Joint UNDP/World Bank Energy Sector Management Assistance Program

Activity Completion Report

No. 081/87

Country: LIBERIA

Activity: POWER SYSTEM EFFICIENCY STUDY

DECEMBER 1987

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.

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LIBERIA

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FOREWORD

The Liberia Energy Assessment report and a subsequent report outlining recommended technical assistance projects identified improving the operation of the Liberia Electricity Corporation (LEC) as one of the country's highest priorities in the energy sector. 1/ LEC is a public corporation responsible for most of the public electricity supply throughout Liberia. At the time of the Energy Assessment it was facing a severe shortage of cash and rapidly deteriorating service reliability.

As a result, the Government of Liberia requested assistance through the joint UNDP/World Bank Energy Sector Management Assistance Program (ESMAP) to undertake a Power Efficiency Study of LEC. The objectives of the study were to determine the causes of LEC's difficulties, suggest solutions, and present them as projects suitable for financing by the international lending community. ESMAP was also asked to prepare a preliminary least-cost generation plan to define the short and medium-term investments required to meet demand.

During the course of the Power Efficiency Study, it became evident that LEC's difficulties are caused by severe internal and external problems that affect the institutional and technical aspects of its operations. The institutional problems are of such magnitude that the mission concluded that restructuring of LEC and formation of a new corporation are prerequisites for any further investment in the utility. Furthermore, since some of LEC's problems are common to, and affected by, the management of other public corporations, it appears that a comprehensive program of public sector management reform is an important precondition for any real improvement in the performance of LEC.

In parallel with the ESMAP review of LEC, the Government and the World Bank have agreed to undertake a strategic study of the public enterprise sector. The objective of this study is to recommend ownership/management arrangements which will improve efficiency in public corporations. This study, now underway, is concentrating on a group of key public enterprises, including the LEC.

In this context, the ESMAP review of LEC and the study of the public enterprise sector are complementary pieces of work. The first one supports the need for restructuring, presents some options for solving the institutional and technical management problems of LEC, and provides a detailed analysis of specific operational improvements to be undertaken. The second, ongoing study concentrates on the strategic aspects

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1/ Liberia: Issues and Option in the Energy Sector, December 1984, Report No. 5279-LBR and Liberia: Recommended Technical Assistance Projects, July 1985, Report No. 038/85.

of public sector management reform in Liberia, of which the LEC is an important part. It will define the institutional framework under which the process of restructuring should be undertaken and evaluate in more detail the options available to implement it.

The following report presents the main findings and recommendations of the ESMAP mission that visited Liberia in June 1985. 2/ The mission acknowledges with thanks the sincere cooperation of LEC's management and staff, their efforts in preparing a position paper on LEC's operating problems, and their willingness to engage in frank and open discussions. Without this level of cooperation it would have been impossible to develop a clear picture of LEC's needs.

2/ The mission comprised: Messrs. Alfred Gulstone (Power Engineer, Mission Leader); Miguel Bachrach (Economist, Team Leader); Alfred Banks (Generation Specialist, Consultant); Willy Pacheco (Distribution Engineer, Consultant); Klaas Kimstra (Diesel Engineer, Consultant); and Daniel Robinson (Financial Analyst, Consultant). Secretarial support in the office was provided by Mrs. Tara Allen.

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Overview

1.1 The quality of electrical service provided by LEC has deteriorated over the last years to the point that extensive load shedding has become common practice during the dry season. Also, the corporation is in serious financial difficulty due to high non-technical losses and poor collections. In financial year 1983/84, LEC supplied energy worth US$47.4 million but its revenue was only about half of this sum, or US$23.7 million. The poor quality of service and the acute financial problem are the two most obvious symptoms of serious operational problems which stem from five fundamental causes:

(a) a lack of autonomy;

(b) the seriously depressed state of the Liberian economy;

(c) poor payment of bills by government institutions and public corporations;

(d) an extremely poor public image; and

(e) a breakdown of management systems.

Fundamental Causes of LEC's Problems

Lack of Autonomy

1.2 Although LEC is theoretically autonomous it operates like a government department. Its pay scales are determined by public service regulations and its general manager is given directives by high level government officials. The pay scales are too low to attract and retain experienced, qualified staff. At the same time the general manager often is directed to hire specific individuals for positions that may or may not be required, resulting in gross overstaffing of the corporation.

1.3 The directives given to the general manager also affect technical operating decisions and investment decisions. He is sometimes instructed to keep supply on for a specific area, requiring the operation of plants that should be shut down for maintenance. He is sometimes instructed to construct rural systems when there are no economic benefits to doing so.

Depressed State of the Economy

1.4 The balance of payments situation in Liberia has deteriorated to the point where foreign exchange reserves at the National Bank of Liberia no longer can service debt payments or meet the cost of oil and other public sector imports. At the time of the mission's visit most public employees had not been paid for two to three months. As a result, LEC cannot obtain foreign exchange to buy fuel and spares, and many of its customers cannot afford to pay their electricity bills.

Poor Payment of Bills by Government

1.5 Government institutions and public corporations are heavily in arrears. They are responsible for US$4.8 million of the utility's US$10.6 million of outstanding bills for the financial year 1983/84.

Public Image

1.6 LEC is now perceived by the general public as an inefficient organization because of its poor service and alleged fraudulent practices by some employees. Also, because of its ineffectiveness in dealing with electricity theft, some customers now consider electricity as a free good supplied by the Government.

Breakdown of Management Systems

1.7 Most of LEC's systems for management, accounting and technical operations have deteriorated. What remains of these systems is little more than a shell which can no longer be depended on for effective operation.

Impact on the Economy and Rationale for Action

1.8 Transforming LEC into a commercially viable entity requires significant investment, the allocation of scarce foreign exchange and, most important, a serious commitment by the Government to refrain from direct interference in LEC's operation. The impact of its present performance on the economy therefore should be assessed in order to determine whether improvement should be attempted or whether the utility should be allowed to continue as it is.

1.9 The most obvious negative impacts on the economy are:

(a) LEC's financial losses increase the Government's fiscal deficit. In 1983/84 unbilled consumption and uncollected bills (excluding those owed by the Government) amounted to about US$19.0 million.

(b) The poor quality of service has provoked the importation of small, relatively inefficient standby generators which worsens Liberia's balance of payments problems.

(c) The quality of service may be inhibiting the formation of small businesses which cannot afford to buy a standby set but which would contribute to economic activity.

1.10 The mission believes that corrective action is warranted on the basis of the above, but only if the Government has the will and commitment to provide the two essential conditions: full autonomy, and access to foreign exchange. Unless these two minimum conditions are met, the provision of funds alone will not suffice to correct the problems.

Possible Solutions

1.11 After a careful consideration of LEC's problems and taking into account the reasons for the failure of previous attempts using selective technical assistance, the mission concluded that major restructuring, extensive improvements in operational practices and possibly a change in ownership are required to improve the operation of the utility. 1/ The objective of these changes is to form a commercially viable entity which provides reliable electric power and operates within a regulatory framework that protects both its customers and its owner(s)/managers. Also, restructuring is intended to provide an appropriate framework to preserve the autonomy of the new entity and to ensure that the improvements made are less prone to retrogression.

1.12 Restructuring is required to solve internal problems by providing management with autonomy, reestablishing basic operating systems, reducing staff to levels compatible with efficient utility practice, and establishing levels of remuneration to attract and retain qualified and experienced staff. Improvements in operational practices are required for restoring system reliability, protecting physical assets from further deterioration and upgrading the skills of the operating staff. Finally, the suggested change in ownership may help to change the public image of the utility and enable the Government to give it the necessary autonomy.

1.13 To achieve the above, it is desirable to form a new corporate entity. This will allow the Government to deal with LEC's debts and receivables, and to solve the problem of excess staff. As part of this process, the Government should hire the services of an expert or a firm

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1/ Technical assistance to improve LEC's operations was provided through two World Bank Power Loans (Third Power Loan (1150-LBR) and the Fourth Power Loan (1600-LBR)).

which, in coordination with the Bureau of State Enterprises (BSE) will assist in identifying options, negotiating a contract and managing the transition towards the new corporate entity. The option of privatizing LEC should be given careful consideration as it provides a good alternative to achieve full autonomy. Terms of Reference for this activity are included in Annex 1.

1.14 The specific ownership/management structure of the new entity will depend on a number of factors (i.e., the Government's preferences, the recommendations of the ongoing public enterprise sector study, the availability of expert firms willing to take over management responsibilities under different types of contract, etc.) which cannot be prejudged at this stage. However, it would seem advisable to aim for a management option which both minimizes the use of scarce public resources while maximizing the Government's commitment towards reform and autonomy. Two options to attain these apparently conflicting goals are:

(a) leasing or selling the concession to generate and sell electricity to a competent utility; or

(b) contracting a firm to manage the new utility under a system of fees subject to minimum performance targets and productivity bonuses.

