponds to approx. 42.5 GJ.
1 ton of coal corresponds to approx. 25.1 GJ.

This trend is also seen in Table 3-1-2 which shows consumption of electricity, petroleum, and coal/coke for 1978 and 1983.

Comparison of these two tables indicates that the share of electric power in total commercial energy consumption is lower in Table 3-1-2 than that in Table 3-1-1. This is because about 30% of the power generated is exported causing the share of electricity to decrease in domestic commercial consumption and those of coal and coke to increase as compared with the shares in production.

Of industrial sectors, the mining industry, the greatest foreign currency earner, consumes the largest amount which in 1983 accounted for 47.5%, or nearly half the entire energy consumption.

Table 3-1-2 Total Commercial Energy Consumption

Year		1978 (Percentage)	1983 (Percentage)
Electricity	(Gwh)	5,635	6,432
	(PJ)	20.29 (29.7)	23.16 (37.8)
Petroleum	(1000MT)	718	588
	(PJ)	30.49 (44.6)	25.01 (40.8)
Coal/Coke	(1000MT)	702	524
	(PJ)	17.62 (25.8)	13.15 (21.4)
Total Domestic Use	(PJ)	68.39(100.0)	61.31(100.0)

Source: Fourth National Development Plant (Draft)
Note: Electricity is represented by its energy content and not by its thermal replacement value.

Table 3-1-3 Percentage of Commercial Energy Demand by Sector

Sector	1979	1980	1981	1982	1983
Mining	45.9	53.8	48.5	53.6	47.5
Commerce	26.7	24.2	26.5	18.4	23.0
Industry	19.5	16.0	15.6	11.9	10.6
Agriculture	2.9	2.4	5.2	11.3	11.6
Transport	5.0	3.6	4.2	4.8	7.2

Source: Financial Report

Zambia's household energy sources are charcoal, firewood, electricity, and kerosene. Although the proportions of these sources vary by region and income standards, wood fuel such as charcoal, firewood, and bagasse make up estimated 80% of the entire household energy demand.

3.1.1 Electricity

Zambia had been an importer of electric power until the 1960s. However, with the completion of two 150-MW power generators, which brought the total generation capacity to 900 MW on the Kafue River and a 450-MW generator, which brought the total capacity to 600 MW, as part of the first phase of the New Kariba North Bank Hydrostation Project in the 1970s, Zambia has become a net exporter. Table 3-1-4 shows Zambia's electricity supply and demand indicating that more than 30% of its total power output is allocated for export.

Table 3-1-4 Electricity Production and Consumption (Gwh)

	Total Domestic Consumption	Total Domestic Production	Net Exports[a]
1979	5,687	8,772	2,735
1980	5,828	9,221	3,166
1981	6,244	9,793	3,347[b]
1982	6,344	10,581	3,935[b]
1983	6,444	10,072	3,760
1984	6,404	9,806	3,033

a Excluding imports from Kariba. b To Zimbabwe only
Source: Monthly Digest of Statistice; Economic Report

Approximately 90% of the country's electricity export is directed to neighboring Zimbabwe, and the rest to Zaire. Total power capacity as of January 1982 was 1,798 MW, of which 1,669 MW was hydroelectric power and 129 MW from diesel power.

3.1.2 Petroleum

As explained previously, Zambia does not have proven petroleum deposits and therefore depends entirely on imports. Crude oil is transported via Tanzania's capital Dar es Salaam through Tazama Pipeline for processing by Indeni Refinery Company at Ndola. Table 3-1-5 shows Zambia's crude oil imports.

Table 3-1-5 Oil Importation

Year	Volume (Barrel)	Volume (Ton)	Value F.O.B. (Kwacha Million)	Value F.O.B. (US$ Million)
1978	6,022,984	780,154	68.1	86.5
1979	5,382,927	699,328	97.1	124.7
1980	5,766,276	761,882	153.9	191.6
1981	5,680,282	750,543	185.0	209.5
1982	5,690,175	748,149	197.9	212.8
1983	5,939,213	774,193	232.6	153.9
1984	N.A.	595,995	N.A.	N.A.

