Joint UNDP/World Bank
Energy Sector Management Assistance Program

Activity Completion Report

No. 094/88

Country: ZAMBIA

Activity: ENERGY SECTOR STRATEGY

DECEMBER 1988

A report of the

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ustry and Energy Department
ld Bank
hington D.C. 20433
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and the

Department of Energy
Ministry of Power,
Transport and Communications
Lusaka
Zambia

ENERGY SECTOR MANAGEMENT ASSISTANCE PROGRAM

PURPOSE

The Joint UNDP/World Bank Energy Sector Management Assistance Program (ESMAP) was started in 1983 as a companion to the Energy Assessment Program, established in 1980. The Assessment Program was designed to identify and analyze the most serious energy problems in developing countries. ESMAP was designed as a pre-investment facility, partly to assist in implementing the actions recommended in the Assessments. Today ESMAP carries out pre-investment activities in 45 countries and provides institutional and policy advice to developing country decision-makers. The Program aims to supplement, advance, and strengthen the impact of bilateral and multilateral resources already available for technical assistance in the energy sector. The reports produced under the ESMAP Program provide governments, donors, and potential investors with information needed to speed up project preparation and implementation. ESMAP activities fall into two major groupings:

- Energy Efficiency and Strategy, addressing the institutional, financial, and policy issues of the energy sector, including design of sector strategies, improving energy end-use, defining investment programs, and strengthening sector enterprises; and

- Household, Rural, and Renewable Energy, addressing the technical, economic, financial, institutional and policy issues affecting energy supply and demand, including energy from traditional and modern sources for use by rural and urban households and rural industries.

FUNDING

The Program is a major international effort supported by the UNDP, the World Bank, and bilateral agencies in a number of countries including the Netherlands, Canada, Switzerland, Norway, Sweden, Italy, Australia, Denmark, France, Finland, the United Kingdom, Ireland, Japan, New Zealand, Iceland, and the USA.

INQUIRIES

For further information on the Program or to obtain copies of the completed ESMAP reports listed at the end of this document, contact:

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ZAMBIA

ENERGY SECTOR STRATEGY

DECEMBER 1988

Energy Efficiency and Strategy Unit
Industry and Energy Department

ACRONYMS AND ABBREVIATIONS

ADB	African Development Bank
Boe	Barrel of Oil Equivalent
BTU	British Thermal Unit
CAPC	Central African Power Corporation
DOE	Department of Energy, Ministry of Power, Transport and Communications
DWT	Dead Weight Tons
ERR	Economic Rate of Return
ESMAP	Joint UNDP/World Bank Energy Sector Management Assistance Program
GDP	Gross Domestic Product
GNP	Gross National Product
GWh	Gigawatt hour
IDA	International Development Association
km	Kilometer
kV	Kilovolt (1,000 Volts)
kWh	Kilowatthour
LPG	Liquid Petroleum Gas
MW	Megawatt
MWh	Megawatthour
NCDP	National Commission for Development Planning
NCSR	National Council for Scientific Research
TDAU	Technology Development and Advisory Unit (University of Zambia)
toe	Ton of oil equivalent
tpa	Tons per annum
TPL	Tazama Pipelines Limited
UNDP	United Nations Development Program
UNZA	University of Zambia
ZAFFICO	Zambia Forestry and Forest Industries Corporation
ZCCM	Zambia Consolidated Copper Mines Limited
ZESCO	Zambia Electricity Supply Corporation Limited
ZIMCO	Zambia Industrial and Mining Corporation Limited
ZR	Zambia Railways

EXCHANGE RATE

OFFICIAL EXCHANGE RATE	SHADOW EXCHANGE RATE
8 Kwacha = US$1	12 Kwacha = US$1
1 Kwacha = US$0.13	1 Kwacha = US$0.08

(March 1988)

ENERGY CONVERSION FACTORS

FUEL	PHYSICAL UNITS PER toe 1/
Liquid Fuel (metric tons) 2/	
LPG	0.92
Gasoline	0.95
Kerosene/Turbo Fuel	0.97
Diesel Oil	0.98
Fuel Oil	1.04
Coal (tons)	1.67
Electricity (MWh)	11.6 3/
Biomass Fuels (tons)	
Firewood	2.84
Charcoal	1.40

1/ 1 toe = 39.68 million BTU
= 6.61 Boe

2/ Regular gasoline = 359.6 gallon/mt
Premium gasoline = 356.9 gallon/mt
Kerosene = 336.6 gallon/mt
Diesel = 314.4 gallon/mt
Fuel Oil = 278.2 gallon/mt

3/ Converted on a heat equivalent basis.

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I. INTRODUCTION

This report outlines the first comprehensive energy strategy for Zambia. It identifies a priority energy sector investment program for the period 1989-93, reflecting the current economic situation, the condition of the energy supply systems, and the most pressing needs of energy consumers. The report also recommends a set of energy policies and technical assistance activities designed to facilitate the achievement of the energy strategy's objectives.

It is issued at an important juncture in Zambia's economic development. Investment resources and skills are, and will remain in short supply. With a large overhang of debt, foreign exchange will be extremely scarce. However, the persistent decline in Zambia's terms of trade may be over, or at least moderating, if the recent improvement in world copper prices is maintained. Zambia's agriculture and manufacturing industries show signs of achieving higher productivity and increased exports, on which the future of the country depends. Hopefully, the energy strategy will help to achieve the long-awaited economic recovery.

The major part of the report was drafted in Zambia by a joint team of Zambian energy planners, international energy consultants and World Bank staff. Further work was undertaken at the World Bank in Washington, principally to verify the main conclusions with experts knowledgeable on Zambia's energy sector and those of neighboring countries. The Zambian team members were drawn from the Department of Energy of the Ministry of Power, Transport and Communications. The international energy consultants were funded by the Swedish International Development Agency (SIDA), through the joint UNDP/World Bank Energy Sector Management Assistance Program (ESMAP).

The Zambian team was led by Mr. Dominic Mbewe, Director of the Department of Energy. He was assisted by Mr. Wilfred Serenje (Energy Planner), Mr. Collins Konayuma (Conservation and Substitution Engineer), Mr. Silvester Hibajene (Household and Renewal Energy Specialist) and Mr. Renato Ezban (Energy Planner and Computer Specialist). The ESMAP team was led by Mr. Robin Broadfield (Energy Economist) and consisted of the following consultants: Mr. Fred Thackeray (Energy Economist); Mr. John Stocks (Mining Engineer); Mr. Robert High (Petroleum Refinery Specialist); Mr. Harald Berg (Power System Economist); Mr. Jean-Réné Leidner (Renewable Energy Specialist); and Mr. Bjorn Gildestad (Transport Energy Economist). Mr. Eric Daffern (Principal Energy Specialist) and Mr. Jack Warren (Senior Petroleum Geologist) represented the World Bank. Ms. Pauline Griller (Staff Assistant) was responsible for word processing in Zambia, and Ms. Paula Earp (Staff Assistant) in Washington.

The team members wish to express their gratitude for the extensive assistance received from individuals and organizations in the Zambian energy sector, without which the production of this report would not have been possible.

II. EXECUTIVE SUMMARY

2.1 Economic Background

The Zambian economy was built largely on the production and export of copper, which, for many years, made the country grow and prosper. GNP per capita rose steadily from US$400 in 1970 to over US$650 in 1981. Copper sales earned substantial quantities of foreign exchange with which to buy foreign capital and consumer goods. Consequently, the economy became highly open, with imports and exports equivalent to nearly 50% of GDP.

In 1975, a persistent decline in the world price of copper set in. Over the next ten years, its real price fell by over 60%. Over the same period, Zambian copper production declined from a peak of 713,000 tons in 1976 to less than 480,000 tons in 1985. As a result, real export earnings fell by two-thirds and imports contracted sharply, although heavy borrowing cushioned some of the fall. From its 1981 peak of US$650, GNP per capita fell to less than US$400 in 1986.

In 1988, Zambia is struggling to recover from this long period of economic decline. With investment down to less than 10% of GDP, a devalued currency, and scheduled debt payments larger than total export revenues, the recovery process will inevitably be hard and long. The objective of this energy strategy is to ensure that Zambia's energy sector makes the maximum possible contribution to that process.

2.2 Energy Resources

Zambia is fortunate in being well-endowed with energy resources. Its woodlands and forests produce over 20 million cubic meters of wood annually (contributing 66% of the nation's total energy needs), although wood demand exceeds supply in some areas. It has over 1,600 MW of installed hydroelectric generating capacity, providing another 13% of energy needs. Proven coal reserves exceed 30 million tons, and satisfy 9% of energy demand. The only major energy import is petroleum, which accounts for about 10% of total imports and satisfies 12% of energy demand.

Zambia's economic problems have had two major implications for the energy sector. First, they have arrested the growth in energy consumption, leaving many of the energy supply systems with excess capacity. For example, demand for electric energy is nearly 20% below capacity, coal production is at least 100,000 tons per year below potential, and the oil pipeline and refinery are running at about 60% of capacity.

Second, economic difficulties have starved the energy sector of the foreign exchange required for essential maintenance and new capital investment. As a consequence, the condition of the power supply system has deteriorated, and subtransmission investment has lagged behind the changing pattern of demand. The oil pipeline has corroded, partly from poor management and inadequate maintenance. Coal output fell for many years, until a recent major rehabilitation program arrested the decline.

Correcting these problems at least cost is one of the major issues in the energy sector. A second and related major issue is how to make better use of the excess capacity once the supply systems are rehabilitated, particularly to ease the burden of energy imports on the balance of payments. A third major issue is how to arrest the localized depletion of Zambia's woodfuel resource, the primary source of household energy supply.

2.3 Energy Strategy Objectives and Constraints

The agreed objectives of the energy strategy are to:

(a) ensure the provision of adequate and reliable energy supplies, at least cost, to the productive sectors of the economy, on which economic recovery depends;

(b) minimize net imports of energy by substituting lower-cost domestic fuels for imports and promoting economically-justified energy exports;

(c) satisfy the basic energy needs of the population;

(d) protect the environment; and

(e) ensure the long-term viability of the organizations responsible for energy production and supply.

With a large overhang of foreign debt, depressed incomes, and low savings, this must be done with very limited investment resources. Assuming energy takes its traditional share of 10-15% of total public investment, and assuming public investment averages about US$200 million per year for the next five years (which is about the maximum that seems feasible), public energy sector investment can average no more than US$20-30 million per year.

2.4 Strategic Direction for the Energy Sector

The energy strategy is focussed on the next five years, 1989-93, when critical decisions must be made to foster economic recovery in a situation of resource scarcity. The strategy seeks to avoid major risks, such as failure of a critical energy supply system--a power station, the oil pipeline or the coal mine, for example. The strategy is conservative in terms of investment expenditure, because investment resources will be very scarce. It avoids large-scale, speculative investments, and emphasizes making better use of existing resources.

The main features of the strategy are:

(a) avoidance of investment in new energy supply facilities which, due to the existence of surplus capacity, are not needed;

(b) an emphasis on high-return investments in the rehabilitation and reinforcement of existing supply capacity and systems;

(c) minimization of energy imports through efficiency measures and the substitution of petroleum by indigenous energy resources;

(d) maximization of economically-justified energy exports;

(e) greater efforts to improve the management and operational efficiency of the energy supply organizations by better training, better rewards, and use of outside expertise, where necessary; and

(f) the establishment of effective systems and capabilities for strategic and contingency planning within the energy supply organizations and their major customers, and the creation of a mechanism to coordinate and systematize the process of national energy planning and policy review.

2.5 Major Strategic Proposals

The major strategic proposals for each energy subsector are summarized at the end of this Chapter. From amongst these, the following strategic energy sector priorities can be highlighted:

(a) selective repairs to the Kafue Gorge power station and rehabilitation of the Victoria Falls power station;

(b) reinforcement and rehabilitation of the electricity subtransmission and distribution systems serving Lusaka, Ndola and Kitwe, to increase access to power supply and reduce the risk of major power outages in these larger cities;

(c) completion of committed power system extension projects;

(d) rehabilitation of the Tazama oil pipeline and the strengthening of its management and maintenance procedures, so as to reduce the risk of a major pipeline failure, which would cause serious environmental damage to Tanzania or Zambia and interrupt critical supplies of petroleum products;

(e) rehabilitation of the Indeni petroleum refinery and investment in measures to reduce refinery fuel use and loss;

(f) energy audits and investments to increase the efficiency of energy use in industry, commerce and transport and to promote the substitution of indigenous electricity and coal for oil;

(g) a large-scale program to produce and market improved charcoal stoves, to reduce the pressure on woodfuel supplies, particularly around the major urban centers;

(h) increases in the price of imported diesel oil to reflect the high scarcity value of foreign exchange;

(i) increases in electricity tariffs to cover ZESCO's financial needs and to better reflect the economic costs of electricity supply;

(j) preparation of contingency plans to cope with the possibility of accidents interrupting vital energy supplies, for example coal (possible dragline failure), and oil (the lack of refinery storage in the event of a pipeline failure);

(k) when urban power transmission and distribution facilities have been strengthened, acceleration of the rate of household electricity connections, coupled with term financing arrangements for connection costs, house wiring and appliance purchase; and

(l) improved operational performance by the major energy supply organizations and better overall energy sector planning.

2.6 Electric Power Issues and Strategy

Although domestic electricity consumption is forecast to rise during the 1990s, previously large exports to Zimbabwe have declined, and will probably remain well below their peak of the mid-1980s. About the year 2000, power demand from ZCCM, ZESCO's largest domestic customer, will start to fall as copper production declines. Existing electric power generating capacity should therefore be sufficient to satisfy domestic electricity demand well into the next century, even if the economy averages 3.5% GDP growth per year. No investment in new power generating capacity is foreseen until after the year 2006.

Although no investment will be needed in new generating facilities, the existing generating stations are in need of selective running repairs and equipment replacement. Most urgent is repair of the liquid chillers and other ancillary equipment at the Kafue Gorge power station. A major failure there would cause serious power shortages. Immediate electrical, mechanical, and civil engineering diagnostic work is needed, followed by a modest repair program, probably costing about US$2 million. Also a priority are civil works and rehabilitation at the Victoria Falls power station (US$2-3 million). Less urgent are minor investments in the northern hydro system (US$0.2 million). Establishment of a generation and transmission spares emergency fund of at least US$100,000 is recommended.

Existing 330 kV transmission capacity will be adequate to handle forecast power loads up to 2006, with the possible exception of the Kabwe-Kitwe link in the late 1990s, if demand growth in the Copperbelt equals or exceeds the high growth scenario.

While growing domestic demand for electricity is not stretching generation and bulk transmission capacity, it has overloaded the subtransmission and distribution system serving Lusaka. Repair and reinforcement of several key substations is urgently needed. Work should begin very shortly on the construction of a new 132 kV ring around Lusaka to replace the overloaded 88 kV system. Including associated substation and subtransmission investments, the first phase of this program, known as the Lusaka Distribution Project, will cost about US$29.9 million.

In addition to Lusaka, about US$10.6 million of investment is needed to replace obsolete switchgear and to reinforce the power networks around Ndola and Kitwe.

Concessionary finance has been obtained for two power transmission extension projects: (a) construction of a new 132 kV line from Lusiwasi to Msoro and a new 66 kV line from Chipata to Lundazi, followed by a new 132 kV line from Msoro to Chipata (US$19 million); and (b) electrification of the Mkushi Farming Block (US$25 million). As these funds are committed, the two projects should proceed to completion.

In the major urban centers of Lusaka and the Copperbelt, the other strategic priority in the power subsector is to accelerate the pace of household connections. To keep pace with urbanization, ZESCO needs to complete about 7,000 new connections per year, but recently has been managing less than 3,000 per year. As a result, the proportion of urban households with electricity is falling, and there is a backlog of applications. Once the necessary transmission and distribution capacity has been installed, investment in new distribution lines and residential connections needs to be stepped up, and ways found to reduce the high upfront charge for house wiring and connection--up to K5,000 (US$625) per household--and the high cost of electric cooking equipment. The most promising option may be to introduce a term payment scheme, whereby the customer can pay for both connection and equipment by installments on the electricity bill. Efforts must also be made to reduce the cost of distribution expansion, for example, by making greater use of overhead lines.

To cover ZESCO's current financial costs, electricity tariffs need to be raised from an average of 5 ngwee/kWh (US$0.006/kWh) to 8 ngwee/kWh (US$0.01/kWh) in early 1988 prices. To finance the recommended five-year power system investment program, average tariffs will need to rise further in real terms to about 11 ngwee/kWh (US$0.014/kWh) by 1993. The only alternatives to higher tariffs are Government subsidization of ZESCO, which is infeasible on budgetary grounds, inadequate provision for future investment, or a further deterioration in its day-to-day operational performance.

The required tariff increase will be less if ZESCO can improve its financial performance and efficiency. Considerable scope for improvement exists, including streamlined metering and billing arrangements, a new billing system, and improved debt collections. Engineering management and planning skills are in short supply and should be strengthened. Terms and conditions of professional staff need to be improved to attract and retain good management and technical staff.

2.7 Petroleum Issues and Strategy

The immediate objectives with respect to petroleum products are to improve the security of supply and to raise the efficiency of supply systems. Coupled with these objectives is the special requirement, because petroleum is wholly imported, to efficiently minimize imports and the call on the country's scarce earnings of foreign exchange.

There is no foreseeable requirement to invest in new supply capacity. Even on the high growth scenario, forecast petroleum demand of 660,000 tons by 2006 is below the capacities of the Tazama pipeline and the Indeni refinery. The current system of importing reconstituted crude via the Tazama pipeline and reprocessing the import mix at the Indeni refinery is the least-cost supply option, and should not be changed. The discounted present value of the costs of the alternative--closing the refinery and importing batched white products by pipeline and rail--is over US$50 million higher.

The following measures are required to improve security and efficiency of supply:

(a) rehabilitation of the Tazama pipeline, on which detailed engineering has started (US$41.2 million in 1989-93, followed by US$30-40 million in 1994-2006);

(b) staff training at Tazama Pipelines Limited, to ensure there is no recurrence of the problems to be remedied under the rehabilitation program, and to enhance operational efficiency;

(c) implementation of the proposal to install strategic storage at the Indeni refinery as a safeguard against possible interruptions of supply (US$3 million); and

(d) scheduled maintenance and critical repairs and improvements to the Indeni refinery, which will reduce the level of refinery fuel use and loss from 7% to about 5.5%.

The priority measures to minimize foreign exchange expenditure on petroleum imports are to:

(a) continue the present commercial and credit arrangements for petroleum supplies, including the innovative practice of importing reconstituted crude, comprising the correct balance of products required to meet demand;

(b) develop profitable export sales through more aggressive marketing and the acquisition of more road tankers (US$ 2 million);

(c) realign the wholesale prices of petroleum products to reflect their economic costs. In particular, increase the price of diesel oil to reflect the scarcity value of foreign exchange so that: (i) cross-subsidization of the middle distillate products by gasoline is reduced; and (ii) there are stronger incentives for conservation in the use of automotive diesel; and

(d) promote petroleum conservation and the substitution of indigenous fuels in the industrial sector through an active program of industrial energy audits, followed by the provision of finance for energy efficiency and substitution investments.

Consideration should also be given to further petroleum promotion, if such measures appear likely to produce a significant response from the private sector. The first step should be to thoroughly analyze existing exploration data. Expenditure of up to US$6.6 million, phased over several years, could be justified.

2.8 Coal Issues and Strategy

With the completion of the Maamba Colliery rehabilitation program, financed by ADB/IDA, the capacity of Maamba Colliery is now 650,000 tons per annum (tpa). This could be raised to about 700,000 tpa by relocation of the main drive of the ropeway, which transports the coal to the railhead at Masuku, and the addition of more buckets. Estimated coal demand in 1988-89 is about 484,000 tons. Demand could reach a maximum of 568,000 tons in 2002 under the high growth scenario.

No major investments are therefore needed in raising coal supply capacity. However, measures should be taken to maintain and improve efficiency. An analysis should be done of the costs and benefits of contingency investment to prevent the possible lengthy disruption of output which could occur if a major component of the walking dragline used for stripping the overburden was to fail. If justified, the investment could be up to US$1 million, including the purchase of essential parts.

It is also important to ensure that adequate foreign exchange is available to cover the purchase of necessary routine spares and replacement machines, as these needs arise.

To guarantee high standards of colliery maintenance, it is essential to ensure the availability of sufficient, adequately skilled personnel. This requires competitive compensation and a training and work experience program for Zambian nationals, which should be supported by technical assistance from experienced expatriate staff.

Rail transport to consumers is a persistent coal supply bottleneck. In addition to investments in additional locomotives and other measures to improve the railway's capability and efficiency, it is suggested that greater use be made of the coal stocking facilities of major coal customers, such as Chilanga Cement and Nitrogen Chemicals of Zambia (NCZ). These companies could build up stocks when the railway is able to deliver to ensure availability of coal when deliveries fall short.

Two changes should be made in coal pricing. The first is to raise the prices to domestic consumers at least to the financial cost of coal production (K447/ton, or US$55.9/ton). The second recommendation, which will assist coal marketing, is to adjust the differential between prices for the grades of coal marketed to better reflect BTU content and the handling and transport cost of coals with high ash.

Household consumer acceptability tests should be run on smokeless coal briquettes. If the results are positive, the financial and economic feasibility of commercial briquette production should be assessed.

2.9 Woodfuel and Household Energy Issues and Strategy

Woodfuel, which is used predominantly as a household cooking fuel, is the country's single largest source of energy. In the rural areas, it is used as firewood; in the urban areas, it is used mainly in the form of charcoal.

Nationally, there is no shortage of woodfuel supply. However, around the principal towns in the Copperbelt, Lusaka Province, and Southern Province, tree-cutting for charcoal production, coupled with agricultural land clearing and woodfuel demand, have created worsening problems of local deforestation.

Improved wood resource management and measures to increase the efficiency of charcoal production and use are the top priorities. The promotion of community plantations and agroforestry are also proven lower-cost supply solutions.

Improved charcoal-burning stoves developed by UNZA typically offer 30% savings in charcoal consumption and a payback period of 2-3 months. The impact on woodfuel consumption of a successful program to disseminate these or similar stoves would be dramatic. If, by 2006, such stoves are used by 90% of urban households, annual charcoal consumption will be reduced from an estimated 1.8 million tons to 1.3 million tons, or by 27%.

With assistance from the UNDP/World Bank ESMAP Household Energy Strategy project it is recommended to:

(a) develop a program for the large scale production, testing and dissemination of improved charcoal stoves;

(b) encourage the adoption of more efficient charcoal kilns, through demonstration and training;

(c) undertake in-depth studies of the financial and economic competitiveness of electricity as a substitute for charcoal in urban household cooking;

(d) devise measures to overcome the present financial and other hurdles which have reduced the rate of household electricity connections to a trickle. Also, consider what measures can be developed to assist potential consumers to finance connection charges and the purchase of electric appliances;

(e) develop a structure of electricity tariffs reflective of the economic and financial cost of supply which will facilitate household electricity use; and

(f) test the consumer acceptability of coal briquettes for urban household cooking and, if the results are positive, analyze the financial and economic prospects for their commercial-scale production as an indigenous substitute for charcoal.

As elements of a complementary effort to preserve wood stocks and encourage reforestation:

(a) increase stumpage fees to cover the economic costs of supply, as incurred by ZAFFICO and the Forest Department;

(b) strengthen natural wood resource management through more effective extension, financed by stumpage fees on commercial wood cutting in natural woodland; and

(c) encourage community and private sector tree planting, without substantial Government funding.

2.10 Renewable Energy Issues and Strategy

Although Zambia has considerable renewable energy potential, particularly in the field of solar energy applications, efforts to promote appropriate renewable energy technologies have been limited and spasmodic.

Good levels of insolation through the country suggest there is scope for the promotion of solar fish and crop drying. The former would substitute for increasingly scarce wood, which is used extensively for fish smoking, and both could reduce losses due to spoilage.

Wind and biogas energy have limited current economic potential. As technologies improve over time, the former could be economic for water pumping, as a substitute for manual labor and for diesel pumping in isolated areas, and the latter perhaps for rural household cooking.

Technical assistance is recommended to promote technology transfer and its application in solar fish and crop drying.

2.11 Conservation and Substitution of Conventional Fuels

Cost reductions, energy savings and the minimization of foreign exchange expenditures are the triple objectives of energy conservation and substitution policy. Appropriate energy pricing is a pre-requisite to achieving improved efficiency of energy use. The aim should be to establish an energy price structure under which financial costs of supply are covered and prices reflect economic costs.

Economically and financially viable opportunities exist for both energy substitution and energy conservation. In the copper industry, the scope for substituting coal for fuel oil is technically constrained. However, there is a significant possibility at the Nkana smelter. After installation of the planned new oxy-fuel furnace, coal probably can be substituted for 18,000 tpa of fuel oil. The investment cost is modest--about K16 million (US$2 million). There is also scope for further substitution of electric power for diesel in underground traction.

In industry, the Department of Energy's audit program has begun to identify opportunities for substituting electricity and/or coal for fuel oil and diesel. Several such opportunities offer the possibility of comparatively small investment costs and rapid pay-backs. Similar opportunities have been identified by the audit program for energy-saving projects.

Action is needed to ensure that the economic potential for industrial energy substitution and conservation is realized. A program of technical assistance in energy conservation and substitution is recommended, to provide skills and resources to the Department of Energy, strengthening the activity begun by the Department's own staff. It is estimated that about two man-years of consultant technical assistance is required at a cost of about US$300,000. Its objective would be to identify a package of high return energy conservation and substitution investments, ready for feasibility analysis and presentation to potential donors. On the basis of indicative estimates prepared by the Department of Energy, the package of recommended investments might be in the range of US$20-25 million, offering annual cost savings of about US$6-9 million.

In road transport, the task of improving energy efficiency is a difficult one. Higher diesel oil prices would be one useful step. On the basis of a preliminary analysis, other tentative recommendations for policy action in this field are:

(a) increase expenditure on road maintenance. This would both improve the energy efficiency of road transport and enhance road safety. Finance could come from higher fuel excise duties;

(b) regularly inspect all Government vehicles to check against poor maintenance and excessive fuel consumption. This requires reactivation of the Preventive Maintenance Section at the Mechanical Services Department;

(c) set minimum fuel efficiency standards for all new vehicles; and

(d) study the scope for developing back-haul freight traffic, and identify ways of promoting it. If the scope proves to be considerable, back-hauling could produce substantial savings in transport fuel consumption.

2.12 Energy Policy and Planning Systems

Coordination between the various Governmental, parastatal and semi-private organizations active in the energy field is relatively weak. There is no adequate institutional mechanism for designing and implementing a coherent strategy for the energy sector, and for systematically addressing the major energy policy issues.

To overcome these weaknesses, and to promote effective sectoral policy coordination and planning, it is recommended that the Energy Development Committee, which oversaw preparation of the energy chapter of the Fourth National Development Plan, be retained as a permanent energy policy coordinating body.

The Committee would be representative of the major ministries and parastatal companies concerned with energy. Chaired by the Permanent Secretary of the Ministry of Power, Transport and Communications, its membership would consist of senior representatives of the Ministry of Mines, the Forestry Department, the NCDP, the NCSR, ZIMCO, ZESCO, ZCCM, and perhaps ZIMCO's constituent energy companies. It would meet at least quarterly, and be supported by a Secretariat drawn from the Department of Energy (DOE) and ZIMCO.

Its functions would be to: (a) oversee the preparation and implementation of the national energy strategy, the annual energy plan and rolling five-year investment plan; (b) review and advise on all significant energy capital expenditures; and (c) advise on all energy policy issues, including price levels and structures.

In order to exercise its secretariat functions efficiently, the DOE must be recognized as the coordinating Government body for energy. Its staff needs to be strengthened by the addition of a Chief Economist, Chief Technical Officer and Senior Financial Adviser.

2.13 Priority Investment Program

The priority energy sector investment program required to support the proposed energy sector strategy over the 1989-93 period totals about US$143 million and is summarized in Table 2.1 below.

Table 2.1: PRIORITY ENERGY SECTOR PROJECTS, 1989-93

Project	Estimated Cost (US$ million, end-1987 prices)
Tazama Pipeline Rehabilitation, Phase I	41.2
Power Generation Rehabilitation	5.0
Lusaka Power Distribution, Phase I	29.9
Ndola/Kitwe Rehabilitation/Reactive Comp.	11.7
Lusiwasi-Chipata-Lundazi Power Trans.	19.0
Mkushi Farming Block Electrification	25.0
Indeni Refinery Rehabilitation and Efficiency	6.0
Strategic Petroleum Storage	3.0
Petroleum Road Tankers	2.0
TOTAL	142.8

Table 2.2 lists two potential projects that could be added to the program if further analysis proves they are justified and funds are available.

Table 2.2: POTENTIAL ENERGY SECTOR PROJECTS, 1989-93

Project	Estimated Cost (US$ million, end-1987 prices)
Industrial Energy Conservation/Substitution, up to	20.0
Petroleum Exploration Promotion, up to	6.6
TOTAL	26.6

Priority energy sector investments for the longer term (1994-2006) that have been identified at this stage are set out in Table 2.3 below. These exclude expenditures on routine maintenance and rehabilitation not yet identified.

Table 2.3: LONG-TERM ENERGY SECTOR PROJECTS, 1994-2006

Project	Estimated Cost (US$ million, end 1987 prices)
Tazama Pipeline Phase II and III	35.0
Lusaka Power Distribution, Phase II	14.6
Kitwe and Ndola Power Subtransmission	16.5
Pensulo-Samfya Power Interconnection	10.5
Power Subtransmission Expansion	50.7
Power Distribution Expansion up to	136.5
Coal Exploration	2.0
TOTAL	265.8

Summary of Major Issues and Recommendations

	Issues	Objectives	Recommendations	Responsible Agency	Priority
A.	**Energy Sector Investment Program**				
1.	Resources available for capital investment in the energy sector will be limited by the shortage of foreign exchange and low domestic saving. Assuming 10-15% of public investment is devoted to energy, sector investment can probably average no more than US$20-30 million for the next five years.	Use the limited resources available for investment in the energy sector on projects that will generate the highest possible economic return.	Devote available capital resources to high-return projects that rehabilitate and reinforce existing energy supply systems and make more efficient use of energy. Improve the operational efficiency of energy supply organizations to reduce supply cost. Systematize energy planning to improve decision-making.	Ministry of Power Transport and Communications Ministry of Mines Ministry of Lends and Natural Resources National Commission for Development Planning ZIMCO	High
B.	**Electric Power**				
1.	Kafue Gorge power station is in need of minor repair in order to operate reliably.	Return the station to good operating condition to reduce the possibility of operational problems.	Undertake selective repairs to key ancillary equipment (chillers, pumps, etc.); check condition of 300 kV cables and water intakes and repair as necessary. Complete critical spares inventory.	ZESCO	High
2.	Victoria Falls power station has operational problems because of neglected electrical, mechanical and civil works repairs.	Return Victoria Falls to satisfactory working order to maximize generation at this run-of-river station and conserve water at Kariba.	Overhaul turbines and generators and replace power cables, switchgear and control equipment in the A station; install surge arrestors on the generator connections in the B station; rectify the vibration problem in the C station, probably by increasing turbine submersion; rehabilitate water intakes.	ZESCO	Med-High

	Issues	Objectives	Recommendations	Responsible Agency	Priority
3.	Critical generation and transmission spares are not always available.	Provide sufficient spares to ensure prompt replacement of critical components in the event of failure.	Establish a spares replacement fund of at least US$100,000 per year that can be drawn on at the discretion of the Divisional Manager, Generation and Transmission.	ZESCO	High
4.	The capacity of the subtransmission and distribution system serving Lusaka is inadequate for current and forecast loads.	Ensure that the subtransmission and distribution system serving Lusaka has adequate capacity to satisfy viable demand.	Begin construction of a 132 kV ring around Lusaka, to replace the over-loaded 88 kV lines; rehabilitate and reinforce key substations.	ZESCO	High
5.	Power distribution in the Copperbelt is becoming progressively less reliable because switchgear and cables have exceeded their useful lives.	Provide reliable power supply to power consumers in the Copperbelt.	Replace distribution switchgear and cables that have exceeded their useful life and reinforce overloaded substations and feeder cables.	ZESCO	Med-High
6.	The average cost of adding a new power customer in the Lusaka area has been about US$4,000. This high cost makes expansion of the power system difficult to justify economically and deters new consumers, because of high connection fees.	Establish optimal engineering standards for distribution engineering and connections that minimize costs at acceptable risk.	Review existing distribution and connection design standards and adopt new lower-cost standards that are consistent with safe operation of the power system.	ZESCO	High
7.	ZESCO's commercial operations (metering, billing and collections) are less efficient than they could be, which raises the financial cost of power supply.	Achieve industry standard levels of efficiency in ZESCO commercial operations.	Improve meter reading and testing; streamline billing systems; improve collections through late payment surcharges and prompt disconnection of non-payers.	ZESCO	High

	Issues	Objectives	Recommendations	Responsible Agency	Priority
8.	ZESCO cannot recruit or retain sufficient qualified staff for efficient operation of the power system due to inadequate salaries and conditions of employment.	Recruit and retain a sufficient number of skilled personnel to ensure efficient operation of the power system.	Improve ZESCO salaries and terms and conditions so that they are at least competitive with those of other parastatal companies.	ZESCO ZIMCO	High
9	Power tariffs are insufficient to cover ZESCO's current financial costs and to finance priority power system investments. Their structure does not reflect the economic costs of power supply.	Set power tariffs to fully cover ZESCO's current financial costs, including debt service, and to reflect economic costs. Plan tariff adjustments that will produce sufficient revenue to finance future operating and debt service requirements, without resort to government subsidy.	Raise average tariffs to about K0.08/kWh in end 1987 prices and adjust the tariff structure to better reflect economic cost. Plan future tariff increases that will cover the cost of future investments and operational improvements.	ZESCO ZIMCO Prices and Incomes Commission	High
10.	Power tariffs are not adjusted promptly, even when fully justified by higher costs.	Establish a tariff adjustment mechanism that results in prompt adjustments when financially justified.	Introduce an automatic annual or semi-annual tariff review system and fixed adjustment date.	ZESCO	High
C.	Petroleum				
1.	The Tazama oil pipeline is leaking substantial and increasing quantities of petroleum products, at considerable environmental and financial cost.	Return the Tazama pipeline to reliable operating condition.	Replace most severely corroded pipeline sections, strengthen management of TPL and improve operator training.	ZIMCO TPL	High
2.	Various Indeni oil refinery components, such as furnace coils, heat exchangers and instruments, have exceeded their useful life.	Ensure that the refinery is in good operating condition through prompt attention to major maintenance needs.	Replace furnace coils, heat exchanger parts and instruments that have exceeded their useful life.	ZIMCO Indeni	High

	Issues	Objectives	Recommendations	Responsible Agency	Priority
3.	Indeni refinery fuel use and loss is averaging about 7% on a weight basis, about 1½% above achievable performance.	Reduce refinery fuel use and loss to industry standards of about 5.5%.	Invest selectively in energy-conserving refinery equipment.	ZIMCO Indeni	Med-High
4.	The prices of kerosene and gasoil are below economic cost.	Price petroleum products at full economic cost to encourage efficient consumption.	Raise the prices of industrial kerosene and gasoil to economic cost, based on a shadow exchange rate of K12/US$1.	ZIMCO Prices and Incomes Commission	High
5.	Oil exploration efforts have not examined all prospective areas and some data needed for exploration planning are lacking.	Encourage a thorough program of private sector oil exploration in all promising areas.	Strengthen the Hydrocarbon Unit by moving it under the Geological Survey and providing further training and technical assistance. Fully interpret existing data.	Ministry of Mines	Medium
6.	Insufficient road petroleum tank wagons are available to efficiently serve domestic and export petroleum markets.	Minimize cost of transporting petroleum products and ensure transport bottlenecks do not result in lost exports.	Purchase additional road petroleum tankers.	ZIMCO	Medium
D.	Coal				
1.	Failure of the walking dragline could result in a lengthy interruption in coal production.	Optimize the risk of a major interruption in coal output.	Analyze the costs and benefits of a contingency plan for repair of the walking dragline and obtain the necessary spares, if justified.	Maamba Colliery	Med-High
2.	Inadequate coal transportation capacity has meant that some orders could not be met in a timely manner.	Ensure that all coal consumers have adequate supplies.	Improve the efficiency of the rail system and ensure provision of sufficient locomotives and wagons to move coal supplies. Encourage consumers to hold larger coal stocks, perhaps through incentive pricing.	Zambia Railways Coal Consumers	High

	Issues	Objectives	Recommendations	Responsible Agency	Priority
3.	Maamba Colliery's financial performance is inadequate. In some years it has not covered its costs and it has never earned an adequate financial surplus.	Price coal so that Maamba's revenues at least cover its financial costs, including debt service.	Raise the price of coal to about K450/ton (US$56/ton) in early 1988 prices.	Maamba Colliery ZIMCO	High
4.	The structure of coal prices does not accurately reflect its calorific value.	Price coal in relation to its calorific value to encourage optimal consumption decisions.	Price coal in early 1988 prices as follows: Premium - K480/t Standard - K455/t Medium - K440/t	Maamba Colliery ZIMCO	Medium
5.	Future coal reserves other than at Maamba are uncertain.	Obtain sufficient data on mineable coal reserves to plan new mining operations as needed.	During the period 1995-2000, undertake a coal exploration program. Advance the program if coal demand rises sharply.	Ministry of Mines	Low
E.	**Woodfuels and Household Energy**				
1.	Stumpage fees are only a fraction of the cost of plantation wood and are not always enforced.	Price wood at or above the cost of production to provide an incentive for replacement and collect payments due.	Raise stumpage fees closer to the cost of wood production and examine ways to improve collection.	Ministry of Lands and Natural Resources ZAFFICO	Medium-High
2.	There is no charge for commercial cutting of wood from natural woodland and little active management of this resource.	Price wood at its replacement cost and enforce collection of fees. Introduce efficient management of natural woodlands.	Introduce a stumpage fee for commercial exploitation of natural wood resources. Strengthen natural woodland management with resulting revenue.	Ministry of Lands and Natural Resources	High
3.	Low-efficiency charcoal cooking stoves are used by the majority of urban households, which results in excessive charcoal consumption.	Substitute high-efficiency stoves for the low-efficiency models currently in general use.	Establish an improved charcoal stove customer testing program. Select the most popular high-efficiency stove and organize mass production and dissemination, using local artisans and markets.	Department of Energy UNZA	High

	Issues	Objectives	Recommendations	Responsible Agency	Priority
4.	Not enough is known about urban household energy demand and supply costs to design a strategy for satisfying urban household energy demand at least cost.	Obtain sufficient information on urban household energy demand and supply to design a least-cost urban household energy strategy.	Organize studies of (a) urban household energy demand; (b) woodfuel marketing and distribution; (c) charcoal production methods; (d) biomass availability in peri-urban areas; and (e) the financial and economic costs of alternative fuels. Prepare and implement a household energy strategy based on these studies.	Department of Energy Ministry of Lands and Natural Resources	High
5.	The high up-front costs of electricity connection, house wiring and appliance purchase are deterrents to household electrification.	Facilitate household electrification, where it is economically justified, through improving its affordability.	Identify steps to reduce the cost of electricity connections, house wiring, and appliances (especially hotplates and cookers) and explore ways to spread those costs over a longer period, e.g. by term payment on electricity bills.	ZESCO Dept. of Energy	High
6.	Coal briquettes may be an acceptable and competitive alternative to charcoal for urban household cooking.	Ascertain whether coal briquettes are an acceptable and competitive charcoal substitute and, if so, begin commercial production.	Organize a consumer acceptance testing program for coal briquettes as household fuel. If they are acceptable, assess their financial and economic feasibility as a charcoal substitute. If briquettes are competitive with charcoal, implement a commercial-scale production and marketing project.	Dept. of Energy UNZA Maamba Colliery	Medium

	Issues	Objectives	Recommendations	Responsible Agency	Priority
F.	Renewable Energy				
1.	Solar fish and crop drying could reduce losses due to spoilage and conserve wood currently used for fish smoking.	Establish the feasibility of solar fish and crop drying. If feasible, promote their use, particularly in areas of wood shortage.	Institute a solar fish and crop drying test program by adopting proven designs and directly involving the Fisheries Department, Agricultural and Fish Cooperatives.	Dept. of Energy Fisheries Department Ministry of Agriculture UNZA	Medium
2.	Wind and biogas are not generally economic in Zambia, but technical advances could change that over time.	Keep abreast with renewable energy technology development to determine when such technologies could be generally viable in Zambia.	Monitor technical development of windpumping, biogas, and other technologies potentially appropriate to Zambian conditions.	Department of Energy UNZA NCSR	Low
3.	Geothermal electricity generation is being tested at Kasaba Bay on Lake Tanganyika. The economic feasibility of this technology has yet to be established.	Ascertain whether and where geothermal electricity generation could be economic.	If the current tests are successful and suggest the technology is viable, assess the costs and benefits of geothermal electricity generation at a small sample of the more promising sites.	Geological Survey Department of Energy ZESCO	Med-Low

Issues	Objectives	Recommendations	Responsible Agency	Priority
G. Energy Conservation and Substitution				
1. Furtner substitution of coal for fuel oil at the Nkana Smelter appears to be technically and economically viable.	Substitute coal for imported fuel oil at Nkana, if feasible.	Confirm whether, after installation of the new oxy-fuel smelting technology at Nkana, coal substitution is technically feasible and economic. If so, implement a substitution program.	ZIMCO	Med-High
2. There appears to be substantial scope for efficiently conserving energy and for substituting indigenous coal and electricity for imported petroleum fuels in industry and commerce.	Identify and implement cost-effective energy conservation and substitution measures in industry and commerce.	Provide technical assistance to the Department of Energy to expand the industrial and commercial energy audit program and identify economically justified energy conservation and substitution measures.	Department of Energy ZIMCO	High
3. Excise duties on transport fuels barely cover expenditure on road construction and maintenance, which is insufficient to keep the road network in good condition. This reduces the efficiency of energy use in transport.	Generate sufficient revenue from vehicle and fuel taxes to cover all road user costs and maintain the roads in good condition.	Consider raising the excise duties on transport fuels, particularly automotive diesel.	ZIMCO Ministry of Power, Transport and Communications Ministry of Finance	Medium
4. Little effort has been made to encourage energy conservation in transport, which is the major user of imported petroleum fuels.	Encourage transport fuel users to use fuel efficiently.	Consider mandating a minimum fuel efficiency standard for all new imported vehicles and introducing maximum speed limits.	Ministry of Power, Transport and Communications	Medium

Issues	Objectives	Recommendations	Responsible Agency	Priority
H. Energy Institutions and Policy				
1. There is no adequate mechanism for establishing and implementing an energy strategy for Zambia.	Develop and implement an energy strategy that satisfies viable demand for energy at least cost.	Retain the Energy Development Committee, representative of the major Ministries and paras+atal companies concerned with energy, to oversee updating and implementation of the energy strategy. Form an expert secretariat from the Department of Energy and ZIMCO.	Government of Zambia	High
2. The Department of Energy is not adequately staffed to act as secretariat to the Energy Development Committee.	Provide the Energy Development Committee with a secretariat capable of performing the analysis needed to update and implement the energy strategy.	Build up the Department of Energy's staff over time to a total of about eight professionals, including a Chief Economist, Chief Technical Officer and Senior Financial Adviser.	Ministry of Power, Transport and Communications	Med-High

III. ENERGY AND THE ECONOMY - CURRENT SITUATION AND FORECASTS

3.1 Structure of the Economy

Manufacturing accounts for 22% of Zambia's GDP, mining, agriculture, and private services for about 14% each, and other sectors for the balance (Table 3.1).