1.15 The first option would be preferred, and has two advantages. First, the Government would be relieved of the need to invest scarce foreign exchange since the lessee would be expected to contribute the necessary resources to attain a set of specified targets. Second, the contractual arrangement would bind the Government to give effective autonomy to management, support the latter's actions in pursuing delinquent customers, and make available foreign exchange for the operation and maintenance of the power system.

1.16 The second option is less preferred insofar as it involves the use of the Government's foreign exchange resources to pay for the management contract and the costs of rehabilitating and upgrading the power system. The attractive feature of this option is that, by providing incentives to increase efficiency, the Government could benefit by retaining part of the improvements in productivity. In this way the Government could recover the initial investment. Economic benefits of the restructuring program are estimated in excess of US$4.5 million per year, and potential financial benefits are estimated at US$13 million per year. With this option the Government would also be legally obligated to provide effective autonomy and access to foreign exchange.

1.17 Regardless of the option chosen, the transition from the existing LEC to the new corporate entity could take about two to three years and may cost as much as US$32 million. This figure includes the cost of rehabilitating the plants and equipment, and upgrading support and technical services. Also, it assumes that the generation and commercial operations will be run by expatriate management from a

competent power utility. This firm would be responsible for the above tasks, rebuilding the customer data base and training Liberian staff in the operation and management of the power system. It is expected that such a program of activities would put LEC at a level of operating efficiency comparable to that of well run utilities in industrialized countries.

1.18 The content of each component of the action program for restructuring LEC is summarized below and spelled out in detail through the rest of the report. The cost estimate and description of each task, presented in Table 1.1, are intended to assist the Government of Liberia in the process of finding and negotiating a contract with a firm willing to take the responsibility of running the power system. While the total costs are estimated at US$32 million, the way these costs are shared between the Government and the firm taking the contract will be a function of the option chosen. The final costs of the whole program will depend on what the Government can negotiate with actual bidders, and may come up to less than the estimated US$32 million.

Restructuring Program

1.19 The restructuring program should be implemented in two phases. The first phase should involve the negotiation of a contract with an external utility for leasing the concession to generate and sell electricity (or a management contract to run the electricity service in Liberia). This process includes:

(a) settling LEC's liabilities and defining how to deal with outstanding arrears from its customers;

(b) solving the problem of excess staff;

(c) negotiating a contract with the interested firm(s). The agreement should specify performance targets, fees, bonuses, rights and obligations of each party, etc.; and

(d) negotiating and agreeing on a regulatory and arbitration framework to protect the interests of all parties involved.

1.20 The second phase of the action program should only be implemented after the first phase has been successfully completed. The second phase will involve the implementation of a series of tasks required to transform the key areas of the existing LEC into well-functioning departments in the new organization. The two most important departments to be improved in this phase are commercial and generation operations. The estimated cost and components of these and other needed improvements are outlined in the following paragraphs. The final cost of the program will depend on the outcome of the negotiations between the Government and the interested firm(s).

Commercial Operations

1.21 The main activities required to improve commercial operations are:

(a) reestablishing the customer data base by physically checking every service connection on the distribution system;

(b) restructuring the billing and metering systems;

(c) establishing guidelines and norms for customer service;

(d) establishing clear collection policies; and

(e) carrying out a complete tariff study.

The cost of this work is about US$9.6 million.

Generation Operations

1.22 There are two aspects to this work, physical rehabilitation, estimated at US$6.3 million, and providing personnel for operation and maintenance, estimated at US$10.1 million. The main components are:

(a) rehabilitating and upgrading the Luke diesel plant;

(b) rehabilitating some of the gas turbines;

(c) rehabilitating the hydroelectric plant;

(d) operating and maintaining the plants (the cost shown is for the two initial years); and

(e) training local staff.

Transmission and Distribution Operations

1.23 This work includes some physical improvements and improvements in record keeping and planning. Some of the components are:

(a) mapping and recording the transmission and distribution systems;

(b) establishing planning and budgeting procedures; and

(c) establishing work procedures and cost control.

The cost of the work is estimated at US$3.0 million.

Support Services

1.24 This includes:

(a) upgrading the vehicle fleet and improving its maintenance;

(b) providing tools and equipment for construction and maintenance crews; and

(c) training construction and maintenance crews.

The cost of this activity is estimated at US$1.9 million.

Physical Facilities

1.25 Significant improvement of physical facilities is required to improve security and work flow. However, the exact needs will be defined during the restructuring of the various departments.

Report Layout

1.26 Further details and supporting analysis are presented in the remainder of the report. Chapter II describes LEC's organization and the supply and demand characteristics of the power system. Chapter III evaluates LEC's performance and discusses the reasons for restructuring the utility. Chapter IV deals with the commercial operation in detail. Chapter V discusses the poor service quality and the work required to improve the generating plants. Chapter VI is a preliminary assessment of the short and medium term investments required to expand generation capacity to meet future load growth. Chapter VII reviews the transmission and distribution operations and defines the improvements required to bring their standards up to those of an efficient utility. Finally, Chapter VIII reviews the operation of some isolated diesel plants serving small communities and recommends various measures to make them more efficient and reliable. The Annexes contain Terms of Reference and all supporting calculations.

Table 1.1: SUMMARY TABLE FOR ALL PROGRAMS

	Professional Services	Travel & Subsistence	Contingency	Management Overhead/Profit	Equipment	Local Costs	Total
TOTAL COST OF THE PROGRAM	14,415,800	3,744,530	2,610,430	2,006,000	7,954,900	606,000	31,357,660
I. ASSISTANCE FOR CORPORATE RESTRUCTURING	210,000	94,000	30,000	0	0	0	334,000
II. COMMERCIAL OPERATIONS	5,130,000	1,210,000	762,000	762,000	1,350,000	403,200	9,617,200
Overall Management and Reorganization	800,000	150,000	88,000	88,000	0	0	1,126,000
Establishment of Data Base	3,840,000	950,000	618,000	634,000	1,350,000	403,200	7,795,200
Metering System Improvements	260,000	40,000	30,000	30,000	0	0	360,000
Billing System Improvements	70,000	30,000	10,000	10,000	0	0	120,000
Tariff Study	160,000	40,000	16,000	0	0	0	216,000
III. GENERATION OPERATIONS	8,184,700	2,082,630	1,370,000	1,179,000	3,449,900	137,800	16,404,030
Thermal Plant Rehabilitation	1,002,300	516,530	334,000	334,000	1,821,900	91,800	4,100,530
Hydro Plant Rehabilitation	202,400	96,100	191,000	0	1,628,000	46,000	2,163,500
Generation Management	6,980,000	1,470,000	845,000	845,000	0	0	10,140,000
Hydro	2,120,000	390,000	251,000	251,000	0	0	3,012,000
Thermal	4,860,000	1,080,000	594,000	594,000	0	0	7,128,000
IV. TRANSMISSION AND DISTRIBUTION OPERATIONS	656,000	264,300	264,030	65,000	1,655,000	65,000	2,969,330
Planning Department	420,000	168,000	69,300	0	105,000	0	762,300
Transmission and Distribution Department	210,000	84,000	159,400	0	1,300,000	0	1,753,400
Metering Department	26,000	12,300	13,830	0	100,000	0	152,130
Reduction in Technical Losses	0	0	21,500	65,000	150,000	65,000	301,500
V. STRENGTHENING OF SUPPORT SERVICES	175,100	69,000	176,400	0	1,520,000	0	1,940,500
Vehicles and Tools	140,000	54,000	159,400	0	1,400,000	0	1,753,400
Communication Equipment	35,100	15,000	17,000	0	120,000	0	187,100
VI. ISOLATED DIESELS	60,000	24,600	8,000	0	0	0	92,600

Source: Mission estimates.

II. DESCRIPTION OF THE POWER SYSTEM

Overview

2.1 The Liberia Electricity Corporation (LEC) is responsible for the major public electricity supply throughout Liberia. LEC was established by legislation in July, 1973 as a subsidiary of the Public Utilities Authority, but became autonomous when the Authority was dissolved in February, 1976. Most of LEC's staff and other resources are dedicated to the Monrovia Power System which accounts for 98% of all power supplied. Ten small isolated power systems operated for the government by a department of the LEC supply electricity to cities and towns located along the coast and in rural areas. 2/

2.2 LEC is organized into eight departments: Administration and Finance, Commercial, Generation, Transmission, Distribution, Transport, Rural Electrification, and a newly organized Corporate Planning and Development Department.