Source: Energy Production and Consumption in Zambia 1978-1983

Oil import decreased from 780,154 tons in 1978 to 595,995 tons in 1984, but has been on the steady increase in terms of Zambian currency at F.O.B. price. This was caused not only by the rise of crude oil price but also by the fall of kwacha since 1983. The seriousness of the impact of rising oil prices on the economy is well exemplified by the payment for importation of petroleum which grew from 13.2% in 1978 to 26.0% in 1983 of the total imports at F.O.B price in U.S. dollars.

Tables 3-1-6 and 3-1-7 show Zambia's petroleum product production and supply. Comparison of these tables indicates that the gap between production and supply, or exportable surplus, was generally growing smaller every year. Still, there was a considerable amount of surplus in such products as regular gasoline, LPG, and asphalt, or bitumen.

Tabel 3-1-6 Production of Refined Petroleum Products (Ton)

PRODUCT	1978	1979	1980	1981	1982	1983
PREMIUM GASOLINE	77,898	73,256	72,258	82,716	74,479	84,095
REGULAR GASOLINE	72,123	61,939	47,903	44,748	35,496	40,253
GASOIL (DIESEL)	287,223	278,134	276,958	251,286	225,623	231,582
LSG	19,629	16,582	37,228	33,963	35,130	35,372
KEROSINE (PARAFFIN)	27,527	28,484	29,627	35,187	30,427	36,661
JET A-1	57,838	63,075	71,085	66,047	53,507	55,603
LPG	8,445	2,274	2,356	3,518	6,276	6,471
HFO	173,280	156,966	170,119	141,007	121,138	92,707
LFO	5,021	8,677	11,377	12,817	7,932	10,310
BITUMEN (ASPHALT)	5,531	7,226	7,086	13,222	10,285	11,604
BUTANE	212	52	117	273	215	270
NAPHTHA	12	220	165	368	249	323
MC 30*	7	293	456	704	1,572	1,684
TOTAL	734,746	697,178	726,735	685,856	602,333	606,935

* Special grade of bitumen used or airport surfaces. 1984 TOTAL 624,299
Source: Energy Production and Consumption in Zambia 1978-1983

Table 3-1-7 Supply of Refined Petroleum Products

PRODUCT	1978	1979	1980	1981	1982	1983
PREMIUM GASOLINE	76,501	71,875	74,336	76,131	78,535	84,601
REGULAR GASOLINE	60,731	56,189	45,489	39,233	31,978	24,760
GASOIL (DIESEL)	235,086	247,964	239,629	239,668	232,622	232,284
LSG	17,760	16,828	35,727	34,781	36,891	35,316
KEROSINE (PARAFFIN)	26,323	27,793	29,566	34,366	30,858	36,660
JET A-1	52,590	62,465	68,780	63,275	54,858	55,266
LPG	7,506	2,078	2,070	2,295	2,252	2,262
HFO	164,355	165,148	173,315	136,756	113,832	111,983
LFO	4,934	8,475	11,168	12,641	7,932	9,330
BITUMEN (ASPHALT)	5,123	7,166	7,617	11,860	8,470	9,010
BUTANE	-	43	119	91	128	91
NAPHTHA	12	220	165	368	249	323
MC 30*	7	464	342	851	1,293	1,843
TOTAL	650,928	666,708	688,323	652,316	599,886	603,729

1984 TOTAL: 556,407
Source: Energy Production and Consumption in Zambia 1978-1983

Sales of petroleum products are shown in Table 3-1-8 for mining, aviation and other industries from 1978 to 1983. The supply of petroleum products to the mining industry, the largest commercial energy consumer, has been dropping; e.g., from 283,000 cubic meters in 1978, about 35% of total supply, to 175,000 cubic meters, or 25%, in 1982. In addition to the mining recession during that period, the replacement of oil for transporting copper ore by cheap and abundant electric power was chiefly responsible for this change.