Table 3.1: SECTORAL COMPOSITION OF GDP, 1985
(%)

Manufacturing	22.0
Mining	14.2
Agriculture	14.5
Services	14.8
Others	34.5
Total	100.0

Source: NCDP.

This structure marks a radical change from 1965, when copper mining accounted for over 40% of GDP. Copper production subsequently peaked at 713,000 tons in 1976. By 1984-85, it had fallen to less than 480,000 tons, before recovering slightly in 1987 to 490,000 tons.

Although copper mining's relative share of GDP has fallen sharply, it remains the dominant influence on the Zambian economy. Despite copper exports having fallen from 667,000 tons per annum in 1970-72 to 480,000 tons in 1985, and prices having declined by 60% in real terms between 1975 and 1986, copper still accounts for about 90% of Zambia's export earnings. In 1987, this percentage was even higher, as world copper prices rose and Zambian exports increased. A further legacy of its copper export dependence is that the Zambian economy is also highly open, the total of imports and exports representing nearly 50% of GDP.

3.2 Recent Economic Performance and Strategy

The persistent decline in world copper prices and Zambian copper production, coupled with then rising oil prices and global recession, caused a severe slowdown in economic growth during the late 1970s. Attempts to maintain domestic production and consumption in the face of falling foreign exchange earnings led to heavy borrowing. By 1986, the external debt was four times GDP and scheduled debt service was 100% of export earnings.

Shortages of foreign exchange reduced investment, which fell by over 60% between 1981 and 1985. By 1985-86, gross fixed capital formation was at an all-time low of 7% of GDP, well below the requirement for replacement and rehabilitation of the existing capital stock.

In the mid-1980s, faced by persistent economic stagnation and a steadily worsening balance of payments and debt situation, the Government launched an ambitious program of economic liberalization. Price controls were removed from most products and subsidies reduced. Interest rates were liberalized and a foreign exchange auction system introduced. The maize and fertilizer marketing monopolies were ended.

Unfortunately, copper prices continued to decline, and the economy did not respond quickly to these measures. The backlog of external payments and the scarcity of foreign exchange resulted in a nearly seven-fold devaluation of the Kwacha between October 1985 and October 1986. Foreign debt service costs rose in proportion, and inflation accelerated sharply, from an average of 20% in 1983-84 to about 60% in 1986.

At the beginning of 1987, the government abandoned the foreign exchange auction and set a fixed exchange rate of K8/US$1. 1/ Interest rate ceilings were reimposed and debt payments limited to 10% of export earnings. Foreign aid flows and commercial bank lending were still far below Zambia's needs, but copper prices rose and provided some relief, reaching US$1.40/lb in late 1987, before settling back to around US$1.00/lb in early 1988. Coupled with a slight increase in copper exports, this partly offset the low level of multi-lateral and commercial lending. However, it was not sufficient to reverse the net outflow of resources or cause a resumption in economic growth.

3.3 Pattern of Energy Supply

In such difficult economic conditions, Zambia is fortunate in having considerable indigenous energy resources, particularly of woodfuels, hydropower, and coal, which satisfy about 90% of its energy needs. With the exception of petroleum, the country is virtually self-sufficient in energy, and is a net exporter of hydropower.

The energy balance for 1986, the last full year for which comprehensive energy data are available, is set out in Table 3.2.

1/ Between early 1987, when the exchange rate of K8/US$1 was established, and end 1987, Zambia experienced inflation of over 50%. Project costs used in this Report were estimated as of end-1987. To reflect the economic value of the currency at this time, a shadow exchange rate of K12/US$1 is used for the economic analysis. In late 1988, the Kwacha was devalued to K10/$US1.

Table 3.2: WB/DOE ENERGY STRATEGY STUDY - ENERGY BALANCE FOR 1986
('000 toe)

FLOWS OF ENERGY	1 SPIKED CRUDE OIL	2 COAL	3 HYDRO-ELEC-TRICITY	4 WOOD	5 TOTAL PRIMARY SOURCES	6 SUPER	7 REGULAR	8 DIESEL/ GAS OIL/ LSG	9 AVIATION FUEL	10 KEROSENE	11 FUEL OIL	12 LPG	13 BITUMEN	14 COKE	15 ELEC-TRICITY	16 CHARCOAL	17 TOTAL SECONDARY SOURCES	18 TOTAL
	SOURCES AND FORMS OF ENERGY																	
	PRIMARY ENERGY					SECONDARY ENERGY												
I. SUPPLY																		
1 Domestic production		358.7	840.2	4482.7	5681.5													5681.5
2 Imports	603.4		0.1		603.5				1.4					24.6			25.9	629.5
3 Variation in stocks	-51.4	-5.8			-57.2	1.0	6.0	3.2	3.7	-1.4	2.5	0.4	0.6				16.0	-41.2
4 Total supply	552.0	352.9	840.3	4482.7	6227.8	1.0	6.0	3.2	5.0	-1.4	2.5	0.4	0.6	24.6			41.9	6269.7
5 Exports		14.1	244.7		258.8		7.3	1.7			0.2	4.1	0.2				13.6	272.4
6 Domestic supply	552.0	338.8	595.5	4482.7	5969.0	1.0	-1.3	1.5	5.0	-1.4	2.3	-3.7	0.4	24.6			28.4	5997.3
II. TRANSFORMATION																		
7 Refineries	-552.0				-552.0	74.6	19.3	246.1	38.9	28.3	84.1	4.1	14.4				509.8	-42.3
8 Electricity utilities		0.0	-595.5		-595.5			-1.7							597.4		595.6	0.1
9 Kilns				-2220.4	-2220.4											532.9	532.9	-1687.5
10 Total Transformation	-552.0	0.0	-595.5	-2220.4	-3367.9	74.6	19.3	244.4	38.9	28.3	84.1	4.1	14.4		597.4	532.9	1638.3	-1729.6
III. DIST./TRANSM. LOSSES																		
11 Losses															59.7		59.7	59.7
IV. TOTAL SUPPLY FOR FINAL CONS.																		
12 Total supply		338.8	0.0	2262.3	2601.1	75.6	18.0	245.9	43.9	26.9	86.4	0.4	14.8	24.6	537.6	532.9	1606.9	4208.0
V. ADJUSTMENT																		
13 Adjustment		-3.1	0.0	-3.3	-6.4	2.5	-6.0	-8.9	5.4	-0.2	-1.0	-1.2	0.4		-0.1	-17.4	-26.6	-33.0
Adjustment in % of final cons		-0.9		-0.1	-0.2	3.4	-24.8	-3.5	13.9	-0.9	-1.2	-74.3	2.6	0.0	0.0	-3.2	-1.6	-0.8
VI. FINAL CONSUMPTION																		
14 Households				1858.9	1858.9					16.0					42.7	548.0	606.7	2465.6
15 Agriculture and forestry				203.3	203.3			14.8		0.3	0.0				8.4		23.6	226.9
16 ZCCM		184.3			184.3	0.8	1.1	63.4		6.2	63.5			24.6	389.3	2.3	551.3	735.5
17 Industry and commerce		141.5		203.3	344.8			36.3		3.6	17.6	1.6	14.4		70.6		144.1	488.9
18 Government/service		16.1			16.1					0.6	6.3				26.6		33.5	49.6
19 Transport						72.3	22.9	140.3	38.6	0.4							274.4	274.4
20 Total final Consumption		341.8		2265.6	2607.4	73.1	24.0	254.8	38.6	27.1	87.4	1.6	14.4	24.6	537.7	550.3	1633.5	4240.9

Notes: (a) The utilization of crop residues, dung, bagasse do not appear on the balance although they are used as fuels. However, very little information is available and the consumption is thought to be comparatively small.
(b) The final consumption of wood for "Agriculture and Forestry" and for "Industry and Commerce" are estimated to total 10% of consumption of wood for household energy use (both firewood and charcoal).

In that year, primary energy production totalled 5.7 million tons of oil equivalent (toe). Two hundred and fifty nine thousand toe were exported, primarily in the form of hydropower to Zimbabwe, and 603,500 toe of petroleum products were imported. Wood was, and is, the dominant source of energy, contributing 72% of total primary supply, followed by hydroelectricity (13%), 2/ petroleum products (9%) and coal (6%).

3.4 Energy Transformation

In 1986, approximately 50%, or about 2.2 million toe of fuelwood was converted into charcoal, at an estimated average conversion efficiency of 25%. Total charcoal production was about 533,000 toe.

The 603,500 toe of petroleum products were imported in commingled form, via the Tazama pipeline from Dar-es-Salaam to Ndola, and separated at the Indeni hydroskimming refinery. Pipeline losses and refinery own use and loss in 1986 totalled 42,300 toe, or 8% of total petroleum product imports. Refinery operations were estimated to account for about 7% of the 8% loss, pipeline and other losses for the balance.

3.5 Pattern of Energy Demand

Final domestic energy consumption in 1986 totalled 4.2 million toe, of which households were estimated to account for 58%, mining for 17%, industry and commerce for 12%, transport for 7%, agriculture for 5%, and Government and services for the remainder.

Household energy demand is met primarily from wood (76%) and charcoal (22%). As most wood is gathered, not bought, accurate figures of consumption are not available. Electricity accounts for just under 2% of domestic energy consumption, and kerosene for the small balance. Population growth is rapid, averaging about 3.5% per year, and urbanization (and hence the use of charcoal) is increasing. Consequently, woodfuel consumption is rising faster than population growth.

The energy demand of the mining industry is met primarily by electricity (53%), coal (25%), diesel and fuel oil (9% each). Mining is the largest domestic consumer of electricity, coal and fuel oil, accounting for 72%, 54%, and 73% of total national consumption of these fuels respectively. Declining copper production has meant stagnant or falling energy demand from the industry for the past 10 years.

Conventional (non-wood) energy use in industry and commerce is dominated by coal and electricity. Wood and charcoal are used in significant, but unknown quantities. In constructing the energy balance, in-

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2/ Converting hydroelectricity on a heat equivalent basis of 1 GWh = 85 toe.

dustry and commerce were assumed to be responsible for 5% of total wood consumption. As a result of Zambia's difficult economic situation, total energy use in the sector has been virtually stagnant for the past 10 years.

The energy needs of the transport sector are met largely by diesel oil (51%), gasoline (34%), and aviation fuel (14%). This sector accounts for 54% of total national demand for petroleum products. Over the past 10 years, transport energy demand has been static, suppressed by falling incomes, the high cost of imported vehicles, and by the scarcity of foreign exchange. If and when these constraints are eased, transport fuel demand could rise, with adverse implications for the balance of payments.

Agriculture and services are not large users of energy. However, the economic strategy of diversification and greater reliance on the use of indigenous resources implies rapid growth in agricultural output. This in turn will mean higher energy demand, particularly for diesel oil and electricity. Due to the low level of current agricultural energy consumption, the effect on aggregate energy demand will be modest. However, in the case of electricity, the investment implications could be considerable.

3.6 Economic Projections, 1988-2006

Future economic growth is highly uncertain, depending on several unpredictable factors. Among the most important are: (a) the price of copper and other export minerals; (b) the levels of official aid flows and foreign commercial lending; and (c) the performance of the domestic agriculture and manufacturing sectors in the face of current severe shortages of imported inputs.

The prospects for sustained higher copper prices in the long-term are not good. World demand is relatively inelastic; substitution, particularly by optical fibers, is continuing; and other producers, including some with lower costs than Zambia, are capable of increasing their output in response to higher short-term prices. Official aid flows to Africa are increasing, but Zambia's share is uncertain. Commercial lending to developing countries has fallen, and Zambia's recent debt service problems are likely to rule this out as a significant source of new money. Consequently, foreign exchange will probably remain scarce, imposing severe constraints on the supply of imported inputs for agriculture and manufacturing.

Due to the current difficult economic situation, GDP is forecast to remain unchanged in 1988. For the period 1989-2006, three alternative economic scenarios have been selected to assist in forecasting future energy demand: a base, a low, and a high case.

(a) The Base Case assumes average annual growth in aggregate real GDP of 2%, which represents an improvement over recent economic performance, but not a return to the high performance of the late 1960s and the early 1970s.

(b) The High Case assumes average annual real GDP growth of 3.5%. Broadly in line with the Government's current economic targets, this represents a substantial improvement in recent economic performance. Starting from the current low base, growth might be above 3.5% in the short-run, and below in the long-run.

(c) The Low Case assumes real GDP remains static. This slight worsening of recent economic performance assumes a pessimistic combination of weak copper prices and persistent shortages of foreign exchange.

It should be stressed that these are only economic scenarios not forecasts. Their purpose is simply to provide a quantitative basis for forecasting the possible evolution of energy demand. While the scenarios are projected through the year 2006, they become increasingly speculative in the later years. Actual economic events will almost certainly not parallel any of the scenarios exactly. As the future economic situation develops over time, the scenarios should be reexamined and more realistic alternatives used to update the energy strategy.

3.7 Energy Strategy Objectives and Constraints

The basic objective of Zambia's national energy strategy is to satisfy demand for energy at the least economic cost, and in a way that is consistent with national development priorities, with the availability of resources, and with the long-term viability of the energy supply organizations. This broad strategic objective can be translated into a number of specific sub-objectives, among the most important of which are:

(a) providing adequate, reliable, least-cost energy supply to the productive sectors of the economy, on which economic development depends;

(b) providing sufficient affordable energy to households, to satisfy their basic energy needs;

(c) without compromising the objective of least-cost supply, minimizing net imports of energy, in order to conserve foreign exchange;

(d) meeting energy needs in an environmentally-sound manner; and

(e) ensuring adequate maintenance of energy supply systems and the financial viability of the organizations responsible for them.

Limited investment resources, both domestic and foreign exchange, are the principal strategic constraint. Currently, the level of domestic savings and investment is extremely low, only 7% of GDP in 1986. The flow of official aid and commercial lending is also depressed, although at least the former should increase. On balance, the outlook is for severe capital scarcity over the next several years.

Therefore, the energy strategy seeks to minimize investment requirements by emphasizing improvement in existing capacity utilization and efficiency. It also sets priorities among the limited investments that are recommended, and ensures that they provide sufficient flexibility to allow the energy sector to adjust to future uncertainty.

In view of the difficult and upredictable economic situation, the focus of the energy strategy is on the next five years, 1989-93. Predicting events and energy priorities beyond this period is highly speculative, and of less importance than getting the near-term priorities right. To take account of emerging energy priorities over the longer term, and the evolving economic situation, the energy strategy must be updated at least every five years, and the energy plan, every year. With this need in mind, the energy strategy report examines the role, skill and manpower requirements of the organizations responsible for energy planning, and recommends steps to ensure that they are adequate for this task.

3.8 Energy Demand Forecasts, 1988-2006

Three domestic energy demand forecasts have been developed, a low, a high, and a base case forecast, corresponding to the three economic scenarios. The purpose of the energy demand forecasts is to determine the energy requirements of the economy under the different demand assumptions, which assists identification of the strategic energy issues in the short, medium, and long-term. Energy exports have been forecast exogenously, using conservative assumptions for each export product and market.

Tables 3.3 and 3.4 show the three alternative forecasts of domestic final energy demand by consuming sector and by energy source for 1996 and 2006. Projected Energy Balances for 1996 and 2006 are set out in Appendix 3.1. The forecast methodology is described in Appendix 3.2.

Table 3.3: FORECAST FINAL ENERGY CONSUMPTION BY SOURCE
(toe '000s)

Sources	1986 Actual		1996 Forecast Low Case		1996 Forecast Base Case		1996 Forecast High Case		2006 Forecast Low Case		2006 Forecast Base Case		2006 Forecast High Case	
	toe	%	toe	%	toe	%	toe	%	toe	%	toe	%	toe	%
Electricity	538	13	594	12	617	12	642	12	483	8	539	9	608	9
Coal/Coke	366	9	325	6	338	6	354	7	317	5	344	5	385	6
White Pet. Prod	418	10	383	8	430	8	468	9	370	6	488	8	605	9
Fuel Oil	87	2	62	1	65	1	68	1	38	1	44	1	50	1
Bitumen/LPG	16	0	16	0	18	0	21	0	16	0	23	0	29	0
Subtotal	1,425	34	1,380	27	1,469	28	1,552	29	1,224	21	1,437	23	1,677	25
Firewood	2,266	53	2,745	54	2,805	54	2,853	54	3,168	53	3,322	53	3,473	52
Charcoal	550	13	961	19	943	18	917	17	1,559	26	1,516	24	1,468	22
Subtotal	2,816	66	3,705	73	3,748	72	3,770	71	4,727	79	4,838	77	4,941	75
Total	4,241	100	5,085	100	5,217	100	5,322	100	5,950	100	6,276	100	6,619	100

Source: Department of Energy.

Table 3.4: FORECAST FINAL ENERGY CONSUMPTION BY SECTOR
(toe '000s)

Sector	1986 Actual		1996 Forecast Low Case		1996 Forecast Base Case		1996 Forecast High Case		2006 Forecast Low Case		2006 Forecast Base Case		2006 Forecast High Case	
	toe	%	toe	%	toe	%	toe	%	toe	%	toe	%	toe	%
Households	2,466	58	3,371	66	3,350	64	3,316	62	4,412	74	4,358	69	4,308	65
Agriculture	227	5	230	5	269	5	305	6	236	4	342	5	448	7
ZCCM	736	17	639	13	639	12	639	12	470	8	470	7	470	7
Industry	489	12	538	11	602	12	663	12	531	9	682	11	848	13
Govt/Service	50	1	50	1	58	1	65	1	50	1	71	1	92	1
Transport	274	6	258	5	298	6	334	6	251	4	352	6	453	7
Total	4,241	100	5,085	100	5,217	100	5,322	100	5,951	100	6,276	100	6,619	100

Source: Department of Energy.

3.8.1 Forecast Sectoral Pattern of Energy Demand

The main features of the domestic energy demand pattern are unlikely to change drastically during the period under consideration. The household sector will continue to dominate total energy demand. Its relative share in overall final demand is forecast to increase from 58% to 69% by 2006 in the base case forecast. This is because the projected rate of growth of population is higher than the asssumed growth rate of the economy. Households rely almost entirely on woodfuels for their energy needs (87%). Therefore, the relative share of woodfuels in total energy consumption is forecast also to increase, as is total consumption of woodfuels, which is expected to rise by about 70% by 2006.

ZCCM will continue to be by far the largest domestic consumer of conventional (non-wood) energy resources, accounting for about 40% of total conventional energy consumption in 2006. However, its dominating role will diminish as copper production declines. The other sectors of the economy are expected roughly to maintain their relative shares of consumption during the period.

Total final domestic energy consumption rises in all three forecasts, the largest contribution coming from fuelwood and charcoal. Domestic consumption of conventional energy decreases in the low scenario from 1986 to 2006. In the base case, conventional energy consumption in 2006 is forecast to be roughly the same as in 1986. In the high case, there is a modest increase in conventional energy consumption over the forecast period. The decrease of energy consumption in the low case is explained by the fact that the energy consumption of ZCCM is forecast to decline by 2006, while the consumption of the other sectors is stagnant. In the base and high case, the growth of the other sectors counterbalances the forecast decline in the consumption of ZCCM.

3.8.2 Forecast Pattern of Energy Demand by Fuel Type

Domestic consumption of petroleum products is assumed to be strongly linked to economic growth. In the high scenario, petroleum product consumption is forecast to increase by 29% from 1986 to 2006, which is much more than the increase of electricity and coal/coke (21% and 3% respectively). This is primarily due to forecast expansion of transport energy demand, which is the largest consumer of petroleum products. The consumption pattern of both electricity and coal, on the other hand, is dominated by a small number of consumers whose consumption is not so strongly linked to average income growth. In the case of electricity, ZCCM is the dominant consumer. In the case of coal, the main consumers are ZCCM, NCZ, and Chilanga Cement. ZCCM's and NCZ's energy demand is largely dependent on technical factors, and is not strongly affected by growth elsewhere in the economy.

A dramatic change is foreseen in the level of electricity exports. From 2,879 GWh (245,000 toe) in 1986, they are forecast to decline to 1,165 GWh (99,000 toe) in 1996. This follows Zimbabwe's drive for greater self-sufficiency in power supply, and more than offsets the modest forecast increase in domestic consumption.

Exports of petroleum products and coal are relatively small and volatile. Recent past export performance is simply projected into the future, implying an annual average of 50,000 tons of petroleum product exports and 35,000 tons of coal exports.

The most important feature of these forecasts is that, even in the high scenario, the forecast consumption of electricity, petroleum products and coal do not surpass the existing capacity of the respective supply facilities over the period to 2006. In the case of electricity, total domestic and export demand is forecast to be below its 1986 level by the end of the period. Unless new export markets can be developed, the surplus of available electric power capacity and energy will therefore increase, relative to 1986. The high scenario demand for petroleum products, which requires 725,000 tons of imports, is within the capacity of both the Tazama pipeline and the Indeni refinery, as currently configured. In the case of coal, the high demand forecast is 570,000 tons (385,000 toe), which is well below the present capacity of the mine.

3.9 Balance of Payments Implications of Energy Forecasts

3.9.1 Recent Situation

Zambia's net balance of energy trade is dominated by two items: petroleum product imports and power export sales to Zimbabwe. During the mid-1980s, the cost of petroleum imports averaged about US$90 million per year. At their peak in 1986, power export revenues were over US$40 million. Taking account of coal and other energy exports, the energy balance of trade was in deficit by just under US$50 million in that year.

In 1987, power export sales declined sharply to less than US$20 million, and the energy balance of trade widened to about US$70 million. In 1988, the picture is likely to be similar, perhaps a little worse, if the further expected decline in power exports materializes.

3.9.2 Forecast Evolution

Over the period 1989-93, petroleum import volumes are forecast to rise at a modest rate of about 2% per year in the base case. Future petroleum prices are highly uncertain. In the short run (1988-89), they appear likely to be stable. Moving into the 1990s, the general consensus is that prices will start to rise as increasing world demand soaks up existing excess supply. In that event, the cost of petroleum product imports is likely to rise over this part of the forecast period. Beyond the mid-1990s, the trend in prices is highly uncertain, but few experts expect a return to mid-1980s low price levels.

With the commissioning of the Hwange II power station, there is little immediate prospect of a recovery in power export sales to Zimbabwe to early 1980s levels. However, sales in the range of 1,000-2,000 GWh per year and 150-250 MW should be possible over the 1989-93 period, producing export earnings of about US$10-20 million per year.

Beyond 1993, power export prospects are highly uncertain. Assuming Zimbabwe continues its policy of self-sufficiency in power, there is little prospect of a major recovery in Zambian exports, despite the low cost of Zambian supplies. However, some export sales should be possible, particularly in years when Zimbabwean capacity is stretched. In its own interests, and those of promoting efficient use of existing power capacity, Zambia should continue to emphasize its potential as a reliable source of substantial quantities of low-cost power. Malawi and Botswana offer potential for modest exports, but nowhere near enough to compensate for the expected drop in Zimbabwean sales.

Coal exports in 1986-87 were about 30,000 tons, earning over US$1 million in foreign exchange. The capacity exists to supply future coal export markets, but the markets themselves are limited and volatile. A major increase in coal exports is therefore not foreseen.

Overall, the outlook is for a deficit in the balance of energy trade of about US$70-80 million over the 1989-93 period. Looking further ahead, the prospect is for further deterioration, assuming petroleum product prices start to increase in the 1990s.

IV. ELECTRIC POWER

4.1 Characteristics of the Existing Power System

The Zambian power system consists of one large, interconnected system, usually known as the main grid; a smaller interconnected system, known as the northeastern system; and several small, isolated systems served by diesel generating units. The main grid and the northeastern system will be interconnected at Pensulo, near Serenje, probably during the course of 1989. The power stations and transmission system are shown on IBRD Map 20984 at the end of this Report.

4.1.1 Installed Generation Capacity

Hydro generating capacity on the main grid totals 1,608 MW. The main hydro stations and their respective installed capacities are Kariba North (600 MW) and Victoria Falls (108 MW) on the Zambezi River, and Kafue Gorge (900 MW) on the Kafue River (Table 4.1). Until recently, the Kariba North and South stations were run as a single complex by the Central African Power Corporation (CAPC). In 1987, they were transferred to the national power utilities of Zambia and Zimbabwe respectively. CAPC was dissolved, and its role of managing the Kariba dam was taken over by the Zambezi River Authority.

The northeastern system consists of four small hydro stations, with a combined capacity of 24 MW, and 2 MW of diesel standby. Seven diesel generators, with a combined capacity of 5 MW, supply the isolated systems.

Zambia Consolidated Copper Mines (ZCCM) owns four gas turbine generators and a waste heat plant, located in the Copperbelt. The gas turbines have a total installed capacity 80 MW, and are kept on cold standby. The waste heat plant has a nominal capacity of 40 MW, but supplies an average of only about 3 MW.

The Zambian power system is interconnected at high voltage with those of neighboring Zimbabwe and Zaire. Zambia exports to and provides standby capacity to Zimbabwe in the event of emergency. In the case of Zaire, major support is given at cost. It has reciprocal access to standby capacity from these two countries.

4.1.2 Available Firm Energy

The estimated firm energy capabilities of the various stations are also shown in Table 4.1. The firm energy capabilities of Kariba North and Kafue Gorge were originally estimated at 4,700 GWh/year and 5,256 GWh/year respectively. Recent hydrological experience suggests that the estimate for Kariba North should be revised downwards, probably to a range of 3,750-4,250 GWh/year. In the case of Kafue Gorge, water-rights have been set aside for agricultural purposes. Although not fully utilized, they justify a downward revision in the plant's firm generation capability to about 5,000 GWh/year. Water-flow measurement is recommended, and could lead to further revision of these firm energy estimates.

Table 4.1: INSTALLED POWER CAPACITY AND ESTIMATED FIRM ENERGY CAPABILITY, 1988

Power Station	Installed Capacity	Firm Energy
	MW	GWh/a
Interconnected System		
Kariba North	600	3,750-4,250
Kafue Gorge	900	5,000
Victoria Falls	108	770
SUBTOTAL	1,608	9,520-10,020
Northeastern System		
Lusiwasi	12	50
Chishimba Falls	6	20
Musonda Falls	5	30
Lunzua	1	5
Diesels	2	-
SUBTOTAL	26	105
Isolated Diesels	5	-
ZCCM		
Gas Turbine a/	80	-
Waste-Heat Thermal b/	40	-
GRAND TOTAL	1,759	9,625-10,125

a/ Standby
b/ Output is typically in the range of 3 MW.

Source: ZESCO and World Bank estimates.

Transmission losses on the interconnected 330/220 kV network are about 3.5%. Assuming a conservative 4,000 GWh/year from Kariba North and using the above estimates for the other stations, the average available firm energy capability of the grid at bulk supply points is 0.965 x 9,875 = 9,529 GWh/year, after completion of the Pensulo substation in 1989.

4.1.3 Potential Generating Capacity

Zambia is drained by two major river systems, the Zambezi and the Luapula. The Zambezi and its major tributaries, the Kafue and the

Luangwa, drain about 75% of the total land area. Zambia's potential hydro reserves on these two river systems are considerable, totalling about 4,000 MW and over 21,000 GWh/year. Zambia also has large coal deposits, which could be used for thermal power generation.

4.1.4 Existing Transmission and Distribution System

The backbone of the power transmission system is 1,900 km of 330 kV lines, connecting the major generating stations with the load centers, of which the largest are the Copperbelt and Lusaka. There are also transmission lines operating at 220 kV (510 km), 88 kV (510 km) and 66 kV (3,100 km). Primary distribution voltages are 33 and 11 kV. The three-phase secondary systems operate at 400 volts.

The transmission and distribution network covers most of the urban areas and larger towns. Ninety-one townships were recorded in the 1980 census, of which 56 were classified as "urban areas". By 1988, 83 had electricity supply--78 from ZESCO and 5 from ZCCM.

4.1.5 Rural Electrification

The Department of Energy sets priorities for the "rural electrification" program, the capital costs of which are funded from the Central Government budget. It consists of the interconnection of the remaining isolated towns to the grid, construction of mini-hydro stations to replace diesel generators, and rehabilitation of existing diesel stations. Operation of the facilities is entrusted to ZESCO. Due to the extreme shortage of funds, recent investments in rural electrification have been modest. They have consisted exclusively of completing ongoing, long-delayed projects.

4.1.6 Generation and Sales

Data on the production and bulk supply of electric energy on the interconnected system, by major source and customer group, for the last five ZESCO fiscal years (April-March), are shown in Table 4.2. Between 1983-84 and 1986-87, energy production was roughly constant at 9,430-9,750 GWh/year. In 1987-88, production declined to 7,727 GWh, due to a sharp fall in export sales to Zimbabwe. This was the result of Zimbabwe increasing generation at its Hwange thermal power station. In 1987-88, energy production was some 1,802 GWh (19%) below the conservative estimate of firm energy availability.

Table 4.2: ELECTRIC ENERGY PRODUCTION
AND BULK SUPPLY ON THE INTERCONNECTED SYSTEM
1983-84 to 1987-88 a/
(GWh)

	1983-84	1984-85	1985-86	1986-87	1987-88
PRODUCTION					
Kariba North	3,788	3,996	3,475	3,337	2,788
Kafue Gorge	5,152	4,677	5,594	5,436	4,407
Victoria Falls	769	756	680	697	624
TOTAL	9,709	9,429	9,749	9,470	7,819
TRANSMISSION LOSSES	264	299	352	287	307
BULK SUPPLY					
Domestic supplies					
ZESCO South	1,217	1,211	1,221	1,288	1,361
ZESCO North	624	630	636	654	656
ZCCM	4,293	4,249	4,138	4,465	4,459
TOTAL Domestic	6,134	6,090	5,995	6,407	6,476
Exports b/					
Zimbabwe	3,312	3,039	3,410	2,776	1,036

a/ ZESCO fiscal year, April-March.
b/ Excluding net transfers of energy to Zaire which in theory sum to zero.

Source: ZESCO.

Simultaneous maximum demand on the Zambian system (including exports) peaked at 1,396 MW in 1984-85. It declined to 1,279 MW in 1985-86, rose to 1,320 MW in 1986-87, then fell in 1987-88, following the reduction in Zimbabwean demand (Table 4.3).

Table 4.3: SIMULTANEOUS MAXIMUM DEMAND a/
ON THE ZAMBIAN INTERCONNECTED SYSTEM
(MW)

Source	1983-84	1984-85	1985-86	1986-87
Zambia	897	895	895	936
Zimbabwe	447	501	384	384
TOTAL	1,344	1,396	1,279	1,320

a/ Including transmission losses within Zambia.

Source: ZESCO.

4.2 Policy Issues and Options

To facilitate economic recovery, the power system must provide reliable and adequate supplies of electricity to the productive sectors of the Zambian economy. A priority is therefore to identify the critical weaknesses in the existing supply system and the actions necessary to overcome them. With surplus power and energy capacity, investment in new generating capacity is clearly not needed, but the existing generating stations must operate reliably. Bulk transmission capacities are adequate for existing loads, but the firm capacity of the 330/88 kV transformers and the 88 kV lines serving Lusaka is less than the city's peak demand. Many of the city's primary and secondary distribution lines are also overloaded. A priority program to eliminate the risk of a major power failure in the capital must be defined.

Other economic priorities are to make better use of indigenous energy resources and to ease the shortage of foreign exchange. Surplus power is available for export; to substitute for imported petroleum and/-or household charcoal; and to increase agricultural irrigation. Therefore, the potential for power exports must be assessed, and a power export strategy proposed that maximizes net revenue from export sales. In industry, the potential for substituting electricity for petroleum products must be identified, as is outlined in Chapter 9. Options for connecting isolated load centers to the grid, and thereby substituting hydro for diesel power, must be evaluated. So too must potential agricultural irrigation schemes.

Satisfying the basic needs of the people is <u>the</u> fundamental objective of the economic recovery program. One of those basic needs is household energy. With rapid urbanization, the cost of charcoal is rising. One option is to accelerate household electrification. The major issues are: (a) whether it is economic to do so; (b) how to minimize the cost (e.g., by using less costly distribution standards); and (c) how to make access to electricity affordable (e.g., by term payment of connections). The issue of timing is also important, because adequate transmission and distribution capacity must be in place before household connections can be increased.

Power tariffs are the final major issue. They must:

(a) cover ZESCO's financial requirements, including operations, maintenance, existing debt, and the local and foreign costs of essential new power system investment;

(b) reflect the economic cost of power supply; and

(c) facilitate the expanded use of electricity by making it as affordable as possible.

4.3 Electricity Demand Forecasts 1988-2006

4.3.1 Zambian Demand

ZCCM is ZESCO's largest customer, accounting for nearly 70% of current domestic electricity sales. ZCCM's demand for electric energy is forecast to rise from 4,482 GWh in 1987 to 5,067 GWh in 1998, then fall, in steps, to 4,037 GWh in 2003, and remain stable for the rest of the forecast period. This pattern results from an assumed slight upward trend in production in the early/mid-1990s, followed by the closure of the Nchanga open pit and the Mufulira smelter at the end of the decade.

With the exception of NCZ and Chilanga Cement, for whom specific demand forecasts are made, other industrial, service and transport sector power demand is forecast to rise in proportion to GDP. Agricultural demand is forecast to grow slightly faster than GDP, as a result of increased irrigation.

Household demand for electricity is forecast under three alternative demand scenarios as follows:

(a) Base - 4,000 new ZESCO connections per year.

(b) High - 7,000 new ZESCO connections per year.

(c) Low - 2,000 new ZESCO connections per year.

The resulting forecast peak loads at ZESCO bulk supply points are shown in Table 4.4.

Table 4.4: FORECAST POWER SYSTEM LOADS AT BULK SUPPLY POINTS AT TIME OF SYSTEM PEAK (MW)

	1987	1998			2006		
		High	Base	Low	High	Base	Low
ZESCO South	246	409	346	279	572	446	311
ZESCO North	652	793	764	735	740	680	619
TOTAL	898	1,202	1,110	1,014	1,312	1,126	930

Source: World Bank estimates.

4.3.2 Export Demand

Zambia's power export potential to its southern African neighbors is limited by their generally favorable power resource endowment, by the existence of excess capacity, by economic constraints, and by politics. Zambia is one of several countries in the region with surplus, low cost hydro capacity. Alternative sources of generation in the region include coal for thermal generation, also low cost and fairly widely available. Together with the difficulties many countries in the region experience in paying for imports in hard currency, the potential for significant Zambian power exports must be regarded as limited and uncertain, the only significant exceptions being short- and medium-term power exports to Zimbabwe, and, in the longer-term, possibly to Botswana also. Exports to Zimbabwe are forecast to range between zero and 2,000 GWh/year up to 1994, and are very speculative thereafter. The interconnections with other neighboring countries, both existing and planned, are not expected to lead to significant energy sales. Prospects for exports to each neighboring country are discussed in Appendix 4.1.

The scope for exports of power is greater than energy, because network interconnections can reduce the capacity investment needed for standby purposes. Connections with Tanzania and Malawi are under consideration, and interconnections with Zimbabwe and Zaire have been in operation for sometime. Power exports to Zimbabwe could range between 150 and 300 MW up to 1994. In addition, there is potential for small additional exports of power to Botswana.

4.3.3 Total System Demand

The base, high, and low electric energy and power demand forecasts are summarized in Table 4.5. Energy losses on the Zambian bulk supply network are estimated to be 3.5% and in the retail system to be 15%. These are assumed to remain constant.

Comparison of columns "d" and "e" of the Table shows that the resulting forecast demands for electric energy and power for 1989-2006 are less than a conservative estimate of firm energy and a rough estimate of available power capacity (1,490 MW) 3/ in every year. The closest demand approaches existing capacity is for energy in the high scenario for year 2006, when firm energy is 500 GWh greater than the forecast demand within Zambia. For some of the diesel power networks, however, capacity will need to be increased over time to keep up with increasing demand, assuming their interconnection is uneconomic.

3/ Installed capacity of 1,754 MW, minus 15% capacity reserve traditionally assumed by ZESCO.

TABLE 4.5
FORECAST OF ELECTRIC ENERGY AND MAXIMUM POWER DEMAND 1988-2006

Year		ZCCM demand GWh a	ZESCO demand GWh b	Losses to bulk points GWh c =3.5%(a+b)	Zambia energy demand GWh d =a+b+c	Available firm generation capability GWh e	Available for export GWh f =e-d	
1987	ICS	4482	2005	227	6714	10575	3861	1)
	SHy	0	85	3	88	105	0	
	IDi	0	7	0	7	0	0	
	Sum	4482	2097	230	6809	10680	3861	
	SCENARIO							
1989	Base	4531	2118	233	6882	9675	2793	
	High	4531	2154	234	6919	9675	2756	
	Low	4531	2075	231	6838	9675	2837	
1992	Base	4943	2391	257	7591	9675	2084	
	High	4943	2562	263	7768	9675	1907	
	Low	4943	2201	250	7394	9675	2281	
1998	Base	5067	2977	282	8326	9675	1349	
	High	5067	3498	300	8865	9675	810	
	Low	5067	2427	262	7756	9675	1919	
2006	Base	4037	3736	272	8045	9675	1630	
	High	4037	4828	310	9175	9675	500	
	Low	4037	2611	233	6881	9675	2794	

Year		SIMULTANEOUS MAXIMUM DEMAND At bulk supply points ZCCM MW a	ZESCO MW b	Trans-miss. losses MW c =6%(a+b)	At gener. plants MW d =a+b+c	Available total capacity MW e	Available for export MW f =e-d	
1987	ICS	544	342	53	939	1468	529	2)
	SHy	0	19	1	20	23	-	
	IDi	0	5	0	5	8	-	
	Sum	544	366	55	965	1499	-	
	SIM	544	356	54	954	1490	536	
	SCENARIO				SIM			
1989	Base	550	360	55	965	1490	525	
	High	550	367	55	972	1490	518	
	Low	550	353	54	957	1490	533	
1992	Base	600	407	60	1067	1490	423	
	High	600	436	62	1098	1490	392	
	Low	600	375	58	1033	1490	457	
1998	Base	615	507	67	1189	1490	301	
	High	615	595	73	1283	1490	207	
	Low	615	413	62	1090	1490	400	
2006	Base	490	636	68	1193	1490	297	
	High	490	822	79	1390	1490	100	
	Low	490	444	56	990	1490	500	

KEY:
ICS= Interconnected system. SHy= Separate hydro system.
IDi= Isolated diesel system. Sum= Total Zesco system.
SIM= Simultanious Max Demand in Zesco main system if SHy had been interconnected in 1987.
ZCCM= Bulk delivery to ZCCM, excluding Zesco North.
ZESCO= Bulk delivery to ZESCO South + North.

1) Actual exports are estimated at 1300 GWh.
2) Actual maximum demand exports to Zimbabwe were 525 MW, but only 372 MW, when measured on occation of maximum simultaneous load. It is unclear to what extent the maximum demand export to Zaire of about 100 MW was coincident with maximum simultaneous load.

4.4 Priority Power System Investment Program

4.4.1 Hydro Generation Investment

The major new generation investment options are the Kafue Lower hydroelectric plant (450 MW, 2,500 GWh/year firm energy), located downstream of the existing Kafue Gorge plant, or further joint developments with Zimbabwe on the Zambezi River, probably Batoka Gorge (1,600 MW), upstream of Kariba. Because forecast demand for electric power and energy is not expected to exceed Zambia's existing generating capacity until after 2006, there is no need for Zambia to begin planning new network hydro-electric generation capacity unless substantial additional firm export sales can be guaranteed. However, if Zimbabwe wishes to proceed with development of the Batoka Gorge site, exploratory work will be needed on a possible future north bank power station in Zambia.

The two key generating stations on the existing interconnected system are Kariba North and Kafue Gorge. Their condition, and that of the other power system assets, is described more fully in a companion ESMAP Power Subsector Efficiency Study. 4/ This report concludes that the Kariba North station is in excellent condition, and no major repair work is required. However, at Kafue Gorge the following work is recommended to bring the power station up to satisfactory working order:

(a) completion of the ongoing NORAD-funded rehabilitation of the turbines and alternators;

(b) replacement of auxiliary systems, including: air conditioning chillers (US$100,000 per unit), pumps, and fan coil units (US$509,000);

(c) installation of an additional 200 m of deep booms to divert weeds from the headrace intake (US$80,000);

(d) inspection and, if necessary, replacement of the 190 kV cables connecting the power station to the pothead yard;

(e) inspection and, if necessary, repair of the waterways; and

(f) provision of essential spare parts, including transformer windings and cylinder gate pistons.