2.3 The main characteristics of the power system are presented in Table. 2.1. The total installed capacity is 177 MW and the peak demand is about 63 MW. However, the hydro capacity, 64 MW in the wet season, decreases to about 5 MW in the dry season (seven months per year). The thermal capacity therefore has to be high enough to cover the peak demand with enough reserve to maintain adequate system reliability. In 1984 total generation was 386.4 GWh, of which 282 GWh (73%) was produced from hydropower and the remaining 104.4 GWh (27%) from gas turbines or diesel engines. The low contribution of the thermal plants is due to the failure of some of the thermal units, which provoked extensive load shedding in the 1984 dry season.

2/ These plants range from 300 kw to 1,300 kW and amount to an installed capacity of 7.8 MW. Generation from these plants in 1983/84 was only 9.3 GWh.

Table 2.1: LEC'S BASIC SYSTEM CHARACTERISTICS (1984)

Frequency	60 Hz
Installed Capacity (Nameplate)	177 MW
Generation Capability d/	156 MW
Peak Demand a/	63 MW
System Peak Power Factor	0.88
Annual Gross Generation:	
Gas Turbine	40.0 GWh
Diesel	64.4 GWh
Sub-total Thermal	104.4 GWh
Hydro	282.0 GWh
Total	386.4 GWh
Annual Net Generation:	381.4 GWh
Purchases from Bong Mine	26.6 GWh
Number of Plant Substations	2
Transformer Capacity	246 MVA
Number of Distribution Substations	14
Transformer Capacity	320 MVA
Transmission and Distribution Lines b/	
69 kV (Overhead)	290 miles
69 kV (Underground)	2.7 miles
12.5 kV (Overhead)	500 miles
12.5 kV (Underground)	30 miles
Number of 12.5/0.4 kV transformers b/	3570
Installed capacity	134 MVA
Number of customers c/	34,200

a/ The demand shown corresponds to a wet season maximum. LEC estimates that peak demand is higher in the dry season but has been curtailed by load shedding due to water shortage and plant problems since 1983.

b/ Estimated figures based on best information available.

c/ Approximate and includes some customers without meters.

d/ Nameplate capacity minus derating.

Source: LEC data and Mission estimates.

Generation

2.4 The LEC system includes hydroelectric, diesel and gas turbine units located at three stations. Table 2.2 lists the units at each station.

Table 2.2: LEC GENERATING STATIONS

Station	Type of Unit	Unit Rating	Installed
Mount Coffee	Hydro	2 x 15 MW	1967
		2 x 17 MW	1972
Luke Diesel	(slow speed)	2 x 13.3 MW	1980
		1 x 13.3 MW	1982
Bushrod	Diesel (med speed)	2 x 2.5 MW	1963
Bushrod	Gas turbine	2 x 15 MW	1967
		2 x 19.1 MW	1973

Source: LEC Data.

2.5 The hydro units are run-of-the-river and are used almost exclusively during the five wet months of the year. 3/ The diesel and gas turbine units are used during the dry months, although some hydro power is generated even during the dry season. 4/

2.6 At present, the peak demand is in the range of 60-65 MW, which is satisfied by the hydro capacity in the wet season. In the dry season, the demand is met first by using all of the available hydro generation, then by the slow speed diesels, followed by the medium-speed diesel and finally by the gas turbines. 5/

2.7 The reserve capacity in the wet season is about 181% and in the dry season 79%. However, due to some major plant failures and unusually

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3/ The wet season in Liberia lasts from July to November.

4/ The amount that can be generated has been decreasing over the past five years. Peak load capability of the hydro plant during the dry season is now only about 5 MW.

5/ The slow-speed diesels burn heavy fuel oil whereas the medium speed diesels and gas turbines burn gas oil.

dry weather, electricity supply has been unreliable especially in the past year. 6/ Although the seasonal nature of the hydro generation requires investment in thermal plant to cover the peak load, it does give LEC unusual flexibility in maintenance since the hydro plant can be maintained in the dry season and the thermal plant in the wet season.

Transmission

2.8 The transmission system consists of a 69 kV network approximately 290 miles long, fed from the two generation sites. With the exception of about 35 miles of steel tower line and about 2.7 miles of underground cable, most of the network consists of 69 kV wood pole lines constructed in stages since 1961. The area covered by the transmission system is shown in IBRD Map 18383.

2.9 The transmission network appears to be sized adequately for present installed generation capacities and loads. Demand is forecast to grow at about one to three percent per annum over the next decade and this level of growth will not require changes in the present configuration.

2.10 Under normal conditions, the transmission system is operated as a radial network. If a line trips the supply is restored by manual switching, either in the 69 kV network or in the low voltage 12.5 kV network.

2.11 LEC is considering the purchase of a SF-6 line breaker for the commissioning of the second Bushrod-Krutown 69 kV tie line which would further increase power exchange capability and system security. In addition, two major transmission expansion projects are now under way. One is referred to as the "third extension" project and is almost complete; the second involves the construction of two transmission lines with lattice type towers. One of these lines will extend to the airport at Robertsfield (48 km) and the other to Robertsport (65 km).

Distribution

2.12 There are 16 distribution substations in the LEC network. Most of the load is in Monrovia City where eight substations are located. The remaining substations are spread out in the greater Monrovia region which

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6/ In addition to the plant failures, there apparently have been occasions on which load was shed instead of operating the gas turbines because of their high cost of operation and LEC's shortage of cash.

covers a radius of about 90 miles from the city center. About half of the substations are of the outdoor type and have been in service since 1961. The newer substations are indoor type and were built after 1977. Two of the substations are located at the generation plants. The substations step down voltage from 69 kV to 12.5 kV, except at Bomi Hills and Bong Mines.

2.13 The total installed capacity of power transformers is over 567 MVA. Of this total, about 246 MVA are installed at the two generating sites. LEC's planning criteria require at least two transformers (each having the capacity to feed 125% of the load) to be installed at a substation. It has standardized on the use of two 20 MVA power transformers at each of the newly built substations.

2.14 The total length of the 12.5 kV overhead distribution system in the Monrovia Electric Grid, including two-phase and single-phase lines, is estimated at 500 miles. No detailed records on the exact length of lines are available. The approximate length of the 12.5 kV underground system, which mostly covers the central portion of Monrovia City, is about 30 miles.

2.15 Service connections are obtained through pole-mounted transformers which step down the voltage from 12.5 kV to 120/208/380 volts depending on requirements. In addition, an underground network in Monrovia has 13 metal-enclosed, pad-mounted transformer stations. It has been designed to provide power only at 230/400 volts, thereby excluding the use of appliances built for 115 volt supply only.

2.16 The power factor on the LEC system is generally good in residential/commercial areas, but it is fairly low in industrial areas where it ranges from 0.62 to 0.75. LEC has taken no action so far to improve the power factor, which should be better than 0.90. Since tariffs are based only on kilowatt hour (kWh) consumption and contain no provision for power factor correction (for example through a kVA maximum demand charge), there is no incentive for customers to improve the power factor.

Generation, Sales and Losses

2.17 Table 2.3 summarizes records of generation, sales and losses for the past six years. Excluding energy sales to Bong Mines, losses have been as high as 36% of net generation.

Table 2.3: GENERATION, SALES & LOSSES FOR THE MONROVIA POWER SYSTEM 1979-1984 (GWh)

	1979	1980	1981	1982	1983	1984
Generation (Gross)						
- by LEC	432.8	428.7	398.9	377.6	367.0	386.4
- From Bong Mines	---	---	6.9	32.9	38.5	26.6
Total	432.8	428.7	405.8	410.5	405.5	413.0
Net Generation	429.7	423.9	401.1	405.9	400.9	408.0
Sales						
- Excluding to Bong Mine	254.0	263.0	247.0	241.0	237.0	243.0
- To Bong Mine	32.1	31.3	20.5	27.9	32.3	33.2
Total	286.1	294.3	267.5	268.9	269.3	276.2
Losses (Of Net Generation)						
- Total System	143.6	129.6	133.6	137.0	131.6	131.8
- % of Net Generation	33.4	30.6	33.3	33.8	32.8	32.3
- Monrovia System Component a/	142.0	128.0	132.6	135.6	130.0	130.1
- % of Monrovia System Supply	35.7	32.6	34.8	35.9	35.3	34.7

a/ Assumes 5% loss on 69 kV lines to BMC.

Source: LEC and Mission estimates.