Overall, the supply of 813,000 cubic meters in 1978 decreased to 725,000 cubic meters in 1983 after peaking in 1980 at 854,000 cubic meters, a reduction of approximately 11%.

Table 3-1-8 Marketing of Petroleum Products by Sectors

(Cubic Meter)

Sector	1978	1979	1980	1981	1982	1983
Mining	283,294	280,076	295,557	261,677	175,110	195,515
	(35)	(33)	(35)	(32)	(25)	(27)
Aviation	61,181	86,972	85,129	76,977	58,986	59,484
	(7)	(10)	(10)	(10)	(8)	(8)
Other	468,490	481,258	473,458	471,846	464,647	469,509
	(58)	(57)	(55)	(58)	(65)	(65)
TOTAL	812,965	848,306	854,144	810,144	698,743	724,508
	(100)	(100)	(100)	(100)	(100)	(100)

Note: Numbers in parentheses are percentages.
Source: Energy Production and Consumption in Zambia 1978-1983

3.1.3 Coal

With estimated reserves of 250 million tons, coal is one of the major domestic sources of energy. There are three important deposits; Mkandabwe with proven and estimated deposits totalling 80 million tons, Mulungshi with 100 million tons, and Siankondobo with 91 million tons.

The Maamba Collieries, being mined now, is located on the Siankondobo deposit, with estimated reserves of 58 million tons. The mining capacity is designed to be 1.5 million tons per year, or 1.2 million tons in terms of coal production. The life of the collieries is considered to be about 40 years.

Table 3-1-9 shows Zambia's coal production, consumption, and export. The output declined from 790,000 tons in 1975 to 514,000 tons in 1984, a drop of 35%, which was caused by rises in production costs and lack of foreign currency reserves for importing spare parts. Coal consumption also fell by approximately 32%; from 732,000 tons to 502,000 tons. Table 3-1-10 shows coal consumption by consumer/sector. The nation's largest consumer is Zambia Consolidated Copper Mines (ZCCM), followed by Nitrogen Chemicals of Zambia (NCZ) and Chilanga Cement Factory (CCF). These three account for about 80% of the country's total coal consumption.

Table 3-1-9 Production, Consumption and Exports of Coal

(Ton)

Year	Production	Local Consumption	Exports
1975	789,562	732,496	21,046
1976	746,329	643,086	10,639
1977	638,108	597,827	792
1978	582,036	597,794	N.A.
1979	598,507	609,679	N.A.
1980	570,212	596,555	N.A.
1981	508,309	489,343	210
1982	605,598	542,637	20,763
1983	453,602	501,733	18,546
1984	514,258	N.A.	N.A.

Source: Energy Production and Consumption in Zambia 1978-1983

Table 3-1-10 Consumption of Coal by Consumers/Sectors (Ton)

CUSTOMER	1975	1976	1977	1978	1979	1980	1981	1982	1983
MINES-	397,178	373,503	362,246	377,363	397,569	343,520	288,712	257,234	228,442
ZCCM	(54)	(58)	(61)	(63)	(65)	(58)	(59)	(47)	(46)
CHILANGA	113,655	109,658	78,556	84,938	67,510	94,203	72,665	74,825	57,349
CEMENT	(16)	(17)	(13)	(14)	(11)	(16)	(15)	(14)	(11)
NCZ	65,676	53,834	66,581	59,472	65,727	74,562	58,771	112,777	131,116
	(9)	(8)	(11)	(10)	(11)	(13)	(12)	(21)	(26)
OTHERS	155,986	106,067	597,816	597,796	609,680	596,556	489,344	542,638	501,732
	(21)	(17)	(15)	(13)	(13)	(13)	(14)	(18)	(17)
TOTAL	732,495	643,067	597,816	597,796	609,680	596,556	489,344	542,638	501,732
	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)

Note: Numbers in parentheses are percentages.
Source: Energy Production and Consumption in Zambia 1978-1983

3.1.4 Wood fuel

Wood fuel is vital as a household energy source, while electric power, oil, and coal are important as industrial energy. Even now, more than 90% of Zambian households use charcoal or firewood for cooking, heating and lighting. In general terms, more than 80% of the households in agricultural areas consume firewood and over 80% in urban areas use charcoal.