The Victoria Falls power station has persistent operational problems and the following work is needed to repair the power station:

4/ Zambia : Power Subsector Efficiency Study. Joint UNDP/World Bank Energy Sector Management Assistance Program, December 1988.

(a) overhaul of the turbines and alternators in the "A" station and replacement of the power cables, switchgear, and control equipment;

(b) installation of surge arrestors on each of the three phases of the generator connections to the cables in the "B" station;

(c) rectification of the vibration problem at the "C" station, probably by increasing the submersion of the turbine and adding volume to the afterbay arrangement; and

(d) installation of bulkhead gates or retrievable steel stoplogs on the water intakes, strengthening of the trashrack cleaners, installation of 200 m of deep booms upstream of the intakes to divert weeds over the main falls, and rehabilitation of the hydraulic systems of the penstock intake gates.

Turbine and generator overhaul and civil engineering repairs are also needed at the Chishimba Falls, Musonda Falls, and Lusiwasi power stations. These should follow commissioning of the Pensulo substation, when substitute power from the main grid will become available.

The potential economic benefits of completing the modest repairs required at the Kafue Gorge power station are considerable, because loss of this station would leave the power system substantially short of capacity and energy. Little of this could be made up from Kariba North, because the lake is at an all-time low. A major failure of the Kafue Gorge station would therefore deprive essential Zambian industries of power supply.

The benefit of rehabilitating the Victoria Falls station to attain its rated capacity is the saving in generation required elsewhere. Because the station is a run-of-the-river installation, any additional generation will require less generation at the Kafue Gorge or Kariba complexes. The economic value of incremental generation on the interconnected system is the marginal cost of power from the highest-cost station, which is the Hwange thermal station in Zimbabwe. The economic benefit to Zambia alone of increased generation is the tariff at which ZESCO sells incremental energy to Zimbabwe, which is US$0.006/kWh. On this basis, and assuming a 70% capacity factor, the benefits of repairing Victoria Falls amount to US$368,000 per annum. At an investment cost of US$2.75 million and an assumed life of 20 years, the project's economic rate of return is about 12%.

In view of its high economic benefits, priority should be given to the repair of Kafue Gorge. There is also a sound case for the rehabilitation of Victoria Falls. The total cost of the two repair and rehabilitation programs is not known accurately. For the purpose of investment planning, an indicative figure of US$5 million over and above the NORAD-funded program at Kafue Gorge is assumed, including about US$100,000 for the necessary diagnostic services.

In addition to essential repair and rehabilitation of the two generating plants, spare parts supply should be improved at all the generating stations. A list of essential spares and preventive maintenance routines should be prepared at the smaller stations. Due to shortages of foreign exchange for spare parts, there is a backlog of parts maintenance and repair on all the existing generating stations, with the exception of Kariba North. Establishment of a fund for the purchase of spare parts totalling at least US$100,000/year is recommended.

On completion of the Pensulo substation in the vicinity of Serenje in 1989, the currently isolated northeastern hydro system will be interconnected with the main grid. This will come at a time when the electric energy and maximum power demand on the northeastern system has largely caught up with the system's available generating capability.

In the short-term, further demand growth in the northeastern area should be covered by supply from the main grid. When the power generation facilities in the area are rehabilitated, temporary augmentation of the supply will be required from the same source. However, supply from the main grid is by a single circuit, and is therefore not firm. Due to the long distances involved, the installation of reactive compensation capacity at receiving points for voltage control may be required.

4.4.2 Diesel Generation

Demand in several of the towns now supplied by diesel generators is expected to grow beyond present generation capacities before 2006. Unless they are linked to the hydro-electric network in the interim, these isolated systems will need investments in additional diesel engines or, if economically feasible, in mini-hydro facilities, in line with the growth of demand. Total investments for this purpose up to year 2006 are estimated at US$0.6 million in the high demand scenario.

4.4.3 Transmission System

On the base and low power demand forecasts, it is estimated that the capacity of the 330 kV transmission network will be adequate to satisfy domestic energy and power demand on the interconnected system through the year 2006. However, 330 kV transmission capacity between Leopards Hill and Kabwe is marginally exceeded in 1998 on the high demand scenario. This situation would be temporary, pending closure of the Nchanga Open Pit and/or the Mufulira smelter, both of which are forecast to occur around 1999.

It is obviously uneconomic to construct an additional transmission line to the Copperbelt to cover a brief period of possible under-capacity. Demand growth in the Copperbelt should therefore be monitored closely during the early 1990s. If it is close to or above the high demand scenario, the options to consider are: (a) reducing load growth in the Copperbelt, e.g., by a temporary tariff surcharge or (b) making greater use of ZCCM's gas turbine generating capacity for peaking.

A project to construct a 132 kV line from Lusiwasi to Msoro, a 66 kV line from Chipata to Lundazi, and later a 132 kV line from Msoro to Chipata, is in progress. The total cost of Phases I and II is US$19 million. Grant financing has been obtained for the project, which should be completed as part of the priority energy investment program.

Funding has also been obtained for a US$25 million project to electrify the Mkushi farming block. Mkushi is an area of large-scale commercial farming, and requires power for irrigation and crop processing. As the project is committed and funded by a soft loan, it too is included in the priority energy investment program.

The only other major potential transmission project is the interconnection of the four isolated western diesel centers (Kaoma, Zambezi, Kasempa, and Kabompo), plus the towns of Lukulu and Chizela, with the main grid at Mongu and Mumbwa. The capital cost of the project is about US$80 million, equivalent to about US$12 million per year, assuming repayment over 25 years at 12%. The benefits consist primarily of savings in diesel fuel, estimated at about US$500,000 per year in financial terms and US$750,000 per year in economic terms, plus avoided diesel replacement and the extension of power supply to new customers in Lukulu and Chizela. As is evident, total benefits are only a small fraction of costs, so the project is clearly not viable.

One further small transmission expansion project is justified in the short-term (1989-93). This is the installation of reactive compensation capacity to raise the capacity of the transmission lines feeding the Copperbelt (US$1.1 million).

4.4.4 Subtransmission and Distribution Rehabilitation

The most urgent subtransmission and distribution investments in the short-term (1988-93) are in the selective reinforcement and rehabilitation of the Lusaka subtransmission and distribution systems. The firm capacity of the existing 88 kV subtransmission system serving Lusaka is 110 MW, and Lusaka's peak demand is already in excess of 120 MW. Also, there is a substantial backlog of requests for power connections in the city, for which secure supply is not available.

These investments have been identified by EKONO, IVO International, FINNIDA, and the World Bank, which all confirm their priority. They are necessary both to eliminate serious overloading of the existing subtransmission and distribution system, and to facilitate additional consumer connections. Failure to reinforce the existing system could lead to major power interruptions to the capital city. The cost of the priority elements of this rehabilitation program is estimated to be US$29.9 million, made up as shown in Table 4.6.

Table 4.6: COMPONENTS AND COSTS OF THE PRIORITY LUSAKA POWER DISTRIBUTION PROJECT

Components		Cost a/ (US$ million)
A.	Lusaka Distribution Project, Phase I	
1.	Establishment of a new Roma 132/33 kV, 2 x 40 MVA, and 33/11 kV, 2 x 10 MVA sub-station including 27.2 km 132 kV transmission line Leopards Hill-Roma	5.1
2.	Establishment of a new 132/33 kV, 2 x 40 MVA and 33/11 kV, 2 x 20 MVA substation at Coventry and 330/132 kV, 2 x 124 MVA extension at Leopards Hill including 28.5 km uprating of existing, 88 kV Leopards Hill-Coventry line to 132 kV	11.4
3.	Load transfer rehabilitation and reinforcement of 33/11 kV substations at Chelston, Dublin and University, including 33 kV connections to Roma	3.0
4.	Extensions, reinforcement and rehabilitation of the 11 kV distribution system in Lusaka	3.1
5.	Engineering and supervision for Phase I above	2.6
	Subtotal	25.2
B.	Other Project Components	
6.	88/33 kV, 30 MVA transformer at Chongwe substation	1.6
7.	Addition of 330/88 kV, 60 MVA transformer at Leopards Hill substation	1.0
8.	Replacement of 33 and 11 kV switchgear at Coventry St. substation	0.5
9.	Change of feed point of Chisamba load to Chongwe substation	0.6
10.	Addition of 88/33 kV, 30/45 MVA transformer at Waterworks substation	1.0
	Subtotal	4.7
TOTAL		29.9

a/ End-1987 prices.

Source: FINNIDA and World Bank estimates.

The FINNIDA prefeasibility analysis 5/ of the Lusaka Distribution Project made some rough estimates of the project's economic benefits. Assuming 5% load growth in the Lusaka area and valuing the economic benefit of electricity to the end-user at US$0.05/kWh and the cost of potential supply interruptions at US$1 million per year, the project has an estimated economic rate of return (ERR) of 30%. Assuming load growth of only 3% and ignoring the economic cost of power interruptions, the ERR is 21%, so the project is clearly justified.

Further investment could be needed in the Lusaka area after 1993 to provide for possible future load growth in the capital. Plans for this investment should be prepared simultaneously with the engineering design work for the priority 1989-93 program.

In addition to Lusaka, selective short-term replacement and reinforcement investments are also needed in the subtransmission and distribution systems serving Ndola and Kitwe, two of the principal Copperbelt towns. The total cost of these investments is estimated to be US$10.6 million, and their components are summarized in Table 4.7.

Table 4.7: COMPONENTS AND COSTS OF THE PRIORITY COPPERBELT SUB-TRANSMISSION PROJECTS

Components	Cost a/ (US$ million)
1. Replacement of obsolete HV and MV switchgear in Ndola and Kitwe	2.6
2. Replacement of obsolete HV and MV switchgear in the Copperbelt	3.8
3. Replacement of underground cable in Ndola industrial area	0.6
4. Reinforcement of existing substations in Ndola residential areas	0.1
5. Fourth bulk supply point in Kitwe industrial area, including new feeder cables	3.0
6. Improvement of telephone and radio communication	0.5
TOTAL	10.6

a/ End-1987 prices.

Source: World Bank estimates.

5/ Lusaka Power Distribution Project, Prefeasibility Report, FINNIDA, September 1987.

The investments are to replace equipment that is obsolete and past its useful life. Their economic benefits are increased supply and the cost of the avoided power interruptions that otherwise would occur. These cannot be estimated accurately, but are relatively large, due to the advanced age and extremely poor condition of the existing equipment and the resulting high probability of system failure. In these circumstances, the projects are considered to be highly economic.

4.4.5 Distribution Expansion

Three scenarios for the future number of new ZESCO connections are presented in Section 4.3.1 above. The base case assumes 4,000 new connections, the high case 7,000, and the low case 2,000 new connections per year. ZESCO has recently averaged less than 3,000 connections per year. This could, and should, be improved by: (a) the supply of additional distribution materials; (b) more aggressive marketing (e.g., discounts to new agricultural consumers); (c) supplying less costly hotplates; and (d) by reducing the cost of new connections.

The average cost per connection on the existing distribution system is estimated to be US$4,500. This high figure is due to the costly standard of underground cable and overhead lines used and the sparse distribution of consumers. Using less costly distribution standards could reduce this figure to about US$2,300 per connection. In the more densely populated urban areas, the cost per connection could be reduced to US$1,000 or less if a large proportion of the households were connected.

Estimated total costs of distribution expansion over the 1988-2006 period are shown in Table 4.8 for the base, high, and low scenarios, assuming use of either: (a) the past standard of construction and density of connections; (b) a lower-cost standard and the same density as in the past; or (c) a lower cost standard and a high density of connections.

Table 4.8: COSTS OF NEW ELECTRICITY CONNECTIONS DURING THE PERIOD 1988-2006 (US$ million) a/

Scenario	Annual Number of Connections	Present standard of connections	Reduced standard with mostly OH-lines	Reduced standard with high density of connections
Base	4000	308	199	68
High	7000	540	349	120
Low	2000	155	100	34

a/ End-1987 prices.

Source: World Bank estimates.

The estimated annual costs of the distribution expansion investment program under the base, high, and low expansion scenarios using the three alternative connection costs is shown in Table 4.9. At the historic average cost of US$4,500 per connection, even the low scenario program would cost US$9 million per annum, a large proportion of which would be in foreign exchange.

Table 4.9: ANNUAL COST OF ELECTRICITY DISTRIBUTION EXPANSION WITH ALTERNATIVE STANDARDS AND CUSTOMER DENSITIES
(US$ million)

Expansion scenario	Historic standard/ low density	Reduced standard/ low density	Reduced standard/ high density
	(US$4,500/connection)	(US$2,300/connection)	(US$1,000/connection)
Base (4000)	18.0	9.2	4.0
High (7000)	31.5	16.1	7.0
Low (2000)	9.0	4.6	2.0

Source: World Bank estimates.

If the rate of new power connections is to be accelerated; (a) the cost per connection must be reduced by adopting cheaper materials and lower standards; (b) investment must be concentrated in high density areas where consumer surveys confirm there is a substantial potential demand for electricity; and (c) consumers must be encouraged to connect by the provision of cheaper wiring and cookers and by term payment schemes.

4.5 Power System Planning and Operational Improvements

4.5.1 System Planning

Prior to 1988, all major generation and high-voltage transmission planning was done by CAPCO. Planning for the generation, transmission, and subtransmission systems is now done by the Planning Department of ZESCO's Engineering Services Division. Planning and reinforcement of the distribution network (33 kV and below) are done by the planning sections of the Distribution Supply Divisions North and South. Local networks are planned by the District Engineers.

ZESCO's planning resources are very limited. The Head of the Planning Department is also Chief Electrical Engineer, and is able to devote little time to planning. On average his staff consists of three engineers, sometimes less. Only the most urgent matters are attended to, and there is virtually no long-term planning. For example, no attempt has been made to update the Power System Master Plan, issued in 1984.

With the transfer to ZESCO of generation and voltage transmission planning responsibilities from CAPCO, strengthening of ZESCO's planning capability is an urgent requirement. The Planning Department should be capable of producing short- and medium-term demand forecasts with which to periodically update the Power System Master Plan, and identifying and appraising priority investment projects. Strengthening of the staff complement, staff training and foreign technical assistance is required, perhaps through cooperation with a major foreign power utility.

4.5.2 Commercial Operations

The ESMAP Power Subsector Efficiency Study includes a detailed review of ZESCO's commercial operations and recommendations for their improvement. This section summarizes the major findings of that report.

Metering. The existing standard of metering contributes to ZESCO's non-technical losses and could be improved. The following improvements are recommended:

(a) inspect, seal and issue new identity numbers for all meters and record their installation, movement, and maintenance history;

(b) strengthen meter workshop staffs and routinely test all meters every 10 years; and

(c) for all new connections, install meters on building exteriors.

Meter Reading. The following actions are recommended to improve the efficiency of meter reading:

(a) reduce the frequency of meter reading from one to two months for all consumers other than those in the "D" category, but continue to bill monthly, based on estimated readings;

(b) redesign the meter books to include only the account number, address and meter number, and with carbon inserts, so a copy of the reading can be sent directly to the Computer Department;

(c) prepare a meter reading, billing and collection mannual;

(d) institute a meter reader training and testing program; and

(e) set productivity standards, measure employee performance, and replace inadequate performers.

Billing. A further contributory factor to ZESCO's inadequate cash-flow is the time which elapses between meter reading and billing, which averages about six weeks. The purchase of a new computer provides an excellent opportunity for improvement. The following changes are proposed:

(a) install a new billing program, tailored to ZESCO's needs;

(b) use the meter reader's data sheet as the source for on-line computer data-entry; and

(c) hand-prepare and deliver bills to large customers.

Collections. The level of non-technical losses within the ZESCO system are believed to be substantial. A program to meter distribution feeders or transformers and compare supplies with recorded sales is recommended. This would allow the major sources of non-technical losses to be identified and remedial action taken.

There is also a problem of excessive payments arrears, which are equivalent to about five months' revenue. To reduce these arrears, it is recommended that:

(a) a surcharge be added to the bills of late payers; and

(b) non-paying consumers be disconnected after two months of non-payment.

4.5.3 Management Information System

ZESCO has no comprehensive, computerized management information system, which means that the flow of technical and financial information to management is slow and incomplete, and data from different sources are sometimes inconsistent. A new accounting system has recently been installed, a technical statistical databook will be set up over the next year, and a computerized billing system is proposed above. When these three databases are operating satisfactorily, a Management Information System that would extract key performance data for management should be established.

4.5.4 Training/Skills

ZESCO operates two training centers and is assisted by regional and international institutions in the training of its employees. It also organizes in-house seminars and courses. The most urgent manpower problem is the inability to attract and retain an adequate number of qualified persons. This is a result of the low salaries paid by ZESCO in comparison to private enterprise firms and even some other parastatal organizations. ZESCO should seek approval to raise the salaries and benefits of skilled personnel to a level at least equal to the best practice in the parastatal sector.

4.5.5 Export Marketing Strategy

As mentioned earlier, most neighboring countries have access to low-cost domestic power supplies. With few exceptions, ZESCO's export prospects are relatively limited. The optimum power export marketing strategy for Zambia therefore is to:

(a) establish a standing joint committee on power cooperation between Zimbabwe (the main potential market) and Zambia, dealing with both power trade and power generation planning. In this context, Zambia should continue to stress the importance of the benefits of long-term power sector cooperation;

(b) promote, through the Southern African Development Coordinating Conference (SADCC), the concept and analysis of the potential for mutual support in power supply, so that regional reserve margins can be minimized and low-cost power can be exchanged on an as-available basis;

(c) encourage contacts between the respective national utilities at senior and middle management to develop mutual confidence in system reliability;

(d) cooperate with other neighbours through standby connections (if achievable at reasonable cost) and small-scale cross border supplies to isolated communities; and

(e) pursue power export opportunities to economically strong, resource weak countries, such as Botswana.

4.6 Power Costs and Tariffs

To achieve the strategic objectives of reliable power supply to existing customers and extension of the supply to economically and financially viable new customers, electricity tariffs must:

(a) cover ZESCO's future revenue requirements;

(b) reflect the marginal economic costs of power to different consumer groups; and

(c) encourage additional economic uses of power, e.g., through off-peak supplies for irrigation, etc.

4.6.1 Existing tariffs and tariff proposals

March 1988 electricity tariffs for selected major consumer categories are summarized in Table 4.10 and the full tariff schedule is set out in Appendix 4.2. By world standards, current tariffs are extremely low, averaging about 5 ngwee/kWh (US$0.006/kWh).

Table 4.10: ELECTRICITY TARIFFS FOR SELECTED CONSUMER GROUPS
(March 1988)

Customer Category	Fixed Charge		Max. Demand Charge		Unit Charge	
	k/month	US$/month	k/kVA/month	US$/kVA/month	ngwee/kWh	US¢/kWh
Bulk (ZCCM)	-	-	402.64	50.33	0.99	0.12
Large Industrial (D3) a/	17,225.0	2,153.13	11.80	3.51	3.51	0.44
Small Industrial (E4) b/	71.5	8.94	-	-	10.14	1.27
Household (E3) b/	15.0	1.88	-	-	7.00	0.88

a/ Maximum demand 300-2,000 kVA.
b/ Unrestricted single phase and up to 15 kVA three phase.

Source: ZESCO.

ZESCO has requested an average 28% tariff increase, to be effective October 1988. However, with inflation averaging about 50% per year, this will be insufficient to prevent a decline in real tariffs during 1988.

4.6.2 Current financial costs of supply on the main hydro network

The average financial cost of power supply in 1987-88 is estimated to be about 8.3 ngwee/kWh, some 50% above forecast average revenue per kWh sold (Appendix 4.3, Table 2, column 1). Consequently, it is anticipated that the utility will make a substantial loss in 1987-88 and a further loss in 1988-89, even if the current tariff request is granted.

4.6.3 Current financial cost of supply of isolated diesel networks

The average financial cost of supply for isolated diesel systems are estimated in Appendix 4.4 and summarized in Table 4.11 below:

Table 4.11: AVERAGE REVENUE AND COSTS OF ISOLATED DIESEL SYSTEMS

Parameter	Kwacha/kWh
Average revenue	0.33
Financial cost	1.26

Source: World Bank estimates.

In order to cover financial costs, tariffs for power supply by diesel need to be increased by nearly 300%. Increases of this magnitude are not recommended, but efforts should be made to reduce the subsidy to isolated diesel electricity consumers.

4.6.4 Tariffs required for future financial viability

Assuming a constant exchange rate and that ZESCO borrows through the Government US$50 million during the period 1989-93 to fund its priority five-year rehabilitation/reinforcement investment program at 8% with 5 years grace and 20 years amortization, and then finances the distribution expansion program from its own resources, it is estimated that, in constant price terms, electricity tariffs would need to average about 11 ngwee/kWh in the Low and Base demand scenarios, and nearly 12 ngwee/kWh in the High scenario to ensure financial viability over the 1989-2006 period. March 1988 tariffs, if maintained in real terms, would generate less than 50% of the revenue required to finance the investment program. The required tariff increase would be less if ZESCO could increase its efficiency, borrow on more concessional terms to finance the 1989-93 investment program, or obtain concessional funds for the 1994-2006 component of its projected investment program.

4.6.5 Tariffs and long-run economic costs

Tariffs should reflect the economic cost of power supply so as to give the correct price signals to new consumers and encourage an economically efficient pattern of future power investment and consumption. Economic cost is best approximated by the long-run marginal cost (LRMC) of supply, which is the cost of an incremental expansion of the power system.

Based on the recommended power system investment program for 1989-2006, and assuming a cost of US$1,000 per new connection at the distribution level, the LRMC of electricity is estimated to be 5.6 ngwee/kWh (US$0.007/kWh) at the 66 kV level; 32 ngwee/kWh (US$0.04/kWh) at the 11 kV level; and Kwacha 1.28/kWh (US$0.16/kWh) at the 400 V level. A comparison of these three estimated LRMCs with current average revenue per kWh for the corresponding large industrial (D3), small industrial/commercial (E4) and household (E3) customer groups (Table 4.11) shows that:

(a) for the large industrial customer, current average revenue (n 6/kWh) is slightly higher than LRMC at the 66 kV level (n 5.6/kWh);

(b) for the small industrial/commercial customer, average revenue (n 17/kWh) is just over 50% of LRMC (n 32/kWh); and

(c) for the household customer, average revenue (n 10/kWh) is less than 10% of LRMC (K1.28/kWh).

Table 4.12: ESTIMATED LONG-RUN ECONOMIC COSTS OF POWER AND CURRENT AVERAGE REVENUES (kWh)

Customer Group	Equivalent voltage level	LRMC Kwacha	LRMC US$	Current Average Revenue Kwacha	Current Average Revenue US$
Large Industrial (D3)	66 kV	0.056	0.007	0.06	0.008
Small Industrial (E4)	11 kV	0.32	0.04	0.17	0.02
Household (E3)	400v	1.28	0.16	0.10	0.01

Source: World Bank estimates.

It is not recommended that tariffs be adjusted to match long-run marginal costs exactly. However, over time, their structure should be brought more closely into alignment with economic costs. This implies that future tariff increases should be proportionately larger at the 33 kV level and below, and proportionately smaller for high voltage consumers. A lifeline tariff should be considered for household consumers of small quantities of power and energy to protect them from the impact of low voltage tariff increases.

4.6.8 Export Tariffs

The present tariff for sales to Zimbabwe is set in Kwacha at a fixed US dollar exchange rate and with agreed annual increases. The price per unit is modest (US$0.01-0.02/kWh, depending on the load factor). Nevertheless, because of their volume, these exports have made an important contribution to ZESCO's overhead. Although the tariffs are above the economic cost of supply, they are below the marginal cost of alternative generation from coal fired plants in Zimbabwe. This might provide the opportunity for some future escalation.

There is an agreed tariff for imports from or exports to Zaire, but Zaire has not paid for imports of power since July 1986. This arrangement is highly uneconomic to Zambia, as Zaire often imports energy during the Zambian peak, which has occasionally led to load-shedding in the Copperbelt. ZESCO has thereby lost revenues from domestic customers, and economic costs have been imposed on Zambia due to lack of power. It would be appropriate for ZESCO to insist on payment or limit the supply to Zaire to a level that can be accommodated without load-shedding.

4.6.9 Off-Peak Tariff

With surplus, low-cost energy, an off-peak tariff could be justified for substantial new uses of electric power if these require no investment by ZESCO in additional distribution capacity. One potential use for such a tariff would be irrigation, which could use power exclusively outside the peak period. Such a tariff would support the Government's drive to increase agricultural output. Another possibility is to encourage the substitution of electricity for higher-cost alternative fuels for off-peak industrial use. ZESCO should seek to identify such opportunities and negotiate special contracts that would result in additional revenue at low financial and economic cost.

4.6.10 Timeliness of Tariff Adjustment

A contributory factor to ZESCO's currently inadequate revenues is the length of time it takes to agree a change in tariffs. In theory, the procedure takes five months. In practice, it often takes over a year. To overcome this problem, it is recommended that tariffs be reviewed automatically at least once each year, on a firm time schedule, and the new tariff announced and implemented by a fixed tariff review date, perhaps April 1.

V. PETROLEUM

5.1 Policy Issues and Options

When world oil prices peaked after 1979, petroleum imports accounted for nearly 20% of Zambia's total foreign exchange earnings. In 1988, oil prices are well below their earlier peak, but petroleum imports still account for over 10% of export revenues. Shortages of foreign exchange are the fundamental constraint to Zambia's economic development. Therefore, minimizing the cost of petroleum imports must be a major objective of the energy strategy. When world oil prices start to rise, as they surely will, and copper exports to decline, the need could become still more pressing.

Against this background, the following petroleum sub-sector issues are examined:

(a) the optimal future petroleum exploration strategy, and the actions required to implement it;

(b) petroleum pricing and taxation policy;

(c) the condition of the Tazama oil pipeline and associated infrastructure, and the steps needed to ensure reliable pipeline operation in the future;

(d) the efficiency of the Indeni refinery;

(e) the oil market conditions under which refinery upgrading should be considered; and

(f) whether continued import of commingled products and their re-refining, or import of finished products would be cheaper.

In Chapter 9, the scope for conservation and substitution of petroleum products is assessed.

5.2 Oil and Gas Exploration

5.2.1 Potential

Although Zambia has no known petroleum deposits, there are four sedimentary basins in the country, the largest of which is the Western Zambia Basin, which covers about 180,000 km^2 of Western Zambia and extends into neighbouring Botswana and Angola. The deepest basin is probably the Luangwa Basin, which lies in the Luangwa Valley, and is perceived to be the most promising basin for oil and gas.

5.2.2 Exploration Promotion Program

Prior to 1982, there had been no seismic surveys or exploratory drilling in Zambia. A World Bank Petroleum Exploration Promotion Project subsequently funded an aeromagnetic survey over much of the country and a limited gravity survey. A comprehensive geological report and model contract were presented to the etroleum industry in June 1935.

Two companies agreed to undertake preliminary surveys and exploration drilling. Placid Oil Co. took up two of the four blocks on offer (one in the Luangwa Valley and one to the west of Lusaka close to the Kafue National Park) and Mobil Oil Co. took up one block to the south of Placid's Luangwa block. The fourth block in Western Zambia was of insufficient interest to attract a bidder.

Placid's agreement, signed in February 1986, was for a four-year exploration period. This started with gravity and seismic surveys in both its blocks. Completion of these surveys during 1986 led to cessation of work on the Kafue Block and a decision to drill in the Luangwa Block, starting in September 1987. In the subsequent six months, two dry holes were drilled.

Mobil signed an agreement about one year after Placid, in January 1987. It has conducted gravity and seismic surveys, interpretation of which was completed in March 1988. It is understood that Mobil did not find promising structures in its Luangwa block and will cease operations in that block.

Placid and Mobil have each expressed an interest in a new area, lying to the north of Lake Kariba, an area which was not included in the initial offering. Placid is also understood to be seeking a partner for continued exploration work in its Luangwa block, and has applied for other exploration acreage north-west of this block.

The Government's Hydrocarbon Unit is planning a seismic survey in the western part of the country, to be financed by the Government at a cost of K8 million.

5.2.3 Environmental Aspects

The Luangwa Valley contains two of Zambia's most important national parks and is an area of international wildlife repute. The Placid exploration activity has been outside the national park, but Mobil's was substantially within it. The model concession agreement accepted by both companies gives the Government the right to suspend operations if necessary to prevent environmental or wildlife damage, and to order restitution. At the exploration stage, the physical damage is primarily the construction of access roads, which will grow back within a year or so. Nevertheless, careful and continual monitoring is required.

5.2.4 Future Exploration Promotion Strategy

The reasons for encouraging international oil companies to explore in Zambia are as strong as ever. Even a limited chance of success is worth pursuing, provided the bulk of risk capital comes from international sources. Although the two tests drilled by Placid are somewhat discouraging, the fact that Mobil and Placid are looking to stay in the country suggests that the area has not been condemned. The Government should therefore consider enhancing its efforts to encourage direct foreign investment in oil exploration.

The objectives of the next phase of the exploration promotion strategy should be to:

(a) sustain the interest of Placid and Mobil in undertaking further exploration, in existing agreement areas and in new ones, at minimum cost to Zambia;

(b) improve the Government's understanding of the country's hydrocarbon potential by analyzing the results of the surveys and drilling carried out by the two companies, which should be made available promptly to the Hydrocarbon Unit;

(c) reinterpret old data on other areas not taken by companies to better assess their potential; and

(d) improve information on the unallocated block in the western part of the country, and follow up with other surveys, where these appear likely to yield useful results.

As a prerequisite for all the above, and to ensure that Zambia gains the full benefit of the oil companies' exploration activities, it is essential to strengthen the Hydrocarbon Unit so that it is able to: (a) monitor the work of the oil companies effectively; (b) undertake further essential data acquisition, and interpretation; and (c) encourage further exploration activity. This requires training of its personnel, provision of operational support, and development of an adequate geological information base.

5.2.5 Recommendations

To ensure the continuation of the exploration effort, follow-up Petroleum Exploration Promotion technical assistance is recommended. This could consist of some or all of the following elements: (a) efforts to upgrade the Block in Western Zambia by seismic surveys; (b) integration of data on the Block in which Placid has not drilled; (c) interpretation of existing airmag data on areas not originally offered; (d) collection of new airmag data on the Chambeshi area and the area north of Lake Kariba; and (e) strengthening of the Hydrocarbon Unit by the addition of an expatriate petroleum specialist and staff training. The total cost is provisionally estimated at up to US$6.6 million, spread over a number of years. The various steps should be planned in line with the availability of grant aid and budgetary resources. Private investors should be encouraged to undertake all or part of the geophysical work.

It is recommended that the Hydrocarbon Unit be linked to and physically relocated near the Geological Survey. This will enable it to share facilities, equipment, and personnel. Subject to obtaining sufficient data, and to strengthening the Unit, a selective, targetted exploration promotion effort is recommended, directed at companies potentially interested in medium-scale deposits appropriate to the regional market. The terms of any future concession agreements will need adjustment to reflect this.

5.3 Petroleum Consumption and Supply

5.3.1 Recent Consumption Trends

Compared with peak sales of 818,565 tons in 1976-77, the current sales of most petroleum products show very sharp declines. In total, sales in 1986-87 were down by one-third, to 546,873 tons, against 10 years' earlier. The only exceptions to the decline were illuminating kerosene and bitumen (Table 5.1).

In recent years, the rate of decline in sales has slowed and, in the case of gas/diesel oil, consumption has actually shown a slight increase. The pattern of consumption as between products has changed markedly. The important features of these changes are a decrease in the share of gasoline and an increase in the share of diesel. The latter has been coupled with an increase in the shares of both illuminating kerosene and jet fuel (the latter, however, having decreased in absolute tonnage), resulting in a sharp jump in the share of middle distillates as a whole from 53.7% in 1976-77 to 61.4% in 1986-87.

The long-term trend statistics shown in Table 5.1 are inclusive of exports by the private oil companies, which are not available separately for most of the years covered. Separate data for domestic and export demand are, however, available for calendar years 1986 and 1987, and are given in Tables 5.2 and 5.3. The striking feature of these data is the sharp increases recorded in 1987 in the domestic consumption of each major product except regular gasoline and light fuel oil. Exports were also much higher, following rather low figure in 1986.

A number of difficulties were experienced in obtaining consistent data on all aspects of petroleum supply and demand and the sectoral breakdown of consumption. Consequently, it is recommended that a greater effort be put into data collection, and that the various operating companies in the sector understand their duty to collaborate promptly in this effort.

Table 5.1: DOMESTIC MARKET SALES OF PETROLEUM FUELS a/
(Tons)

Product	1976/77	1977/78	1978/79	1979/80	1980/81	1981/82	1982/83	1983/84	1984/85	1985/86	1986/87	% Change 1976/77 to 1986/87	% Shares 1976/77	% Shares 1986/87
Gasoline														
Premium	145,333	92,029	75,046	62,382	73,562	78,331	80,813	86,544	80,620	77,465	77,297	(47)	17.8	14.1
Regular	40,931	68,223	72,639	45,084	44,097	39,377	30,231	24,545	23,546	24,426	20,651	(49.5)	5.0	3.8
Total gas	186,264	160,252	147,685	107,466	117,659	117,708	111,044	111,089	104,166	101,891	97,948	(47.5)	22.8	17.9
Gas Oil														
Diesel (incl. LSGO b/	362,652	317,052	303,128	241,640	273,229	275,405	271,154	261,015	247,035	220,714	266,379	(26.5)	44.3	48.7
I-Kerosine	24,687	24,111	26,929	27,545	29,608	34,347	32,515	35,098	29,073	25,968	26,901	9	3.0	4.9
Jet A-1	52,527	58,686	54,745	64,670	64,634	59,207	53,199	54,391	45,769	39,941	42,363	(19.4)	6.4	7.8
Fuel Oil														
HFO	174,238	181,616	162,086	164,992	172,298	134,052	106,391	111,570	97,013	80,995	72,473	(58.4)	21.3	13.3
LFO	857	3,732	5,567	9,669	11,909	11,093	7,794	12,787	22,812	17,827	20,622	c/	0.1	3.8
Total FO	175,095	185,348	167,653	174,661	184,207	145,145	114,185	124,307	119,825	98,882	93,095	(46.8)	21.4	17.1
Bitumen	9,200	7,695	5,561	7,888	8,588	14,065	13,419	14,175	15,307	15,902	14,362	56	1.1	2.6
LPG	8,140	9,553	5,979	2,069	2,363	2,802	6,967	2,169	6,535	6,544	5,037	(38.1)	1.0	0.9
Others	-	-	-	300	399	552	396	394	218	603	788	-	-	0.1
Total	818,565	762,697	711,680	626,239	680,687	649,32	602,879	602,638	567,928	510,385	546,873	(33.2)	100.0	100.0

a/ Includes exports by the oil companies, but not exports by ZIMOIL (formerly ZNEL).
b/ Low sulphur gas oil.
c/ Large increase.

Source: ZIMCO.

Table 5.2: PETROLEUM PRODUCT CONSUMPTION AND EXPORTS, 1986
('000 tons)

	Domestic Sales	Exports	Total
Premium gasoline	73.8	-	73.8
Regular gasoline	17.6	7.1	24.7
Kerosene	26.0	-	26.0
Jet fuel	41.1	-	41.1
Gas oil a/	242.6	1.7	244.3
Light fuel oil	19.8	0.1	19.9
Heavy fuel oil	68.8	0.1	68.9
LPG	4.5	4.5	
Bitumen	14.8	0.2	15.0
Naphtha	0.3	-	0.3
Other	0.4	0.2	0.6
TOTAL	505.2	13.9	519.1

a/ Including low-sulphur gas oil.

Source: ZIMCO.

Table 5.3: PETROLEUM PRODUCT CONSUMPTION AND EXPORTS, 1987
('000 tons)

	Domestic Sales	Exports	Total
Premium Gasoline	83.6	5.2	88.8
Regular Gasoline	9.8	26.4	36.1
Kerosene	31.3	-	31.3
Jet Fuel	50.2	-	50.2
Gas Oil a/	257.5	19.9	277.4
Light Fuel Oil	15.4	0.3	15.7
Heavy Fuel Oil	74.9	-	74.9
LPG	0.2	6.3	6.5
Bitumen	14.1	2.5	16.6
Other	0.7	0.4	1.1
TOTAL	537.6	61.0	598.6

a/ Including Low-sulphur gas oil.

Source: ZIMCO.

5.3.2 Supply Arrangements and Sources

Under the terms of a contract between the Government and the Kuwait Petroleum Co. (KCP), signed in April 1987, petroleum supplies in 1987-88 were purchased wholly as a mix of products. The mix comprised specified proportions of each major product to match anticipated demand. The contract included provisions for extension on the basis of mutual agreement, and negotiations for such extension were completed on similar, but revised terms, in March 1988.

The commingled products are imported through a Single Point Mooring (SPM) terminal at Dar-es-Salaam, delivered to a tank farm, and transferred to the Tazama pipeline for transport 1,700 km across Tanzania to the Indeni refinery near Ndola in Zambia. At Indeni, the petroleum product mixture is re-processed to yield approximately the products demanded by the markets.

Terms of the supply contract and the financing terms are good. FOB prices are based on Platts at Arabian Gulf, and the contract incorporates a freight charge based on the published World Scale rate. There seems to be little purpose in disturbing these arrangements, for example to explore wider cooperation with neighboring countries in bulk purchase of petroleum.

5.4 Petroleum Pricing

5.4.1 Financial Analysis

While wholesale petroleum product prices in 1987 were not subsidized overall, gasoline was priced about 75% above financial cost and kerosene about 7% below financial cost, measured as import parity plus pipeline and refinery cost. (Table 5.4)

Table 5.4: PETROLEUM PRODUCT FINANCIAL COSTS AND PRICES, 1987

Cost/Price	Kerosene	Gas Oil	Gasoline	Fuel oil
	US$/ton			
CIF Dar-es-Salaam	169.6	144.8	158.7 a/	85.6 b/
Pipeline, off-loading, etc.	27.0	27.0	27.0	27.0
Cost of refinery input	196.6	171.8	185.7	112.6
Cost of refinery output c/	205.9	179.9	196.5	119.2
	Kwacha/m^3			
Financial cost (K/m^3) d/	1,283	1,197	1,200	927
Wholesale price ex-storage (K/m^3)	1,190	1,350	2,120	950
Wholesale price/financial cost	0.93	1.13	1.77	1.02

a/ Premium gasoline estimated by adjusting the CIF cost of naphtha for value of by-products.

b/ CIF cost of fuel oil, adjusted for bitumen and gas oil yields.

c/ Assuming refinery fuel use and loss of 5.5%.

d/ Using exchange rate of K8.2/US$1.

Source: ZIMCO and World Bank estimates.

5.4.2 Economic Analysis

Estimates of the end-1987 economic costs of supply of each major product are shown in Table 5.5 and 5.6. These are based on the conversion of CIF costs from US dollars to Kwacha using a shadow exchange rate of K12/US$1. They also differ from the costs shown in Table 5.4 by the exclusion of financing charges. These estimates show that, for each major product except gasoline, the end 1987 wholesale price was substantially below the estimated economic supply cost. While these differences persist, it will be important to use the economic cost in all policy analysis and decisions relating to the substitution or conservation of gas oil, kerosene, and fuel oil.

Table 5.5: KEROSENE AND GAS OIL ECONOMIC COSTS AND WHOLESALE PRICES, 1987 (Price/ton)

Item	Kerosene	Gas Oil
CIF cost	US$169.6	US$144.8
At K12/US$	K2,035	K1,738
Cost of pipeline transport, refinery, etc. a/	US$24.0 = K197	K197
Total costs per ton input to refinery	K2,232	K1,935
Total costs per ton output	K2,337	K2,026
Economic costs per m^3	K1,996	K1,721
Wholesale price m^3	K1,279	K1,365

a/ Excluding finance charges.

Source: ZIMCO and World Bank estimates.

Table 5.6: PREMIUM GASOLINE AND FUEL OIL ECONOMIC COSTS AND WHOLESALE PRICES, 1987 (Kwacha)

Item	Gasoline	Fuel Oil
Economic cost per ton	K2,267	K1,339 a/
Economic cost per m^3	K1,688	K1,270
Wholesale price m^3	K2,120	K950

a/ After adjustment of CIF cost for value of bitumen at 1987 requirement and gas oil yielded in processing.

Source: ZIMCO and World Bank estimates.

5.4.3. Taxation Policy

The pricing of kerosene below gas oil, the reverse of their international cost relationship, has been reinforced by fiscal policy, which, in 1987, taxed kerosene at K0.192/liter and gas oil at K0.378/liter. The effects of this on wholesale prices inclusive of duty are illustrated in Table 5.7.

Table 5.7: PRICES AND DUTIES ON KEROSENE AND GAS OIL (K/m3)

Price Component	October 1985	August 1987
Kerosene		
Wholesale price	1,206	1,279
Tax	100	192
Total	1,306	1,471
Gas Oil		
Wholesale price	1,272	1,365
Tax	320	378
Total	1,592	1,743

Source: ZIMCO.

5.4.4 Pricing Recommendations

As a consequence of subsidizing kerosene in the past, it has been used in lieu of gas oil as an industrial fuel. Its consumption has therefore been much more buoyant than that of most other petroleum products. In 1987, the consumption of kerosene increased by more than 20%. To combat this, ZIMCO decided in 1988 to dye kerosene for industrial use and to raise its wholesale price to K1,481/m^3. This resulted in a pre-tax price of about 86% of the economic cost, as estimated in Table 5.5.

Consideration should be given to further increasing the price of industrial kerosene. This would make it easier to raise diesel prices by reducing the incentive for kerosene substitution. There are twin arguments in favor of such a move. In industry, a higher price for diesel would strengthen the incentive for its substitution by indigenous electricity or coal. In its use as automotive fuel, a higher price for diesel would reduce the present large and distorting differential between diesel and gasoline prices. This would be an administratively easy and effective means to promote fuel conservation in road transport.

The relationship between gasoline and diesel prices and taxes and the adequacy of those taxes in terms of covering road user costs are discussed in Chapter 9. In the light of this discussion, and of the economic cost estimates given above, it is recommended that diesel prices be increased significantly to bring them closer to those of gasoline, whilst maintaining a differential between the price of diesel and industrial kerosene reflective of the latter's higher economic cost.