2.18 A previous joint UNDP/World Bank Mission prepared an electricity demand projection based on: economic growth in the light of the very depressed market for iron ore; recovery of sales to the public which have fallen since 1979, presumably under the influence of the changing political circumstances; and the global recession following the 1979/80 oil price rises. Table 2.4 shows this projection, which is based on an integration of GDP projections and certain critical assumptions about reforms and financial recovery within the LEC. These assumptions include a reduction in the unbilled use of power, improved maintenance of thermal plant, and an exchange/supply arrangement with the Bong Mining Company (BMC) which is assumed to terminate by the end of the decade. Sales are projected to increase by 2.8% per annum and LEC generation by an average of 1.4% over the period 1984-2003, and 3.0% and 1.2% respectively over the 1984-93 period. Losses on the public component on

the power system are projected to decrease overall from about 35% to about 17% within the next 10 years and to stay at that level thereafter. 7/

2.19 The LEC system load comprises industrial, commercial and residential loads. Their percentage shares and those for other categories based on energy sales are as follows:

- Industrial - 8%
- Commercial - 25%
- Residential - 40%
- Public Corporations - 12%
- Government - 9%
- Street Lighting 6%

2.20 Although the system as a whole has a relatively high load factor (about 68%), typical feeder load factors were found to be about 49% in industrial areas, 57% in commercial areas and 71% in residential areas. Seasonal changes of the load are small except for the peak load which is slightly higher during the dry season than during the wet season.

7/ This level does not reflect the present mission's views on the target economic loss levels but is the assumption that was used to derive the forecast.

Table 2.4: ENERGY DEMAND PROJECTIONS FOR THE MONROVIA POWER SYSTEM (GWh)

	Generation			Sales			Losses			
Year	LEC	Purchases from BMC	Total Supply a/	Mines	Public	Total	Non-Technical	Technical b/	Total	Percentage of Net Generation c/
1982	377.6	23.9	405.9	27.9	241.0	268.9	84.6	52.4	137.0	35.9
1983	367.0	38.5	400.9	32.3	237.0	269.3	79.9	51.7	131.6	35.3
1984	386.4	26.6	408.0	33.2	243.0	276.2	79.2	52.6	131.8	34.7
1985	391.0			35.0	239.0	274.0				
1986	395.7			30.0	263.0	298.0				
1987	400.5			25.0	292.0	322.0				
1988	405.3			25.0	308.0	333.0				
1989	410.1			23.0	320.0	343.0				
1990	415.1			23.0	315.0	338.0				
1991	420.0			15.0	329.0	344.0				
1992	425.0			6.0	343.0	349.0				
1993	430.1			5.0	348.0	353.0				
1994	435.3			0	356.0	356.0				

a/ After discounting station service use.

b/ Assumed to be 12.9% of net generation up to 1987 and reduced to 10% from then on.

c/ Monrovia system losses calculated by discounting 5% of transmission line losses on sale to mine from total and deducting mine sales from total supply.

Source: Report No. 5279-LBR and Mission estimates.

2.21 The mission estimates that of the 35% losses registered in 1984 about 13% are technical losses and the remaining 22% are non-technical. Table 2.5 shows the breakdown of technical losses.

Table 2.5: DISTRIBUTION OF LEC TECHNICAL SYSTEM LOSSES - 1984

	Losses			
	Demand a/		Energy	
	(MW)	(%)	(GWh)	(%)
Transmission Lines	2.6	4.0	11.2	2.7
Substation and Generating Plant Power Transformers	1.6	2.5	12.2	3.0
Primary Distribution Lines	0.5	0.8	1.9	0.5
Distribution Transformers	0.9	1.4	6.1	1.5
Secondary Distribution Lines and Services	4.9	7.8	21.5	5.2
TOTAL	10.5	16.5	52.9	12.9

a/ The demand loss shown is at peak.

Source: Mission Estimates.

III. OVERVIEW OF LEC'S PERFORMANCE

Overview

3.1 The mission's main objectives were to assist the Government of Liberia by defining practical steps to: reduce LEC's system losses which exceed 32% of net generation; and improve the reliability of its generating plant to avoid the extensive daily load-shedding that occurs in the dry season. An additional objective was to define a preliminary least cost generation expansion plan which compared rehabilitating and upgrading plant with adding new plant to meet future demand.

3.2 While pursuing its objectives, the mission realized that high losses and poor reliability, which result from operational problems in the commercial and generation departments, are only the two most visible symptoms of a number of fundamental problems which affect all aspects of LEC's operations. It also became obvious that although the present management is committed to improving LEC's operations it is unlikely to succeed unaided since many of the fundamental problems are external to LEC. Furthermore, the internal problems are serious enough to require major restructuring.

3.3 The following paragraphs summarize the main symptoms of LEC's problems, discuss the fundamental causes and propose three possible approaches for transforming the utility into a commercially viable operation. However, given that at least two previous technical assistance efforts have failed to achieve lasting improvement in LEC's operations, and given the unprecedented depression of the Liberian economy we should first answer three questions:

(a) Why have previous efforts failed?

(b) Is it worth trying to correct the existing problems?

(c) Under what circumstances are further efforts and investment in LEC justified?

Previous Attempts

3.4 The first attempt to improve LEC's performance was through a component of the Third Power Loan (1150-LBR) made in 1975. This financed a group of six expatriate consultants to strenghten LEC's management capabilities and to train its staff in management. The work started in late 1975 and was never properly completed. The consultants left before the end of their contract. The major reasons for the failure of this attempt were:

(a) unclear management responsibilities for the consultants and a lack of authority to implement changes;

(b) lack of coordination within the group, which did not work as a coherent team;

(c) inability to train local staff due to a lack of qualified local counterparts. This is attributed to the low level of salaries and lack of incentives for qualified personnel to work at LEC.

3.5 The second attempt to improve LEC's performance was partially financed by the remainder of the Third power Loan (1150-LBR) and by the Fourth Power loan (1600-LBR). In this case the TATA group was hired to establish a Management Support Team. Work started in July 1978 and lasted until July 1980. LEC financed the services of the management group for an additional year, and in June 1981 the group was disbanded. Only three experts were retained.

3.6 The second attempt was somewhat more successful. The management team's work was more cohesive, and the group prepared a Management Improvement Program which gave first priority to reducing losses and making improvements in billing, collection and accounting. However, the little progress made gradually dissipated as the team was disbanded. The major causes of failure in this case were:

(a) implementation of the program and training of staff was hindered by LEC's inability to hire enough qualified staff to do the tasks due to inadequate renumeration;

(b) implementation was also thwarted by the inability of some team members to translate concepts into practical actions; and

(c) the work was hindered by the lack of suppport from the GOL in some key areas (e.g. payment of Government electricity bills and prosecution of individuals found stealing electricity).

3.7 The main lessons to be learned from these attempts are that:

(a) external management/assistance groups should work as a single team;

(b) these teams must be given authority and line responsibility;

(c) these teams must have full GOL support; and

(d) the utility must be allowed to pay competitive salaries in order to attract and retain qualified local staff.

Why Should the Problems be Corrected?

3.8 LEC's poor performance has a negative impact on the Liberian economy. This occurs in different ways. Some the most obvious ones are:

(a) it increases the fiscal deficit;

(b) it stimulates a drain of scarce foreign exchange and contributes to the misallocation of resources;

(c) it may be an obstacle to the development of small scale enterprises.

3.9 The effect of LEC's losses on the fiscal deficit is substantial. Taking the 1983/84 fiscal year as an illustrative example, unbilled consumption was about US$13.1 million, and uncollected bills (other than Government bills) were about US$5.8 million. The total revenue lost was almost US$19 million.

3.10 Low reliability of power supply resulting in massive load shedding during the dry season has stimulated the import of standby diesel sets by residential, commercial and industrial customers. It is difficult to estimate the magnitude of the phenomena, but it appears to be a significant and (at the time of the mission) an ongoing process. If this trend continues, the drain on foreign exchange will increase both on account of new generators and on account of spares and parts needed to serve a relatively large and diversified population of generators. This trend also carries an obvious misallocation of resources since economies of scale from larger units (and hydroelectric resources) are foregone.

3.11 The establishment of small-scale enterprises also may be hindered by the low reliability of the system. In other words, a commercial operation requiring reliable power supply may not be able to afford the cost of a standby diesel set. It therefore appears that the provision of reliable electricity service at a reasonable cost would help to remove one obstacle to economic recovery.

Preconditions for Further Investments

3.12 Despite the seriousness of existing problems and the clear need to correct them, further investment in LEC would only be justified under certain conditions. Among these are:

(a) the utility should be given full effective autonomy (especially the right to hire and fire, and set competitive pay scales);

(b) the utility should be guaranteed free access to foreign exchange;

(c) the GOL should settle its outstanding bills and regularly pay for its consumption of electricity;

(d) the GOL should support LEC's actions to reduce non-technical losses; and

(e) the utility must be structured as a commercially viable enterprise operating within a regulatory system that protects its customers and shareholders.