Table 3-1-11 shows estimated production of charcoal and firewood based on the Forest Department's Annual Report and a joint report by the UNDP and World Bank. Figures of the table are based on data obtained by the Forest Dept. Actually, a large volume of charcoal and firewood produced does not enter these statistics. Accordingly, the figures shown in the table may be understatements of real energy consumption.

Table 3-1-11 Recorded Production of Firewood and Charcoal

(thousand m^3 wood equivalent)

Year	Firewood*	Charcoal	Total
1976	79	437	516
1977	89	202	391
1978	42	352	394
1979	51	279	330
1980	54**	294**	348**
1981	43**	304**	347**
1982	89**	414**	503**
1983	129**	443**	572**

* : Harvested under license only.
** : The same conversion factor as used in Table 3.6 of Zambia: Issues and Options in the Energy Sector January 1983. (Report of the Joint UNDP/World Bank Energy Assessment Program) is applied.
Original Source : Annual Report of Forest Department (1976-1983)

An estimated wood fuel consumption for 1984 is shown in Table 3-1-12, which indicates that no less than 4.9 million cubic meters of wood fuel was consumed. When examined in light of the figures given in Table 3-1-11, it is found that licensed production of this type of fuel is about 10% of the total consumption. Another finding is that wood fuel consumption in Copperbelt for refining copper shares nearly 40%.

Table 3-1-12 1984 Estimates of Woodfuel Consumption Province

Province	Firewood		Charcoal		Total
	(Ton)	(1000m^3 wood equivalent)*	(Ton)	(1000m^3 wood equivalent)**	(1000m^3 wood equivalent)
Lusaka	3,384	4	54,972	785	789
Central	35,371	42	26,802	383	425
Copperbelt	N.A.	N.A.	114,018	1,629	1,629***
North Western	98,312	116	11,071	158	274
Eastern	81,408	96	56,584	808	904
Luapula	122,472	144	52,506	750	894
Total	340,947	402***	315,953	4,513	4,915***

* : These figures are derived on condition that specific gravity of wood is equivalent to 0.85.
** : These figures are derived on condition that 70kg of charcoal is produced from 1 m^3 wood.
*** : These figures do not include copperbelt's figure of firewood.
Original Source : Interim National Energy Council Consumption Report.

Table 3-1-13 cites an estimated consumption of charcoal and firewood in 1981 from the same UNDP/World Bank joint report. The combined consumption of charcoal and firewood amounted to seven million cubic meters according to this report. Moreover, the Status and Impact of Wood Fuel in Urban Zambia reports that charcoal consumed by households in urban areas in the central and Copperbelt areas in 1983 was 333,000 tons and that of firewood, 624,000 cubic meters. Assuming that 70 kg of charcoal is produced from one cubic meter of firewood, these figures correspond to about 5.4 million cubic meters of wood.

Table 3-1-13 Estimates of Charcoal and Firewood Consumption, 1981
(1000 cu. m. wood equivalent)

Urban household	3,830
Rural household	2,962
Copper Smelters 1/	186
Agriculture (tobacco, tea, ...)	43
Traditional Industries	n.a.

1/ 40% consumed as charcoal.
Source: Zambia: Issues and Options in the Energy Sector, January 1983.

As stated above, Zambia's recent wood fuel consumption is estimated to be between five and seven million cubic meters of wood, or 32 to 45 peta joule, though there are wide variations among different sources.