Higher prices for diesel oil would have a fairly small impact on industrial costs. Few industries other than cement, bricks, glass and steel, are energy intensive, and even a large price increase for petroleum products will have small impact on total costs and subsequent inflation. Similarly, the inflationary impact of price increases for autodiesel is often over-emphasized and used as an excuse to continue subsidization. Transport fuel is a modest component of the total cost of consumer items in Zambia, and is a sensitive but not dominant item in the cost of passenger transport operations.

5.4.5 Retail Prices and Petroleum Marketing Company Margins

Retail petroleum prices have been adjusted 11 times over the last 8 years, reflecting both changes in the international oil market and the exchange rate of the Kwacha. ZIMCO regularly monitors international price movements so that Government approval can be sought for adjustments in good time. The lengthy time-span from loading supplies in Kuwait to sales from Indeni allows ample time for this process. Consequently, the major factor affecting the financial position of ZIMOIL and the other petroleum marketing companies is being handled very satisfactorily.

The marketing companies are allowed a wholesale margin of 6% for motor fuels and lower rates for other products. Retailers are allowed a margin of about 6%. These rates are generous, and the various oil distributors are quite profitable. There is an additional transport charge, set according to distance, resulting in different Government-prescribed prices in each of 61 towns.

Because retail petroleum prices are set by Government, there is little real competition among the distribution companies. This lack of competition inevitably leads to costs higher than would be experienced if the companies competed on price as well as location and service. Moreover, for the volume of products sold, there are a large number of outlets, resulting in high overheads per gallon sold. A move to ceiling prices, rather than fixed prices, is recommended to promote price competition. The Government could also allow ZIMCO to compete with existing distributors for bulk supplies to large enterprises.

5.5 Demand Forecasts

5.5.1. Domestic

The forecast evolution of petroleum product consumption on the base, low and high scenarios is shown in Table 5.8.

Table 5.8: FORECAST CONSUMPTION OF PETROLEUM PRODUCTS UNDER ALTERNATIVE GDP GROWTH SCENARIOS ('000 tons)

	1989	1996	% Incr. (decrease) 1989-96	2006	% Incr. (decrease) 1996-2006
Base Case					
Gasoline	104.3	88.8	(14.9)	95.5	7.6
Jet fuel	50.2	43.6	(13.2)	53.3	22.2
Kerosene	21.0	33.7	60.4	40.6	20.5
Gas oil/Diesel	262.5	265.0	1.0	286.3	8.0
Fuel oil	108.2	66.5	(38.5)	45.3	(31.9)
Other	16.3	18.6	14.1	23.0	23.7
TOTAL	562.5	516.2	(8.2)	544.0	5.4
Low Case					
Gasoline	104.3	79.2	(24.1)	72.0	(9.1)
Jet fuel	50.2	37.4	(25.5)	37.4	-
Kerosene	21.0	33.5	59.5	40.8	21.8
Gas oil/Diesel	262.5	233.2	(11.1)	205.4	(12.0)
Fuel oil	108.2	63.3	(41.5)	39.2	(38.1)
Other	16.3	16.0	(1.8)	16.0	-
TOTAL	562.5	462.6	(17.8)	410.8	(11.2)
High Case					
Gasoline	104.3	97.4	(6.6)	119.1	22.3
Jet fuel	50.2	49.2	(2.0)	69.2	40.6
Kerosene	21.0	33.5	59.5	40.6	21.2
Gas oil/Diesel	262.5	287.7	9.6	349.5	21.5
Fuel oil	108.2	69.7	(35.6)	51.4	(26.3)
Other	16.3	21.3	30.7	29.7	39.4
TOTAL	562.5	558.8	(0.7)	659.5	18.0

Source: World Bank estimates.

The key features of the forecasts may be summarised as follows:

(a) the recent growth of gas oil/diesel consumption is forecast to slow sharply, and, in the low scenario, a decline is foreseen;

(b) kerosene consumption is forecast to rise in proportion to the expected increase of the number of households. But, as a consequence of higher prices for industrial kerosene, the sharp increases in recent years are not expected to continue;

(c) fuel oil consumption is expected to fall sharply, mainly due to the forecast decline in demand from the copper industry during the mid-1990s, assuming the Nkana smelter converts to coal; and

(d) gasoline consumption is forecast to decline initially and then to increase moderately by 2006 as the effects of higher diesel prices are felt.

In Chapter 9, the scope for substituting electricity for fuel oil and other petroleum products in copper mining and in industry is discussed. The above forecasts incorporate the effects of the planned substitution of coal for fuel oil at ZCCM's Nkana smelter. Other substitution possibilities are more speculative, and their possibile demand effects are not considered.

5.5.2 Exports

With an underutilized bulk supply pipeline and refinery, Zambia appears prima facie to be a logical source of petroleum product supply to its similarly land-locked neighbors. The Tazama pipeline--albeit needing substantial rehabilitation investments--and the Indeni refinery are sunk costs, offering a comparatively cheap mode of bulk supply, not only to Zambia, but potentially to those areas of Zaire, Zimbabwe, Malawi, Botswana, and Tanzania which are accessible.

In the past, as much as 80,000 tpa of products have been exported to the neighboring region. In 1987, which was a "good" year for exports, they totalled 61,000 tons. The exports have been primarily of regular gasoline, gas oil, and LPG. However, there are obstacles to a continuing high-level of exports. Competition in many cases, e.g., Malawi and Botswana, comes from keenly priced deals made by South Africa. Malawi is also constructing facilities for supply from Dar-es-Salaam. Lack of foreign exchange to pay for imports can be a problem. This applies, for example, to Zaire. And on the supply side, there is the ever-present possibility of Zambia's inability to supply, due to a lack of sufficient road and rail wagons or a temporary shortage of foreign exchange. This not only leads to interruption of agreed exports, but also to hesitancy on the part of importers to rely on future supplies from Zambia.

Looking to the future, average exports of 50,000 tons per annum are forecast. The strategic objective should be to maximise profitable exports on a year-to-year basis, after giving priority to domestic requirements. Pricing policy for exports will need review, to ensure that prices both cover costs and are competitive with alternative sources of supply.

5.6 The Tazama Pipeline

Rehabilitation of the 20 year-old Tazama oil pipeline is probably the highest priority energy investment for Zambia. Sections of the pipeline are badly corroded by incursion of sea water and external chemical action. Detailed engineering analysis has shown that the resulting leakage is extensive and worsening. This threatens both severe ecological damage along the pipeline route and a major interruption of petroleum product supplies to Zambia.

The initial investment required for the core program to rehabilitate the line is estimated to be US$41.2 million, covering repairs to the pipeline, corrosion protection, mechanical, pump plant, electrical, instrumentation, telecommunications, civil works, tank farm, and engineering services. Some five years later, a further program of expenditure will be necessary, amounting to around US$15-20 million, and five years later, about another US$15-20 million.

Detailed engineering for repair of the pipeline between km 79 and km 155 has been done, and the construction work is scheduled to be completed in December, financed by a US$12 million loan from Italy. Reflecting the urgency of measures to tackle the critical corrosion problems in the other worst-affected pipeline sections, Zambia has approached the Italian Government for an extra US$10 million loan so that the whole task of emergency repair work can be undertaken as one job. A further US$19.2 million is still required to complete the first phase of the overall repair program.

The need for extensive rehabilitation results from many years of inadequate maintenance, little attention to obvious corrosion problems, theft of corrosion protection systems, and lax control of offshore operations, resulting in prolonged and extensive seawater incursions. Tazama's previous management did not focus its limited resources on these priority issues.

In recent months, ZIMCO and Tazama's management have taken steps to rectify the situation. Tazama's management has been reorganized and more experienced technical personnel appointed to key positions. ZIMCO has been taking a more active interest in the company and providing the type of support needed to make it a viable entity. The pipeline tariff is now fixed to cover the cost of rehabilitation investment and to provide for adequate maintenance. Continued support from ZIMCO and the retention of some expatriate assistance will be required to ensure satisfactory performance in the future.

5.7 Indeni Refinery

Opened in 1973, the Indeni hydroskimming refinery has a capacity of 1.1 tons per annum. The two principal issues relating to the refinery's current operational performance are:

(a) The necessity of major maintenance at a refinery that is now 15 years old. Immediate outlays of some US$3 million are estimated to be required for investments in instrumentation, replacement of furnace coils, heat exchanger parts, and other work. In subsequent years, further expenditures will be necessary which cannot be forecast with any certainty. It is anticipated that at least some US$3 million of the initial requirement may be obtained from Italy.

(b) The possibility of efficiency improvements, which would reduce the rate of refinery fuel use and loss. Now at around 7%, this is not particularly high for a refinery of its type, size, and age. It is important to bear in mind that this percentage is calculated on a weight basis, and is therefore higher than when calculated on a volume basis. However, there is scope for improvement, and Indeni management have identified steps to reduce fuel use and loss to about 5.5%. These consist of replacement of the hot oil heater; installation of ejectors for the Bitumen Vacuum Unit, reformer feed, vacuum feed and hydrotreater feed pre-heaters; modification of the crude pre-heat system; installation of a pre-flash tower; and installation of an API separator. Their total cost is about US$3 million.

As a separate matter it is also proposed, but not yet decided by the Cabinet, to invest US$3 million in strategic storage at Indeni, to provide sufficient feedstock to cover operations should there be a breakdown of supplies. This is a relatively small investment for the security it brings.

In general, the refinery is well run, despite the fact this it is operated on a cost-plus basis. Overall operating costs, excluding fuel use, average US$2.50 per barrel, reflecting rather high manning levels. Payment is on a processing fee basis at cost plus a 30% dividend to the shareholders, the company being owned 50/50 by AGIP and ZIMCO. It would be appropriate to investigate whether the fee structure can be revised to give an incentive for efficiency, and to target ways to gradually reduce manpower levels.

5.8 Storage, Transport and Terminal Facilities

Petroleum storage facilities are operated at Dar-es-Salaam and Indeni. At Dar-es-Salaam, there are six tanks owned by Tazama Pipelines to receive imports of commingled products brought ashore by pipeline from the single-point mooring (SPM), through which tankers of around 100,000 deadweight tons (DWT) are off-loaded. These tanks comprise three of 37,000 m^3 and three of 40,000 m^3. One of each size category is currently not operational, pending repair. Rehabilitation of the tank farm is included in the estimates cited above for expenditures needed to rehabilitate the Tazama Pipeline system. The same needs for strengthening management and operational skills apply at the tank farm as to the pipeline.

At Indeni, there are two tank farms, one providing operational storage for the refinery, and one storage from which the oil companies draw their supplies. In total, this storage comprises 60,000 m^3 feedstock, 106,800 m^3 white products, 36,440 m^3 fuel oil and bitumen, 12,200 m^3 intermediate products, and 1,800 m^3 LPG. The tanks are in generally good condition.

Transport of finished products from the Indeni terminal is mainly by road wagons over short distances to the principal petroleum consuming areas in the Copperbelt. To Lusaka, transport is by both road and rail. Road tankers are in short supply, and additional numbers are needed. These are included in the priority investment program in the sum of US$2 million. To the extent that rail terminal facilities can be improved, coupled with greater efficiency and new investment in the railway, increased use of the railway for long-distance movement of petroleum products would bring significant savings both in costs and in energy use per ton transported. Expenditure on distribution storage and rail-handling facilities is recommended only for the Zambian market, and not for export, because foreign markets are too uncertain. The proposed terminal at Livingstone needs to be reconsidered from this viewpoint, as sales potential to Zimbabwe and Botswana appears to be limited. A study of that potential should be completed and the market potential clearly established before any investment is made.

5.9 The Economics of Refinery Closure

5.9.1 The Issue

There has been much debate as to the relative costs of the existing petroleum import and processing arrangements vis-à-vis the alternative of closing the Indeni refinery and converting the Tazama pipeline to transport batched white products in lieu of commingled products. This option is re-examined here to take fully into account current and forecast demand patterns for petroleum products and updated capital costs. Details of the analysis are set out in Appendix 5.1.

The principal cost components of the two options are:

Refinery Case (existing system)

(a) rehabilitation of the Tazama pipeline, as presently configured, to transport commingled products;

(b) refinery operating and maintenance costs.

White Products Case

(a) rehabilitation of the Tazama 8-inch line to eliminate use of the 12-inch loops, to avoid excessive batch contamination;

(b) additional ocean freight costs from using 30,000 DWT products carriers rather than 100,000 DWT commingled products carriers;

(c) import by rail of fuel oil, bitumen, and jet fuels, which can not be moved through a white products line; and

(d) purchase of gasoline rather than naphtha (which presently can be upgraded to gasoline by the refinery).

Estimates of the above costs were used to prepare a spreadsheet analysis of the total costs, over the period 1987-2006, for the supply of products to meet the base case petroleum product demand forecast. This forecast assumed maximum technical substitution of fuel oil by ZCCM. These costs were discounted to Net Present Value at a discount rate of 12%.

5.9.2 Results of the Analysis

This detailed analysis shows that it is less costly to continue with the present transport/refining system than to close the refinery and convert the pipeline to a white products line. The estimated NPV of the costs of supply from closing the refinery and converting the Tazama line to white products is US$221.6 million, which is US$52 million higher than the NPV of the costs of rehabilitating the existing pipeline and continuing to import and refine commingled products on terms such as those currently in force. (Table 5.9).

Moreover, the current import arrangement requires substantially less investment than refinery closure and pipeline conversion, because the latter would necessitate rehabilitation of the 8-inch pipeline sections that are currently looped. Therefore, it is more consistent with a constrained energy investment program, which is all that can be financed in Zambia's current economic situation.

Table 5.9: NET PRESENT VALUE OF THE COSTS OF ALTERNATIVE PETROLEUM SUPPLY ARRANGEMENTS (US$ million)

	Existing Commingled Products Refinery Case	Alternative White Products Pipeline Case
Ocean freight cost (net)	-	31.66
Interest on working capital	15.44	4.84
Pipeline capital cost	42.75	64.90
Pipeline operating cost	32.46	50.84
Rail cost	-	69.38
Refining cost	78.61	-
Total cost	169.26	221.62

Source: World Bank estimates.

While continued refinery operation is economic at present, refinery closure and conversion of the pipeline to a white products pipeline should be reconsidered if and when a major refinery rehabilitation investment is contemplated on a scale that could possibly outweigh the net benefits of the present system.

By then, the comparative costs of the present and alternative supply systems are certain to have changed in at least one respect, because the first stage of the pipeline rehabilitation project will have been completed. This expenditure will then be a sunk cost, and no longer relevant for the economic analysis of alternative supply options. It is estimated that this will reduce the NPV of the cost of the existing system by about US$26 million immediately after rehabilitation.

5.10 Potential Refinery Conversion

The possible upgrading of the Indeni refinery by the addition of a hydrocracker was studied extensively between 1983 and 1985. The consultants' studies concluded that the highest economic return was obtainable from large-scale investment in a high-pressure hydrocracker. A slightly lower rate of return was obtainable from a smaller investment in a mild hydrocracker. Due to a shortage of investment funds and the volatile world petroleum market, no investment was made.

Since 1985, the structure of world petroleum prices has changed in a way that makes refinery upgrading less economic. Growth in Zambian demand for petroleum products has also been substantially less than was forecast several years ago. When reevaluated in the light of these changed circumstances, refinery conversion is now no longer economic. This section summarizes the results of this analysis, which are set out fully in Appendix 5.2.

The primary function of a refinery conversion scheme would be to upgrade low value heavy fuel oil (HFO) into more valuable products, notably kerosene, gas oil and gasoline. Different kinds of conversion facilities produce different mixes of final and intermediate products which can be further upgraded. At the same time, they leave a certain amount of residual product. This is generally unsuitable for further cracking, but can be used as HFO in boilers. There is a clear physical and economic limit on how small this residual fraction can be, generally in the region of 15% of total refinery output.

Zambia currently imports a mix of petroleum products. The residual fuel oil fraction (from which the HFO and bitumen is produced) is about 20%. Minor refinery modifications could reduce the minimum residual fuel oil fraction to about 10% through continuously recirculating most of the fuel oil through the refinery. This would enable Zambia to avoid minimum fuel oil production being a constraint on the fuel substitution options detailed in this Energy Strategy, but at the cost of increased refinery fuel use.

Investments in hydrocracking depend for their economic viability on a sustained and substantial price differential between the major product used (HFO) and the major product produced (gas oil). This would only arise if the present worldwide refinery over-capacity were to be eliminated, and if crude oil or HFO prices were to fall sharply as a result of oversupply.

Global demand for refined petroleum products shows little prospect of near or medium-term growth at a rate that would put upward pressure on the prices of refined petroleum products. As shown in Annex 5.2, at less than 80% hydrocracker utilization, the sustained margin between fuel oil and gas oil prices must exceed US$70/ton to yield a break-even rate of return on a hydrocracker investment. Such margins have been seen for only short time periods over the last decade. To justify the investment, they would need to be achieved, on average, over 15 to 20 years.

In the case of Zambia, there are two additional constraints on such an investment. First, the minimum economic size of hydrocracker is bigger than Zambia can currently use. In particular, gasoline demand would have to grow by 50% for the reformer (the part that produces the gasoline) to run at a sufficient level to produce enough hydrogen byproduct for feedstock to the hydrocracker. Second, the volume of fuel oil consumed in Zambia as the preferred fuel (economic as well as physical) is probably less than the minimum fuel oil production from the hydrocracker. In effect, all schemes for substituting coal or electricity for fuel oil would have to be abandoned. When copper production and smelting begin to decline in less than ten years, a surplus of fuel oil would result, which could only be sold at distressed prices.

Were commercial quantities of crude oil to be discovered in Zambia on a scale that precluded exports, it is then highly likely that hydrocracking would be justified at some location, probably, but not necessarily, at Indeni. The physical characteristics of the scheme would depend on the type of crude discovered, particularly aspects such as paraffins, wax, gravity, volatiles, sulphur, gas content, distillate fraction etc. It is not useful to speculate in advance on what might be needed. Should export quantities of crude oil be discovered in Zambia, it would probably be most profitable, depending on the quantities and nature of the oil, to export most or all of the crude, with Zambia operating a topping refinery at the oil field and continuing to import other products as needed.

VI. COAL

6.1 Reserves

Zambia's single coal mine at Maamba exploits the near out-crop areas of thick coal development in part of the Siankondobo coalfield, north of Lake Kariba. Major faults divide the coalfield into two main structural units known as the Kazinze and Izuma Basins. In the Izuma Basin, a single thick seam is developed, whilst in Kazinze, the seam is split into two components by a laterally persistent sandstone band. In both basins there is no clear geological demarcation of the top contact of the coal; ash content of about 25% in the main seam grades into coaly mudstones with 40% ash or more. Hence the calculation of mineable coal is controlled by technical/economic factors rather than geological criteria. Maamba coal is defined as "a mineral which, when washed, produces a product containing not more than 16% ash, with a minimum recovery rate of 70% in the Coal Preparation Plant."

Based on this definition, and a maximum stripping ratio of 8 m^3 overburden: 1 ton coal, proven open pit reserves total about 30 million tons, of which 13 million tons are in Kazinze and 17 million tons in Izuma. At a mining recovery rate of 95%, and preparation plant recovery rate of 65%, reserves of saleable coal total about 19 million tons. Geometrical constraints on pit layout will further reduce this figure. It is conservatively estimated that proven open pit reserves of saleable coal total at least 13 million tons, sufficient for 25 years at present production rates.

It is recommended that no account be taken of possible underground reserves at Maamba because of serious technical and safety difficulties associated with deep mining in these strata.

Coal resources are known to exist in the Luangwa, Luano, and Lukusashi areas, and the Western Zambia trough system. Of greater interest are resources in the Zambezi Valley, in reasonable proximity to current Maamba workings.

6.2 Policy Issues and Options

The major issues and options with respect to coal are:

(a) the long-term demand for coal, taking account of substitution options, and the future investments required to ensure adequate supply;

(b) the current limited capability of the rail system to transport coal supplies, and the possibility of improvement and/or increasing customer stockpiles as a security measure in the event of future transport difficulties;

(c) the level and structure of coal prices that will best reflect the financial and economic costs of production and supply; and

(d) the potential for using reject fines to make coal briquettes as a substitute for charcoal as an urban household fuel.

6.3 Recent Production and Sales

Maamba Colliery was originally designed to produce over 1 million tons of saleable coal per annum. Its actual capacity has never approached this design target. Table 6.1 gives production and sales figures since 1980.

TABLE 6.1: COAL PRODUCTION, SALES AND PRICES, 1980/81-1987/88
(tons)

Year	Production			Average FOB sales price	
	Run-of-mine	Washed coal	Sales	Kwacha/ton	US$/ton
1987/88	906,123	572,792	512,022	348.87	43.35
1986/87	784,056	511,970	531,409	218.66	28.43
1985/86	816,445	538,406	499,063	108.10	40.00
1984/85	711,960	510,021	448,537	60.09	33.65
1983/84	772,963	482,901	509,040	45.16	36.13
1982/83	n/a	n/a	542,853	37.86	n/a
1981/82	802,614	552,242	539,137	33.53	n/a
1980/81	842,822	575,425	571,062	31.64	40.18

Source: Maamba Collieries.

In the early 1980s, production was generally able to meet demand, with some consumer dissatisfaction on quality and delivery uncertainties. In the period 1983-86, capacity was badly impaired by lack of equipment and spare parts, and demand generally outstripped supply. By mid-1986, the major elements of a rehabilitation program, mainly funded by the African Development Bank (ADB), were well in hand. Since that date, capacity has exceeded demand.

6.4 Current Production

The main elements of the production system at Maamba comprise: prestripping by truck and shovel; stripping by walking dragline; excavation and haulage of run-of-mine coal and sandstone waste; treatment in the Coal Preparation Plant; and transport by aerial ropeway to the Masuku railhead. Capacity is effectively limited by the aerial ropeway (Table 6.2). Relocation of the main drive of the ropeway to a point just before the railhead and the addition of more buckets could increase capacity to about 700,000 tons.

Table 6.2: PRODUCTION CAPACITY AT MAAMBA COLLIERY

Process	Annual Capacity	Saleable Coal (tons)
Prestripping	3.5 million bcm a/	770,000
Stripping	2.4 million bcm	690,000
Raw Coal Production	1.2 million tons	760,000
Coal Preparation	-	750,000
Ropeway Transport	-	650,000 b/

a/ Bank cubic meters.
b/ After rehabilitation. Currently it is about 600,000 tons.

Source: World Bank estimates.

For the past two years, Maamba coal has been sold in four grades, according to quality. Table 6.3 indicates the proportion of output falling into each grade category. From 1988, the production of base grade coal will be discontinued.

Table 6.3: COAL PRODUCTION BY GRADE QUALITY

	Premium (-14% ash)	Standard (15-17% ash)	Medium (17-19% ash)	Base (19-21% ash)
Proportion of output	10%	27%	24%	39%

Source: Maamba Collieries.

Maamba coal has inherently poor washability characteristics. Quality of output could be improved only by significant reductions in Preparation Plant recovery and throughput, and commensurate reductions in saleable coal reserves.

6.5 Market Prospects

6.5.1 Overview

Three coal demand forecasts have been prepared, equivalent to the base, high, and low GDP growth rate assumptions, and taking account of firmly planned energy substitution investments. These forecasts are summarized in Table 6.4, and their justification explained in the balance of this section.

Table 6.4: ANNUAL FORECAST COAL DEMAND
(tons)

	Demand Scenario		
Year	Low	Base	High
1988-89	485,000	500,000	540,100
1989-90	440,000	460,000	500,000
1990-91	440,000	450,000	455,000
1991-92	490,000	500,000	505,000
1992-93	525,000	540,000	500,000
1997-98	490,000	515,000	540,000
2002-03	490,000	525,000	560,000

Source: World Bank estimates.

6.5.2 Copper Industry Demand

ZCCM is Maamba Collieries' largest customer. Its Kabwe Division has a life of two years, which could be extended to five years, subject to current studies. Coal demand from this source is estimated to be 22,000 tons/year for five years in all demand scenarios and zero thereafter.

In the Copperbelt, the only ZCCM coal user of significance is the Nkana smelter. ZCCM policy is to maximise the use of Nkana because of the need to produce acid, and to maximise the use of coal. This yields a total coal demand of 148,000 tons in 1988-89, which drops to 111,000 tons for a period of four years during commissioning of the proposed new modified smelter technology, which must initially be fuel oil-fired. From 1993-94 onwards, it is assumed the new furnace will convert to coal, and estimated Nkana coal demand will remain constant at about 135,000 tons per annum through to 2006. In 1992-93, an additional demand of about 35,000 tons is envisaged at the Luanshya smelter during a planned major overhaul of the Mufulira electric smelter. ZCCM demand is not sensitive to rate of GDP growth, and hence the above forecasts are used in all three demand scenarios.

6.5.3 Other Consumers' Demand

Nitrogen Chemicals of Zambia (NCZ) at Kafue is currently undergoing rehabilitation, and has a forecast coal demand of 135,000 tons/year until rehabilitation is complete in 1989-90. Thereafter, demand should rise to about 185,000 tons/year, which is equivalent to the estimated maximum practical throughput of the plant. NCZ's coal demand is not directly related to GDP or the agricultural sector growth rate.

Chilanga Cement, the third largest customer, forecasts coal consumption of about 65,000 tons in 1988-89. Potential increased activity in the construction sector will be partially offset by decreased cement sales to ZCCM, and the company has significant export sales, which are vulnerable. In the base case, constant consumption of 65,000 tons is assumed. For the low case, a drop in demand to 60,000 tons is envisaged from 1989-90 onwards, reflecting possible weaker cement export sales. In the high case, compound growth of 2% per annum is assumed.

Other significant existing users of Maamba coal include Zambia Sugar, Dunlop, Zambia Breweries, Premium Oil, R.O.P., National Breweries, and retail sales. Forecast consumption for these consumers in 1988-89 is about 80,000 tons, which has been escalated at a rate equal to GDP growth in the out-years.

No allowance has been made for possible substitution of coal for petroleum products in industry, although this is technically and economically feasible. This is mainly because electricity is generally the preferred fuel, so most industrial conversions have involved its substitution for petroleum products.

6.5.4 Exports

Maamba's export market is volatile. In recent years, exports fluctuated from under 10,000 tons to over 30,000 tons in 1986-87. Maamba forecast 57,000 tons for 1988-89, mainly to Zaire and Tanzania, but this is probably optimistic. Maamba fears it may lose the Tanzanian market in 1990, and sales to Zaire are vulnerable to competition from Zimbabwe, partly because Zambia Railways' transport charges are US$15/ton higher than those of Zimbabwe Railways. Without undertaking a major export marketing study, there is no rational basis for forecasting future export demand. Historic data and recent performance suggest that average export sales are unlikely to exceed 35,000 tons/year.

6.5.5 Briquettes

Japanese and German studies have demonstrated the technical feasibility of producing coal briquettes from Maamba reject fines and other locally available ingredients, for possible household energy use. The National Council for Scientific Research has completed all necessary bench-scale testwork. However, there has been no consumer acceptance testing nor feasibility analysis of commercial-scale production. Hence the economic viability of household briquette production remains to be established. These steps are recommended to determine the feasibility of commercial production. Pending their completion, it is not possible to estimate potential demand. Any potential coal briquette project should take account of the limited rail transport capacity from Maamba and include provision for adequate transport facilities.

6.5.6 Possible Iron and Steel Projects

Zambia is considering two possible iron and steel projects, to be located at Kabwe, north of Lusaka:

(a) a pilot sponge iron plant with an output capacity of 15,000 tpa for possible implementation in 1991-92; and

(b) a 200,000 tpa capacity iron and steel project for possible implementation in the late 1990s.

Smelting would be by electric arc furnace, using coal as a reductant and small quantities of HFO for start-up.

The pilot project would require about 20,000 tons of coal per year, which is well within Maamba's capacity to supply. The full-scale project would require up to 230,000 tons of coal per year. Combined with Maamba's other markets, this would raise total coal demand to about 755,000 tpa from around the year 2000. This is substantially above the capacity of the existing coal stripping, ropeway and rail transport system, and at the capacity margin of Maamba's other production facilities (see Table 6.2). In order to meet this demand, Maamba would need to invest in additional stripping equipment and a new transport system from the mine to the railhead. Zambia Railways would need to invest in additional locomotives and wagons to move the coal from the Masuku railhead to Kabwe. The program for developing new sources of coal supply would also need to be accelerated. The cost of these investments must be included in the cost-benefit analysis of the iron and steel project. Their magnitude and high foreign exchange content will reduce the potential project's net financial and economic benefits.

6.6 Coal Transport and Storage Requirements

Because of the distances involved and tonnages to be moved, there is no economic alternative to rail transport of coal from the Masuku rail terminal, other than moving small tonnages by road. Table 6.5 summarizes Maamba's rail transport needs for the peak year of the base case demand forecast.

Table 6.5: RAIL TRANSPORT OF COAL IN BASE CASE PEAK DEMAND YEAR (1992-93)

Destination	Distance (Km)	Tonnage	Ton-Km (x 10^6)
Kafue	266	185,000	49.2
Chilanga	298	33,000	9.8
Lusaka	314	37,100	11.6
Kabwe	434	22,000	9.5
Ndola	627	68,500	42.9
Kitwe	693	157,800	109.4
Tanzania	496 (Kapri)	20,000	9.9
Malawi	Road Trans.	2,000	
Zaire	627 (Ndola)	13,000	8.2
TOTAL	-	538,400	250.5

Source: World Bank estimates.

Rail transport of coal has been a persistent supply bottleneck. Analysis of Zambia Railways' (ZR) existing capacity suggests that, at its current level of operating efficiency, ZR cannot fully satisfy current or projected future demand for rail transport of coal. Unless either its efficiency is improved, or additional locomotives are obtained, problems of inadequate rail service will persist. As efficiency improvement will take time, acquisition of additional locomotives is strongly recommended.

One way for coal consumers to minimize the problem of unreliable rail transportation is to hold larger stocks of coal, to be replenished whenever ZR is able to run a coal train. The disadvantages are the higher cost and risks of deterioration, particularly during the rains.

The two largest coal consumers, ZCCM Nkana and NCZ, have storage for at least two months' coal consumption. Maximum use of this storage is recommended, as is the provision of expanded storage facilities at other coal customers. In return for holding more stock and accepting fewer deliveries at times more suitable to ZR, coal consumers may be able to negotiate a lower rail transport charge per ton, which would offset at least part of the cost of the additional stocks.

6.7 Mine Operational Improvements and Contingency Planning

The ADB/IDA funded rehabilitation program has restored the coal mine to a position where capacity exceeds current and firmly-forecast demand. To maintain sufficient capacity, adequate supplies of foreign exchange for spares and replacement machines must be made available. The mine must also have adequate skilled personnel to guarantee high standards of maintenance. This necessitates a continual training and work experience program for Zambian nationals, supported by limited technical assistance from experienced overseas personnel.

A planned, internally-funded project to take control of mining and processing magnetite for the Coal Preparation Plant is essential if plant capacity is to be maintained. This is now underway.

Current capacity estimates (Section 6.4) assume normal breakdowns and repairs. The walking dragline presents special risks. Failure of a major component (e.g., the drive shaft) could dramatically reduce capacity for an extended period. Such components are not available ex-stock and typically have delivery times of at least six months. Allowing for raising credit, shipping, etc., such a failure could drastically reduce output capacity for six months or more. Mining the Izuma basin by truck and shovel provide some protection against such an eventuality. However, it is recommended that an analysis be done of the probability of major dragline failure and the costs and benefits of holding critical spares. If this is found to be economically justified, the critical spares should be procured.

6.8 Long-Run Economic and Financial Cost and Prices

Maamba Colliery's financial performance over the last several years has been relatively poor. Prior to 1987 it made losses for a number of years. Accumulated losses of K23 million (US$2.9 million) peaked in March 1986. A modest profit in 1987 reduced these slightly. Between 1989 and 1993, Maamba faces a decline in sales as the Nkana smelter is converted to a new oxy-fuel technology, which initially must run on fuel oil. It is not reasonable to expect Maamba to recover all the resulting lost revenue through higher prices, but prices must cover the long-run economic cost of coal production and/or Maamba's future financial obligations, whichever is the higher.

It was not possible to estimate accurately the long-run average incremental cost of coal, which is the preferred indicator of its economic cost. This is because no major new investment or expansions of capacity are envisaged, and there is no way of accurately predicting the future level of output in response to small variations in maintenance and rehabilitation expenditure. Instead, economic cost was estimated by discounting forecast 10-year capital and operating costs, exclusive of taxes and duties, with foreign inputs shadow priced at K12/$US1, and dividing by discounted future output. Because costs are roughly constant over time, this should provide a relatively accurate picture. On this basis, the estimated economic cost of coal is K359/ton (US$44.9/ton).

The long-run financial cost of coal, i.e., the price on average over the next 10 years needed to cover Maamba's debt obligations and operating costs, including taxes and duties, is estimated to be K447/ton in 1988 prices (US$55.9/ton).

The average realized price per ton of coal in the last quarter of 1987 was K355.2 (US$44.4/ton). The draft 1988-89 revenue budget proposes an average price of K400/ton (US$50/ton). Exports are normally priced at US$38/ton.

As is evident from the above cost estimates, the financial cost of coal is the binding constraint on pricing. It is therefore recommended that, at a minimum, Maamba's proposed price of K400/ton be approved for fiscal year 1988-89. This is still nearly K50 below Maamba's long-run financial cost of production, but above its economic cost. A further increase will be required in 1989/90 to fully cover Maamba's financial costs. In the event of devaluation, the increase must be sufficiently large to cover the resulting higher Kwacha cost of servicing Maamba's foreign debt.

Coal exports should be priced at a level that, at a minimum, covers both economic cost and short-run financial cost. Moreover, prices to the consumer should be competitive with alternative coal supplies and the prices of competing fuels. Within these constraints, it may be possible to increase revenues and profitability by charging different prices to different export customers.

6.9 Recommended Pricing Structure

From 1988, Maamba coal will be sold in three quality grades, with a discount for fines in the lowest grade. The price differential between each grade should accurately reflect:

(a) difference in energy content;

(b) additional transport cost for higher ash; and

(c) additional handling costs for higher ash.

Based on the longest haul, to Kitwe in the Copperbelt, each percentage point of ash adds K2/ton (1988 prices) to transport cost for equivalent energy delivered. To allow for additional handling costs, it is suggested that this figure be doubled. An appropriate tariff structure would then be:

Premium (-14% ash)	-	Top Price
Standard (15-17% ash)	-	Top Price x 0.965 - K12
Medium (+17% ash)	-	Top Price x 0.942 - K16

To achieve an average price of K450/ton (the long-run financial cost), the price of each grade would be:

Premium (10.5% of output)	- K480/t
Standard (26.9% of output)	- K455/t
Medium (62.6% of output)	- K440/t

It is suggested that a discount for fines be given only in the rainy season when there is consumer resistance because of handling problems.

6.10 Investment Priorities

6.10.1 1989-1993

Current capacity at Maamba Colliery exceeds forecast demand throughout the planning period to 2006 on all three demand projections. Except for normal maintenance and replacement investment, the only identified need is for possible contingency investment against major dragline breakdown. The study to assess whether this is justified could be undertaken internally or by consultants, at an estimated cost of US$50,000. Further expenditures could then be needed to implement the plan, probably involving purchase of critical spares, the estimated cost of which is up to US$1 million.

6.10.2 1994-2006

The only other required investment additional to normal replacement expenditure is US$2 million for exploration to identify additional reserves of coal. The suggested timing is 1995-2000. Should a major new demand for coal be identified, such as from an iron and steel plant, the exploration program should be brought forward.

VII. WOODFUEL AND HOUSEHOLD ENERGY

7.1 Supply and Consumption Estimates and Forecasts

Wood is Zambia's principal household fuel, and the nation's largest single source of energy. In the rural areas, household woodfuel consumption is mostly in the form of firewood. In the growing urban areas, it is mostly in the form of charcoal. Wood and charcoal are also used as industrial and commercial fuels.

At the risk of oversimplifying, there is little evidence at present of a rural fuelwood shortage in Zambia. Locally, however, mainly in the Copperbelt, Lusaka, the Central and Southern Provinces, tree-cutting for agriculture and charcoal production has contributed to deforestation and consequent ecological deterioration.

7.1.1 Woodfuel Supply

Woodlands and forests are estimated to cover about 50 million ha, 66% of Zambia's total land area. Miombo (58%) is the predominant woodland type, followed by Kalahari woodland. 7.4 million ha (15%) are protected state forests. Industrial forest plantations cover 59,000 ha and other forests about 2 million ha. The balance of about 40 million ha (80%) is unreserved natural woodland.

The standing volume of timber is estimated to be in the range 2,700 million m^3 to 4,700 million m^3, according to the FAO. 7/ Annual yields vary widely from under 0.3 m^3/ha to over 0.8 m^3/ha, being generally higher in the north and lower in the south, where average rainfall is less. Total national stem volume yield per year is estimated to be about 14 million m^3. Total above-ground biomass is in the range of 33-70% above this, i.e., 19-24 million m^3. In addition, there are isolated farm trees and shrubs, the volume and yield of which are unknown.

Although a large proportion of Zambia is still covered by forest and woodland, the spatial distribution of forests and population are very different. As Table 7.1 shows, highly populated regions have fewer forest resources than less populated areas.

7/ Zambia: Wood Energy Consumption and Resource Survey; FAO; November 1986. FO:DP/ZAM/82/E08, Document No. 2.

Table 7.1: REGIONAL DISTRIBUTION OF POPULATION AND FORESTS

Province	% of total population	% of total forest
Copperbelt	23	6
Lusaka	14	2
Southern	12	7
Northern	11	8
Eastern	11	9
Central	9	10
Western	8	22
Luapula	7	12
North Western	5	25

Source: FAO Wood Energy Consumption and Resource Survey.

7.1.2 Charcoal Supply

There are no reliable statistics available, but it is estimated that about half the wood consumed for energy purposes is converted into charcoal. With very minor exceptions, all the charcoal is made with traditional earth kilns or clamps. Their yield is generally low--about 15% on a weight basis. Nearly all charcoal is made from indigenous tree species.

Only about 5% of charcoal is made by producers using sources of wood licensed by the Forest Department. They pay a stumpage fee of K8 per cord (US$1/cord) for wood from Forest Department-managed sources. The stumpage fee is based on 1983 prices and costs. The main sources of the other 95% of supply are natural woodland within traditional law domains and designated forest reserves. Transporters are charged a removal fee of K0.5/bag if no stumpage fee has been paid, but only a small proportion of the fees are collected.

About 25,000 rural households are believed to be engaged, at least part-time, in charcoal production, and a still larger number in transport and trading of charcoal. Sources of supply are diffused around the major markets of Lusaka and the Copperbelt. Both markets also draw supplies from neighbouring provinces, such as Central, Southern, and North Western.

7.1.3 Firewood and Charcoal Consumption

Results of the FAO Wood Energy Consumption and Resource Survey showed that per capita annual consumption of fuelwood was about 728 kg (1 m^3), and that of charcoal, about 101 kg (1.1 m^3 of wood equivalent). Consumption patterns differ between rural and urban areas. Fuelwood consumption is higher in rural than in urban areas (1,243 kg versus 98 kg per capita per year); charcoal consumption is higher in the urban than in the rural areas (194 kg versus 23 kg per capita per year). Aggregate national woodfuel consumption by households was estimated to be about 14.4 million m^3 in 1985, 8/ and consumption of roundwood and sawnwood about 1.3 million m^3, giving total national wood consumption in 1985 of about 15.7 million m^3 (11 million tons). With population growth, this had probably reached 16-17 million m^3 by 1988. The woodfuel component is split roughly 50-50 between firewood and wood for producing charcoal. The estimated sectoral distribution of woodfuel consumption is shown in Table 7.2.

Table 7.2: ESTIMATED SECTORAL WOODFUEL CONSUMPTION, 1985

	Firewood		Charcoal (wood equivalent)	
	million m^3	million tons	million m^3	million tons
Households	6.4	4.9	7.9	5.5
Agriculture	0.7	0.3	-	-
Industry/Commerce	0.7	0.3	-	-
TOTAL	7.8	5.5	7.9	5.5

Source: Department of Energy.

7.1.4 Current Supply/Demand Balance

Estimates of the current sustainable yield of Zambia's forests and woodlands (19-24 million m^3) and the current consumption of woodfuels and sawn wood (16-17 million m^3) suggest that woodfuel demand is not causing deforestation on a national scale. However, two aspects of Zambia's woodfuel supply situation give cause for immediate concern: (a) localized deforestation, due to regional imbalances between woodfuel supply and demand; and (b) agricultural land clearing, which is probably depleting wood resources more rapidly than energy demand. Over the longer term, progressive local and regional deforestation is in prospect unless ways can be found to reduce the woodfuel demand of a growing population.

The variation in the current regional woodfuel supply/demand situation is illustrated by estimated provincial stem volume increment and woodfuel demand balances prepared by the Department of Energy for 1986. These show that North Western, Western, Central, Eastern, Northern, and Luapula Provinces produce more stem volume than they consume woodfuel. However, Copperbelt Province consumes 1% more woodfuel than the annual stem volume increment, Southern Province 23% more, and Lusaka Province nearly 300% more. When account is taken of total aboveground biomass, this means that Southern Province is consuming most of

8/ Op. cit. page 19.

its aggregate woodfuel supply each year, and Lusaka Province is in a serious wood supply deficit situation. Lusaka is either obtaining a large proportion of its needs from neighboring provinces, thereby worsening their supply situation, or is destroying its wood resources at a rapid rate, or both.

All three provinces with the most serious woodfuel supply situation are in the central "spine" of the country. This means that the problems of shrinking local woodfuel resources and resulting environmental degradation are heavily concentrated in that central region. Sources of woodfuel supply are also becoming progressively more distant from centers of demand. The result is rising charcoal transport costs and higher prices to the consumer.