Main Symptoms

3.13 The mission's overall impression is that most of the systems required to operate an efficient utility have been in place at LEC at some time, but have become ineffective. More attention seems to be placed now on form and appearance than on substance.

Commercial Department

3.14 LEC collects revenue for only about one half of the energy used by its customers as a result of problems with billing and collections. In fiscal year 1983/84 LEC's customers used about US$47.4 million worth of energy, were billed US$34.4 million, and paid only US$23.7 million.

3.15 The ineffectiveness of the Commercial Department in billing and collections is LEC's most serious problem since it limits the cash collected and thus has a direct impact on all aspects of its operation.

Generation Department

3.16 LEC's frequent and extensive load shedding during the dry season is caused by generation failures. The main problems are a shortage of spare parts, inadequately trained staff and substandard generating plant auxiliaries. In terms of priority this is second only to the commercial department. Unless generation operations are improved expensive plant may be seriously damaged.

Transmission and Distribution Department

3.17 The transmission and distribution systems, although acceptable at present, are beginning to show signs of inadequate maintenance and poor operating practices. With regard to maintenance, earth wires are broken and not repaired, the conductor is spliced with different sizes, connections are twisted. With regard to operations, records are almost non-existent and switching is done without proper procedures.

3.18 These problems, though not as urgent as the commercial or generation problems, will lead to poor service quality in the future.

Transport Department

3.19 Most of the vehicles are in poor condition caused by a shortage of spare parts, a shortage of cash to buy new vehicles, and inadequate control of maintenance. The problems in this department affect the entire operation of the utility.

Accounting Department

3.20 The mission did not study accounting procedures in detail but successive auditor's reports indicate that the accounts are unreliable.

Fundamental Problems

3.21 Lec's efficient operation is inhibited by the following fundamental problems:

(a) a lack of effective autonomy;

(b) the poor performance of Liberia's economy;

(c) poor payment of bills by government institutions;

(d) a poor public image; and

(e) allegation of apparent fraudulent practices by employees.

Effective Autonomy

3.22 Theoretically LEC is an autonomous entity with no requirements to report to any government ministry. In practice it operates like a government department with the general manager taking orders directly from high level government officials. Four examples of this disruptive arrangement are:

(a) the utility is grossly overstaffed; 8/

(b) pay scales are tied to those of the remainder of the public sector and are inadequate to attract and retain skilled staff;

(c) it appears that plant is sometimes run against the better judgement of technical staff to satisfy government directives to maintain supply in certain areas at certain times; and

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8/ It has one employee for every 23 customers. A typical ratio is about one employee for every 130 customers.

(d) rural electrification is sometimes pursued even through there are no clear economic benefits associated with it.

Performance of Liberia's Economy

3.23 The Liberian economy has been facing difficult times since 1974. The combined effects of a heavy oil import bill and a large debt burden at a time when Liberia's main exports were depressed resulted in sluggish growth. Between 1974 and 1979 GDP growth averaged less than 1% per annum.

3.24 The military Government that came into power in April 1980 took a series of steps that further aggravated the situation. A doubling of the public sector minimum wage without regard to productivity and indiscriminate hiring into the swollen ranks of the central government and public corporations exacerbated the fiscal crisis. Ocassional harassment and interference in the running of private firms and public agencies together with a severe shortage of public funds for investment hurt the economy and discouraged private investment. As a result, between 1980 and 1983 real GDP declined by about 17% and per capita consumption declined by about 14%. The balance of payments situation has deteriorated to the point where the National Bank of Liberia no longer has the foreign reserves to pay for oil or public sector imports, or to service debt payments.

3.25 The extremely prolonged poor performance of Liberia's economy affects LEC's operations in two major ways: first, there is a shortage of foreign exchange which makes it difficult, and sometimes impossible, for LEC to buy fuel, lubricants, spare parts and technical services. Second, many customers who previously could afford electricity have now become too poor to do so and some have resorted to stealing electricity rather than forego the service.

Poor Payment of Bills By Government

3.26 Government institutions and public corporations have the worst payment history. In 1984 LEC was able to collect only 42% of the amount billed to government institutions and only 54% of the amount billed to public corporations. It should be noted, however, that LEC owes a considerable amount to the local government-owned refinery for fuel.

Poor Public Image

3.27 LEC has lost the respect of the general public, mainly because of providing poor quality electricity service and extremely poor customer service. The extensive load shedding caused by the failure of generating plants and the slow and inefficient response to customer queries and complaints have generated, in the public's mind, an image of LEC as an inefficient and corrupt organization. As a consequence, LEC has lost the support of a significant portion of its customers who feel that they should not be paying for poor quality service, errors in billing, and

other people's consumption. For these reasons customers who would pay promptly under normal circumstances are refusing to do so at present.

3.28 To compound the loss of support by previously "good" customers, there is now a perception by many people that electricity is a free service to be provided by the government, or that it is relatively easy to take without paying for it. Given the disarray of LEC's commercial operations a large number of customers correctly perceive that the chances of being detected or punished for stealing electricity are almost negligible. This has resulted in a mushrooming of illegal connections.

Allegation of Apparent Fraudulent Practices by Employees

3.29 The mission noted that, for the most part, LEC employees appeared honest, dedicated and hard-working. However, it also heard of unconfirmed reports of alleged high levels of electricity theft which could have involved collusion from some LEC employees. This could include such abuses as the offering of illegal reconnections to consumers even within LEC's compound. Such corrupt practices, if widespread, would be hard to pinpoint to specific individuals.

3.30 Some evidence of the above alleged practices was presented to the mission by reports of three independent auditors who, in successive years, reported serious deficiencies in LEC's billing and accounting procedures. The independent auditors also mentioned their perception of a single case of potential payroll irregularities involving basic rates of pay higher than those shown on the personnel files to which they had access. The mission did not confirm any of these allegations from its own direct knowledge, however.

Possible Solutions

3.31 The objective of any further investment in electricity in Liberia should be to produce reliable supply at minimum cost to the economy. Given LEC's problems with debt, poor collections, overstaffing and a poor public image, the mission believes that this objective can be achieved most efficiently by restructuring LEC and forming a new company that can be operated as a commercial, profit-making enterprise. The new company should be free of direct government control and should operate within a clearly defined regulatory framework to protect both its customers and its shareholders.

3.32 The major actions required to achieve the above are to:

(a) settle LEC's liabilities and arrears;

(b) review and reform the ownership/management structure of LEC, in accordance with the recommendations of the ongoing public enterprise sector study;

(c) organize and staff the new entity as appropriate for a utility of its size;

(d) reestablish the customer data base;

(e) repair and upgrade equipment; and

(f) improve physical facilities.

3.33 The above can be achieved in three ways:

(a) by selling the assets and the concession to supply electricity if someone is willing to buy them;

(b) by immediately hiring a management company to restructure LEC, form a new utility and operate it through a lease of the concession to generate and sell electricity or through a management contract with a fee linked to performance; or

(c) by first improving the two critical areas, commercial operations and generation operations, using foreign companies under contract while studying the best way to restructure the utility.

3.34 The former two approaches are preferred since they are more likely to be successful. The main problem with the third approach is that it will probably produce temporary relief thus postponing restructuring of the utility. As past experience shows, these improvements are likely to be short-lived unless the fundamental structure of the utility is changed. Privatization of LEC is an option that requires further consideration as it appears to be a solution that will provide the company with the full autonomy needed to solve its operational problems.

3.35 The remainder of the report defines some of the building blocks needed to improve LEC's performance, regardless of the option chosen. The report assumes that the initial actions will be carried out using expatriate management to set systems in place. Terms of Reference for the restructuring are included in Annex 1. The cost of this activity is estimated at US$896,000.

IV. COMMERCIAL OPERATIONS

Overview

4.1 LEC collects revenue for only about one half of the energy used by its customers. 9/ In fiscal year 1983/84, LEC's customers used about US$47.4 million worth of energy, were billed about US$34.4 million and paid only about US$23.7 million. Table 4.1 shows a breakdown of how the energy generated was used and LEC's collection performance for the fiscal year 1983/84. 10/

4.2 LEC's poor billing performance is caused mainly by widespread theft and fraud, and to a lesser extent by billing and metering errors. Its poor collection performance is caused mainly by the failure of government departments and public corporations to pay their electricity bills and LEC's inability to enforce disconnections of its commercial and domestic customers. This appears to be at least partly due to second-hand alleged reports of corruption, but it is also because the Liberian economy is in recession, and many customers can no longer afford electricity service.

4.3 The results of LEC's poor financial position can be seen in almost all aspects of its operation, but the most obvious result is the rapidly deteriorating service quality. LEC has been unable to buy spare parts and fuel and cannot pay the salaries that would retain skilled staff. The resulting poor service quality has caused some customers to delay paying bills or refuse to pay altogether.

4.4 This chapter discusses some of the reasons for LEC's inability to bill for all of the electricity used and to collect full payment for the bills it issues. It examines the reasons for the failure of previous attempts and suggests a new approach to solve the billing and collection problems. Finally, it provides estimates of the costs and benefits of the suggested work.

9/ LEC issues bills for about 72% of the energy used and is paid for about 69% of the bills issued.

10/ The energy and dollar amounts are quoted as approximate since the mission could not verify them.

Table 4.1: ESTIMATED POWER GENERATION, BILLING AND REVENUE COLLECTION, 1983/84

	GWh	US$ million	% of Energy Used
Gross Generation			
Hydro	275.81		
Thermal	97.72		
Transfer from BMC a/	29.80		
TOTAL	403.33		
Transfer to BMC a/	32.84		
Station Use/Auxiliary Consumption	6.97		
Net Generation	363.52	54.5	
Technical Losses	46.89	7.0	
Net Generation for Sale	316.63	47.5	100.0
Energy Billed	229.23	34.4	72.4
Unbilled Consumption b/	87.40	13.1	27.6
Uncollected Bills	71.39	10.7	22.5
Revenue Collection	157.84	23.7	49.9

a/ Based on an agreement between LEC and the Bong Mining Company by which BMC supplies LEC with energy during the dry season in exchange for LEC's supply of energy to BMC's Monrovia operation year round and to BMC's mine during the rainy season.

b/ Excluding technical losses.

Source: Mission Estimates.

Billing Performance

4.5 LEC's billing of its customers is seriously impaired by its unreliable and incomplete customer data base. Widespread reports of irregularities appear to explain why the data base is so unreliable, to the extent that LEC is now unsure of how many customers are connected to its system. It is therefore unable to systematically check meter readings, to determine the location of specific meters or to respond to queries by customers about their accounts.

4.6 The following methods which appear to be used by customers to steal electricity have contributed to the present state of the customer data base:

(a) direct unauthorized connections to the distribution lines;

(b) unauthorized reconnection of services disconnected for non-payment of bills;

(c) meter tampering; and

(d) installation of services using stolen meters.

4.7 Unfortunately, second-hand reports on some of the above appear to indicate that these acts have been done with the collusion of LEC's staff. There have also been allegations to the effect that apparently some LEC employees get free electricity and distribute it to their neighbors for a fee.

4.8 Some of the reasons for the alleged disregard for legal norms are:

(a) Liberia's economy is performing poorly and many people can no longer afford electricity service but are unwilling to relinquish it;

(b) LEC in many cases does not deal with its customers in a business-like manner; for example, since there are no fixed rules regarding the time for a service installation a customer may be tempted to bribe an employee to facilitate the connection;

(c) it is easy to steal electricity without being caught since LEC's efforts at controlling theft are sporadic and largely ineffective;

(d) there are no laws dealing specifically with electricity theft, and prosecution under the laws governing the theft of goods is expensive and time consuming; and

(e) second-hand reports appear to indicate that some of LEC's employees have apparently been reported to offer customers illegal reconnections for a small fee.

4.9 LEC has some controls in its billing and metering systems to monitor and limit electricity theft. Unfortunately the controls are not systematically applied. In some cases, the controls appear to have been deliberately subverted. For example, in the billing system, meter readings are no longer fed directly into the billing computer. The energy used is computed by clerical staff and then fed into the computer. This practice causes the use of excessive staff and introduces

an opportunity for fraudulent practices. In the metering system, customers have been discovered tampering with meters repeatedly and have not been censored. There was at least one case where a customer caught tampering with the meter four times is still connected.

4.10 Apart from the alleged irregular practices, meters are not tested routinely. Furthermore, since meters are often in short supply many services are connected without meters. As a result billing information is unreliable.

4.11 The above problems and others relating to payroll have been mentioned by successive auditors in their annual reports on LEC's accounts. Some of the auditors' findings are summarized in Table 4.2 and their recommendations are summarized in Table 4.3. LEC seems to have responded to these criticisms by changing auditors ever year for the past three years.

Customer Data Base

4.12 LEC has made some efforts to improve its customer data base and reduce electricity theft. The most notable is the Block Mapping project which was started in 1975.

4.13 The block mapping project was designed to assign consumer account numbers to particular physical locations within the city of Monrovia and cross-reference these to a new computerized sales ledger. A British firm, Whinney Murray, started the block mapping project during 1975 and worked with expatriates for about three years. Of the nearly 20,000 customers that existed at the time, only slightly more than 10% of the accounts were checked and renumbered. They disconnected unauthorized connections, examined and tested meters, and allowed no new connections, disconnections or reconnections in a particular block while the mapping was in progress.

4.14 The Block Mapping Project was abandoned in 1979 and, according to the auditor's report in 1981, the main deficiencies contributing to the failure of the project were: (a) lack of sufficient qualified staff in the block mapping groups, (b) insufficient instructions issued to the groups, (c) lack of proper follow-up, and (d) diminished enthusiasm and effectiveness. In years that followed, LEC attempted to carry on with the block mapping exercise, but this gradually died out, vehicles broke down, and supplies of meters and other materials dwindled. In 1980 some of the personnel engaged in block mapping were transferred to Area Directorates and the rest were used occasionally in meter maintenance activities and mass-disconnection efforts.

4.15 Between September and October 1983, the block mapping activity was revived with two four-man crews. However, this activity ceased in December 1983 after having made an additional status check and restoring approximately 10 blocks of the 500 contemplated in the project. The exercise remained dormant until July 1985 when the manager of Corporate

Planning was instructed to reactivate it. However, because of a lack of meters and technical personnel to do the field work, the Corporate Planning Department will not be able to complete the block mapping function as it was originally conceived.

4.16 Samples of block mapping drawings examined by the mission showed an extreme amount of detail on the particular area being mapped. They include every house, all secondary conductors, drop wires to service meters, meter numbers, corresponding account numbers, number of conductors, transformers, etc. As a result, the length of time between the preparation of the sketch in the field and the final drawing of the map was excessive. Out of four drawings examined, the least amount of time was three months and the most 25 months. Due to the excessive amount of time spent mapping the blocks, there was not sufficient time to do the physical rehabilitation work of installing or repairing meters, registering illegal connections, etc., which would have an impact on the efficiency of billing and collection.

4.17 The main lesson from the failure of the Block Mapping project is that any attempt to solve LEC's billing and metering problems must be comprehensive and well thought out. Like any other data base, systems to update and maintain it must be in place and working before the field work is done.

Table 4.2: SUMMARY OF MAJOR FINDINGS OF INDEPENDENT AUDITORS (1981-83)

Auditor I (1981)	Auditor II (1982)	Auditor III (1983)
1. Serious weakness in the Corporation's billing system making it impossible to determine whether or not the Coporation is recording all the revenue due it and collecting it.	1. Lack of sufficient system of control to ensure the completeness and accuracy of billing satisfactory alternative procedures to rely on for auditing purposes.	1. Statistical records showing that 31% of all power produced was not billed. Engineering studies indicate losses in the system should not be more than 15%. Losses are due to illegal power connections, meter tampering, defective meters and the use of flat rate instead of metered consumption for billing purposes.
2. Lack of follow-up on collecting arrears for a large number of inactive accounts (10,000).	2. Unexplained difference of US$8.6 million between electricity produced and billed.	2. Failure to bill about 20% of customer accounts on the master files due to an out-of-date master file, missing meter cards, etc.
3. Lack of controls to assure that existing data on payroll are accurate.	3. Financial losses resulting from meter deficiencies, flat rate billing of consumers and unbilled consumption.	3. No guarantee time policy to connect new consumers; this could encourage unauthorized connections.
4. Cases of consumers who paid their bills consistently but were disconnected and those who seldom paid but were left connected.		4. Some customers several months in arrears supplied with electricity and others disconnected for non-payment or reconnected upon payment of insignificant sums in arrears.
5. No controls on the payment of fines, which are recorded on a cash basis, leaving scope for misappropriation.		5. Some customers not metered and where meters exist immediate action not taken to repair or replace defective ones.
6. Applications register not always cross-referenced to deposits and connection fees.		6. Selected personnel records tested revealed basic rates of pay higher than on personnel files.
7. On average, bills were produced for only 75% of active accounts recorded. Unable to obtain satisfactory explanation from Management.		
8. Serious lack of control over meter cards.		

Source: Reports of independent auditors for fiscal years 1981, 1982 and 1983.