The second major problem is destruction of woodland by agricultural land clearing. A major culprit is the "chitemene" system of agriculture, which is estimated to cover 130,000 km^2. It involves lopping trees and burning the cut wood to make mineral ash to enrich the soil. As traditionally practiced, the cleared areas are cultivated for about six years, during which the soil is leached of its nutrients. The area is then abandoned and the woodland regenerates.

This land use system can sustain a rural population density of up to four people per km^2. Beyond this, pressure becomes too high for full regeneration, so soil fertility falls, erosion sets in, and regeneration is further weakened. With Zambia's growing population, this system is leading to progressive deforestation of rural areas where population density exceeds this limit.

The encouragement of smallholder and commercial farming, which is one of the Government's strategic objectives, is adding further to the pressure on wood resources. Twenty percent of the land area has already been cleared for agriculture in Eastern, Northern, Southern, and Luapula Provinces, and farming is becoming progressively more intensive around the main urban centers of the Copperbelt, Lusaka, and along the line of rail.

7.1.5 Demand Forecasts and Their Implications

Very little is known about levels of and trends in industrial and agricultural woodfuel consumption. For demand forecasting purposes, the two sectors' estimated 10% share of total wood consumption is forecast to grow at the same rate as GDP--2% per year in the base case forecast.

Household woodfuel consumption, which accounts for at least 90% of the total, is forecast to grow at the same rate as forecast urban/rural household formation. The pattern of urban and rural household use of firewood and charcoal is that estimated by the FAO Wood Consumption and Resource Survey, and it is assumed that no change is made in cooking equipment or techniques. The proportion of urban households using conventional fuels in place of charcoal is assumed to remain constant over the forecast period.

The resulting base case woodfuel demand forecast through 2006 is summarized in Table 7.3

Table 7.3: BASE CASE WOODFUEL DEMAND FORECAST
(Million tons)

Province	Actual 1986	Forecast 1989	1996	2000	2006
Copperbelt	2.14	2.46	3.22	3.57	4.20
Lusaka	0.96	1.15	1.64	2.07	2.74
Central	1.93	2.34	3.36	4.05	5.12
Eastern	1.27	1.40	1.71	1.93	2.28
Southern	1.47	1.66	2.13	2.51	3.09
Northern	1.30	1.43	1.74	1.95	2.27
Western	0.93	1.01	1.20	1.33	1.53
North Western	0.84	0.94	1.17	1.31	1.53
Luapula	0.79	0.86	1.04	1.17	1.35
TOTAL (national)	11.63	13.27	17.22	19.90	24.10

Source: Department of Energy.

As is evident from the forecast, national woodfuel consumption is expected to double by about 2006, unless steps are taken to moderate demand growth. The likely effect will be to exhaust the natural wood stock of Lusaka Province, probably before the year 2000. Deforestation will accelerate in parts of the Copperbelt, Central, and Southern Provinces during the 1990s. The remaining provinces will not suffer extensive deforestation over the forecast period.

In addition to woodfuel supply deficits in the heavily populated region along the line of rail, there will be increasingly severe shortages in several smaller centers. Among the areas likely to be worst affected are Mongu in Western Province, which is in an area of savannah grassland; parts of Eastern Province, particularly around areas of intensive commercial and semi-commercial farming; and near some of the lakes and rivers in Northeastern and Luapula Provinces, where wood is used extensively to smoke fish.

7.2 Prices and Economics Costs

7.2.1 Prices

Data on the prices of fuelwood are very scanty. Prices per m^3 of stackwood in 1983 for different areas are shown in the first column of

Table 7.4. Cumulative inflation between 1983 and 1988 has been about 500%, so nominal woodfuel prices are likely to have risen sharply from these levels.

Table 7.4: FUELWOOD PRICES IN JULY 1983
(Kwacha)

	Per m3 of Stackwood	Per GJ
Lusaka	9.22	0.88
Kabwe	8.80	0.84
Ndola	30.68	2.93
Mansa	10.84	1.03

Source: "The Status and Impact of Woodfuel in Urban Zambia," E.N. and S.B.M. Chidumayo, Department of Natural Resources, 1984.

Statistics are available for retail charcoal prices during 1983-86, and are summarised in Table 7.5. These indicate an approximate tripling of nominal prices between July 1983 and November 1986.

Table 7.5: RETAIL PRICES OF CHARCOAL PER LARGE BAG a/
(Kwacha)

	Lusaka	Kitwe	Ndola	Livingstone
1983	4.00-4.50	n.a.	6.00-7.50	n.a.
1984	5.30-7.00	5.00	8.10-8.55	5.30-5.50
1985	7.70-8.00	7.80-8.00	10.50	n.a.
1986	12.00	15.00	18.00	10.00-13.0

a/ Usually about 40.5 kg.

Source: Prices and Incomes Commission.

In real terms, charcoal prices remained roughly constant between 1983 and 1986 (Table 7.6).

Table 7.6: INDEX OF NOMINAL AND REAL CHARCOAL PRICES IN LUSAKA

	Charcoal Prices (Large Bags)	GDP Deflator
1983	100	100
1984	141	118
1985	183	167
1986	282	306

Source: Prices and Incomes Commission.

Retail market prices of charcoal are consistently higher than the prices authorized by the Government. For example, in 1985 the officially authorized price in the Copperbelt was K3.50/bag, contrasting sharply with prices from K7.80/bag upwards quoted in the markets of Kitwe and Ndola. Charcoal prices also vary seasonally, being higher during the rainy season from November through April.

An important feature of the charcoal market is that small, affordable quantities fetch much higher unit prices than large bags. This is illustrated by data for Lusaka in January 1986, shown in Table 7.7

Table 7.7 CHARCOAL PRICES FOR VARIOUS QUANTITIES IN LUSAKA, JANUARY 1986
(Kwacha)

	Price	Price per kg	Price per GJ
Bag (40 kg)	10.40	0.26	7.9
Buckets (5 kg)	4.05	0.81	24.5
Tins (2 kg)	2.20	1.10	33.3
Heaps (1 kg)	1.73	1.73	52.4

Source: "SADCC Energy Development - Fuelwood"; ETC Foundation; The Netherlands; April 1987.

The approximate composition of charcoal prices from producer through to retailer is shown in Table 7.8.

Table 7.8: ESTIMATES OF THE COMPOSITION OF CHARCOAL PRICES IN LUSAKA
SEPTEMBER 1986
(Kwacha per 40Kg sack)

Price paid to charcoal producers on-site	5.0
Transport charge (truck hire round-trip)	4.0
Average wholesale and retail margin	3.0
Retail price in Lusaka markets	12.0

Source: Estimated from "SADCC Energy Development - Fuelwood"; April 1987.

7.2.2 Economic Costs

The economic costs of charcoal production are almost certainly higher than its market price. Even on a highly conservative estimate, the 1986 economic cost of plantation wood was about K3.1/GJ (Appendix 7.1). To this must be added the cost of charcoal production, estimated at K3.6/GJ, giving a total economic cost ex-source of K6.6/GJ. This compares with the September 1986 producer price of K3.5/GJ or K5.0 per sack (Table 7.8).

The principal cause of the large difference between economic costs and market prices is that the latter do not reflect the costs of replacing the wood used, because most charcoalers pay nothing for wood.

Estimated 1986 average economic costs of transport from charcoal producer to market are K4.6/GJ. Added to the above estimate of the economic costs of production, the estimated 1986 economic cost of plantation-wood charcoal delivered to market is K11.2/GJ. This is nearly double the 1986 market price of K6.2/GJ (K9.0/sack).

7.3 Household Energy Policy Objectives

The principal objectives of Zambia's household energy strategy should be to:

(a) minimize the cost to the economy of meeting basic household energy needs;

(b) provide adequate supplies of household energy to Zambian families at the lowest possible cost;

(c) avoid subsidizing the supply of household energy and thereby adding to Government's budget deficit; and

(d) develop sustainable methods of exploiting Zambia's woodland resources.

7.4 Policy Issues

The first major issue with respect to household energy policy is how much emphasis to put on public plantation forestry. The problem with public plantation foresty is that it is not financially viable unless: (a) the price paid for the wood (stumpage) covers the cost of production; and (b) the stumpage fees are collected.

The second issue is whether there are other, more cost-effective ways of increasing wood supply than public plantation forestry, such as improved management of natural woodland, agroforestry (farm forestry) or communal forest schemes.

A third key issue is the extent to which woodfuel and charcoal conservation measures can alleviate the problem of increasing wood shortages, and whether they are more or less cost-effective than steps to increase woodfuel supply. Small-scale experiments have been undertaken, but their full potential has not been thoroughly assessed.

The fourth key issue is whether woodfuel substitutes, such as electricity, coal briquettes or kerosene, can be supplied at a lower economic cost than woodfuel. If so, can they be made available at prices which are both affordable to households and high enough to cover their cost of supply?

7.5 Household Energy Options

7.5.1 Supply Initiatives

(a) Forest Plantations

Zambia has about 59,000 ha of forest plantations. Of these, 52,000 ha are located in the Copperbelt, and are managed by ZAFFICO, a parastatal, and are used to produce sawn wood and pulp. ZAFFICO also has 10 Mark V metal charcoal kilns which are used for carbonizing wood waste. The remaining 7,000 ha of plantations are managed by the Forestry Department. Scattered around the country, they provide mainly timber and poles, but also some woodfuel for nearby rural communities.

Faced by an extreme shortage of funds, the Government cannot afford to subsidize new woodfuel plantations. Any new plantations must therefore be financially viable. The 1986 estimated cost of growing plantation wood for charcoal production is K3.1/GJ, or K4.5 per 40 kg charcoal bag (Appendix 7.1). This is almost equal to the then average price per bag realized by a typical charcoal producer for supply to Lusaka. That charcoaler could clearly not have afforded a stumpage fee equivalent to K4.5 per bag and still sold charcoal at the then current price. Designated woodfuel plantations in the areas supplying charcoal to Lusaka, some 100-150 km distant from the capital, do not therefore appear to be viable at 1986 charcoal prices.

Two factors would improve the viability of woodfuel forestry: (a) locating the plantation on land with a low opportunity value near a major charcoal consumption center (probably Lusaka), thus saving on charcoal transport costs; and (b) producing high-value poles and sawn timber in addition to woodfuel. Future analysis of potential woodfuel plantation projects should concentrate on projects with at least one and preferably both of these attributes.

(b) Management of Natural Woodlands

In terms of its impact on available woodfuel supply, more active management of natural woodlands can be a cost-effective alternative to plantation forestry. The objectives are to improve woodland husbandry and cutting practices, and thereby raise wood yields. The two major target audiences are the professional charcoalers and local villagers. They can be taught; (a) how to protect woodland from the incursion of animals; (b) when optimally to cut wood; (c) how to cut so as to maximize re-growth and (d) efficient charcoaling methods. The supply of efficient cutting tools can also help. The key to success is convincing the charcoalers and villagers of the benefits to them of efficient woodland management. This requires an additional effort by the extension services, reinforced by effective stumpage fee collection for commercial wood cutting, which itself can help pay for the extension service.

(c) Community Plantations/Agroforestry

Two further alternative means of increasing woodfuel supply are the promotion of community plantations and agroforesty or farm forestry (combining agricultural and woodfuel development, e.g., between fields or in small coppices). Experience elsewhere in Africa has shown that these are lower-cost solutions than public plantations, because much of the labor input and land has no or low financial and opportunity cost, and yields per ha are higher. However, such schemes require that public tree nurseries be established and effectively managed, and that extension services again be strengthened, to teach sound tree care practices. Both initiatives require additional public funds, which are unlikely to be forthcoming in large measure. Hence the potential scope for such action appears to be limited and dependent on the collection of more stumpage fees.

7.5.2 Conservation Initiatives

The two major options to conserve woodfuel use are to introduce more efficient methods of charcoal production and more efficient charcoal stoves.

(a) Efficient Charcoal Production

Above-ground earth clamps, with horizontal wood stacking, are used for charcoal production throughout Zambia. Relative to other countries, the clamps are large, sometimes exceeding 40 meters in length. Cycle time is two weeks and yield is 15-20% by weight.

ZAFFICO operates several Mark V metal kilns at its sawmills. These have a cycle time of 5 days and yield 25-30% by weight. Their disadvantages are their cost and lack of portability, especially in the rainy season. Their cost alone (K30,000) effectively rules out their widespread use in small-scale charcoal production. However, their high yield does make them suitable where there is a sustained supply of raw material within a short distance, e.g., at sawmills and plantations.

Several other initiatives have been taken to test improved charcoal production methods. The Forest Products Research Division in Kitwe has experimented with brick kilns, Argentine half orange kilns, and oil drum kilns. None of these have been widely diffused.

Experience elsewhere has shown that costly fixed or portable kilns are not viable as a means of increasing small-scale charcoal production efficiency. The key is introducing more efficient versions of traditional techniques, coupled with effective charcoal producer training.

(b) <u>Efficient Charcoal Stoves</u>

The staple food is nshima--maize meal, boiled over low heat for about 30 minutes. It is eaten with a relish, including vegetables and small quantities of meat, fish or chicken. Total cooking time is relatively long--up to one hour or more.

There is little need at present for more efficient wood stoves in Zambia because of the general absence of a rural energy "crisis". However, a strong case can be made for introducing more efficient charcoal stoves in urban areas.

The standard charcoal stove--or mbaula--is a single-wall, cylindrical, metal stove made from scrap metal. It costs about K10. A large amount of heat is lost through convection, and its fuel efficiency is low--about 10-15%.

Several versions of an improved mbaula have been developed by the School of Engineering at the University of Zambia (UNZA). One of the simpler versions, suitable for manufacture by local artisans, costs about K30 and has a thermal heating efficiency of about 22%. Charcoal savings of up to 70% have been achieved, relative to the mbaula, although 30% appears more typical. At this lower figure, the payback period for the consumer is 2-3 months. A still more efficient model of more complex design has also been developed. This would need to be manufactured commercially.

Following UNZA's preliminary stove efficiency and consumer acceptability tests, it has been wisely decided that efforts will be concentrated on the simpler improved stove model, which will be produced by local artisans in the markets. An information and dissemination campaign will be launched to encourage consumers to test them. Further work may also be done to refine the design, perhaps by the use of a ceramic liner and simplification of the manufacturing process.

Improved charcoal stove programs have proved successful elsewhere in Africa in reducing charcoal use per household. In Kenya, for example, many urban households now used an improved ceramic stove developed in 1982/83 by local artisans with Ministry of Energy assistance. The high relative price of charcoal in Zambia suggests that the prospects for an improved stove program here are good also.

If so, the potential impact on woodfuel consumption is considerable. Assuming the improved stove program results in use of an improved stove by 30% of urban households by 1996 and 90% by 2006, charcoal consumption would be nearly 30% lower in 2006 than without the program (Table 7.9).

TABLE 7.9: CHARCOAL CONSUMPTION WITH AND WITHOUT IMPROVED STOVES
('000 tons)

	Actual	Forecast			
Consumption	1986	1991	1996	2001	2006
Without improved stove	706	910	1,173	1,468	1,838
With improved stove	706	868	1,068	1,197	1,342
Decrease %	0	5	9	18	27

Source: Department of Energy.

7.5.3 Fuel Substitution Options

Rapid increases in the market price of charcoal and the existence of excess electric power generation capacity have stimulated interest in the potential for substituting electricity (and possibly kerosene) for charcoal in urban areas.

Estimating the cost to the consumer of alternative household fuels, in order to test the financial feasibility of fuel substitution, requires the following main parameters:

(a) comparative household fuel prices;

(b) the purchase cost of appropriate cooking devices and estimates of their useful lives;

(c) the combustion efficiency of each device; and

(d) the cost of any ancilliary equipment, e.g., electrical wiring and connection.

Estimates of the comparative financial cost of alternative fuels for household cooking in 1988, based on these data inputs, are shown in Table 7.10. For the purposes of this calculation, the estimated cost of an electrical connection and house wiring has been amortized over 20 years.

Although the estimates must be treated with caution, they show that:

(a) the cost of cooking with the traditional mbaula (K107.8/month) is about 30% greater than with an improved charcoal stove (K74.5/month), despite the latter's higher up-front cost;

(b) the cost of cooking with a kerosene pressure stove (K72.1/month) is roughly the same as with an improved mbaula (K74.5/month), but would be higher if the kerosene subsidy was removed;

(c) the relative cost of electricity is highly sensitive to the treatment of the very large up-front capital costs for house wiring, connection and appliance purchase. If these costs are amortized over 20 years, electric hot plate cooking (K45.4/month) is the cheapest household cooking option. If they are financed from a five year loan at a 12% rate of interest, the cost of cooking by electric hotplate rises to K156.2/month, more than twice the cost of cooking with an improved charcoal stove (K74.5/month). Similarly, an electric cooker/oven is competitive at K88.8/month if amortized over 20 years, but very expensive (K411.0/month) if the capital cost is repaid over five years at 12%.

7.5.4 Economic Analysis

The comparisons shown in Table 7.10 are of the financial or market costs, and not the economic costs of alternative cooking fuels. These latter can be, and indeed almost certainly are, very different from the financial costs. Unfortunately, they are hard to estimate accurately, although some broad conclusions can be stated.

Table 7.10: EQUIVALENT MONTHLY COSTS OF ALTERNATIVE HOUSEHOLD COOKING DEVICE/FUEL COMBINATIONS IN LUSAKA, 1988 a/

Device and fuel used	Efficiency of device	Combustion heat requirements	Heat value of fuel	Weight of fuel needed per month	Retail price of fuel	Running cost per month	Life of device	Purchase cost of device	Cost of wiring & connection b/	Total cost per month
	%	m/j	mj/kg	kg	Kwacha/kg	Kwacha	months	Kwacha	Kwacha	Kwacha
Mbaula/Charcoal	15	3,167	30	106	1.0	106.0	6	10		107.8
Improved stove/Charcoal	22	2,159	30	72	1.0	72.0	12	30		74.5
Wick Burner/Kerosene	37	1,284	42	31	2.7	83.7	36	150		87.9
Pressure Stove/Kerosene	50	950	42	23	2.7	62.1	60	600		72.1
		kWh		kWh	Kwacha/kWh					
Single Hot Plate/Electricity	62	210	-	210	0.1	21.0	72	850	5,000	45.4 c/ or 156.2 d/
Cooker/Oven/Electricity	75	176	-	176	0.1	18.0	96	12,000	5,000	88.8 c/ or 411.0 d/

a/ For comparative purposes it is assumed that a household of 5/6 people consumes 47mj of energy per month.
b/ Assumes 50% of the average K10,000 cost of house wiring and connection is attributed to cooking.
c/ Assumes that costs of connection and of wiring are amortized over a working life of 20 years using the straight line method.
d/ Assumes house wiring and connection is financed by a five-year loan at 12% interest.

Sources: "SADCC Energy Development - Fuelwood"; Department of Energy and World Bank estimates.

As the earlier estimates showed, the price of plantation wood charcoal is below its economic cost. But the price of household electricity to new consumers is also below its economic cost, because of the high cost of future distribution extension and household connections. Electric wiring and connection materials are also imported, and the economic cost of these materials is understated at the current exchange rate. Accurate estimates of the comparative economic cost of charcoal and electric cooking should be made to ascertain which is the lower cost household fuel to the country.

Undervaluation of the Kwacha, and the kerosene subsidy, mean the economic cost of kerosene is about 80% above its market price. If a shadow exchange rate of K12/US$1 is assumed and the subsidy eliminated, the economic cost of kerosene cooking would be nearly twice the financial cost shown in Table 7.10.

7.6 Policy Recommendations

(a) Tree Planting and Woodland Management

Efforts should be made to improve the management of natural woodland through a strengthened extension service. This should be financed by the introduction and collection of a stumpage fee for commercial wood cutting in areas of natural woodland.

Community and private sector tree planting efforts that do not require extensive Government funding should be encouraged. One option is to lease woodland tracts to private individuals or groups for charcoal production, in return for a commitment that the leasee will undertake a replacement tree planting program in each area cut.

(b) Improved Charcoal Kilns and Stoves

Recognizing that it has insufficient knowledge of charcoal production, marketing and substitution options to develop optimal efficient charcoal kiln and stove programs, the Government has requested technical assistance from the UNDP/World Bank Energy Sector Management Assistance Program (ESMAP) to help assemble key data and prepare a household energy strategy. Preparation of the strategy will involve the following steps:

(i) Urban household energy demand survey, to establish patterns of household energy use between different fuels, levels of consumption, responses to changing fuel prices and availability, and to provide a basis for monitoring the effectiveness of improved stove and other household energy programs.

(ii) Woodfuel marketing and distribution study, to identify sources of charcoal, transportation and marketing networks, and to accurately cost the charcoal production process.

(iii) Charcoal production survey, focussed on traditional charcoal producers, to assess traditional production methods, measure efficiencies achieved, and identify steps to improve traditional kilning techniques and incentives for their adoption.

(iv) Survey of biomass availability, in the catchment areas of urban settlements covered by the energy demand survey.

(c) Fuel Substitution

Analysis is needed urgently, and is planned under the ESMAP-assisted project to:

(i) refine the estimate of the financial cost of alternative fuels and estimate their comparative economic costs;

(ii) identify steps to reduce the financial burden of electricity connection and wiring, and the cost of hotplates and cookers, either by using less expensive equipment and/or by spreading the cost over a lengthy period;

(iii) identify steps to increase the sustainable rate of electricity connections and reduce distribution expansion costs;

(iv) assess the impact of increased household use of electricity on the long run economic and financial cost of electricity; and

(v) propose a structure of electricity charges that will facilitate additional household energy use, but reflect the financial and economic cost of household electricity supply, e.g., lifeline tariffs for small consumers.

In contrast to electricity, kerosene and LPG do not appear to offer much potential as substitute household fuels. This initial conclusion will be checked out by the ESMAP project. If it proves correct, kerosene and LPG substitution should not be actively pursued.

Work on coal briquettes has not yet reached the stage where their charcoal substitution potential can be assessed accurately. However, initial production trials suggest that a technically-acceptable household fuel can be produced. Consumer acceptability testing is now needed. If the results are positive, prefeasibility analysis of commercial-scale briquette production should determine whether coal briquettes lle financially and economically viable as a substitute household fuel.

VIII. RENEWABLE ENERGY

8.1 Policy Options

Being a land-locked, oil-importing developing country, Zambia is a prime candidate for the application of new and renewable sources of energy. However, accumulated experience nationwide with these technologies is small, and limited to particular settings, such as missions (solar panels) and private farms (windpumps).

Because of this low base, programs aimed at making use of renewable energy sources should initially concentrate on a few well-proven and relatively simple technologies. Energy converters that are reliable and can be repaired locally have a better chance of penetration. This chapter first reviews the scope for applying four of the more promising renewable techologies in Zambian conditions--solar water heating, solar drying, wind water pumping, and biogas. Later, it briefly discusses the potential for geothermal power generation, a test facility for which is under construction.

8.2 Institutions

The following institutions are involved in applying renewable energy technologies in Zambia:

(a) Technology Development and Advisory Unit (TDAU), University of Zambia

Although the TDAU has experienced management problems in the last couple of years, it still has the best equipped and largest workshop on campus and a staff of 12. The new management has a pragmatic approach, and see the TDAU as a link between the University and industry.

TDAU's present involvement with renewable energy concerns the design and implementation of a micro-hydro installation for water pumping and direct mechanical application, based on a locally made cross-flow turbine. Design parameters have also been evaluated for a small wind water pump.

(b) Department of Mechanical Engineering, University of Zambia

Renewable energy activities in the Department are limited to solar cooling applications.

(c) Department of Water Affairs, Ministry of Water, Lands and Natural Resources

The Department of Water Affairs of the MAWD has put into service close to 100 wind water pumps, mainly based on the

Southern Cross design. Today, practically all the wind pumps are out of operation for lack of spare parts.

(d) National Council for Scientific Research (NCSR)

NCSR, attached to the Ministry of Higher Education has tested service biogas digestors in three centers.

(e) Department of Energy, Ministry of Power, Transport and Communications

The Department carries out a coordinating and supervisory function in energy-related matters. It is now demonstrating renewed interest in NRSE by receiving and forwarding requests in this field.

As is evident, involvement with new and renewable sources of energy in Zambia has been limited. Diffusion of the technology, linked to increases in welfare (in monetary or social terms), should be the next step. This requires identifying and implementing a diffusion strategy, as well as quantifying and providing the necessary funds.

8.3 Solar Energy Potential

8.3.1 Technical Potential

Zambia enjoys very high solar radiation in all parts of its territory. Global radiation measurements have been made for Lusaka, Livingstone and Ndola since 1977-78 and for Mfuwe, Kasama, Mongu, and Mansa since 1981. The results are summarised in Table 8.1.

Solar radiation is relatively steady throughout the year, thus reducing the requirements on surface collector areas and storage capacities of solar energy converting equipment.

Table 8.1: GLOBAL SOLAR RADIATION AND RAINFALL VALUES IN ZAMBIA

Station	Altitude (m asl)	Global Radiation (kWh/yr)	Annual Rainfall (mm/yr)
Lusaka Int. Airport	1,154	1,921	850
Kasama	1,384	2,020	1,250
Mansa	1,258	1,980	1,150
Mfuwe	570	2,335	1,050
Ndola	1,270	1,905	1,250
Mongu	1,053	2,300	950
Livingstone	951	2,147	750

Source: Meteorological Department.

8.3.2 Solar Conversion Devices

Solar conversion devices are essentially of two types:

-solar thermal energy converters
-solar photovoltaic energy converters

Solar thermal energy converters include a wide range of apparatus, ranging from reflecting surface collectors to solar dryers. Reflecting surface collectors make use of direct solar beams in order to achieve high temperatures (200 to 650°C). Flatplate collectors comprise the wide scope of solar conversion devices which supply low-grade heat (from 40 to 150°C). Solar dryers consist of an enclosure, much like a greenhouse, and may or may not include an additional, external flat plate collector to increase thermal energy availability.

Solar photovoltaic (PV) energy converters have semi-conductor cells disposed in panels, which convert solar energy into direct-current electricity, at efficiencies of the order of 10%. The cost per kWh ranges between US$0.50 and US$0.80. PV electricity is therefore restricted to essential, low-power, remote applications (telecommunications, signalling, vaccine refrigeration, clinic lighting, etc.).

8.3.3 Existing solar energy applications

The Department of Mechanical Engineering at UNZA has assembled an experimental cooling device. Funding of K36,000 has been requested to carry out a research pilot project. The Ministry of Health has installed sanitary solar water heaters in a few mission hospitals. (Mission hospitals account for 100 out of 1,054 health institutions in the country). No private applications of solar energy are known to exist in Zambia.

8.4 Solar Water Heating

8.4.1 The Technology and its Potential Application

One of the potential applications of solar energy in Zambia is for water heating for urban households. A standard modular system could either be designed locally (e.g., at the University of Zambia) or preferably adapted from a standard already available in other countries (Israel, Colombia, etc.). A typical modular design for a family of 4 to 5 would comprise a $2m^2$ flat plate collector, a 150 liter storage tank, and piping to the washrooms and kitchen. The thermo-syphon principle should be applied to avoid the use of electrical pumps. Critical points are: (i) the choice of materials to avoid corrosion problems; and (ii) the disposition of elements and tubing dimensioning for the proper operation of the thermo-syphon concept. The converter could be manufactured in Zambia, using local materials, i.e., copper for the plate and tubing, cobalt for blackening of the absorption surface.

Urban households with water supply and significant hot water demand could potentially use such systems, although initial capital costs would limit affordability. In addition, the market could extend to the service sector in urban areas (hotels and hospitals), in which case larger central systems could be designed.

Under Zambian conditions, a typical household solar water heater should be capable of heating 150 liters of water daily to a temperature of 60°C. In case of overcast skies, lower temperatures of up to 40°C can be expected.

8.4.2 Financial and Economic Analysis

It is estimated that the annual cost of electric water heating for a family using 100 liters of water per day is K1,035 in early 1988 prices, and the cost of solar water heating is K835 (Appendix 8.1, Section A). Solar water heating is therefore financially viable in 1988 market conditions. If, as is recommended, electricity tariffs are raised, solar water hearing will become financially more attractive. However, solar water heating is not economic in a household with existing mains electricity supply because of the low marginal cost of electric energy. For this reason, solar water heaters should not be subsidized or promoted with public funds.

8.5 Solar Fish and Vegetable Drying

8.5.1 Potential of Fish Drying

Solar dryers have considerable potential application in the fishing sector. Fishing takes place all year round, making a fixed investment in this sector more attractive than in a seasonal activity. Major fisheries in the country produced the following quantities of fish in 1985 (Table 8.2).

Table 8.2: FISH CATCH, 1985
(Tons)

	REGION							
Season	(1)	(2)	(3)	(4)	(5)	(6)	(7)	Total
Jan-Apr	851	1,189	3,534	4,097	1,120	7,167	182	19,863
May-Aug	613	3,005	6,727	1,183	1,066	2,868	696	17,769
Sep-Dec	588	2,739	5,809	1,457	533	1,465	759	14,026
Total	2,052	6,933	16,070	6,737	2,719	11,500	1,637	51,658

Key: Region 1: Lake Kariba; Region 2: Kafue River; Region 3: Lake Bangweula; Region 4: Lake Mweru/Luapula River; Region 5: Lake Mweru/Wa-Ntipa; Region 6: Lake Tanganyika; Region 7: Lukanga Swamp

Source: Ministry of Agriculture and Water Development.

Fish is very important in the Zambian diet, being the main source of protein. Yearly per capita consumption averages 12.15 kg (wet) in the Lusaka area, 5.7 kg in the Copperbelt.

Most of the fish is sun-dried e.g., 99% of the catch from Lake Bangweulu, and some is smoked. Solar dryers would be superior because:

(a) with sun drying, 10 to 15% of catch is lost due to poor processing (too little drying, leading to decomposition, or too much drying, leading to breakage during transportation). The lost value is estimated at K10 million in 1987;

(b) solar driers improve the nutritional value and appearance of dried fish;

(c) wood for smoking is becoming scarce, and smoking produces a bitter taste; and

(d) the water quantity to be removed by drying is enormous, as the dry weight of most fish is 1/3 of their initial weight. Assuming 30,000 tons evaporation/annum, this leads to a thermal energy requirement for evaporation of 90TJ, or 25GWh.

8.5.2 Potential of Vegetable Drying

At least one farming cooperative has been successfully using a solar vegetable drier for the past seven years. The appearance of dried vegetables is substantially improved through solar drying, which has helped the cooperative to expand its market, including exports to Botswana.

8.5.3 Implementation

A project to introduce solar fish dryers on a trial basis is recommended. Project supervision should be allocated to the DOE, which would monitor the progress and adjust the strategy should performance be inadequate.

First, the most cost-effective design should be identified and tested at the laboratory level, presumably at the UNZA. It is not necessary to start from scratch; proven designs exist worldwide. Technical assistance for transferring know-how on parameter optimization in the design of fish solar dryers (e.g., Brace Research Institute, Montreal, Canada) is recommended, in the form of a one year expert technician.

Provincial Fisheries Officers (6) and Fisheries Development Officers (16) from the Fisheries Department should be involved at the early stages of product design. They could provide valuable feedback on materials and design selection. Pilot test runs in selected regions should be carried out under their supervision.

Fishermen's cooperatives are the most likely organizations for acquiring the technology and constructing solar dryers, with technical assistance from the extension service of the Fisheries Department.

Experience with the use of solar vegetable drying should also be assessed. If this suggests that the technology has potential, the UNZA could evaluate alternative designs in the laboratory and initiate pilot tests of the more efficient designs with selected farming cooperatives.

8.6 Long-Term Solar Potential

In time, the flat plate collector applied research group can fulfill more demanding design tasks on solar converting devices for manufacturing enterprises, such as concentrating collectors, photovoltaic collectors, and enter more specific markets, such as refrigeration, air cooling, water pumping, etc.

8.7 Wind Energy

With the relatively modest wind speeds in Zambia and the current state of windmill design, wind energy is unlikely to be economic for larger-scale water pumping for villages or agricultural irrigation. However, it may be appropriate for remote and small-scale water demands, i.e., for isolated habitations and small livestock herds. Only limited research on wind conditions and on windmill design is recommended to identify models most suitable for such applications in Zambian conditions.

8.7.1 Technical Potential

Existing data, which are less than adequate, suggests that average wind speeds are:

Kabwe	2.7 m/s	Lusaka	3.5 m/s
Kasama	2.5 m/s	Mongu	3.2 m/s
Livingstone	1.6 m/s	Ndola	2.3 m/s

Source: Meteorological Department.

In Central Province (Lusaka), the "windiest" region, the highest winds are recorded in September (4.2 m/s) and the lowest in January (2.0 m/s). This pattern tends to be general for the whole country. Due to the wind distribution about the mean, higher wind velocities are often reached during part of the day. Lusaka, for instance, exhibits speeds higher than 4 m/s during 10 hours per day for eight months per year, during daytime. The highest gust ever recorded was at 40 m/s.

Wind resource data currently available in Zambia are insufficient for a definitive evaluation of wind pumping potential. A one-year data measurement and analysis program is therefore recommended, involving multiple-station measurement, station characteristic recording, and statistical analysis.

8.7.2 Potential and Actual Application in Water Pumping

Humans require an average of 25 liters of water per person per day. Cattle consumption averages 40 liters/day. Crop irrigation requires up to 86,000 liters/ha/day, in the peak month of October. As less than 50% of the rural population has access to safe water, the technical scope for village water pumping systems is very large. Also, 79% of households engaged in agriculture are small subsistence farmers. In the event of drought, maize, the staple food, has to be imported. Simple, appropriate technology irrigation would enable a farmer to have two crops per year and lead the country to self-sufficiency. Not only maize but wheat would also greatly benefit from irrigation.

The relatively low-wind regimes in Zambia are not ideal, but do not totally exclude exploitation of the wind resource for this purpose. Multiblade slow moving windmills with high initial torque (as oppposed to high speed 1, 2, or 3-bladed wind electric generators) are technically suitable for water pumping or direct mechanical applications in Zambian wind conditions.

The Water Affairs Department of the Ministry of Agriculture and Water Development (MAWD) has installed about 100 windmills for water pumping, mainly in Central Province. Only a handful are still operating, due to lack of maintenance and spares. The equipment installed was generally high capacity (rotor diameters of 7.6 meters), high tower windmills. The TDAU has prepared the preliminary design of a small windmill for water pumping. Funds are being requested for building a prototype. Some private farms have successfully installed windmills for water pumping, which appear to render good service.

8.7.3 Financial Analysis

In village applications, wind power generally substitutes for human effort in drawing water. Whether or not it is financially viable depends on the value of labor time. For a typical 100-person, 50-cattle village, a borehole and windpump would cost K6.65/m^3 of water, compared to K2.25/m^3 for a borehole and handpump (Appendix 8.1, Section B). Use of the windpump would eliminate the need for 2.5 hours of handpump labor per day.

In larger-scale agricultural applications, such as crop irrigation, wind pumping is competing against diesel. Assuming a pumping load of 10,000 m^3/year, diesel pumping would cost K1.57/m^3 and wind pumping K2.31/m^3. The fact that the economic cost of diesel oil is an estimated 50% above its price would narrow the gap by about 20%. Windpumping is therefore only justified if the supply of diesel or repair of diesel equipment is unreliable.

8.8 Biogas

8.8.1 Technical Potential

In 1981, Zambia had 2,225,000 head of cattle, 370,000 sheep and goats, and 235,000 hogs.

The conversion of cattle manure into biogas has potential in the Zambian setting without putting too much effort into manure collection. Cattle are tended in the daytime by a member of the family, who keeps them out of the crop fields. At night, cattle are brought into kraals. Handling cow or pig dung does not pose any social problem in Zambia.

In a biogas digestor, methanisation of manure takes place in the absence of oxygen. Manure and water are introduced in equal quantities in the biodigestor, which then produces gas, due to the action of anaerobic bacteria. Temperature and constant composition of the feed are critical parameters for the correct operation of the biodigestor. In a continuous process, mixture is constantly fed into the biodigestor. Sludge comes out through the other end. Feed can be any organic material (dung, agricultural waste, etc.). The neutral sludge is an ideal fertilizer, free of odors and unattractive to flies, etc. The heat content of biogas is 20,000 to 28,000 KJ/m^3, as compared to 35,000 KJ/m^3 for natural gas.

There are two basic biogas digestor designs. One consists of a floating dome biogas holder, usually made of steel, which floats on the mixture. Often called the "Indian design", it has the advantage of maintaining constant gas pressure. The second consists of a fixed dome, usually made of bricks or concrete. This is sometimes referred to as the "Chinese design".

8.8.2 Current Applications

In Zambia, the NCSR has shown the most interest in biogas applications. It has developed a standard size 10-11 m^3 digestor, suitable for providing gas to three households for lighting and cooking. The digestor is fed weekly, after the initial feeding, with three pails of manure and five pails of water. No temperature problems affecting gasification have been encountered with the experimental units, where mean temperatures of 21.1°C in January and 16.1°C in July are to be found.

NCSR has also just completed the construction of a Chinese-type biogas digestor to compare with the Indian-type that it has used so far.

NCSR has recently installed a pilot biogas plant in a village in the Southern Province supplying energy to three households. Overall costs for the individual items were as follows:

Item	Cost (Kwacha)
Tank dome	11,000
Pit construction and materials	2,700
Steel plumbing over long distances	5,000
Total	18,700

Operating results of this plant are not yet available.

8.8.3 Financial Cost and Benefits

Assuming a conservative daily production rate of 1 m^3 and a yearly cost of K3,300 (annuity with interest 12% over 10 years) the cubic meter cost of biogas is K9.00 or K0.36/MJ. Diesel oil costs K0.08/MJ. Based on these estimates, biogas technology does not appear to be financially or economically competitive in Zambia. However, this conclusion should be reassessed in the light of experience with the field trials currently underway.

8.8.4 Recommendations

Biogas is the only source of renewable energy which can reach high cooking temperatures and which can easily be converted into motive power and electricity. The technology should therefore not be totally discarded. However, work should be limited to monitoring developments elsewhere, and to pilot testing by the inter-organization research team established by the NCSR for this purpose.

8.9 Geothermal Energy

The Government, through the Geological Survey, and with a grant from the Government of Italy, have embarked on a pilot scheme of geothermal resource utilization for electricity generation. The stated criteria for development of the resource are: (a) presence of suitable geothermal resources; (b) proximity to reasonably large population centers; and (c) isolation from the national electric grid.

The pilot scheme which is presently being developed is a low temperature (88°C-95°C) fresh water resource. The area is located on the southern tip of Lake Tanganyika on Kasaba Bay. It has a population of about 50,000, a thriving fishing and tourist industry and some cattle ranching.

Two small (500 kW) generators have been supplied by Italy and will be installed in 1988. The turbines will be of the binary type, which utilize a secondary fluid with a fairly low boiling point to extract enthalpy from the geothermal fluid.

Italian aid has also funded a national geothermal resource survey. If the pilot generation scheme is technically successful, and the survey identifies other promising sites, a small number should be selected for detailed cost/benefit analysis. The principal selection criteria should be: (a) resource availability and cost; (b) potential electricity demand; and (c) remoteness from the grid. The cost-benefit analysis will involve determining whether geothermal electricity is economically and financially viable and cost-effective compared to diesel generation.

If the cost/benefit analysis appears to justify the development of further geothermal generation plants, the Ministry of Power, Transport and Communications and ZESCO should be involved in the investment decision. To ensure effective operation and maintenance, ZESCO might also be asked to take responsibility for the plants' operation and upkeep.

IX. CONSERVATION AND SUBSTITUTION OF CONVENTIONAL FUELS

9.1 Policy Issues and Options

Experience in other countries has convincingly demonstrated that resources spent on energy conservation and substitution often produce a higher return than expenditure on expanding the supply of energy. The objective of energy conservation and substitution policy and planning is to identify the opportunities to take these high return actions, and to take steps to ensure that they are implemented.

Appropriate energy pricing is the most important factor in ensuring that consumers make the correct decisions as to what forms of energy and how much energy to use. That is why each fuel chapter of the energy strategy has recommended energy prices that reflect the financial and economic cost of the fuels concerned.

In addition to pricing, there are other actions that the authorities can take to promote efficient energy choice and use. These include: (a) the provision of foreign exchange for energy measurement or control devices, or for new equipment that uses a lower cost fuel; (b) assistance in the conduct of energy audits to identify energy conservation and substitution opportunities; and (c) training to energy managers and operatives in energy management techniques.

It is logical to concentrate these efforts on the users of the highest cost fuels. In Zambia, the highest cost fuels, both financially and economically, are imported petroleum products. These are also the fuels with the highest foreign exchange content. The last two columns of Table 9.1 compare the 1988 market prices of the two most heavily-used industrial process fuels, light fuel oil (LFO) and gasoil/diesel, with the prices of coal and electricity, allowing for typical efficiencies in use. For a large industrial user, coal was 31% of the cost of LFO and 25% of the cost of diesel; electricity (D3 tariff) was 44% of the cost of LFO and 35% of the cost of diesel.

The major users of petroleum fuels, and hence the appropriate targets for energy conservation and substitution efforts, can be identified from the Energy Balance (Table 3.2). Road transport is by far the largest user, accounting for 56% of petroleum product consumption, followed by ZCCM (mining) 28%, and industry and commerce (12%).

This chapter deals first with the scope for energy substitution then with the scope for energy conservation.