Table 4.3: SUMMARY OF MAJOR RECOMMENDATIONS OF INDEPENDENT AUDITORS (1981-83)

Auditor I (1981)	Auditor II (1982)	Auditor III (1983)
Inactive Files 1. No further transfers should be made to the "inactive" ledger without the Managing Director's approval and any further movements on the ledger should be properly monitored. Efforts should be made to collect outstanding amounts from inactive consumers (about US$4.5 million). **Billing** 2. The discrepancy between the number of active accounts on file and those billed should be investigated. To ensure that meter reading is not prevented by unauthorized personnel and that meter cards do not disappear, all meters be read monthly; a control card with detailed information on the consumer be kept in each meter book; and any permanent changes in meter cards should have the approval of the commercial manager. **Disconnections/Fines** 3. Lists of all customers disconnected should be sent to the Accounts Department with a copy of a faulty meter report. 4. The Accounting Department should maintain the reports in alphabetical and numerical sequences and should open a separate ledger for fines receivable. 5. Fines receivable should be posted, receivable accounts up-dated when the fine is received. 6. If meter tampering is found a second time, steps should be taken to remove all LEC equipment from the customer's premises.	1. Information on recommendations not available.	**Billing** 1. Anti-fraud unit should [illegible] connection and disco[illegible]rion of meter. 2. Consumption levels of customers billed on a flat rate should be checked periodically to make sure that their consumption does not exceed the normal flat rate range. 3. For meter tampering, customers should be fined and their electricity shut off for two months. 4. Master file needs updating. 5. Existing computer program should be adjusted to report on unbilled accounts. 6. Meter cards should be rigidly controlled. **New Connections** 7. Time schedule should be established for new connections. 8. New applicant records should be reviewed for correlation of connection with meter installation. Efforts should be made to connect and install meters simultaneously. **Disconnection and Reconnection** 9. Disconnection factors should be built into computer programs. 10. Amount of arrears to be paid before reconnection should be stated clearly. **Metering** 11. Meter readers should be rotated every two months, surprise test checks should be conducted, and the technical and commercial managers should ensure speedy installation, service and repair of meters. **Payroll** 12. Employee files should be updated, proper identification cards issued and payroll data processing supported by a fully authorized attendance sheet.

Source: Reports of independent auditors for fiscal years 1981, 1982 and 1983.

Collections

4.18 LEC's poor collection performance is heavily influenced by the accounts of government departments and public corporations which are constantly in arrears. Table 4.4 shows the breakdown of outstanding accounts.

Table 4.4: SHARE OF BILLED CONSUMPTION BY SECTOR AND COLLECTION PERFORMANCE

Sector	Billing		Collection	
	US$ million	% of Total Billing	US$ million	% of Billing
Residential	13,713	40	9.164	67
Commercial	8,685	25	7.570	87
Industrial	2,775	8	2.596	94
Public Corporations	4,122	12	2.215	54
Government of Liberia	5,031	15	2.091	42
TOTAL	34,326	100	23.687	

Source: LEC.

4.19 The government departments and public corporations are responsible for 27% of the bills issued but pay only about 50% of them. The residential and commercial sectors, which together account for 65% of the bills issued, are also performing poorly. This poor performance mainly results from LEC's inadequate customer data base and apparent widespread irregularities making it virtually impossible to effectively disconnect customers who do not pay. In the case of the Government, it does not appear to have the necessary autonomy and may be prevented from disconnecting government installations in the name of "national security".

4.20 The prerequisites for LEC to improve its collection performance are:

(a) Full autonomy and freedom from political interference.

(b) Restoration of the customer data base.

(c) Restoration of credibility with its customers and development of a modern business approach to selling electricity.

Recommendations

4.21 The mission believes that the only feasible way to restore LEC's financial viability is to hand over management of its commercial operations to an independent expert company under a management contract. The emphasis for the first two years of the contract will be on establishing a reliable customer data base and efficient operating systems with appropriate checks and balances. The management contract could be renewed for a further period if it proves successful.

4.22 The main functions included in the contract will be:

(a) metering;

(b) billing;

(c) collections and customer relations;

(d) new service installations; and

(e) disconnections and reconnections.

4.23 For maximum efficiency the company should use computerized systems for dealing with the above functions and should acquire pre-packaged "turnkey" software rather than try to develop software piece-meal. The use of turnkey software may require a change in the existing computer hardware. In addition the company should investigate the use of hand-held billing machines by meter readers. Table 4.5 presents a summary of costs for the program and the composition of staff in each component.

4.24 The most demanding aspect of the work will be to establish the customer data base which will require a physical survey of every customer connection on the system. It is an excellent opportunity to secure service connections to install meters when they are missing and to bring in existing meters for testing. The survey teams will encounter many illegal connections. To deal with these, a "soft" approach would be preferable where an illegal customer is given the opportunity of signing a service contract and becoming a "good" customer.

Table 4.5: ESTIMATE OF COSTS FOR IMPROVING COMMERCIAL OPERATION

I. Overall Management	
Professional Services a/	800,000
Travel & Subsistence	150,000
Contingencies	88,000
Overhead/Profit	88,000
	1,126,000
II. Establishment of Data Base	
Professional Services b/	3,840,000
Travel & Subsistence	950,000
Contingencies	618,000
Overhead/Profit	634,000
Equipment c/	1,350,000
Local Costs d/	403,200
	7,795,200
III. Metering System Improvements	
Professional Services e/	260,000
Travel & Subsistence	40,000
Contingencies	30,000
Overhead/Profit	30,000
	360,000
IV. Billing System Improvements	
Professional Services	70,000
Travel & Subsistence	30,000
Contingencies	10,000
Overhead/Profit	10,000
	120,000
V. Tariff Study	
Professional Services	160,000
Travel and Subsistence	40,000
Contingencies	16,000
	216,000

a/ Management team of five professionals to reorganize and run commercial operations for two years.

b/ A team of one professional (80,000 p.a.) to manage the mapping exercise for two years; eight (65,000 p.a.) mapping crew supervisors and twenty-four (55,000 p.a.) line crew foremen for a period of two years.

c/ Includes vehicles, computer hardware and software, 12,000 meters and sockets, conductors and accessories and service conductors.

d/ Includes costs of 16 helpers for crew supervisors and 48 line crew members for two years.

e/ One manager and one meter technician to reorganize the department for a period of two years.

Source: Mission estimates.

4.25 The use of digitizing software for the mapping and customer account numbering will speed up the process and avoid some of the problems encountered in the previous "block mapping" exercise.

4.26 The main actions required by the management firm are to:

(a) Evaluate overall management and reorganization requirements. Evaluate and implement the necessary reorganization required, establish reporting requirements, monitor customer accounts, establish revenue collection targets, and initiate investigative action when required in cases of theft, fraud or other abuses of the system.

(b) Establish adequate customer data base. Identify the location of all connections, produce clear, concise maps on each location, assign new account numbers, establish reasonable billing cycles, and provide for the frequent rotation of meter readers to reduce the possibility of fraud.

(c) Improve the standards and practices of meter maintainance. Use experienced meter engineers and technicians to reorganize the metering department and improve the standards and practices of the meter maintainance and inspection group.

(d) Review the billing system in conjunction with management reporting requirements. Determine the adequacy of current hardware and software and skills of data processing staff. If necessary, procure and install new equipment and supply data processing personnel.

It should be stressed that the third party management should operate the Commercial Department as "concession", with full responsibility and authority over the commercial operation.

Tariff Study

4.27 As a complement to the commercial management program, a complete tariff study is alsc recommended. The study's main objective is to review and update existing electricity pricing structures in major consumer centers and rural areas. The study, to be carried out by independent consultants, should include: computation of long run marginal costs at the various voltage levels of the system; analysis of existing tariff structures; formulation of tariff changes based on marginal costs, load forecasts, and reference expansion plans; and a detailed implementation plan. Cost of the study is estimated at US$216,000, of which US$160,000 covers professional services of three specialists for a period of about five months.

4.28 The total cost of the improved commercial management program, including the tariff study, is estimated at US$9.6 million, of which US$.4 million are local costs and US$9.2 million are foreign costs. The detailed Terms of Reference for the commercial management program are presented in Annex 2 and for the tariff study in Annex 10.