Table 9.1: FINANCIAL COST OF ENERGY FROM VARIOUS FUEL SOURCES COMPARED ON THE BASIS OF THERMAL VALUE, AT REPRESENTATIVE EFFICIENCY OF USE AND AT PRICES AS OF JAUNUARY 1988

Fuel	Price Per Unit (Kwacha)	Unit	Gross Heat Equivalent Per Unit	End User Cost Per Unit-Gross	Typical Efficiency of use	Cost Per Net Heat Energy Produced	Fraction of LFO Cost	Fraction of Diesel Cost
			(MJ)	(K/GJ)	(%)	(K/GJ)		
Ton (ex ref.)	1,060.00	Ton	40,950	25.89	0.80	32.36		
LIGHT FUEL OIL								
Litre Retail	1.720	Litre	38.3	44.91	0.80	56.14	1.00	0.81
Ton (ex ref.)	885.00	Ton	40,820	21.68	0.75	28.91		
HEAVY FUEL OIL								
Litre Retail	1.20	Litre	38.7	30.98	0.75	41.30	0.74	0.59
Ton (ex ref.)	1,487.50	Ton	42,750	34.80	0.80	43.49		
GASOIL/DIESEL								
Litre Retail	2.02	Litre	36.3	55.58	0.80	69.47	1.24	1.00
KEROSENE	1.53	Litre	34.5	44.35	0.80	55.43	0.99	0.80
COAL	325.00	Ton	25,000	13.00	0.75	17.33	0.31	0.25
LPG	1,125.00	Ton	45,430	24.76	0.80	30.95	0.55	0.45
ELECTRICITY								
D3 Marginal a/	0.0403	kWh	3.6	11.19	0.95	11.78	0.21	0.17
D3 Average (60% LF) b/	0.0842	kWh	3.6	23.40	0.95	24.63	0.44	0.35
D2 Marginal	0.0613	kWh	3.6	17.03	0.95	17.92	0.32	0.26
D2 Average (60% LF)	0.1101	kWh	3.6	30.59	0.95	32.20	0.57	0.46
ZCCM Marginal	0.0085	kWh	3.6	2.36	0.95	2.49	0.04	0.04
ZCCM Average (85% LF)	0.0392	kWh	3.6	10.89	0.95	11.46	0.20	0.16

a/ Marginal prices do not include the effect of demand kVa on the bill but do include 15% government tax.

b/ Average prices include the impact of demand calculated for a 60 % load factor, 75% power factor, a fixed charge of K17,225, and demand charge of K13.81/kVA/month; and K1,722.50 fixed charge and K11.80/kVA/month for the D3 and D2 rates, respectively, as well as 15% tax.

Retail price includes Government duty and K150/Ton delivery.

9.2 Fuel Substitution in the Copper Industry

9.2.1 Technical Scope

Major ZCCM consumers of petroleum products and their maximum requirements are listed in Table 9.2.

Table 9.2: MAJOR ZCCM PETROLEUM PRODUCT CONSUMERS

Consumer	Annual Petroleum Consumption
1. Nchanga Open Pit	46 million liters diesel in 1988-89, falling to 24 million litres in 1998-99
2. ZCCM underground mines	Approx. 16 million liters of diesel
3. Ndola Lime	25,000 tons HFO in lime kilns
4. Mufulira smelter	19,000 tons HFO in furnaces and driers
5. Kabwe	8,500 tons HFO in furnaces, through 1993
6. Nkana smelter	18,000 tons HFO in furnaces and 18,000 tons HFO in wirebar production.

Source: ZCCM.

Petroleum product substitution possibilities in ZCCM are technically constrained. For quality reasons, Ndola Lime and the Nkana wirebar furnace must continue using HFO. The Kabwe plant has a maximum life of five years, which precludes consideration of substitution there. Mufulira smelter could convert from 19,000 tons of HFO to 30,000 tons of coal/year by the installation of coal grinding and handling plant, but at a capital cost of about K100 million. Nkana smelter could reduce HFO use by 18,000 tons/year and increase coal consumption by 29,000 tons/year by investment of K16 million on improved coal storage and handling facilities, provided the proposed new oxy-fuel smelting technology can be adapted to use coal.

Technically, the ZCCM underground mines could further substitute diesel with electric powered load-haul-dump units, cutting their consumption of diesel by up to 75%. This would need to be implemented gradually over 5-10 years, and would involve virtually no net capital expenditure, beyond normal vehicle replacement. However, there would be operator resistance to this change, due to the lesser convenience of electric vehicles. Recommended higher diesel oil prices would increase the substitution incentive and return.

Nchanga open pit could reduce diesel consumption by up to 10% by implementing a third stage electric trolley assist. Capital costs and fuel cost savings have not been studied in detail, mainly because of the pit's limited (10-year) life.

9.2.2 Financial Analysis

Substitution of coal for HFO at Mufulira would require capital investment of K100 million and yield annual fuel cost savings of K6.0 million (assuming 1 ton HFO = 1.6 tons coal, and prices/ton delivered of K1260 for HFO and K590 for coal). The future of Mufulira smelter beyond 10 years is questionable. Hence this investment is not justified on financial grounds.

Substitution of coal for HFO at the Nkana smelter would yield annual fuel cost savings of K5.69 million for an estimated investment of K16 million. 8/ Reducing the annual saving to K4 million, to allow for extra handling costs of coal, and discounting at 12%, this project shows a NPV of K6.63 million over a 10-year life. Its implementation is recommended.

9.3 Fuel Substitution in Industry and Commerce

The Department of Energy's industrial energy audit program has begun to examine the scope for the substitution of low cost indigenous fuels for imported petroleum products in industry and commerce. The focus of this work is on the scope for substituting diesel or LFO with electricity and coal.

Nine facilities that currently use diesel boilers or ovens provided information from which the financial costs and benefits of electricity substitution were estimated. Of the nine installations, it was estimated that six could achieve a payback of less than five years from electric boiler/furnace substitution. In the other four cases, payback was longer, due to relatively low fuel consumption. The results of this analysis are summarized in Table 9.3.

Ten facilities provided information on light fuel oil substitution potential. From this, it was estimated that five of the ten could realize paybacks of five years or less from electriticity substitution. The results of the analysis are shown in Table 9.4.

8/ This low cost assumes relocating existing equipment from another site.

Table 9.3: FUEL SUBSTITUTION POTENTIAL IN COMPANIES WITH DIESEL FIRED BOILERS/FURNACES

Company	LOC	Installed Capacity	Annual Fuel Consumption	Annl Fuel Costs	Equivalent Elec Boiler Capacity a/	Apprx Annl Energy Cost of Elec	Apprx Invest in New Plant b/	Annl Fuel Savings	Annl Fuel Cost Savings	Pay-Back Period
		(KG/HR)	(Liters)	(Kwacha)	(kW)	(Kwacha)	(Kwacha)	(Liters)	(Kwacha)	(Years)
Dairy Produce Board	Lus	2,000	300,000	605,550	1,471	211,943	788,235	195,000	393,608	2
Bonar Colwyn Textiles	Ndo	227	24,500	49,453	167	17,309	89,465	15,925	32,145	3
Copper Harvest Foods	Ndo	1,000	360,000	726,660	735	254,331	394,118	234,000	472,329	1
Gamma Pharmaceuticals	Ndo	1,200	20,650	41,682	882	14,589	472,941	13,423	27,093	17
Lyons Brooke Bond	Ndo	1,800	255,500	515,727	1,324	180,504	709,418	166,075	335,222	2
Monterey Printing	Ndo	3,100	192,000	387,552	2,279	135,643	1,221,765	124,800	251,909	5
Supa Baking	Lus	2,000	260,000	524,810	1,471	183,684	788,235	169,000	341,127	2
Piggot Maskew	Kit	4,490	198,037	399,738	3,301	139,908	1,769,588	128,724	259,829	7
Zambia Pork Products	Lus	2,500	28,156	56,833	1,838	19,892	985,294	18,301	36,941	27
Total		18,317	1,638,843	3,308,005	13,468	1,157,802	7,219,053	1,065,248	2,150,203	3

Notes: a/ The equivalent electrode boiler installed capacity is calculated on the basis of a feedwater temperature of 66°C and a pressure of 10 Bars, which results in a steam production of 1.3 kg/hr per kW consumed.

b/ The approximate investment cost is based on one supplier's quotation of US$66/kW.

Source: Department of Energy.

Table 9.4: FUEL SUBSTITUTION SAVINGS IN COMPANIES WITH HFO/LFO FIRED BOILERS/FURNACES

Company	LOC	Installed Capacity	Annual Fuel Consumption	Annl Fuel Costs	Equivalent Elec Boiler Capacity	Apprx Annl Energy Cost of Elec	Apprx Invest in New Plant	Annl Fuel Savings	Annl Fuel Cost Savings	Pay-Back Period
		(KG/HR)	(Liters)	(Kwacha)	(kW)	(Kwacha)	(Kwacha)	(Liters)	(Kwacha)	(Years)
Speciality Food	Lus	4,500	163,429	224,878	3,309	98,946	1,773,529	73,216	125,932	14
Zambia Breweries	Ndo	12,500	1,838,226	3,161,749	9,191	1,391,169	4,926,471	1,029,407	1,770,579	3
Ndola Knitting	Ndo	4,500	90,568	155,777	3,285	68,542	1,760,584	50,718	87,235	20
Mukuba Textiles	Ndo	2,200	133,730	230,016	1,618	101,207	867,059	74,889	128,809	7
Swarp Spinning	Ndo	3,200	365,000	627,800	2,353	276,232	1,261,176	204,400	351,568	4
Zambezi Paper	Ndo	12,000	694,045	1,193,757	8,824	525,253	4,729,412	388,665	668,504	7
Zambia Pork Prods.	Lus	4,500	93,388	281,098	3,309	123,683	1,773,529	91,520	157,415	11
Dairy Produce Bd.	Lus	5,200	475,000	817,000	3,824	359,480	2,049,412	266,000	457,520	4
Mulungushi Textiles	Kab	12,500	2,224,665	3,826,423	9,191	1,683,626	4,926,471	1,245,812	2,142,797	2
Kafironda Limited	Muf	7,700	1,116,650	1,920,638	5,662	845,081	3,034,706	635,324	1,075,557	3
Total		68,800	7,194,700	12,439,135	50,564	5,473,220	27,102,349	4,049,951	6,965,916	4

Notes: See Table 9.3

Source: Department of Energy.

One important caveat concerning the results is that they did not take account of any investment required in new electricity supply facilities to handle the plants' increased power requirements. Where such investment is required, it could substantially raise the projects' capital cost, and hence increase the pay-back period.

Nevertheless, from the results of the study, it is likely that a number of substitutions would prove financially viable, resulting in substantial import fuel savings and increased electricity demand. The example of a recent electric boiler substitution at Kafue Textiles illustrates one such case. The cost of the new electric boiler, transformer, cables, switchgear and their installation totalled K9.0 million (US$1.1 million) in 1986. As a result of the investment, annual energy costs have been reduced by K6.9 million (US$869,000), giving a pay-back of 1.3 years. Other large users of process diesel and LFO could potentially achieve similar results. Higher electricity tariffs, which are needed to cover ZESCO's financial costs, will reduce the benefit of electricity substitution. In the case of diesel plant, this will be partially offset by the recommended higher diesel prices.

9.4 Energy Conservation in the Copper Mining Industry

ZCCM, which is responsible for all major mining operations other than coal, is a major user of diesel oil, primarily for moving waste materials and ore-bearing rock in its open-cast and underground mines. It is also a substantial user of fuel oil in its smelting, lime and wire bar operations.

ZCCM is a sophisticated enterprise, which has access to considerable engineering skills and investment resources. The company's energy management efforts are therefore of a high standard, relative to those of other Zambian energy users.

ZCCM is acutely conscious of the high cost of its diesel consumption, and is taking steps to rationalize the number of diesel vehicles in use and trips made. The fleet is relatively modern and energy efficient.

There is little scope for further improvement in the efficiency of ZCCM fuel oil use, although there is scope for substitution of coal for fuel oil and electricity for diesel, as discussed above.

9.5 Energy Conservation in Industry and Commerce

There are fewer than 60 significant petroleum fuel consuming industrial companies and commercial institutions in Zambia (i.e., with boilers over 1 ton/hour capacity) and an estimated 67 significant industrial and institutional users of coal and electricity (Table 9.5).

Table 9.5: INSTALLED INDUSTRIAL PROCESS HEATING UNITS

Geographical Area/Operator	Diesel Facilities	Diesel Units	LFO/HFO Facilities	LFO/HFO Units	Coal Facilities	Coal Units	Electricity Facilities	Electricity Units
Lusaka Area	9	11	15	25	12	21	19	29
Copperbelt	19	28	10	19	25	46	11	19
Govt. of Zambia	5	11	0	0	n.a.	n.a.	1	3
TOTAL	33	50	25	44	37	67	31	51

Source: Department of Energy.

As of March 1988, six industrial plants had been subject to detailed audit under the Department of Energy's industrial energy audit program--Zambia Breweries, Dairy Produce Board, Kapiri Glass Products, Kafironda (explosives), Zambia Pork Products, and Premium Oils. Preliminary discussions of energy conservation potential had been held with a further 30 plants.

A summary of the pattern of energy use and the estimated potential for energy conservation savings from the six audited plants is presented in Table 9.6. Total potential energy conservation savings identified at the six plants were K3.4 million (US$419,000) annually, an average of 18% of total annual energy costs.

The major deficiencies found in energy practices were:

(a) oversized energy using and heat producing systems;

(b) failure to trim energy requirements of combustion systems or process equipment in proportion to reduced production;

(c) failure to attend to regular maintenance (a "breakdown" philosophy);

(d) lack of energy management awareness and information systems; and

(e) lack of understanding of actions that can reduce energy waste.

Many of the potential improvements could be achieved at little or no cost. However, total investment of K2.6 million (US$330,000) shown as "Cost of Energy Savings" at the foot of Table 9.6, will be necessary at the six plants to achieve the full savings. All the investments have a pay-back of less than two years.

Table 9.6: SUMMARY OF ENERGY SAVING OPPORTUNITIES AT SIX AUDITED PLANTS

Item	Plant					
	Zambia Breweries	Dairy Produce Board	Kapiri Glass Products	Kafironda Explosive	Premium Oils	Zambia Pork Products
Electricity						
Demand (kVA)	1,800	390	3,060	1,000	1,334	300
Consumption (MWh)	6,322	2,098	20,500	4,500	5,215	1,234
Annual Cost (K '000)	777	400	1,560	490	665	156
Coal						
Consumption (Tons)	7,380	0	20	0	7,259	0
Annual Cost (K '000)	2,399	0	7	0	2,613	0
Light/Heavy Fuel Oil						
Consumption (Tons)	0	503	2,908	1,382	0	109
Annual Cost (K '000)	0	818	3,609	2,033	0	161
Process Diesel						
Consumption (Tons)	0	0	0	590	0	34
Annual Cost (K '000)	0	0	0	1,074	0	49
Process LPG						
Consumption (Tons)	0	0	927	0	0	0
Annual Cost (K '000)	0	0	1,515	0	0	0
Total Energy (GJ)						
TOTAL ENERGY COST (K '000)	3,176	1,218	6,691	3,597	3,278	365
ENERGY COST SAVINGS (K '000)	450	230	450	1,200	1,000	25
PERCENT SAVINGS	14	19	7	33	31	7
ANNUAL FOREX SAVINGS (US$)	56,250	28,750	56,250	150,000	125,000	3,125
COST OF ENERGY SAVINGS (K '000)	50	250	840	1,300	0	0
COST OF ENERGY SAVINGS (US$)	6,250	31,250	105,000	162,500	0	0

Source: Department of Energy.

An outstanding example of the potential benefits of the industrial energy audit program is afforded by Kapiri Glass Products, one of the six plants audited. Between 1986, the year of the energy audit, and 1987, glass production rose by nearly 50% but total energy cost actually fell by 22%. Specific energy cost per ton of output improved by 48% in only one year (Table 9.7).

Although it is impossible to generalize accurately from such a small sample, the results of the six energy audits suggest there is considerable potential for industrial energy conservation cost savings. If the 18% potential savings of the six sample plants are typical, these savings could be worth over US$1 million per year.

Unfortunately, there are significant technical and financial barriers to the realization of this potential, in particular:

(a) a lack of technical awareness among managers and supervisors about maintenance practices and how to improve systems performance; and

(b) an acute shortage of foreign exchange and high duties on imported inputs which limit purchases of energy monitoring and control equipment.

An aggressive energy conservation program is therefore recommended to overcome these barriers.

9.6 Energy Conservation at NCZ and Chilanga Cement

The Department of Energy has maintained close contact with the two companies which are Zambia's biggest industrial consumers of energy after ZCCM, namely NCZ and Chilanga Cement. Each of these has developed an energy conservation program.

NCZ has identified 10 conservation projects, with an estimated cost of K17.2 million, estimated to yield annual savings totalling K24.48 million. Prima facie, not all these proposals appear viable, but they give an indication of the scope for high-return conservation measures in a sizeable industrial plant. NCZ has already implemented a project to replace fuel oil-fired boilers with low grade coal-fired boilers.

Chilanga Cement has already achieved substantial energy savings and forsees the possibility of further large savings in the future. The savings already achieved by Chilanga Cement in the past nine years include:

(a) reduction of coal consumption at its Chilanga plant by 16% by the installation of new gas analysis equipment, the refurbishing of electrofilters and improving kiln run factors and operation;

Table 9.7: KAPIRI GLASS PRODUCTS PLANT
ANALYSIS OF COMPARATIVE ENERGY PERFORMANCE, 1986 AND 1987

	1986	1987	% CHANGE FROM 1986 to 1987
ELECTRICITY (kWh)	20,449,004	18,327,947	(10.37)
FUEL OIL (Tons)	2,907	1,974	(32.09)
LPG (Tons)	927	490	(47.16)
TOTAL ENERGY (Gigajoules)	243,859	174,559	(28.42)
PRODUCTION (Tons)	8,569	12,834	49.77
SPECIFIC ENERGY (GJ/Ton)	29	14	(52.28)
TOTAL ENERGY COST (Kwacha)	6,311,383	4,932,417	(21.85)
SPECIFIC ENERGY COST (Kwacha/Ton)	737	384	(47.82)

Source: Department of Energy.

(b) reduction of coal consumption at the company's Ndola plant by 23% by rehabilitation measures; and

(c) reduction of diesel consumption at the Ndola plant to 50% of its 1980-81 level by a number of technical improvements and the introduction of a coal-fired furnace.

For the future, the possibility is forseen to reduce coal consumption further by on-site investigative/training work by supplier specialists and the installation of modern fuel control systems. Such measures might save between 7,000 and 10,000 tons of coal annually, at a saving of between K3.9 and K5.6 million, according to the company's estimates made in November 1987. Another project is under study at the Chilanga works to install a high efficiency separator, which would reduce electrical energy consumption by 30%.

9.7 Recommendations on Energy Substitution and Conservation in Industry

An aggressive program of action is needed to identify and realize the potential energy savings from conservation and substitution measures in mining, industry and commerce. Action is proposed under three heads: (a) policy; (b) technical assistance; and (c) investment financing.

9.7.1 Policy

The major objectives of energy conservation and substitution policy are to give the right incentives and correct information to fuel users so that they make efficient energy choices and decisions.

Of critical importance is appropriate energy pricing. To ensure optimal energy use, prices should be set at a level that both covers financial costs and reflects economic costs. Moreover, the structure of fuel prices should be similar to their economic cost structure, so as to give the right incentives for fuel choice. The major energy price recommendations of this report are to: (a) raise the price of diesel oil to reflect its economic cost, based on an appropriate shadow value for the Kwacha; and (b) raise average electricity tariffs to cover ZESCO's financial costs of supply.

Other policy measures that should be considered to encourage efficient energy use are:

(a) provision of guidelines to new investors on the comparative cost of alternative fuels, and encouragement to consider electricity and coal ahead of petroleum products;

(b) compulsory energy audits for all industrial petroleum fuel users with boilers of more than 1 ton/hour capacity, charged at 50% of the cost of the audit; and

(c) financial and economic appraisal of the energy implications of major new industrial projects by the Department of Energy.

9.7.2 Technical Assistance

To identify the full potential for energy conservation and substitution measures in industry and commerce and to bring a package of high return investments to prefeasibility status, ready for feasibility analysis and presentation to potential donors, a program of energy conservation and substitution technical assistance to the Department of Energy is recommended. This would complement and strengthen the conservation/substitution activity already undertaken by DOE staff. About 2 man-years of consultant technical assistance would be required, at a total cost of about US$300,000, including salaries and expenses. This would finance: (a) extension of the on-going energy audit program to all major industrial and commercial users of petroleum products; (b) training of plant engineers in energy management techniques; and (c) preparation of a comprehensive prefeasibility report on energy conservation and substitution potential.

9.7.3 Investment

The size of the priority energy conservation and substitution investment program that would emerge from the recommended technical assistance project is impossible to predict. However, if electricity substitution is found to be viable in only 25% of the larger diesel and LFO users, the priority electricity substitution investment program could be in the range of US$10-15 million and produce savings of about US$2-3 million/year in reduced imports of petroleum fuels. In addition, it is probable that the analysis would identify and confirm options for coal substitution. This could result in another US$5 million of investment and US$2-3 million in savings. High return energy conservation investments could be of a similar magnitude, say about US$5 million, and result in a further US$2-3 million in imported energy savings.

Such an investment package, in the range of US$20-25 million and with annual benefits of US$6-9 million, should prove very attractive to a multilateral or bilateral donor. The foreign exchange resources could then be on-lent by the Government to industrialists for approved conservation or substitution projects.

9.8 Energy Conservation in Road Transport

Although the road transport sector is by far the largest user of petroleum fuels, no systematic effort has been made to explore the scope for improving the efficiency with which energy is used in this sector. In part, this is because the task of improving transport energy efficiency is extremely difficult. Demand for transport is highly inelastic and there are few effective substitutes for petroleum fuels for most transport purposes. The range of effective policy measures is therefore limited, and their impact uncertain. The preliminary analysis in this section explores some of the main potential areas for policy action, including transport fuel pricing and taxation, road maintenance and vehicle maintenance and repair. It also presents some tentative recommendations for action.

9.8.1 Level and Distribution of Fuel Consumption in Transport

302 million liters of diesel and gasoline were consumed in the road transport sector in 1986, of which 177 million liters were diesel oil and 125 million liters were gasoline. Fuel use by different type and size of vehicle was estimated from the number of vehicles of each type on the road and the average fuel consumption of each type of vehicle. The number of vehicles in operation was estimated from data on new registrations and assumptions about the average life of different types of vehicle. The results are shown in Table 9.8.

Table 9.8: ESTIMATED FUEL CONSUMPTION BY TYPE OF VEHICLE, 1986
(million liters)

	Gasoline	Diesel
Cars	39	2
Vans	46	13
Trucks	9	157
Buses	31	5
TOTAL	125	177

Source: Department of Energy.

The above figures give a general picture of fuel use and suggest a number of special features of the Zambian transport sector. In particular, it is worth noting that a number of private cars use diesel, probably to take advantage of low prices, and many of the vans are diesel engined, presumably for the same reason. The high proportion of gasoline use in buses is probably a reflection of their age.

9.8.2 Transport Fuel Pricing and Taxation

Appropriate pricing of transport fuels is the single most important measure to promote efficient fuel choices and consumption decisions by transport energy users.

(a) Fuel Prices and Excise Duty Rates

The composition of fuel prices, from wholesale to retail pump sales, is shown in Table 9.9. In 1988, the wholesale price of premium gasoline was 57% higher than that of diesel, and regular gasoline, 40% higher.

Table 9.9: LEVEL AND COMPOSITION OF TRANSPORT FUEL PRICES, LUSAKA 1988
(Kwacha per liter)

Price Component	Fuel Type		
	Premium	Regular	Diesel
Wholesale price	2.120	1.930	1.350
Excise Duty	0.636	0.579	0.378
Terminal fee	0.007	0.007	0.007
Transport	0.205	0.205	0.205
Oil Company margin	0.178	0.163	0.116
Dealer's margin	0.194	0.175	0.123
Retail Price	3.34	3.06	2.18

Source: ZIMCO.

Because diesel oil is considered to be a crucial input to transport, mining and agriculture, its wholesale price, which is subject to approval by the Government, has been kept well below that of premium and regular gasoline. This price discrimination in favour of diesel is further enhanced by the effects of the excise duty. In Kwacha per liter, the excise duty is 68% higher for premium gasoline than for diesel and 53% higher for regular gasoline than for diesel. In 1988, gasoline is relatively more highly taxed than it was in 1985, when the proportions were 31% and 19% (Table 9.10).

Table 9.10: EXCISE DUTY ON GASOLINE AND DIESEL OIL

KWACHA PER LITER	1985	Feb 1986	Jan 1987	Aug 1987
Premium	0.42	0.45	0.59	0.636
Regular	0.38	0.41	0.54	0.579
Diesel Oil	0.32	0.33	0.35	0.378
RELATIVE TO DIESEL (%)				
Premium	131	136	169	168
Regular	119	124	154	153
Diesel Oil	100	100	100	100

Source: ZIMCO.

In Chapter 5, it is recommended that the prices of white petroleum products be aligned more closely with their economic costs. This requires that the price of diesel oil be raised, with the objective, in respect of automotive diesel, of promoting its conservation in use. In other countries, gasoline is typically priced at no more than 25% above diesel oil, so that the customer (user) is neutral in choice of fuel.

(b) International Price Comparisons

The prices of transport fuels in Zambia are low not only relative to economic cost, they are also low compared to those of neighboring countries (Table 9.11).

Table 9.11: COMPARATIVE INTERNATIONAL FUEL PRICES, FEBRUARY 1987
(Zambian Kwacha per liter)

	Fuel		
Country	Premium	Regular	Diesel
Zambia	3.06	2.80	1.96
Zimbabwe	-	5.51	3.02
Malawi	-	5.07	4.36
Kenya	4.37	4.09	2.73

Source: ZIMCO.

This decision to keep fuel prices low, relative to those in other neighbouring countries, induces a relatively larger volume of transport energy demand in Zambia than is considered affordable elsewhere in the region. It may also promote attempts to trade fuel purchased cheaply in Zambia to users in neighboring countries, for instance from heavy vehicles in cross-border transport.

9.8.3 Road Maintenance Expenditures and Policies

The Zambian road network consists of 17% bitumen roads, 23% gravel roads and 60% unclassified--mainly earthen tracks. A recent examination of the state of the trunk road network covered 38% of the bitumen roads, a total of 2,375 km, all of which were primary arterial routes, carrying substantial amounts of international transit traffic. The study showed that 14% of the most important roads in Zambia are of an unacceptable standard, and more than 40% are of poor or lower standards, measured by the roughness of the surface. There can be little doubt that improved standards of road construction and maintenance would have a significant impact on improving energy efficiency in road transport.

Whilst there is no justification for a one-to-one ratio between Government expenditures on the roads and the taxes which it collects from road users, it is of interest to note that, whereas the Road Department's capital and recurrent budget in 1986 totalled K105 million, the Government's revenues from the excise taxes on gasoline and diesel amounted to only K113 million, barely covering these costs and making virtually no net contribution to public revenue. Of course, there were other taxes and duties on transport vehicles, but these are not very significant. Higher fuel excise duties should be considered to finance a more effective road maintenance program and to reduce the budget deficit, while simultaneously encouraging energy conservation.

9.8.4 Condition of the Vehicle Fleet

Large parts of the vehicle fleet in Zambia are in poor condition, due to lack of maintenance, excessive use, overloading, and rugged driving conditions. Surveys show that private cars, on average, are driven about 40,000 km annually in Zambia, more than twice the average distance travelled in Europe. This reflects the ongoing effort to satisfy increasing transport demand with an insufficient and declining number of vehicles.

New vehicle registrations fell by 65% in the ten years of the period 1974 to 1984, from 14,000 to 5,000 per year. Spare parts for cars are expensive and scarce, limited by the scarcity of foreign exchange. Tires and inner-tubes, which are produced locally, tend to be of poor quality.

The vehicle fleet's age and state of repair affect consumption of both fuel and lubricants. Excessive fuel use may also originate from improperly regulated ignition and insufficient pneumatic pressure in tires. As fuel itself is not scarce, car owners may tend to trade repair and spare parts costs off against fuel costs.

In theory, vehicles that are more than five years old are required to be inspected at least every year. This provides a check against poor running condition and excessive fuel consumption. However, lack of capacity at the Road Traffic Commissioner has rendered efficient inspection difficult. The Prevention Maintenance Section at the Government's Mechanical Services Department is not in operation, which has severely affected the state of repair of official vehicles. Both these organizations should be functioning properly to ensure adequate vehicle maintenance and fuel efficiency.

9.8.5 Possible Steps to Raise the Efficiency of Energy Use in Transport

In addition to an increase in diesel prices and excise duty, and other measures discussed above, the following additional possibilities should be considered to conserve energy use in road transport:

(a) Minimum Standards of Fuel Efficiency for Imported Vehicles

A minimum of fuel efficiency could be mandated for all new imported vehicles.

(b) Driver Training

Formal driver training should be implemented by transport companies with special emphasis on:

- energy efficient speed levels;
- smooth acceleration;
- no idling; and
- detecting and mending minor faults.

(c) Transport Information System

Route planning should be undertaken to avoid empty runs and an information system could be established whereby transport users could find excess return transport capacity.

(d) Speed Limits

Speed limits could be introduced on all roads outside built-up areas, for example 100 km/hour. This would be both a safety and an energy saving measure.

(e) Bicyles

The use of bicyles could be promoted through advertizing campaigns, separate cycle tracks, and more efficient production of domestic bicyles.

(f) Transfer of goods and passengers from road to rail transport

Rail is generally a more energy efficient means of transport than road for large quantities of goods over medium to long distances. This and other factors explain why road haulage rates are 70% higher than rail rates per ton-kilometre. Unfortunately, Zambian Railways has serious efficiency problems and shortages of locomotives and wagons, resulting in erratic deliveries and slow services. Attempts at increasing rail traffic will not be successful until these have been solved. Addressing them should be a priority.

X. ENERGY PLANNING SYSTEMS AND INSTITUTIONAL CAPABILITIES

Sound economic and technical choices between energy policy options and investments and effective coordination between government, parastatal companies and the private sector in the design and implementation of energy programs are essential for efficient energy supply and use. This Chapter outlines the steps recommended to strengthen energy policy and planning systems in order to achieve these results.

10.1 Energy Institutions and Current Planning Systems

The Department of Energy in the Ministry of Power, Transport and Communications (DOE) has the primary role in energy planning and policy formulation. With the assistance of the National Commission for Development Planning (NCDP) and the other ministries and departments concerned with energy, it is responsible for preparing the Energy Chapter of the Governmment's five-year National Development Plan. It advises on the choice of publicy-funded energy projects for inclusion in the Plan, and works to obtain donor funding for them. It also conducts practical analysis to identify opportunities for energy conservation and substitution and for cost-effective application of renewable energy technologies. Presently, it is involved in a large-scale study of the options for improving the supply and use of household energy. The DOE has a professional staff of six as well as two technical assistance advisers, both of whom are working in the area of household energy. In the past, it has also received technical assistance in the areas of energy conservation/substitution and energy planning.

The DOE's work in preparing the five-year energy development plan is guided by the Energy Development Committee, which is representative of all the major ministries and public organizations concerned with energy. In addition to the DOE, the Committee members include the Ministry of Mines, the Forestry Department of the Ministry of Lands and Natural Resources, the NCDP, the National Council for Scientific Research (NCSR), Zambia Electricity Supply Corporation Limited (ZESCO), and Zambia Industrial and Mining Corporation Limited (ZIMCO). Although the committee's continuation to oversee implementation of the plan was recommended in the original Fourth National Development Plan, this recommendation was not followed. However, in 1988, the Comittee was reconstituted to oversee preparation of the revised Fourth National Development Plan.

A second Ministry with important energy planning responsibilities is the Ministry of Mines. This has overall responsibility for Maamba Collieries, for the Hydrocarbon Unit, which coordinates oil exploration, and for Zambia Consolidated Copper Mines Limited (ZCCM), the largest energy user. The Ministry of Lands and Natural Resources is responsible for forestry policy and its implementation, and therefore has a major role to play in the key issue of woodfuel supply. Other ministries, such as the Ministry of Commerce and Industry, which has oversight responsibility for the ZIMCO industrial companies, have a less direct role in energy policy formulation.

ZIMCO itself is a key institution in the energy sector. It is the parastatal holding company for all the large suppliers and users of energy. In effect, it has responsibility for implementing most of the energy investment and policy decisions of the Government. It is also responsible for implementing investments in energy-using industries whose actions have a major impact on the level and pattern of energy use. It has in-house technical expertise to analyze and advise on energy issues which are either the responsibility of or affect its constituent companies.

In the past, there have been two major weaknesses in the formulation and implementation of energy plans and policy.

(a) The Energy Development Committee, which is responsible for the five-year Energy Development Plan, has not met on a regular basis to systematically coordinate energy policy.

(b) The skills and resources of the DOE and ZIMCO have been limited, relative to the task of providing regular advice on all key energy planning and policy issues. The DOE has particularly lacked skills in the areas of energy economics, planning, and financial analysis. These are areas that need to be strengthened if the Department is to perform effectively.

10.2 Recommendations

These weaknesses have been recognized and action is being taken to correct them. The first step has been to reconstitute the Energy Development Committee. The proposal to retain the Committee beyond completion of the revised Fourth National Development Plan is strongly supported. Meeting regularly, say four times per year, or more often, if needed, its continuing role would be to ensure the coordination and review of all major decisions involving the supply and use of energy. Its specific functions would include:

(a) overall supervision of the preparation and implementation of the national energy strategy, annual and rolling five-year energy plans;

(b) review of all significant energy capital expenditures;

(c) advice on all energy policy issues, including prices, tariff levels and tariff structures, and the financial viability of energy enterprises.

The Committee's Secretariat should consist of the DOE, together with one of more representatives of ZIMCO to provide operational knowledge and company liaison. The DOE would undertake the major part of the Secretariat's work.

Plans are in hand to strengthen the DOE so that it can effectively execute the role required of it. Including existing positions, the recommended staffing of an expanded DOE is as follows:

Director: (in post)

Role: Provide strong overall management and technical leadership and liaison with senior officials, corporate representatives, and donor agencies.

Chief Economist, Senior Energy Planner, and Senior Economist:

Role: Economic analysis of major energy issues and options. Economic review of energy pricing levels and structures. Maintenance and improvement of energy database. Energy project investment analysis. Preparation of national energy plans and periodic update of five-year energy strategy. Liaison with energy suppliers and energy users.

Chief Technical Officer and one Technical Officer:

Role: Advice on technical options in energy supply and use, and identification of efficient new technologies. Promotion of energy conservation and substitution analysis, actions, investments, and training.

Senior Financial Adviser:

Role: Advice on financial viability and performance of energy supply organizations. Analysis of the financial implications of investment policy/strategy and pricing, and monitoring of its implementation.

Household and Renewable Energy Specialist:

Role: Development and implementation of a household energy strategy. Analysis of policies to improve the supply and efficiency in use of traditional fuels. Applications of appropriate renewable energy technologies.

Principal Support Staff:

Computer Analyst/Programmer:

Role: Support to the DOE in analytical work and in maintaining the energy database.

Statistician:
Role: Prepare and maintain an energy database.

Clerical Officer:

Role: Administration, Office Routines.

It must be emphasized that staff skills, experience and "stature" will be more important to the success of the DOE than numbers and job descriptions. The individuals appointed need operational experience with Zambia's energy companies and a salary structure that recognizes that energy planning and policy is an important function in Zambia.

10.3 Operational Energy Institutions

There is no need for significant changes in the overall structure and role of the operational energy companies. The need throughout, in some cases more than others, is for managerial strengthening, staff training, and improved performance incentives. In parallel with the more proactive role envisaged for the DOE in advising on energy policy, ZIMCO could usefully strengthen the management, coordination, and strategic direction of its constituent energy suppliers and major energy consumers. This would entail coordination with the companies at the planning stage, to ensure compatibility of their energy plans, policies, and investments; monitoring of the subsequent implementation; and advice on the overall managment of the operations of the companies.

ZIMCO should effectively coordinate the energy companies in their support of the Energy Development Committee, and channel to the Committee, through the DOE, information on major corporate energy investments, pricing and tariff policy, and recommendations on energy strategy. In support of this role, ZIMCO would coordinate the maintenance of energy data in the companies. ZIMCO's energy group will need to be reinforced so that it can take on this wider role. It requires additional expertise in power and coal, and in economic analysis.

The institutional issues relating to the individual energy corporations were discussed in Chapters 4 to 6. In general, there should be stronger emphasis on strategic planning, on identifying key weaknesses and preparing contingency plans, on strengthening management and internal systems, and on a more careful definition of staffing needs. Institutional strengthening is an important issue identified by this report.

An enhanced private sector role is suggested in petroleum exploration, where renewed efforts to interest foreign oil companies would be appropriate. As indicated in Chapter 5, the margins allowed to petroleum distribution companies are high, and so are their unit costs. Cost-cutting should be encouraged through the various options open to Government. Allowing ZIMOIL to compete in bulk fuel supplies would strengthen competition.

Table 1: WB/DOE ENERGY STRATEGY STUDY - ENERGY BALANCE FOR 1996
BASE CASE SCENARIO
('000 TOE)

FLOWS OF ENERGY	PRIMARY ENERGY					SECONDARY ENERGY												
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	SPIKED CRUDE OIL	COAL	HYDRO-ELEC-TRICITY	WOOD	TOTAL PRIMARY SOURCES	SUPER	REGULAR	DIESEL/ GAS OIL/ LSG	AVIATION FUEL	KEROSENE	FUEL OIL	LPG	BITUMEN	COKE	ELEC-TRICITY	CHARCOAL	TOTAL SECONDARY SOURCES	TOTAL
I. SUPPLY																		
1 DOMESTIC PRODUCTION		322	786	6735	7843													7843
2 IMPORTS	607				607									26			26	634
3 VARIATION IN STOCKS																		0
4 TOTAL SUPPLY	607	322	786	6735	8450									26			26	8476
5 EXPORTS		10	100		110	4	22	17			0	6	2				51	161
6 DOMESTIC SUPPLY	607	312	686	6735	8340	-4	-22	-17			0	-6	-2	26			-24	8316
II. TRANSFORMATION																		
7 REFINERIES	-607				-607	73	45	275	45	36	65	8	18				565	-42
8 ELECTRICITY UTILITIES			-686		-686										686		686	0
9 KILNS				-3930	-3930											943	943	-2987
10 TOTAL TRANSFORMATION	-607		-686	-3930	-5223	73	45	275	45	36	65	8	18		686	943	2194	-3029
III. DIST./TRANSM. LOSSES																		
11 LOSSES																69	69	69
IV. TOTAL SUPPLY FOR FINAL CONS.																		
12 TOTAL SUPPLY		312		2805	3117	68	23	258	45	36	65	2	16	26	617	943	2101	5218
V. ADJUSTMENT																		
13 ADJUSTMENT																		0
ADJUSTMENT IN % OF FINAL CONS.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
VI. FINAL CONSUMPTION																		
14 HOUSEHOLDS				2329	2329					24					57	941	1021	3351
15 AGRICULTURE AND FORESTRY				238	238			17		0					13		31	269
16 ZCCM		88			88	1	1	45		7	43				425	3	551	639
17 INDUSTRY AND COMMERCE		205		238	443			32		4	15	2	16	26	90		159	602
18 GOVERNMENT/SERVICE		19			19					1	7				31		39	58
19 TRANSPORT						67	21	164	45	1							299	299
20 TOTAL FINAL CONSUMPTION		312		2805	3117	68	23	258	45	36	65	2	16	26	617	943	2101	5218

Notes: (a) The utilization of crop residues, dung, bagasse do not appear on the balance although they are used as fuels. However, very little information is available and the consumption is thought to be comparatively small.

(b) The final consumption of wood for "Agriculture and Forestry" and for "Industry and Commerce" are estimated to total 10% of consumption of wood for household energy use (both firewood and charcoal).

Table 2: WB/DOE ENERGY STRATEGY STUDY - ENERGY BALANCE FOR 2006
BASE CASE SCENARIO
('000 TOE)

FLOWS OF ENERGY	1 SPIKED CRUDE OIL	2 COAL	3 HYDRO-ELEC-TRICITY	4 WOOD	5 TOTAL PRIMARY SOURCES	6 SUPER	7 REGULAR	8 DIESEL/GAS OIL/LSG	9 AVIATION FUEL	10 KEROSENE	11 FUEL OIL	12 LPG	13 BITUMEN	14 COKE	15 ELEC-TRICITY	16 CHARCOAL	17 TOTAL SECONDARY SOURCES	18 TOTAL
	SOURCES AND FORMS OF ENERGY																	
	PRIMARY ENERGY					SECONDARY ENERGY												
I. SUPPLY																		
1 DOMESTIC PRODUCTION		335	699	9639	10673													10673
2 IMPORTS	651				651									19			19	669
3 VARIATION IN STOCKS																		
4 TOTAL SUPPLY	651	335	699	9639	11324									19			19	11342
5 EXPORTS		10	100		110	4	22	17			0	6	2				51	161
6 DOMESTIC SUPPLY	651	325	599	9639	11214	-4	-22	-17			0	-6	-2	19			-32	11182
II. TRANSFORMATION																		
7 REFINERIES	-651				-651	78	46	306	55	45	44	8	22				605	-46
8 ELECTRICITY UTILITIES			-599		-599										599		599	
9 KILNS				-6317	-6317											1516	1516	-4801
10 TOTAL TRANSFORMATION	-651		-599	-6317	-7567	78	46	306	55	45	44	8	22		599	1516	2720	-4846
III. DIST./TRANSM. LOSSES																		
11 LOSSES															60		60	60
IV. TOTAL SUPPLY FOR FINAL CONS.																		
12 TOTAL SUPPLY		325		3322	3647	74	24	290	55	45	44	2	20	19	539	1516	2628	6276
V. ADJUSTMENT																		
13 ADJUSTMENT																		
ADJUSTMENT IN % OF FINAL CONS.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
VI. FINAL CONSUMPTION																		
14 HOUSEHOLDS				2741	2741					33					70	1514	1618	4358
15 AGRICULTURE AND FORESTRY				291	291			21		0					29		51	341
16 ZCCM		88			88	1	1	34		5	24			19	298	2	382	470
17 INDUSTRY AND COMMERCE		214		291	505			34		5	11	2	20		103		176	681
18 GOVERNMENT/SERVICE		23			23					1	9				38		48	71
19 TRANSPORT						73	23	200	55	1					1		354	354
20 TOTAL FINAL CONSUMPTION		325		3322	3647	74	24	290	55	45	44	2	20	19	539	1516	2628	6276

Notes: (a) The utilization of crop residues, dung, bagasse do not appear on the balance although they are used as fuels. However, very little information is available and the consumption is thought to be comparatively small.
(b) The final consumption of wood for "Agriculture and Forestry" and for "Industry and Commerce" are estimated to total 10% of consumption of wood for household energy use (both firewood and charcoal).

Table 3: WB/DOE ENERGY STRATEGY STUDY - ENERGY BALANCE FOR 1996
LOW GROWTH SCENARIO
('000 TOE)

FLOWS OF ENERGY	SOURCES AND FORMS OF ENERGY																	
	PRIMARY ENERGY					SECONDARY ENERGY												
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	SPIKED CRUDE OIL	COAL	HYDRO-ELEC-TRICITY	WOOD	TOTAL PRIMARY SOURCES	SUPER	REGULAR	DIESEL/ GAS OIL/ LSG	AVIATION FUEL	KEROSENE	FUEL OIL	LPG	BITUMEN	COKE	ELEC-TRICITY	CHARCOAL	TOTAL SECONDARY SOURCES	TOTAL
I. SUPPLY																		
1 DOMESTIC PRODUCTION		308	761	6748	7817													7817
2 IMPORTS	549				549									26			26	576
3 VARIATION IN STOCKS																		
4 TOTAL SUPPLY	549	308	761	6748	8367									26			6	8393
5 EXPORTS		10	100		110	4	22	17			0	6	2				51	161
6 DOMESTIC SUPPLY	549	299	661	6748	8257	-4	-22	-17			0	-6	-2	26			-24	8232
II. TRANSFORMATION																		
7 REFINERIES	-549				-549	65	43	244	39	35	62	7	16				511	-38
8 ELECTRICITY UTILITIES			-661		-661										661		661	
9 KILNS				-4004	-4004											961	961	-3043
10 TOTAL TRANSFORMATION	-549		-661	-4004	-5214	65	43	244	39	35	62	7	16		661	961	2132	-3081
III. DIST./TRANSM. LOSSES																		
11 LOSSES															66		66	66
IV. TOTAL SUPPLY FOR FINAL CONS.																		
12 TOTAL SUPPLY		299		2745	3043	61	20	228	39	35	62	2	14	26	595	961	2042	5085
V. ADJUSTMENT																		
13 ADJUSTMENT																		
ADJUSTMENT IN % OF FINAL CONS.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
VI. FINAL CONSUMPTION																		
14 HOUSEHOLDS				2338	2338					24					50	958	1032	3370
15 AGRICULTURE AND FORESTRY				203	203			15		0					11		26	229
16 ZCCM		88			88	1	1	45		7	43			26	425	3	551	639
17 INDUSTRY AND COMMERCE		194		203	398			28		4	12	2	14		81		141	538
18 GOVERNMENT/SERVICE		16			16					0	6				27		33	49
19 TRANSPORT						60	19	140	39	0							258	258
20 TOTAL FINAL CONSUMPTION		299		2745	3043	61	20	228	39	35	62	2	14	26	595	961	2042	5085

Notes: (a) The utilization of crop residues, dung, bagasse do not appear on the balance although they are used as fuels. However, very little information is available and the consumption is thought to be comparatively small.
(b) The final consumption of wood for "Agriculture and Forestry" and for "Industry and Commerce" are estimated to total 10% of consumption of wood for household energy use (both firewood and charcoal).

Table 4: WB/DOE ENERGY STRATEGY STUDY - ENERGY BALANCE FOR 2006
LOW GROWTH SCENARIO
('000 TOE)

FLOWS OF ENERGY	SOURCES AND FORMS OF ENERGY: PRIMARY ENERGY					SECONDARY ENERGY												
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	SPIKED CRUDE OIL	COAL	HYDRO-ELEC-TRICITY	WOOD	TOTAL PRIMARY SOURCES	SUPER	REGULAR	DIESEL/ GAS OIL/ LSG	AVIATION FUEL	KEROSENE	FUEL OIL	LPG	BITUMEN	COKE	ELEC-TRICITY	CHARCOAL	TOTAL SECONDARY SOURCES	TOTAL
I. SUPPLY																		
1 DOMESTIC PRODUCTION		308	637	9665	10610													10610
2 IMPORTS	510				510									19			19	529
3 VARIATION IN STOCKS																		
4 TOTAL SUPPLY	510	308	637	9665	11120									19			19	11139
5 EXPORTS		10	100		110	4	22	17			0	6	2				51	161
6 DOMESTIC SUPPLY	510	299	536	9665	11011	-4	-22	-17			0	-6	-2	19			-32	10978
II. TRANSFORMATION																		
7 REFINERIES	-510				-510	60	41	230	39	44	38	7	16				474	-36
8 ELECTRICITY UTILITIES			-536		-536										536		536	
9 KILNS				-6498	-6498											1559	1559	-4938
10 TOTAL TRANSFORMATION	-510		-536	-6498	7544	60	41	230	39	44	38	7	16		536	1559	2570	-4974
III. DIST./TRANSM. LOSSES																		
11 LOSSES															54		54	54
IV. TOTAL SUPPLY FOR FINAL CONS.																		
12 TOTAL SUPPLY		299		3168	3466	55	18	214	39	44	38	2	14	19	483	1559	2484	5951
V. ADJUSTMENT																		
13 ADJUSTMENT																		
ADJUSTMENT IN % OF FINAL CONS.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
VI. FINAL CONSUMPTION																		
14 HOUSEHOLDS				2761	2761					34					60	1558	1652	4413
15 AGRICULTURE AND FORESTRY				203	203			15		0					17		33	236
16 ZCCM		88			88	1	1	34		5	24			19	298	2	382	470
17 INDUSTRY AND COMMERCE		194		203	398			25		4	8	2	14		81		133	531
18 GOVERNMENT/SERVICE		16			16					0	6				27		33	49
19 TRANSPORT						55	18	140	39	0							252	252
20 TOTAL FINAL CONSUMPTION		299		3168	3466	55	18	214	39	44	38	2	14	19	483	1559	2484	5951

Notes: (a) The utilization of crop residues, dung, bagasse do not appear on the balance although they are used as fuels. However, very little information is available and the consumption is thought to be comparatively small.
(b) The final consumption of wood for "Agriculture and Forestry" and for "Industry and Commerce" are estimated to total 10% of consumption of wood for household energy use (both firewood and charcoal).

Table 5: WB/DOE ENERGY STRATEGY STUDY - ENERGY BALANCE FOR 1996
HIGH GROWTH SCENARIO
('000 TOE)

FLOWS OF ENERGY	SOURCES AND FORMS OF ENERGY: PRIMARY ENERGY 1 SPIKED CRUDE OIL	2 COAL	3 HYDRO-ELEC-TRICITY	4 WOOD	5 TOTAL PRIMARY SOURCES	SECONDARY ENERGY 6 SUPER	7 REGULAR	8 DIESEL/ GAS OIL/ LSG	9 AVIATION FUEL	10 KEROSENE	11 FUEL OIL	12 LPG	13 BITUMEN	14 COKE	15 ELEC-TRICITY	16 CHARCOAL	17 TOTAL SECONDARY SOURCES	18 TOTAL
I. SUPPLY																		
1 DOMESTIC PRODUCTION		337	813	6673	7822													7822
2 IMPORTS	654				654									26			26	680
3 VARIATION IN STOCKS																		
4 TOTAL SUPPLY	654	337	813	6673	8476									26			26	8503
5 EXPORTS		10	100		110	4	22	17			0	6	2				51	161
6 DOMESTIC SUPPLY	654	327	713	6673	8366	-4	-22	-17			0	-6	-2	26			-24	8342
II. TRANSFORMATION																		
7 REFINERIES	-654				-654	78	47	300	51	36	68	8	21				608	-46
8 ELECTRICITY UTILITIES			-713		-713										713		713	
9 KILNS				-3820	-3820											917	917	-2903
10 TOTAL TRANSFORMATION	-654		-713	-3820	-5186	78	47	300	51	36	68	8	21		713	917	2237	-2949
III. DIST./TRANSM. LOSSES																		
11 LOSSES															71		71	71
IV. TOTAL SUPPLY FOR FINAL CONS.																		
12 TOTAL SUPPLY		327		2853	3180	73	24	284	51	36	68	2	19	26	642	917	2147	5322
V. ADJUSTMENT																		
13 ADJUSTMENT																		
ADJUSTMENT IN % OF FINAL CONS.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
VI. FINAL CONSUMPTION																		
14 HOUSEHOLDS				2316	2316					23					67	914	1004	3320
15 AGRICULTURE AND FORESTRY				268	268	.		20		0					16		36	304
16 ZCCM		88			88	1	1	43		7	43			26	425	3	549	638
17 INDUSTRY AND COMMERCE		217		268	486			36		5	17	2	19		99		177	663
18 GOVERNMENT/SERVICE		21			21					1	8				35		44	65
19 TRANSPORT						73	25	185	51	1							337	337
20 TOTAL FINAL CONSUMPTION		327		2853	3180	73	24	284	51	36	68	2	19	26	642	9179	2142	5322

Notes: (a) The utilization of crop residues, dung, bagasse do not appear on the balance although they are used as fuels. However, very little information is available and the consumption is thought to be comparatively small.
(b) The final consumption of wood for "Agriculture and forestry" and for "Industry and Commerce" are estimated to total 10% of consumption of wood for household energy use (both firewood and charcoal).

Table 6: WB/DOE ENERGY STRATEGY STUDY - ENERGY BALANCE FOR 2006
HIGH GROWTH SCENARIO
('000 TOE)

	SOURCES AND FORMS OF ENERGY																	
	PRIMARY ENERGY					SECONDARY ENERGY												
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
FLOWS OF ENERGY	SPIKED CRUDE OIL	COAL	HYDRO-ELEC-TRICITY	WOOD	TOTAL PRIMARY SOURCES	SUPER	REGULAR	DIESEL/ GAS OIL/ LSG	AVIATION FUEL	KEROSENE	FUEL OIL	LPG	BITUMEN	COKE	ELEC-TRICITY	CHARCOAL	TOTAL SECONDARY SOURCES	TOTAL
I. SUPPLY																		
1 DOMESTIC PRODUCTION		376	775	9589	10740													10740
2 IMPORTS	791				791									19			19	810
3 VARIATION IN STOCKS																		
4 TOTAL SUPPLY	791	376	775	9589	11531									19			19	11550
5 EXPORTS		10	100		110	4	22	17			0	6	2				51	161
6 DOMESTIC SUPPLY	791	366	675	9589	11422	-4	-22	-17			0	-6	-2	19			-32	11389
II. TRANSFORMATION																		
7 REFINERIES	-791				-791	96	52	383	72	46	50	9	28				736	-55
8 ELECTRICITY UTILITIES			-675		-675										675		675	
9 KILNS				-6116	-6116											1468	1468	-4648
10 TOTAL TRANSFORMATION	-791		-675	-6116	-7582	96	5[illegible]	383	72	46	50	9	28		675	1468	2878	-4703
III. DIST./TRANSM. LOSSES																		
11 LOSSES															67		67	67
IV. TOTAL SUPPLY FOR FINAL CONS.																		
12 TOTAL SUPPLY		366		3474	3840	92	30	366	72	46	50	3	26	19	607	1468	2779	6619
V. ADJUSTMENT																		
13 ADJUSTMENT																		
ADJUSTMENT IN % OF FINAL CONS.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
VI. FINAL CONSUMPTION																		
14 HOUSEHOLDS				2717	2717					32					[illegible]	1466	1590	4308
15 AGRICULTURE AND FORESTRY				378	378			28		1					41		69	447
16 ZCCM		88			88	1	1	34		5	24			19	298	2	382	470
17 INDUSTRY AND COMMERCE		248		378	626			44		6	14	3	26		127		221	848
18 GOVERNMENT/SERVICE		30			30					1	12				49		62	92
19 TRANSPORT						91	29	261	72	1							454	454
20 TOTAL FINAL CONSUMPTION		366		3474	3840	92	30	366	72	46	50	3	26	19	607	1468	2779	6619

Notes: (a) The utilization of crop residues, dung, bagasse do not appear on the balance although they are used as fuels. However, very little information is available and the consumption is thought to be comparatively small.
(b) The final consumption of wood for "Agriculture and Forestry" and for "Industry and Commerce" are estimated to total 10% of consumption of wood for household energy use (both firewood and charcoal).

ENERGY DEMAND FORECASTS

1. Methodology

Three energy demand scenarios have been calculated, a base case, a low case and a high case scenario. The three energy demand scenarios correspond to the three economic growth scenarios. The demand scenarios are based on the energy balance for 1986.

2. Household Sector

Households are subdivided into those with and without electricity for both urban and rural areas. It is then assumed that the proportionate consumption of each fuel per household will remain the same in each group from 1986 to 2006. The energy demand of the household sector is then calculated from the growth of households in each subgroup.

The only difference between the three demand scenarios is the assumed number of electricity connections made per year (Table 1).

Table 1: NO. OF ELECTRICITY CONNECTIONS PER YEAR

Scenario	Connections per year
Base case	4,000
Low case	2,000
High case	7,000

The demographic forecast of the Central Statistical Office from the 1980 population census has been used to forecast the total number of households in the years 1986-2006.

Table 2: 1980 POPULATION CENSUS
FORECASTS OF HOUSEHOLDS
('000s)

	1986		1996		2006
Urban	554.5		960.7		1553.0
Rural	844.8		1025.1		1152.0
Total	1399.3		1985.8		2705.0
Av. annual growth %		3.6		3.1	

The above assumptions lead to the following number of urban households with and without access to electricity. The number of rural households with electricity is negligible.

Table 3: URBAN HOUSEHOLDS WITH AND WITHOUT ELECTRICITY

Households	1986 %	2006 Base Case	2006 Low Growth	2006 High Growth
With Electricity	38	24	19	32
Without Electricity	62	76	81	68
Total	100	100	100	100

According to the 1980 Population Census, 38% of all households had access to electricity. By 1988, ZESCO customers were equivalent to about 20% of all households. This means that, on average, two households have access to electricity for each ZESCO connection. This ratio is assumed to remain constant in the forecast, i.e., for each new connection, two households get access to electricity.

3. ZCCM

The energy consumption of ZCCM is assumed to be the same in all three demand scenarios. The consumption is estimated on the basis of information from ZCCM.

The forecast ZCCM consumption of electricity, diesel, coal and fuel oil are shown below, together with the assumed copper production. The ZCCM consumption of all other fuels is assumed to vary in proportion with copper production.

Table 4: ZCCM ENERGY CONSUMPTION FORECAST

Year	Diesel	Coal	Fuel Oil	Electricity	Copper Production
	'000 MT	'000 MT	'000 MT	GWH	'000 MT
1988	65	170	66	4,773	482
1989	65	133	84	5,000	505
1990	65	133	82	5,050	510
1991	65	133	80	5,240	529
1992	57	133	78	5,420	548
1993	50	136	60	4,950	500
1994	50	136	48	4,950	500
1995	50	136	46	4,950	500
1996	44	136	44	4,950	500
1997	44	136	42	4,950	500
1998	44	136	38	4,950	500
1999	33	136	36	3,960	400
2000	33	136	35	3,960	400
2001	33	136	35	3,960	400
2002	33	136	30	3,960	400
2003	33	136	30	3,465	350
2004	33	136	25	3,465	350
2005	33	136	25	3,465	350
2006	33	136	25	3,465	350

4. Industry and Commerce

The energy consumption of two of the major industrial energy consumers, NCZ and Chilanga Cement, have been estimated individually on the basis of information from the two companies. The energy consumption of all other consumers in the sector is assumed to grow at the same growth rate as GDP in the three economic scenarios. However, to take account of conservation measures in industry, the forecast consumption of diesel and fuel oil is reduced linearly by 15 and 55% respectively over the 20-year period.

Chilanga Cement

The forecast energy consumption of Chilanga Cement is given in Table 5.

Table 5: FORECAST ENERGY CONSUMPTION OF CHILANGA CEMENT

Fuel	1986	After 1989		
		Base Case	Low Growth	High Growth
Elect. MWh	43,750	39,375	- 10%	+ 2% pa
Coal '000 MT	72	66	- 10%	+ 2% pa

NCZ

The forecast energy consumption of NCZ, which is assumed to be the same in all three scenarios, is shown in Table 6.

Table 6: FORECAST ENERGY CONSUMPTION OF NCZ

Fuels	1986	After 1989
Coal '000 MT	91	185
Electricity GWh	172	310
Fuel oil '000 MT	0.24	0
Diesel '000 MT	8.74	2.7

5. Agriculture and Forestry

Special growth rates for the consumption of electricity in the sector are assumed to take account of an anticipated large increase in hecterage under irrigation. The forecast assumptions are shown in Table 7.

Table 7: FORECAST GROWTH IN ELECTRICITY CONSUMPTION IN AGRICULTURE
(% per year)

Scenario	1988-96	1996-2006
Base	6	8
Low	3	5
High	8	9

The consumption of all other fuels is assumed to grow at the same rate as GDP in the three scenarios.

6. Transport, Government and Services

The energy consumption of these sectors is assumed to grow at the same percentage rate as GDP. The only exception is gasoline in the transport sector. To take account of the tendency for the consumption of diesel for transport purposes grow faster than the consumption of gasoline, a lower growth has been assumed for gasoline consumption. The assumptions are given in Table 8.

Table 8: FORECAST CONSUMPTION OF GASOLINE IN TRANSPORT AS PERCENT OF DIESEL (%)

Scenario	1986	1996	2006
Base	68	54	48
Low	68	56	52
High	68	52	46

ELECTRIC ENERGY AND POWER EXPORT POTENTIAL

1. Angola. The potential for exports of Zambian power lies in short extensions of the Zambian grid to supply isolated communities in Angola. Based on a study for mini hydro in Mwinilunga, the export potential in the mid 1990s is put at 1 MW.

2. The Botswana Government plans to make its power system independent of South Africa, and to limit its imports from other sources to 20%, (e.g., about 25 MW potential for Zambia). Zambia presently supplies about 1 MW direct to north-eastern Botswana via a short spur from the Livingstone-Sesheke 66 kV line. To meet Botswana's needs in other areas, the power would most cost-effectively be wheeled through Zimbabwe. Zimbabwe's policy in this respect is to sell power from its own grid to Botswana (possibly with corresponding purchases from Zambia) at the average of Zimbabwe's and Botswana's marginal generation cost, providing this does not exceed 80% of Botswana's marginal cost. This arrangement would apply for 5 years from commissioning the line at end 1990, and is then subject to renegotiation, at which time Zambia has the right to be involved.

If Botswana were to import power to the Francistown area through a direct line from Zambia, the cost per kWh can be estimated as follows. The investments for a 500 km long 330 kV line, from Livingstone, plus a 220/330 kW transformer in Livingstone is about US$80 million. A 25 MW base load demand for 7,000 h/year means supply of 175 GWh/year, a capital cost of about US$0.06/kWh. This unit cost could be compared with and set a limit to the unit price Botswana will be prepared to pay to Zimbabwe for the corresponding volume of imports via Zimbabwe.

The assumed growth rate of the existing small scale supplies is taken as 4% p.a. for maximum demand and 1% p.a. for energy.

3. Malawi has enough low-cost hydro-potential to meet its medium term needs, hence it has no economic incentive to buy power for its main grid from Zambia. Moreover, the Government of Malawi apparently prefers to retain substantial independence in its own power system. An interconnection between Chipata in eastern Zambia and Lilongwe could be of interest to Malawi as backup to its own system, and possibly for energy supplies, until Malawi's next project (Tedzani) comes on stream in about 1994. However, in discussion with Zambia, Malawi has not shown strong interest in anything other than a stand-by connection. The economics of this are questionable.

In addition to the above, there are some border areas in northern Malawi where the least cost power supply would probably be from Zambia or from Tanzania. The quantities involved are fairly minimal.

4. Mozambique has considerable power capacity potential from the Cahora Bassa hydroelectric system which is currently not operating due to rebel activity. Hence no exports from Zambia are anticipated during the study period. When peace is restored in Mozambique, there could be viable minor power exports/imports between the two countries to areas close to the common border.

5. Namibia has one small town in the Caprivi Strip within economic reach of the Zambian power system. Because of present political conditions, no export of power is assumed for the study period.

6. The Tanzanian and Zambian power systems could be interconnected. However, the investment by Zambia to achieve this appears to be excessive in relation to the potential benefits (back-up supply rather than anticipated exports of firm power) and it is assumed that the project will not be developed before 2006. In addition, two small isolated border areas at Tunduma and Sumbawanga are identified with export potential of 4.0 MW and 1.2 MW respectively.

7. Zaire. Since 1956 the Shaba province of Zaire has been connected to Zambia's Luano substation through a single 220 kV line with a capacity of about 100 MW (this link operated at up to 150 MW in the 1970s, but is now limited to 100 MW). Zaire has surplus low-cost hydro capacity, and consequently the potential for power exports is low. The interlink is used as mutual reinforcement and to exchange energy without any payment for energy between the two countries . Recently, the interconnection has worked to Zaire's advantage, with exports from Zambia often at peak hours and re-imports at offpeak hours. This has apparently cause load shedding the Copperbelt. In accordance with an agreement with SNEL signed in July 1986, ZESCO is billing peak power exports to SNEL, but has not been paid. ZESCO should reconsider the basis on which it continues to operate the interlink both commercially and in terms its implications for meeting Copperbelt demand. For example, ZESCO could insist on payment or seek say 150% offpeak energy in exchange for peak energy.

8. Zimbabwe.

8.1 Past exports. Exports of electric energy to Zimbabwe via the 330 kV tie-line at Kariba since 1980 have been as follows:

Table 1: EXPORT OF ELECTRIC ENERGY TO ZIMBABWE

Year	Exports (GWh) a/
1980/81	3,167
1981/82	3,533
1982/83	3,785
1983/84	3,311
1984/85	3,038
1985/86	3,410
1986/87	2,776
1987/88	1,036 b/

a/ Indicated exports are on the basis of April-March results.
b/ Extrapolated from 11 months' results.

The reduction in exports during 1987-88 is explained by the fact that Zimbabwe is relying increasingly on indigenous electric energy produced in the coal-fired thermal plant at Hwange, a new stage of which has recently been commissioned at a cost above that of importing power from Zambia.

The first unit of the first stage of the Hwange thermal plant, comprising 4 x 120 MW installed capacity, was commissioned in 1983. The last unit of the second stage, comprising 2 x 220 MW installed capacity, was commissioned in February 1987.

8.2 Short and medium term prospects. An indication of likely future export sales is that the present agreement between Zambia and Zimbabwe does not include any long-term export commitment. Zimbabwe simply declares its specific import demand for the coming six months, which is firm in a three-month perspective. Up-dating of the declared demand takes place each month on rolling basis.

Power exports have varied considerably from month to month since mid-1987. They can be assumed to continue doing so in the short run. For the medium-term, it is possible to anticipate exports of up to 250 MW and 1,000 GWh/year until around 1994, with possible variations in the range of 125-300 MW and 0 to 1,500 GWh/year.

These figures include possible demand from Botswana during the period 1991-94. It is doubtful if Zimbabwe will have firm power available for exports to Botswana during this period, and Zimbabwe may therefore have to import from Zambia for reexport to Botswana.

The estimates of Zimbabwean power import requirements are predicted on the basis that Zambia and Zimbabwe continue to cooperate on sharing reserve requirements and emergency back-up. Clearly, Zimbabwe will benefit more than Zambia from this arrangement, although it does not involve Zambia in any costs. The estimates given above are also based on the assumption that the two countries are each entitled to half the actual energy generated annually from the Kariba complex, adopting the currently-used long-term estimate of average annual availability of 9,800 GWh and firm energy availability of 8,400 GWh. However, a lower value for firm energy availability may well be appropriate in view of the low flows in the Zambezi during the 1980s. Estimates of this lower firm energy capacity vary between 7,600 and 8,400 GWh for medium and long-term planning purposes (as opposed to short-term operational considerations).

8.3 Long-term prospects. The long-term demand for exports to Zimbabwe is highly uncertain, and no quantification is attempted here.

When Zimbabwe requires access to further substantial capacity and energy in the future, the following options are available:

(a) Imports from Zambia, provided Zambia has excess production capability to offer. This arrangement could include purchases from the future Kafue Lower hydroelectric plant, located downstream of the existing Kafue Gorge plant, with 450 MW installed capacity and yielding additional 2,500 GWh/yr energy production.

(b) Further hydropower development on the Zambezi River, most probably a 1600 MW plant at Batoka Gorge, upstream of Kariba. This could be done jointly with Zambia or in stages, e.g. a first stage of up to 800 MW on the south bank, for which Zimbabwe would bear the dam costs and enjoy full water rights until Zambia bought in.

(c) Further extensions to the Hwange thermal plant.

(d) Imports from Mozambique's Cahora Bassa hydro plant.

The Kariba South Extension Project (300 MW) is not expected to make a substantive contribution to Zimbabwe's power supply, especially for firm capacity, and would not influence its demand for power imports.

With respect to further development on the Zambezi, it is anticipated that Zimbabwe will bring up the issue at a time when Zambia is not yet prepared to commit itself to the considerable investment required; the reason being that Zambia will still have surplus capacity and the option of developing Kafue Lower.

In such a situation, Zambia should explore with Zimbabwe the possibility of leasing the land required to construct a plant. If satisfactory conditions were to be offered, Zambia might agree that Zimbabwe implement say Batoka Gorge, provided that Zambia at a later stage was allowed to buy into the selected scheme at a price based on a previously agreed formula.

A deterrent for Zimbabwe receiving long-term supply from Zambia is that such import has to be paid for in foreign convertible currency, according to existing supply terms. Bearing in mind the substantial net merchandise exports from Zimbabwe to Zambia, there is scope for resolving this problem. If an arrangement could be achieved whereby payment was at least partly effected in Zimbabwean currency, imports from Zambia would become considerably more attractive.

9. A summary of the above discussion is quantified in the following Table. The three sets of export projections, high, medium, and low, demonstrate the estimate range of uncertainty of future export demand. They are not related to the three scenarios for domestic demand. In the investment plans and financial projections, the medium alternative is used for all three scenarios.

Appendix 4.1
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PROJECTED EXPORTS OF ELECTRIC PEAK POWER (MW) AND ENERGY (GWH)

Power - MW

		1989	1990	1991	1992	1996	1999	2006
Zimbabwe	Med	150	200	200	200			
	High	300	300	300	300			
	Low	125	125	125	125			
Zaire	Med	100	100	100	100	100	100	100
	High	100	100	100	100	100	100	100
	Low	100	100	100	100	100	100	100
Tanzania	Med	0	0	0	0	0	0	0
	High	0	0	0	0	100	100	100
	Low	0	00	0	0	0	0	0
Malawi	Med	0	0	0	0	0	0	0
	High	0	0	0	50	50	50	50
	Low	0	0	0	0	0	0	0
Botswana	Med	1	1	1	1	1	1	1
	High	1	1	1	1	1	1	1
	Low	1	1	1	1	1	1	1
Angola	Med	0	0	0	0	0	0	0
	High	0	0	0	0	0	1	1
	Low	0	0	0	0	0	0	0
Total	Med	251	301	301	301			
	High	401	401	401	451			
	Low	226	226	226	226			

Energy - GWh

		1989	1990	1991	1992
Zimbabwe	Med	1,000	1,000	1,000	1,000
	High	1,500	1,500	1,500	1,500
	Low	0	0	0	0
Total	Med	1,000	1,000	1,000	1,000
	High	1,500	1,500	1,500	1,500
	Low	0	0	0	0

Table 1: ZESCO ELECTRICITY TARIFFS, JANUARY 1, 1988

ENERGY TARIFF "L", "E", AND "E"

TARIFF - "L"	A	B	C	D	E	F	G	H	I	J	K	L
Load Limiter rating: Amperes (in Kwachas)	1	1.5	2	2.5	3	5	6	7	7.5	10	12.5	15
Monthly charges (in Kwachas)	4.6	5.4	6.3	6.5	7.7	11.1	14.8	16.1	17.5	21.7	25.9	29.4

TARIFF E1 - Restricted to 5 Amperes, single phase:	Fixed monthly charge:	2.50 Kwacha
	Unit charge:	7.00 Ngwee
TARIFF E2 - Restricted to 15 Amperes, single phase:	Fixed monthly charge:	4.90 Kwacha
	Unit charge:	7.00 Ngwee
Isol. hydro. = EC) Tariff E3 - Domestic only: unrestricted,	Fixed monthly charge:	15.00 Kwacha
Diesel = EG) single phase and up to 15 kVA, three phase:	Unit charge:	7.00 Ngwee
ED) TARIFF E4 - Commercial only: unrestricted, single phase	Fixed monthly charge:	71.50 Kwacha
EH) and up to 15 kVA three phase	Unit charge:	10.14 Ngwee
TARIFF E5 - (no fixed charge)	Unit charge:	1.50 Ngwee

MAXIMUM DEMAND TARIFF "D"

DA) TARIFF D1 - Maximum demand less than 300 kVA	Fixed monthly charge:	91.00 Kwacha
DE)	M.D. charge per kVA/month:	15.43 Kwacha
	Unit charge:	6.89 Ngwee
DB) TARIFF D2 - Maximum demand from 300 to 2,000 kVA	Fixed monthly charge:	1,722.50 Kwacha
DF)	M.D. charge per kVA/month:	13.81 Kwacha
	Unit charge:	5.33 Ngwee
TARIFF D3 - Maximum demand over 2,000 kVA	Fixed monthly charge:	17,225.00 Kwacha
	M.D. charge per kVA/month:	11.80 Kwacha
	Unit charge:	3.51 Ngwee

SURCHARGES ON ISOLATED NETWORKS; Tariffs E3, E4, and D will attract surcharges as follows:

(a) The 20% surcharge on isolated networks fed from hydroelectric sources remains unchanged.
(b) The 150% surcharge on isolated networks fed from diesel power stations remains unchanged.

SECURITY DEPOSITS:

(a) Restricted supply (maximum 5 Amperes)	30.00 Kwacha
(b) Restricted supply (over 5 Amperes)	50.00 Kwacha
(c) Unrestricted domestic	200.00 Kwacha
(d) Other consumers (excluding M.D. consumers)	500.00 Kwacha

RECONNECTION CHARGE:	100.00 Kwacha
METER TESTING CHARGE:	30.00 Kwacha

INSPECTION OF INSTALLATION CHARGE:

(a) Residential houses	50.00 Kwacha
(b) Commercial and industrial premises	90.00 Kwacha

GOVERNMENT SALES TAX:	15 percent

Table 2: ZESCO CONSUMERS PER TARIFF CATEGORY
Financial Year 1987-88

TAR	Number of Consumers	Consumption kWh '000s	Revenue K '000s	kWh per Consumer	Revenue per Consumer	Revenue per kWh (K)
LA	1,824	2,460	307	1,400	170	0.13
LB	159	74	10	500	60	0.14
LD	108	74	8	700	70	0.11
LF	4,418	3,215	588	700	130	0.18
LI	368	788	77	2,100	210	0.10
LL	50	215	17	4,300	340	0.08
Subtotal	6,927	6,826	1,007	940	150	0.15
E1	2,918	2,545	269	900	90	0.11
E2	16,066	31,810	3,479	2,000	220	0.11
E3	68,396	393,578	38,506	5,800	560	0.10
E3H a/	4,798	20,110	2,709	4,200	560	0.13
E3D b/	293	783	263	2,700	900	0.34
E4	9,542	79,590	13,171	8,300	1,380	0.17
E4H a/	1,529	10,122	2,341	6,600	1,530	0.23
E4D b/	132	524	346	4,000	2,620	0.66
Subtotal	103,674	539,062	62,084	5,200	590	0.11
D1	2,272	241,897	30,728	106,500	13,520	0.13
D1H a/	242	27,843	4,471	115,100	18,480	0.16
D1D b/	26	3,045	1,159	117,100	44,580	0.38
D2	222	260,561	26,624	1,173,700	119,920	0.10
D2H a/	22	20,57[illegible]	3,258	935,100	148,090	0.16
D3	37	602,925	38,420	16,295,300	1,038,380	0.06
Subtotal	2,821	1,157,442	104,660	410,300	37100	0.09
S1 c/	1,535	7,740	101	5,000	70	0.01
Total	114,957	1,710,470	166,852			

a/ Consumers supplied from the isolated hydro system.
b/ Consumers supplied from the isolated diesel systems.
c/ ZESCO staff

Source: ZESCO.

ZESCO FINANCIAL FORECASTS 1988-2006

For the purpose of tariff planning, projections of ZESCO expenditures and revenues are made in constant prices in each fiscal year up to the year 2006. The results are presented for a selection of years in Tables 1 and 2. The basic assumptions made are summarized in Table 1. The budgeted expenditures in year 1987-88 are used as a base. The formulas used for expenditures in future years are also indicated in Table 1.

The corresponding revenue requirements are calculated in Table 2. On the basis of these assumptions, the results indicate that the real tariff level should be increased by 54% in 1988 and by about 90-100% in the mid-1990s to cover ZESCO's operating costs and debt repayment obligations.

Table 1

FINANCIAL FORECASTS FOR ZESCO

Projections of revenue requirements in constant (1987/88) prices.

1. GENERAL ASSUMPTIONS AND EXPENDITURE PROJECTIONS

	YEAR:	1987/88	1993	1993	1993	1999	1999	1999	2006	2006	2006	Present
	Scenario:		High	Base	Low	High	Base	Low	High	Base	Low	tariff
ASSUMPTIONS	Unit											K/kWh
Retail units	GWh	2097	2258	2118	1905	3106	2611	2082	4104	3176	2219	0.12
-households	GWh	524	386	419	332	810	692	509	1179	974	646	
-larger customers	GWh	1573	1872	1699	1573	2296	1919	1573	2925	2202	1573	
Sold to Zimbabwe	GWh	1000	0	0	0	0	0	0	0	0	0	0.015
Sold bulk ZCCM	GWh	4733	4963	4963	4963	4655	4655	4655	4037	4037	4037	0.033
Sold totally	GWh	7830	7221	7081	6868	7761	7266	6737	8141	7213	6256	0.0540
Total consumers		104000	119500	116500	114500	161500	140500	126500	210500	168500	140500	
Connections/year		2000	7000	4000	2000	7000	4000	2000	7000	4000	2000	
MWh by diesel	MWh	7	9.2	8.3	7.3	11.4	9.5	7.6	14	11	8	
USD debt service/y	USD000	11644	11644	11644	11644	11644	11644	11644	0	0	0	
Ditto, new invest.	USD000	0	4000	4000	4000	6500	6500	6500	6500	6500	6500	
Distr extn invtm/y	K 000	64000	56000	32000	16000	56000	32000	16000	56000	32000	16000	1000
- of which forex	USD000		4900	2800	1400	4900	2800	1400	4900	2800	1400	USD/conn
Transmission inv/y	K 000	0	31333	31333	31333	4246	4246	4246	4246	4246	4246	
- of which forex	USD000	0	3513	3513	3513	300	300	300	300	300	300	
Distr rehab inv/yr	K 000	0	25333	25333	25333	0	0	0	0	0	0	
- of which forex	USD000	0	2840	2840	2840	0	0	0	0	0	0	
Gener inv/yr	K 000	0	2000	2000	2000	2000	2000	2000	2000	2000	2000	
- of which forex	USD000		200	200	200	200	200	200	200	200	200	
Accumul investmnts	K 000	0	687996	543996	447996	1061472	773472	581472	2122944	1546944	1162944	
Assets	K 000	2650000	3337996	3193996	3097996	3711472	3423472	3231472	4772944	4196944	3812944	

New loan ("grant") USD 40 million in 1992, at 8%, 5 year grace period + 20 years payback
New loans USD 10 million in 1992 at 8% interest, 5 grace period + 20 years payback

EXPENDITURES (K 000)		93H	93B	93L	99H	99B	99L	06H	06B	06L
Salaries, fixed	34012	34012	34012	34012	34012	34012	34012	34012	34012	34012
Salaries, variable	14576	51016	29152	14576	51016	29152	14576	51016	29152	14576
Wages, fixed	2042	2042	2042	2042	2042	2042	2042	2042	2042	2042
Wages, variable	8162	9378	9143	8986	12675	11027	9928	16520	13224	11027
Maintenance, present assets	13334	26955	26918	26908	27103	26892	26881	27194	26874	26854
Maintenance, new assets	0	2408	1904	1568	3715	2707	2035	7430	5414	4070
Generation fuel	4406	5797	5201	4605	7189	5996	4804	8812	6924	5035
Supplies	5905	9687	7468	5988	10018	7657	6082	10404	7877	6193
Transport	25827	38999	27635	25827	36674	29443	25827	45197	32284	25827
Admin expenses, fixed	15520	15520	15520	15520	15520	15520	15520	15520	15520	15520
Admin expenses, variable	3880	4458	4346	4272	6025	5242	4719	7853	6286	5242
Electric purchase	274	274	274	274	274	274	274	274	274	274
Kariba complex	88210	88210	88210	88210	88210	88210	88210	88210	88210	88210
ZCCM transmission costs	14988	14988	14988	14988	14988	14988	14988	14988	14988	14988
Exchange losses	57194	57194	57194	57194	57194	57194	57194	57194	57194	57194
Debt service, exist loans	93152	93152	93152	93152	93152	93152	93152	0	0	0
Debt service, new loans	0	32000	32000	32000	52000	52000	52000	52000	52000	52000
Equity investments, domest	64000	23037	15837	11037	19043	11843	7043	19043	11843	7043
Equity investments, forex	0	91629	74829	63629	43203	26403	15203	43203	26403	15203
Working capital increase	15000	17236	16803	16514	23293	20264	18245	30361	24303	20264
Dividends 8% on assets	212000	267040	255520	247840	296918	273878	258518	381836	335756	305036
SUM EXPENDITURES	672482	885032	812148	769141	894264	807895	751253	913109	790580	710610

Source: World Bank estimates.

TABLE 2

FINANCIAL FORECASTS FOR ZESCO
Projections of revenue requirements in constant (1987/88) prices.

2. REQUIRED REVENUES TO COVER EXPENDITURES

	YEAR:	1987/88	1993	1993	1993	1999	1999	1999	2006	2006	2006	
	Scenario:		High	Base	Low	High	Base	Low	High	Base	Low	
REQUIRED REVENUES	Unit											K/conn
Connection fees	K 000	4897	3500	2000	1000	3500	2000	1000	3500	2000	1000	500
Other incomes	K 000	15833	18193	17736	17432	24587	21390	19258	32047	25653	21390	
Grants received	K 000	0	0	0	0	0	0	0	0	0	0	
New loans taken	K 000	0	0	0	0	0	0	0	0	0	0	
Required own finance	K 000	651752	863340	792412	750710	866177	784506	730994	877563	762928	688220	
Existing tariffs give	K 000	422829	434739	417939	392379	526335	466935	403455	625701	514341	399501	
Required own/"Existing tariffs give"		1.54	1.99	1.90	1.91	1.65	1.68	1.81	1.40	1.48	1.72	
Required average ngwe/unit	Ngwe/kWh	8.3	12.0	11.2	10.9	11.2	10.8	10.9	10.8	10.6	11.0	

3. SENSITIVITY ANALYSIS OF REVENUE REQUIREMENTS IF CONNECTION FEES ARE ASSUMED TO BE 10 % AND NOT 50 % OF COSTS

Connection fees	K 000	4897	1400	800	400	1400	800	400	1400	800	400	200
Other incomes	K 000	15833	18193	17736	17432	24587	21390	19258	32047	25653	21390	
Grants received	K 000	0	0	0	0	0	0	0	0	0	0	
New loans taken	K 000	0	0	0	0	0	0	0	0	0	0	
Required own finance	K 000	651752	865440	793612	751310	868277	785706	731594	879663	764128	688820	
Existing tariffs give	K 000	422829	434739	417939	392379	526335	466935	403455	625701	514341	399501	
Required own/"Existing tariffs give"		1.54	1.99	1.90	1.91	1.65	1.68	1.81	1.41	1.49	1.72	
Required average ngwe/unit	Ngwe/unit	8.3	12.0	11.2	10.9	11.2	10.8	10.9	10.8	10.6	11.0	
Rel change in "required own"		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	

Source: World Bank estimates.

ESTIMATES OF FINANCIAL COST OF ELECTRICITY SUPPLY BY DIESEL

Isolated diesels are located in the following ZESCO districts:

- ZESCO Northern Division: Kabompo, Kasempa, Mwinilunga, Zambesi;
- ZESCO Southern Division: Kaoma, Luangwa, Lundazi (Lukulu is to be added as a new diesel-supplied district during 1988).

ZESCO's representatives estimate that the cost of the Northern and Southern systems are similar. Due to a lack of specific data for the Southern Division, data from the Northern Division are used to estimate the specific costs for all ZESCO diesel districts.

Appendix 4.4
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TABLE 1

ISOLATED DIESEL STATIONS
SALES DATA, FINANCIAL REVENUES, EXPENDITURES & LOSSES
Data from Zesco northern division 1986/87

		TOTAL	Kabompo	Kasempa	Mwini-lunga	Zambezi
GENERATION DATA						
Units generated	kWh	3945455	1060800	973736	843523	1067376
Generation fuel	litre	1478887	347328	343173	408367	380022
Rel fuel consumptn	l/kWh	0.37	0.33	0.35	0.48	0.36
SALES DATA						
Consumers		1270	284	300	312	374
Units sold	kWh	3522324	988560	775364	754053	1004347
Sales revenue	000 K	1105.564	276.292	307.533	240.515	281.224
Other revenues	000 K	42.593	3.297	8.942	18.032	12.322
Other/sales revenue	%	3.85	1.19	2.91	7.50	4.38
Total revenues	000 K	1148.157	279.589	316.475	258.547	293.546
Consumptn/consumer	kWh	2773.5	3480.8	2584.5	2416.8	2685.4
Sales rev/consumer	K	870.5	972.9	1025.1	770.9	751.9
Units gener-sold	000 kWh	423131	72240	198392	89470	63029
Unsold units/gener	%	10.72	6.81	20.37	10.61	5.91
Total rev/unit sol	K/kWh	0.33	0.28	0.41	0.34	0.29
Total rev/unit gen	K/kWh	0.29	0.26	0.33	0.31	0.28
EXPENDITURES						
Fuel & lubric oil	000 K	3319.9	776.4	676.2	987.7	879.6
Employees costs	000 K	820	186.8	208.8	217.8	206.6
Maintenance	000 K	73.5	27.5	12.2	25.4	8.4
Transport	000 K	174	53.3	45.1	39.3	36.3
Consumables &c	000 K	18.5	3.1	4.7	9.1	1.6
Admin & other cost	000 K	41.8	13.5	7.9	10.5	9.9
TOTAL expenditures	000 K	4447.7	1060.6	954.9	1289.8	1142.4
Depreciation	000 K	175.8	41.6	33.3	50.6	50.3
SUM expendit+depr	000 K	4623.5	1102.2	988.2	1340.4	1192.7
Fuel cost/unit gen	K/kWh	0.84	0.73	0.69	1.17	0.82
Fuel cost/cubic m	K/m3	2244.9	2235.4	1970.4	2418.7	2314.6
Expendit/unit gene	K/kWh	1.13	1.00	0.98	1.53	1.07
Expendit/unit sold	K/kWh	1.26	1.07	1.23	1.71	1.14
Exp+dep/unit gener	K/kWh	1.17	1.04	1.01	1.59	1.12
Exp+dep/unit sold	K/kWh	1.31	1.11	1.27	1.78	1.19
LOSS						
Expend-total reven	000 K	3299.5	781.0	638.4	1031.3	848.9
Ditto/total reven	%	287.4	279.3	201.7	398.9	289.2
Exp+dep-rev	000 K	3475.3	822.6	671.7	1081.9	899.2
Ditto/total reven	%	302.7	294.2	212.3	418.4	306.3
INCREASE REQUIREMENTS FINANCIALLY to cover expenditures						
Exp/rev /unit generated		3.87	3.79	3.02	4.99	3.89
Exp/rev /unit sold		3.87	3.79	3.02	4.99	3.89

ZESCO LONG-RUN MARGINAL COSTS OF SUPPLY

The estimated long-run marginal economic cost of supply is the sum of capacity and energy costs per unit for a new customer in the hydro power supplied network. The marginal cost for generation capacity is estimated at nil during the project period. The marginal cost of transmission and distribution capacity is estimated in Table 1 for three customer types. As the marginal energy costs for generation, transmission and distribution is estimated to be nil, the total long-run marginal economic cost is equal to the marginal capacity costs for transmission and distribution. The results are given in Table 2.

Table 1:

INVESTMENT ESTIMATES FOR A NEW CONSUMER

	Large Industr. consumer	Small Industr. consumer	House-hold
Voltage level	66 kV	11 kV	400 V
Assumed power level connected load	3 MVA	1 MVA	0.5 KVA
Part of line and transformer costs incl breaker & switchgear, USD			
330 kV to 220 kV	120000	40000	20
220 kV to 66 kV	120000	40000	20
66 kV to 11 kV	0	110000	55
11 kv to 0.4 kV	0	0	180
Connection cable costs			
Length, km/ new consumer	5	1	0.02
Unit cost USD/km	125000	100000	37500
total cost, USD	625000	100000	750
Meter costs, USD	200	150	100
Total investments per average new consumer, USD	865200	290150	1125

ESTIMATES OF TOTAL ANNUAL CAPACITY COSTS PER THE NEW CONSUMER

	Large Industr. consumer	Small Industr. consumer	House-hold
Voltage level	66 kV	11 kV	400 V
Assumed power level connected load	3 MVA	1 MVA	0.5 KVA
a. Capital costs			
The above investments correspond to annual capital costs in USD per year (12%,25 yrs)	110226	36965	143
b. Maintenance costs			
% of above investments	1	1	1
resulting USD/year	8652	2902	11
c. Operating costs			
Meter reading, billing &c, USD/year	5	5	5
d. SUM a+b+c, USD/year	118883	39872	160

TABLE 2 to Appendix 4.5

LONG RUN MARGINAL ECONOMIC COSTS OF ELECTRICITY SUPPLY
Projections of MEC in constant (1987/88) prices, based on expenditure projections in Appendix 4.3

		YEAR:	1987/88	1993	1993	1993	1999	1999	1999	2006	2006	2006	
SCENARIO		Alt:		High	Base	Low	High	Base	Low	High	Base	Low	
Salestax reducn factr (fin to econ)			0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	S
Imp charg reducn fact (fin to econ)			0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	C
	PER CENT FOREX	PER CENT MARGINAL											
Salaries, fixed pa	5	0	0	0	0	0	0	0	0	0	0	0	
Salaries, variable	0	100	14576	51016	29152	14576	51016	29152	14576	51016	29152	14576	
Wages, fixed part	0	0	0	0	0	0	0	0	0	0	0	0	
Wages, variable pa	0	100	8162	9378	9143	8986	12675	11027	9928	16520	13224	11027	
Maintenance, prese	75	2	367	741	740	740	745	740	739	748	739	738	
Maintenance, new a	75	100	0	3311	2618	2156	5108	3722	2798	10217	7445	5597	
Generation fuel	90	100	4006	5271	4729	4186	6536	5451	4367	8011	6295	4578	
Supplies	30	33	1950	3198	2466	1977	3308	2528	2008	3435	2601	2045	
Transport	60	60	20145	30419	21555	20145	28606	22965	20145	35254	25181	20145	
Admin expenses, fi	5	0	0	0	0	0	0	0	0	0	0	0	
Admin expenses, va	2	100	3919	4503	4390	4314	6085	5294	4767	7932	6349	5294	
Electric purchase	0	0	0	0	0	0	0	0	0	0	0	0	
Kariba complex	95	0	0	0	0	0	0	0	0	0	0	0	
ZCCM transmission	0	0	0	0	0	0	0	0	0	0	0	0	
Distr extn inv/yr	70	100	86400	75600	43200	21600	75600	43200	21600	75600	43200	21600	SC
Transmission inv/y	70	50	0	21150	21150	21150	2866	2866	2866	2866	2866	2866	SC
Distr rehab inv/yr	70	0	0	0	0	0	0	0	0	0	0	0	SC
Gener inv/yr	80	0	0	0	0	0	0	0	0	0	0	0	SC
Working capital in	0	100	15000	17236	16803	16514	23293	20264	18245	30361	24303	20264	
Dividends 8% on as	0	0	0	0	0	0	0	0	0	0	0	0	

2. CALCULATIONS

		1987/88	1993 High	1993 Base	1993 Low	1999 High	1999 Base	1999 Low	2006 High	2006 Base	2006 Low
SUM MARG ECON COST,	K 000	154524	221823	155945	116345	215838	147210	102040	241960	161355	108730
Ditto/kWh total	K/kWh	0.0197	0.0307	0.0220	0.0169	0.0278	0.0203	0.0151	0.0297	0.0224	0.0174
MEC/kWh bulk	K/kWh	0.0001	0.0001	0.0001	0.0001	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
MEC/kWh retail	K/kWh	0.0737	0.0982	0.0736	0.0611	0.0695	0.0564	0.0490	0.0590	0.0508	0.0490
MEC , household	K 000	154524	221823	155945	116345	215838	147210	102040	241960	161355	108730
Ditto, household	K/kWh	0.2948	0.5740	0.3718	0.3502	0.2665	0.2127	0.2004	0.2053	0.1656	0.1682
MEC large customer	K 000	68124	146223	112745	94745	140238	104010	80440	166360	118155	87130
Ditto, large custo	K/kWh	0.0433	0.0781	0.0664	0.0602	0.0611	0.0542	0.0511	0.0569	0.0537	0.0554

3. RESULTING MARGINAL ECONOMIC COSTS/kWh

		1987/88	1993 High	1993 Base	1993 Low	1999 High	1999 Base	1999 Low	2006 High	2006 Base	2006 Low
Total supply	K/kWh	0.0197	0.0307	0.0220	0.0169	0.0278	0.0203	0.0151	0.0297	0.0224	0.0174
	USD/kWh	0.0025	0.0038	0.0028	0.0021	0.0035	0.0025	0.0019	0.0037	0.0028	0.0022
Retail supply	K/kWh	0.0737	0.0982	0.0736	0.0611	0.0695	0.0564	0.0490	0.0590	0.0508	0.0490
	USD/kWh	0.0092	0.0123	0.0092	0.0076	0.0087	0.0070	0.0061	0.0074	0.0064	0.0061
Household	K/kWh	0.2948	0.5740	0.3718	0.3502	0.2665	0.2127	0.2004	0.2053	0.1656	0.1682
	USD/kWh	0.0368	0.0718	0.0465	0.0438	0.0333	0.0266	0.0250	0.0257	0.0207	0.0210
Large customer	K/kWh	0.0433	0.0781	0.0664	0.0602	0.0611	0.0542	0.0511	0.0569	0.0537	0.0554
	USD/kWh	0.0054	0.0098	0.0083	0.0075	0.0076	0.0068	0.0064	0.0071	0.0067	0.0069
Bulk supply	K/kWh	0.0001	0.0001	0.0001	0.0001	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
	USD/kWh	0.00001	0.00002	0.00002	0.00002	0.00002	0.00002	0.00002	0.00002	0.00002	0.00002

Source: World Bank Estimates

COST-BENEFIT ANALYSIS OF REFINERY CLOSURE

1. INTRODUCTION

The option evaluated is to close down the Indeni petroleum refinery and to switch the Tazama pipeline to transport white petroleum products in lieu of commingled products. This option has been extensively discussed hitherto, but is re-examined here to take fully into account the future demand pattern for petroleum products, updated capital costs for the pipeline options, and the recent change to the import of reconstituted crude oil. The cost factors taken into account are summarised in the following section.

2. THE COSTS USED IN THE ANALYSIS

Pipeline Rehabilitation

The Tazama pipeline consists of an 8-inch line incorporating four 12-inch loops to expand capacity. To transport batched white petroleum products, it would be technically infeasible to utilize the loops. Hence it would be necessary to revert to the original 8-inch line, replacing sections as necessary. This line, including the existing pumping stations, has the potential to transport 646,000 tpa of white products. For this purpose, it would need rehabilitation, the cost of which has been estimated at US$99 million. This sum includes an estimate of US$32 million for a new tank farm of 107,000 m^3 total capacity, which would be needed at Dar-es-Salaam. The total expenditure of US$99 million would be phased, comprising an initial expenditure of about US$54 million and a subsequent expenditure some five years later of US$45 million.

To rehabilitate the existing Tazama pipeline to continue carrying commingled products would initially cost about US$41 million, to be spent during 1988-90. Further investment of US$15 million would be required in 1996-97 and again in 2003-04.

Operating Costs

Operating costs of a rehabilitated 8-inch white products line are estimated at about US$4.6 million per year. The cost of product contamination at the interface is dealt with by mixing estimated interface quantities with the next lowest value product. However, because of the small quantitites involved, relative to the amount of contamination, it would be necessary to stop the import of regular gasoline. Special measures, including new tanks at Dar and Indeni, would be necessary to handle an adequate minimum batch size for kerosene.

Costs of Jetty Rehabilitation and Dredging

Costs of jetty rehabilitation and dredging at Dar were not taken into account due to lack of information.

Closure of the Refinery

No costs have been included for closure of the refinery. These would need to be carefully assessed and quantified, should circumstances arise where refinery closure could be recommended. Refinery closure costs will include mothballing, care and maintenance costs, employee costs, compensation to Agip as part owner, and a consequental technical assistance contract for the products pipeline and to replace services currently provided by Agip.

Overland Transportation of Aviation Kerosene and Black Products

In the event of refinery closure, it would be necessary to transport Zambia's required supplies of aviation kerosene, fuel oil and bitumen by the Tazara Railway. Aviation kerosene demand is forecast at 48,000 tons in 1991 and 53,000 tons in 2006. The minimum requirements for fuel oil are forecast at 104,000 tons in 1991, declining thereafter to 76,500 tons in 1996 and about 55,300 tons in 2006. 1/ Bitumen requirements are forecast at just over 15,000 tons in 1991, rising thereafter throughout the study period to about 21,000 tons in 2006.

Harbour Dues and Refinery Costs

It is assumed that the refinery operates with a 5.5% (by weight) fuel and loss and operating costs are made up as follows:

	US$/mt
Harbour Dues	2.20
Processing Fee	12.00
Maintenance	2.00
Inspection & Sundry	0.10
Overheads	0.95
Total	17.25

These costs are taken directly from the 1986-87 ZIMCO operating statistics. The maintenance costs are added to take account of the higher costs incurred in operating a refinery over 15 years old.

1/ This assumes maximum feasible substitution of heavy fuel oil by ZCCM, i.e., substitution of coal for fuel oil at the Nkana smelter.

Ocean Freight

The costs of freight from Mina Al Ahmadi to Dar are taken as US$4.0/mt for commingled products, in line with the current supply contract with KPC. This figure compares with the US$12.5/mt estimated for the corresponding shipment of white products in smaller vessels mentioned above.

Input and Product Prices

The prices of the petroleum products refined and/or purchased are required in the analysis. However, as will be explained later, the analysis is set up on a cost basis to minimize their importance. The only use made of these valuations is in estimating the cost of the refinery losses and in valuing the product upgrading by the refinery. Since the large volumes of gas oil and kerosene pass through the refinery with only minor changes, the sensitivity of the result to the price forecasts made is minor. One of the important benefits of the existing system is that Zambia buys virgin naphtha instead of gasoline, using Indeni to make the gasoline.

There is no fully satisfactory basis for forecasting the levels and relative prices of petroleum products over time. The basis taken in this report is to assume a reasonable return to a modern upgrading refinery. The fixed costs on a typical modern upgrading refinery break down as shown below for a medium sized refinery with a capacity of 250,000 bpcd.

	US$/mt
Manpower	1.85
Investment related overheads	3.00
Cost of working capital	2.00
Total	6.85

Operating on Arab Light crude oil at FOB cost of US$15.75/bbl, assuming a freight rate of US$8.5/mt and running for maximum mogas yield, the following price profile gives the required margin.

	US$/mt
LPG	120.00
Naphtha	147.78
Premium Mogas	182.00
Dual Grade Kero	167.58
Gas Oil/Diesel	142.43
3.5% Sulphur HFO	95.08

3. METHODOLOGY OF THE ANALYSIS

The objective of the analysis is to compare the costs of the white product pipeline and refinery closure option with the costs of continuing to operate the line as a commingled pipe and running the refinery. This approach minimizes the effect of volatile crude oil and product prices.

A spreadsheet model was developed covering the years 1989 to 2006. The model is in three sections. The first computes the costs of the white product pipeline/refinery closure option, the second section computes the costs of the commingled import/refinery operation option. The third section of the model compares the costs developed in the other two sections. The Net Present Value (NPV) of the costs were calculated using a discount factor of 12%.

The analysis is facilitated by the fact that the refinery uses commingled products. The relative values of crude oil and products are therefore not relevant. Except for the ability to upgrade naptha to gasoline, the costs of the products at Kuwait are essentially the same, whether they are commingled or shipped as separate products.

Similarly, since the product demand at the refinery is unchanged by the method by which they are supplied, market prices in Zambia are not relevant when comparing the two cases.

Product prices are only relevant in the refinery simulation, where: (a) some of the intermediate products are converted into finished products; and (b) in valuing the refinery losses. This is covered in the next section.

The capital costs of both options were inserted in the appropriate years of the analysis. The operating costs of both were split into fixed and variable elements, with the former accounting for 75% of the total costs in 1989.

The product demand forecast used is the base case developed for this Report.

4. SIMULATING THE REFINERY OPERATION

The object of the refinery simulation is to calculate the product purchase requirements from the known product demand pattern. It is then possible to calculate the cost of operating the refinery.

The first step was to set up a very simple refinery model using a linear programming system. This model also included a representation of the transportation and pipeline costs. It is used to test the methodology described in the previous section, prior to developing the more accurate spreadsheet model described above. It was also used to develop the refinery operating modes required by the spreadsheet analysis.

There are three ways in which the refinery upgrades the product it receives from the pipeline namely:

- Converting Naphtha to Gasoline
- Extracting Bitumen from Re-processable Residue
- When possible, extracting Gas Oil from Reprocessable Residue

The following yields were developed for use in the spreadsheet model:

Mode Feedstock Products	Mogas Naphtha	Bitumen Residue	Gas Oil Residue
Mogas	0.812	-	-
Gas Oil	-	0.142	0.053
HFO	0.133	0.469	0.892
Bitumen	-	0.334	-
Fuel & Loss	0.055	0.055	0.055

These yields are based on Kuwait crude oil. The yield of heavy fuel oil in the first column is to allow for the production of petroleum gases and hydrogen in the reformer which will be burnt by the refinery, thus increasing the heavy fuel oil available for sale.

The second column in the table shows the way in which the imported reprocessable residue can be converted into bitumen. The sulphur in the feedstock is concentrated into the bitumen. This allows some of the gas oil which was blended into the resid. at Kuwait so as to meet sulphur specifications to be extracted and sold as diesel at Indeni.

The third column is harder to assess. It represents the fact that some of the residue is fired to heat the refinery. The refinery can process fuel oil with higher than 3.5% sulphur without exceeding sulphur emission controls because some of the material burnt is well below the control level. The extent to which this is possible is unclear and thus a conservative estimate has been made.

To complete the refinery yield information, it is assumed that there is 5.5% fuel and loss on kerosene and gas oil, which are processed and recovered little changed.

The refinery operating costs were described in section 2 above.

The steps in the spreadsheet calculation are as follows:

1. Calculate the naphtha requirement--mode 1 in the table.
2. Calculate the residue needed to make the bitumen--mode 2.
3. Calculate the balance of the HFO demand using mode 3.
4. Calculate the balance of the gas oil demand as gas oil import.

This procedure provides a fairly accurate simulation of the refinery which is implementable in the spreadsheet model.

5. CONCLUSIONS

The spreadsheet model shows that the NPV of the costs of the option of continued refinery operation is US$52 million less than that of the white products pipeline/refinery closure option. The build-up of the costs is shown in the following Table.

COMPARISON OF NPVs

	COMMINGLED PRODUCTS/ REFINERY CASE	WHITE PRODUCTS PIPELINE CASE
Ocean freight cost	-	31.66
Interest on working capital	15.44	4.84
Pipeline capital cost	42.75	64.90
Pipeline operating cost	32.46	50.84
Rail cost	-	69.38
Refining cost	78.61	-
Total cost	169.26	221.62

The cost of running the refinery is the largest single cost of the current supply system, but this is more than offset by the combined cost of the additional freight costs for white products from Kuwait to Dar, the high cost of rail freighting the heavy fuel oil and aviation kerosene from Dar to Indeni, and the higher costs of pipeline rehabilitation and operation in the white products case.

The conclusion is robust for all feasible patterns of petroleum product demand, i.e.: (a) if all fuel oil is replaced by gas oil and coal; or (b) if fuel oil use is minimized through aggressive coal substitution. It holds even if ZCCM were to eliminate the use of fuel oil altogether.

However, the option to reconvert the pipeline to white products will need periodic review as circumstances change, particularly if major refinery rehabilitation is contemplated on a scale that would substantially change the NPVs set out above.

THE ECONOMICS OF ADDING A MILD HYDROCRACKER TO THE NDOLA REFINERY

1. Introduction

The addition of a mild hydrocracker to the Ndola refinery was extensively studied by ZIMCO's consultants UOP between 1983 and 1985. Several configurations were considered. Eventually, the addition of a low pressure UOP MHC Unibon unit, together with a new vacuum distillation unit, was recommended. This was considered to be the highest return investment with available capital. Had unlimited finance been available, it was calculated that a high pressure hydrocracker would have provided a better return. Capital shortage and narrowing margins led to deferral of the hydrocracker proposal.

In the present re-evaluation, the oil product demand forecasts have been substantially reduced, relative to those used in the UOP study (see Table 1). Furthermore, crude and product prices have fallen since the UOP study, which also affects the results.

Table 1: COMPARATIVE 1988 OIL PRODUCT DEMAND FORECASTS
(Tons)

	UOP Study	Present Study
	('000 mt/year)	
LPG	14,997	6,770
Mogas	214,182	98,850
Atk	110,689	50,200
Kerosene	55,808	26,150
Diesel	519,285	260,000
HFO	109,379	99,250
Bitumen	16,754	14,400
Total	1,041,094	555,620

Source: UOP report and World Bank estimates.

This preliminary investigation shows that the economics of hydrocracking have deteriorated since 1985, and so detailed re-analysis has not been undertaken. In this section the results of that preliminary investigation are presented and the circumstances indicated which might lead to a need to re-examine the situation in detail.

2. Methodology

The size of the mild hydrocracker is taken to be that proposed in the UOP report, namely 440 t/cd. Reduction of the size of the unit to reflect the lower demand shown in Table 1 would not lead to great savings on a small unit such as this, where engineering and erection costs predominate. Total capital costs of US$35.1 million were taken directly from Section 1 and 6 of the 1985 UOP report, as were the manpower costs. They were not escalated to 1988 costs. Had this been done, the results would have been even less favorable. 10% interest charges were assumed, with a loan repayment period of 15 years. Maintenance costs were taken as 3% of the BLPP and offsite facilities cost of US$30.47 million calculated in the UOP report.

The function of the hydrocracker is to upgrade low-value heavy fuel oil (HFO) to more valuable products, notably kerosene and gas oil. To obtain an estimate of the value added by the hydrocracker, it is assumed that the value of its feedstock was that of HFO. The products from the hydrocracker were assigned their market value. In the case of the naphtha produced, it was assumed that this would be processed to gasoline in the reformer with a yield loss of 18% by weight. This method of analysis avoids the need to place a value on crude oil, since only the relative value of products are required. The prices used were the same as those in Appendix 5.1 for the refinery closure analysis. These are based on FOB Gulf prices.

The yields from the mild hydrocracker were estimated from data provided in Exhibit D-3 (Case 1 - Design Basis Modifications MHC Unibon and New Vacuum Unit World Bank Demand Scenario) of the final UOP Report in 1985. The yields presented in the above were adjusted to represent only processing of vacuum distillate. The yields thus calculated were compared with those similarly adjusted from Exhibit D-5 of the same report and good agreement was obtained. The yields derived are presented in Table 2.

Table 2: ESTIMATED OVERALL HYDROCRACKER YIELDS

	Wt%
LPG	1.92
Gasoline	3.62
Kerosene	22.83
Gasoil	31.71
HFO	33.19
Total	93.27
Fuel & Loss	6.73 a/

Source: World Bank estimates.

a/ Includes reformer yield loss, vacuum distillation, fuel, steam, and power.

In the UOP study, use of Arabian Light crude oil was assumed. However, these yields are likely to be typical of the processing of most

Middle-East vacuum distillates, including Kuwait crude, from which the current reconstituted crude oil is derived.

There is a potential problem with hydrogen production for the hydrocracker because of the low gasoline demand. The required hydrogen is produced by the reformer, which is run to produce gasoline. If the demand for the latter is low, insufficient hydrogen is produced to completely load the hydrocracker. Based on the revised product demands in Table 1, it was estimated that the hydrocracker could not run at more than 68% of capacity, due to the hydrogen supply constraint.

At the low refinery throughputs implied by the Table 1 demands, problems with fuel oil blending might also arise if a hydrocracker were added because of the high proportion of vacuum residue produced. This would require additional blending and fuel oil production, and, in turn, dictates the minimum saleable quantity of fuel oil, a quality essentially the same as that currently consumed. In this preliminary analysis, that possibility has been ignored. It has been assumed that the components produced can be blended.

3. The Revised Economics of Mild Hydrocracking

The yields presented in Table 2 were used to calculate the value of products from the hydrocracker, using the prices from Appendix 5.1. The detailed calculations for the base case are presented in Table 3.

Table 3: ESTIMATED PROFIT (LOSS) FROM HYDROCRACKER INSTALLATION

Hydrocracker product yields a/	Weight %	US$/ton	US$/ton
LPG	1.92	120.00	
Gasoline	3.62	185.00	
Kerosene	22.83	170.58	
Gas oil	31.71	145.43	
HFO	33.19	98.8	
(1) Average hydrocracker yield			126.62
(2) Hydrocracker Feedstock Cost @ HFO value			(98.08)
Hydrocracker capital and Operating Costs b/			
	US$ '000	US$/ton	
Manpower	142.7	1.37	
Maintenance	914.1	8.80	
Capital Charge	4614.7	44.40	
(3) Total capital and operating cost			(54.7)
(4) Net Profit (Loss) (1)-(2)-(3)			(26.03)

Source: World Bank estimates.

a/ Assuming operation at 301.3 tons/day (H2 limited).
b/ Assuming 345 days operation per year.

It can be seen from Table 3 that, with the base case assumptions outlined in section 2, the hydrocracker is unprofitable to the extent of US$26.03/ton of feedstock processed.

4. Sensitivity Tests

The returns to hydrocracking are sensitive to the difference between the HFO and gas oil price and to the assumed operating level. To test these sensitivities, a series of simulations were done. The results are shown in Table 4.

Table 4: SENSITIVITY TO HFO PRICE AND UTILIZATION

HFO Price	Utilization rate		
(US$/mt)	60%	80%	100%
60	(8.15)	7.32	16.59
70	(15.27)	0.31	9.65
80	(21.00)	(6.37)	2.97
90	(28.62)	(13.05)	(3.71)

Source: World Bank estimates.

Even using 1985 capital costs, these show that the hydrocracker is economicaly viable only when the HFO price is very low and the utilization is high. The higher utilization level of the hydrocracker could only be achieved by increased product demand (particularly gasoline and fuel oil) in Zambia. The higher gasoline production would have the effect of increasing the hydrogen feed available to the hydrocracker. The low HFO price required to achieve profitability would imply a fall in the HFO price relative to gas oil to well below the historical average difference of US$70/t.

5. External Factors Which Could Favour Hydrocracking

In section 4, two circumstances which could favor the construction of a mild hydrocracker were identified, namely:

- Higher gasoline demand in Zambia.
- Substained low HFO price relative to gas oil.

It is also possible that refining margins could improve in a sustained way, making refining more profitable than it has been for the last decade. This is likely to happen only when existing refining capacity in the Gulf becomes fully utilized and there is a sustained oversupply of crude oil. Under such circumstances, the availability of products for blending the reconstituted crude oil would become tight and their price would rise. It might then become profitable for Indeni to refine crude oil. In such circumstances, an upgrading refinery of some sort could provide a higher return than the existing refinery.

Should this situation arise, a completely new analysis of the situation would be required, taking into account the product demand forecasts and prices prevailing at the time. Such a study would not necessarily be limited to a review of hydrocracking. Other upgrading processes should also be studied.

REPLACEMENT COST OF PLANTATION WOOD FOR CHARCOAL PRODUCTION

The following is a simple cost model for the production of plantation woodfuel from exotic tree species in Zambia. Costs are based on information supplied by ZAFFICO for industrial plantation forestry. They measure the estimated cost of wood on the stump, i.e., excluding costs of felling, stacking, etc.

Major Assumptions

The following major assumptions were made:

(a) woodfuel yield is $20m^3$ solid per ha per year at 15% moisture content;

(b) five-year rotation, yielding $100m^3$ solid per ha per rotation;

(c) calorific value of charcoal = 16/GJ/ton = 11.4 GJ/m^3 solid;

(d) vegetation cleared from plantation site has no economic value;

(e) discount rate 12%.

COST MODEL

Year	Activity	Cost per ha		Yield (m^3/ha)	
		Actual	Discounted	Actual	Discounted
		--------(Kwacha)-------			
1	Stumping, clearing burning	970			
	Seedlings	390			
	Planting and beating up	200			
	Weeding	450			
	Fire protection	50			
	Supervision	163			
	Total	2,223	1,985		
2	Weeding	450			
	Fire protection	50			
	Supervision	163			
	Total	663	528		
3	Fire protection & supervision	213			
		} 408			
4	Fire protection & supervision	213			
5	Fire protection & supervision	213		80	45
			} 663		
6	Weeding, fire protection & supvn.	663			
7-10	Fire protection & supervision	639		130	42
			} 377		
11-15	Same as 6-10	1,302		115	21
16-20	Same as 6-10	1,302	214	95	10
21-25	Same as 6-10	1,302	122	80	5
	Total	8,733	4,297	500	123

Results

Discounted cost of production = K4,297/ha
Discounted yield over 25 years= 123 m^3/ha
Cost per m^3 = K4,297/123 = K34.9
Cost per GJ = K34.9/11.4 = K3.1

COST/BENEFIT ANALYSIS OF RENEWABLE ENERGY TECHNOLOGIES

This appendix presents the detailed cost-competitiveness calculations for solar water heating and wind pumping of water that are summarized in Chapter 8.

A. SOLAR WATER HEATING - COST COMPETITIVENESS CALCULATIONS

Electric heating: Assumptions:

Water usage: 100 liters/day

Geyser and Piping Thermal Losses 15%

Geyser Efficiency 90%

Cost of Geyser: K2,896 for a 90l boiler, K3,860 for a 130l boiler

Cost of Electricity: K0.07/kWh

Lifetime: 5 years: interest 12%; annuity: 0.277

Fixed costs: K802/yr (based on the 90l geyser)

Electricity Costs: K233/yr

Total yearly cost: K1,035/yr

Solar Collector:

Water usage: 150 liters/day (available temperature is lower)

Cost of completely installed modular system: K5,000

Lifetime: 15 years, interest 12%; annuity 0.147; maintenance 2% of investment

Total yearly cost: K835/yr

B. WIND PUMPING POTENTIAL AND COMPETITIVENESS

Potential

As shown in the Table below, a 1.7 m rotor diameter wind water pump could meet the needs of a small village in the Lusaka or Ndola area:

Lusaka

(1) depth [m]	(2) demand [l/d]	(3) wind m/2 [Wh/m2/d]	(4) wind [Wh/d]	(5) pump [Wh/m3]	(6) water [l/d]	(7) nbr [units]
10	25	291	661	39	17,000	680
10	40	291	661	39	17,000	425
60	25	291	661	234	2,800	112
60	40	291	661	234	2,800	70

Ndola

(1) depth [m]	(2) demand [l/d]	(3) wind m/2 [Wh/m2/d]	(4) wind [Wh/d]	(5) pump [Wh/m3]	(6) water [l/d]	(7) nbr [units]
10	25	226	661	39	13,200	528
10	40	226	661	39	13,200	330
60	25	226	661	234	2,200	88
60	40	226	661	234	2,200	55

Notes:

(1) Depth of a standard hand dug well or a borehole.
(2) Unit demand of water each day.
(3) Power on the shaft of a standard multiblade wind power pump, for each m^2 of rotor area (yearly average).
(4) Daily energy produced by a 1.7m rotor diameter wind power pump (yearly average).
(5) Required energy for pumping $1m^3$ water, either from a 10m deep well or a 60m borehold (90% of all boreholes in Zambia have this depth), considering an overall pump and transmission efficiency of 70%.
(6) Resulting daily amount of water which can be pumped (column 4 divided by column 5).
(7) Resulting number of persons or cattle whose daily requirements can be met (column 6 divided by column 2). Supply from a borehole, requiring more energy, meets the demand of less people, etc.

Cost Effectiveness of for Village Water Pumping

The cost comparison is computed on the basis of the m^3 cost for satisfying the water requirements of village in the Central Province, numbering 100 persons and 50 head of cattle, i.e., 4.5 m^3 per day from a 60m borehole, or 1,650 m^3.

Windpump

Cost	K8,000
Lifetime	15 years; annuity 14.7%
Maintenance:	2% of initial investment
Yearly Cost:	K1,336
Borehole	K16,000
Lifetime:	20 years; annuity 13.4%
Maintenance:	1% of cost
Yearly cost:	K2,304
Total Cost/yr:	K3,640
Number of Windmills	3
Total yearly cost:	K10,920
Cost of $1m^3$	K6.65

Handpump

Cost:	K5,000
Lifetime:	10 years; annuity 17.7%
Maintenance	10%
Yearly Cost:	K1,385
Borehole Cost:	K2,304
Total yearly Cost:	K3,689
Cost of $1m^3$	K2.25

Hand-pumping would be carried out during 2.5 hours each day at an average rate of 0.5 liters/second.

Cost Effectiveness of Irrigation

The cost comparison is with diesel engine water pumping, as this is the only alternative for water irrigation in remote places. Computations consider the cost per m^3 for pumping 10,000 m^3/year from a borehole.

Diesel pumping:

Diesel engine (smallest available 6HP)	K26,000
pump	K5,000
frame	K2,000
pulleys	K1,000
TOTAL	K34,000

Maintenance: yearly 10% of initial investment
Lifetime: 10 years; annuity 17.7%
Consumption: 2.4 $cm^3/m^3/m$ (i.e., 10% overall efficiency) with head of 60m: $72cm^3/m^3$ at K2.80/liter

Annual fixed costs: 34,000 x (0.177 + 0.10)	K9,418
Annual fuel costs: 0.144 x 2.8 x 10,000	K4,032
Borehold annual costs	K2,304
Total	K15,754
Cost per m3 of water	K1.57

Wind Pumping

Wind energy convertor and pump:	K30,000
Installation: K5,000	
Maintenance: yearly 2% of initial investment	
Lifetime: 20 years; annuity 13.4%	
Annual fixed cost	K5,390
Borehole annual cost	K2,304
Total cost per unit	K7,695
Total cost for 3 units	K23,082
Cost per m3 of water	K2.31

ENERGY SECTOR MANAGEMENT ASSISTANCE PROGRAM

Activities Completed

Country	Project	Date	Number
Energy Efficiency and Strategy			
Africa Regional	Participants' Reports - Regional Power Seminar on Reducing Electric System Losses in Africa	8/88	087/88
Bangladesh	Power System Efficiency Study	2/85	031/85
Botswana	Pump Electrification Prefeasibility Study	1/86	047/86
	Review of Electricity Service Connection Policy	7/87	071/87
	Tuli Block Farms Electrification Prefeasibility Study	7/87	072/87
Burkina	Technical Assistance Program	3/86	052/86
Burundi	Presentation of Energy Projects for the Fourth Five-Year Plan (1983-1987)	5/85	036/85
	Review of Petroleum Import and Distribution Arrangements	1/84	012/84
Costa Rica	Recommended Technical Assistance Projects	11/84	027/84
Ethiopia	Power System Efficiency Study	10/85	045/85
The Gambia	Petroleum Supply Management Assistance	4/85	035/85
Ghana	Energy Rationalization in the Industrial Sector of Ghana	6/88	084/88
Guinea-Bissau	Recommended Technical Assistance Projects in the Electric Power Sector	4/85	033/85
Indonesia	Energy Efficiency Improvement in the Brick, Tile and Lime Industries on Java	4/87	067/87
	Power Generation Efficiency Study	2/86	050/86
Jamaica	Petroleum Procurement, Refining, and Distribution	11/86	061/86
Kenya	Power System Efficiency Report	3/84	014/84
Liberia	Power System Efficiency Study	12/87	081/87
	Recommended Technical Assistance Projects	6/85	038/85
Madagascar	Power System Efficiency Study	12/87	075/87
Malaysia	Sabah Power System Efficiency Study	3/87	068/87
Mauritius	Power System Efficiency Study	5/87	070/87
Panama	Power System Loss Reduction Study	6/83	004/83
Papua New Guinea	Energy Sector Institutional Review: Proposals for Strengthening the Department of Minerals and Energy	10/84	023/84
	Power Tariff Study	10/84	024/84
Senegal	Assistance Givan for Preparation of Documents for Energy Sector Donors' Meeting	4/86	056/86
Seychelles	Electric Power System Efficiency Study	8/84	021/84
Sri Lanka	Power System Loss Reduction Study	7/83	007/83
Syria	Electric Power Efficiency Study	9/88	089/88
Sudan	Power System Efficiency Study	6/84	018/84
	Management Assistance to the Ministry of Energy and Mining	5/83	003/83

Activities Completed

Country	Project	Date	Number
Energy Efficiency and Strategy (Continued)			
Togo	Power System Efficiency Study	12/87	078/87
Uganda	Energy Efficiency in Tobacco Curing Industry	2/86	049/86
	Institutional Strengthening in the Energy Sector	1/85	029/85
	Power System Efficiency Study	12/88	092/88
Zambia	Energy Sector Institutional Review	11/86	060/86
	Power System Efficiency Study	12/88	093/88
Zimbabwe	Power Sector Management Assistance Project: Background, Objectives, and Work Plan	4/85	034/85
	Power System Loss Reduction Study	6/83	005/83
Household, Rural, and Renewable Energy			
Burundi	Peat Utilization Project	11/85	046/85
	Improved Charcoal Cookstove Strategy	9/85	042/85
Côte d'Ivoire	Improved Biomass Utilization--Pilot Projects Using Agro-Industrial Residues	4/87	069/87
Ethiopia	Agricultural Residue Briquetting: Pilot Project	12/86	062/86
	Bagasse Study	12/86	063/86
The Gambia	Solar Water Heating Retrofit Project	2/85	030/85
	Solar Photovoltaic Applications	3/85	032/85
Global	Proceedings of the ESMAP Eastern & Southern Africa Household Energy Planning Seminar	6/88	085/88
India	Opportunities for Commercialization of Non-Conventional Energy Systems	11/88	091/88
Jamaica	FIDCO Sawmill Residues Utilization Study	9/88	088/88
	Charcoal Production Project	9/88	090/88
Kenya	Solar Water Heating Study	2/87	066/87
	Urban Woodfuel Development	10/87	076/87
Malawi	Technical Assistance to Improve the Efficiency of Fuelwood Use in the Tobacco Industry	11/83	009/83
Mauritius	Bagasse Power Potential	10/87	077/87
Niger	Household Energy Conservation and Substitution	12/87	082/87
	Improved Stoves Project	12/87	080/87
Peru	Proposal for a Stove Dissemination Program in the Sierra	2/87	064/87
Rwanda	Improved Charcoal Cookstove Strategy	8/86	059/86
	Improved Charcoal Production Techniques	2/87	065/87
Senegal	Industrial Energy Conservation Project	6/85	037/85
Sri Lanka	Industrial Energy Conservation: Feasibility Studies for Selected Industries	3/86	054/86
Sudan	Wood Energy/Forestry Project	4/88	073/88
Tanzania	Woodfuel/Forestry Project	8/88	086/88
Thailand	Accelerated Dissemination of Improved Stoves and Charcoal Kilns	9/87	079/87
	Rural Energy Issues and Options	9/85	044/85
	Northeast Region Village Forestry and Woodfuel Pre-Investment Study	2/88	083/88
Togo	Wood Recovery in the Nangbeto Lake	4/86	055/86
Uganda	Fuelwood/Forestry Feasibility Study	3/86	053/86

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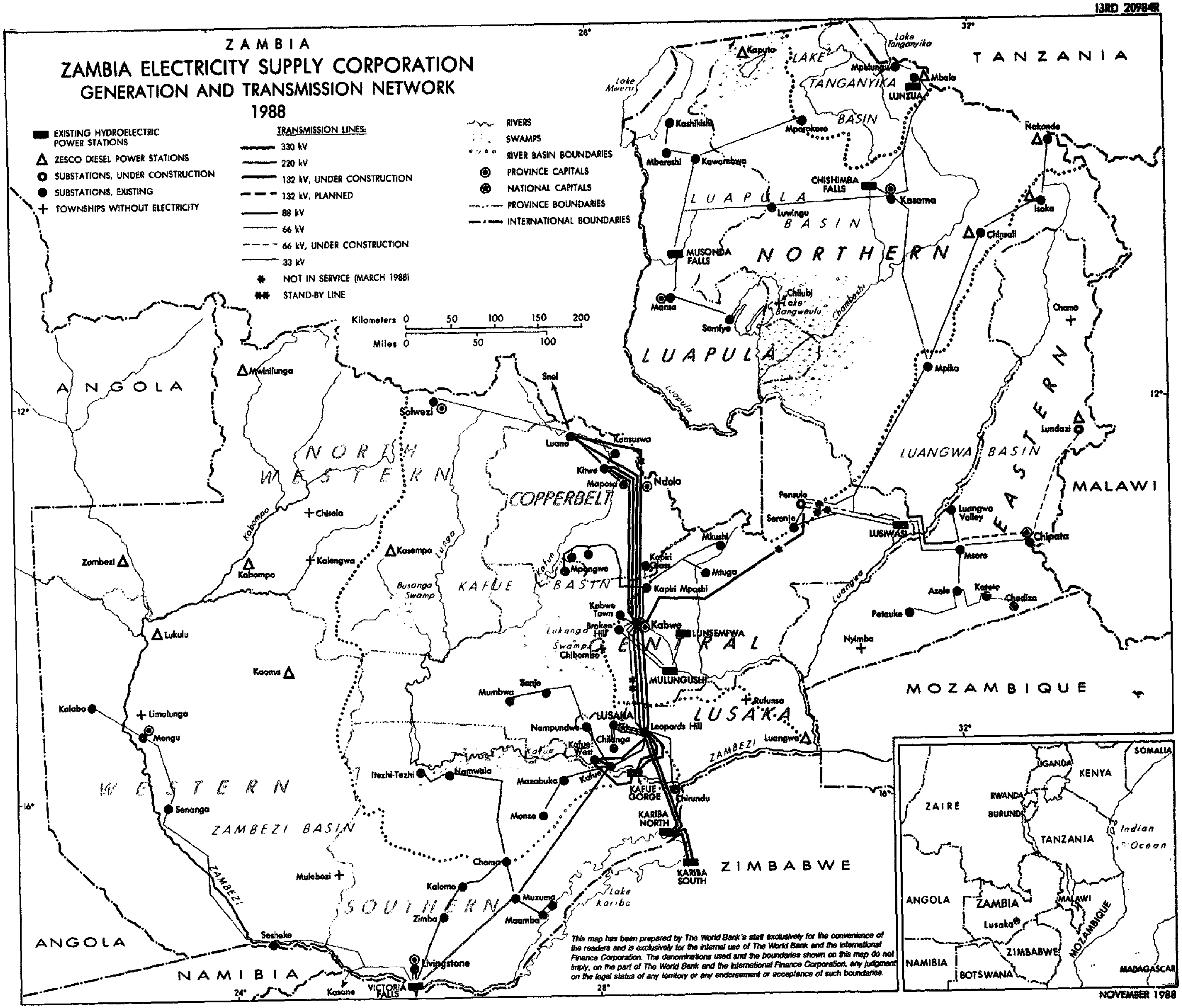

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