Benefits of Improved Billing and Collection

4.29 In order to give an order-of-magnitude illustration of the potential financial impact of a third party managing the commercial operations, the mission has prepared three scenarios for billing and collection performance. Scenario I assumes no improvement in billing and collection performance. Scenario II assumes a 8.0% increase in billing during the first year of the project, increasing by a further 10% in the second year, and by 5% in years 3-5. It also assumes a 100% collection rate from the Government and public corporations and gradual improvements in the other sectors. Scenario III assumes no improvement in the collection from the Government. The results of these scenarios are given in Table 4.6. In Scenario I, the net present value of financial losses would be about US$87.5 million. Scenario II shows that incremental imprpvements in the billing combined with the improved collection targets could have a very strong impact on LEC's revenue. The net present value of financial losses would be US$31.3 million, representing a reduction of US$56.2 million. Finally, in Scenario III the net present value of losses would be US$53.8 million, representing an improvement of US$33.7 million, which would result from the program of improvements recommended above. It must be stressed, however, that the success of the program requires a very strong commitment from the GOL, made explicit through the press and public campaigns, in order to change the prevailing attitude of customers.

Table 4.6: SCENARIOS FOR REDUCING FINANCIAL LOSSES
(US$ million)

	Year 1	Year 2	Year 3	Year 4	Year 5
SCENARIO I: No Change					
Value of Total Energy Consumed	47.49	47.97	48.45	48.98	49.42
Value of Energy Billed	34.38	34.73	35.08	35.43	35.78
Value of Energy not Billed	13.11	13.24	13.37	13.51	13.64
Value of Energy Collected	23.64	23.88	24.12	24.36	24.60
Value of Energy not Collected	10.74	10.85	10.96	11.07	11.18
Financial Loss	23.85	24.09	24.33	24.57	24.82
Net Present Value (at 12% discount rate)	87.52				
SCENARIO II: Improvements in Billing and Collection					
Value of Total Energy Consumed	47.49	47.97	48.45	48.93	49.42
Value of Energy Billed	38.00	43.17	46.03	46.48	46.95
Value of Energy not Billed	9.50	4.80	2.42	2.45	2.47
Value of Energy Collected	32.41	37.47	42.14	44.39	45.78
Value of Energy no Collected	5.58	5.70	3.89	2.09	1.17
Financial Loss	15.08	10.50	6.31	4.54	3.64
Net Present Value	31.28				
SCENARIO III: Improvements in all but Government					
Value of Total Energy Consumed	47.49	47.97	48.45	48.93	49.42
Value of Energy Billed	38.00	43.17	46.03	46.49	46.95
Value of Energy not Billed	9.50	4.80	2.42	2.45	2.47
Value of Energy Collected	26.98	31.30	35.55	37.74	39.06
Value of Energy not Collected	11.02	11.88	10.48	8.74	7.89
Financial Loss	20.52	18.67	12.90	11.18	10.36
Net Present Value	53.78				

V. QUALITY OF SERVICE AND GENERATION OPERATIONS

Overview

5.1 The reliability of power supply in Liberia has deteriorated significantly during the past two to three years. During the dry seasons prior to the mission's visit LEC was shedding load extensively and for long periods. The mission did not examine outage records in detail, but was informed that outages were widespread during the dry season, occurring up to six days per week. 11/ The mission was also informed that many of the more affluent customers, including industrial and commercial establishments, were sufficiently inconvenienced to cause them to install standby diesel sets to avoid expected shortages during the 1985/86 dry season.

5.2 The main causes of declining reliability are repeated failures of the three 13.3 MW diesel units (the backbone of the power supply during the dry season) and shortages of cash to purchase fuel for the gas turbine units. The use of the latter has also been restricted since their operation and maintenance cost exceeds the present tariff (US ¼7¢/kWh). However, operational errors at the hydroelectric plant have also caused major plant damage and outages. The following paragraphs present the main problems in the operation of the thermal generating plants and propose solutions to restore availability and prevent future damage to the units. The total cost of the program to rehabilitate the diesel plant and operate it for two years is estimated at about US$11.2 million and savings are estimated at about US$3.3 million per year. 12/ The cost of operating and maintaining the hydroelectric plant is estimated at US$3 million. The cost of hydro plant rehabilitation, defined in Chapter VI, is estimated at US$2.2 million. Table 5.1 summarizes the composition of the generation management program. The cost of the rehabilitation work is detailed in Annex 4.

11/ This information is fully consistent with the condition of the thermal plants visited by the mission.

12/ The savings are based on an estimate of the value of improved reliability and fuel savings. The value of avoiding major plant damage is not included.

Table 5.1: GENERATION MANAGEMENT PROGRAM FOR 2 YEARS

I. THERMAL PLANTS	
Operation	
1. One Power Station Superintendent	200,000
2. Four Shift Charge Engineers	680,000
3. Four Control Room Operators	640,000
4. Twelve Engine Drivers	1,440,000
	2,960,000
Subsistence and Travel	690,000
Contingencies	365,000
Overhead/Profit	365,000
	4,380,000
Maintenance	
1. Two foremen (technical and electrical)	320,000
2. Three mechanics	420,000
3. Two electricians	280,000
4. Two fitters	240,000
	1,260,000
Travel and subsistence	270,000
Contingencies	153,000
Overhead/Profit	153,000
	1,836,000
General	
1. One store keeper	140,000
2. One chemist	170,000
3. One instrument mechanic	160,000
4. One training and safety specialist	170,000
	640,000
Travel and subsistence	120,000
Contingencies	76,000
Overhead/Profit	76,000
	912,000
II. HYDRO PLANT	
Operation	
1. One power station superintendent	200,000
2. Four shift charge engineers	680,000
3. Four control room operators	640,000
	1,520,000
Travel and subsistence	270,000
Contingencies	179,000
Overhead/Profit	179,000
	2,148,000

Table 5.1 GENERATION MANAGEMENT PROGRAM FOR 2 YEARS (Continued)

Maintenance	
1. 2 foremen (mechanical and electrical)	320,000
2. 1 mechanic	140,000
3. 1 electrician	140,000
	600,000
Subsistence & travel	120,000
Contingencies	72,000
Overhead/Profit	72,000
	864,000

Main Problems

5.3 The diesel plant failures are caused by both external and internal problems. LEC informed the mission that two major failures of Unit 3 at the Luke Plant were caused by external problems. The first was due to a mismatch of the engine and generator and the second was due to an assembly deficiency. 13/

5.4 Fuel quality is another important external factor. For example, units 1 and 2 have suffered excessive component wear because of the presence of high concentrations of catalytic fines in the fuel, compounded, in the case of the piston rods, by the use of a softer than required surface coating. 14/ The wear on the piston rods caused one engine, at the time of the mission's visit, to lose up to 70 barrels of lubricating oil per day. The most recent, and perhaps most serious fuel problem was the fouling of the entire fuel purification and forwarding system by sludge which precipitated from a batch of fuel purchased from the Liberian Petroleum Refining Corporation (LPRC). The problem apparently was caused by LPRC's mixing of incompatible fuels. 15/

5.5 The most important internal problems are the lack of well-trained operation and maintenance staff and overstaffing in unskilled positions. The lack of skilled personnel not only reduces the efficiency of day-to-day operations, but threatens to compromise plant security.

13/ The failure of Unit 3 is the subject of litigation between LEC and the manufacturer.

14/ LEC informed the mission that the manufacturer had recently recommended the use of a harder surface on the piston rods.

15/ The fuel remaining in LEC's tanks was analyzed and shown to be outside of LEC's minimum specifications and unsuitable for use in the engines.

Overstaffing has generated a poor work atmosphere since a substantial number of people in the plant are idle most of the day.

5.6 Finally, the mission found that the auxiliary systems are less than adequate, making it difficult for LEC to operate the plant. For example, there is no back-up fuel purifier to facilitate maintenace on the fuel purifying and forwarding system.

Proposed Solutions

5.7 Improving the availability and efficiency of generating plants will require:

(a) rehabilitating the diesel engines at the Luke plant and upgrading the plant facilities and auxiliary systems;

(b) providing well organized, skilled personnel to operate and maintain the diesel, gas turbine and hydroelectric plants; and

(c) removing the defective fuel from LEC's tanks and instituting procedures to test fuel samples before acceptance in the tanks.

5.8 This action is, in the mission's opinion, indispensable to maintainig the integrity of the plant and improving its availability. It should be regarded as necessary "insurance" to protect LEC's investment of more than US$35 million in the Luke Plant.

Diesel Engine Rehabilitation and Plant Upgrading

5.9 The main steps involved in rehabilitating the Luke engines and upgrading the plant facilities and engine auxiliaries are:

(a) reconditioning the diesel engines;

(b) reconditioning and upgrading instrumentation;

(c) providing a fire fighting system;

(d) reconditioning and upgrading the fuel purification and forwarding system;

(e) upgrading the intermediate cooling water to sea water heat exchange system;

(f) providing a water softener to provide softened make-up water for the jacket water system;

(g) improving the disposal of used oil, sludge and solid waste by using an incinerator;

(h) reconditioning the laboratory for fuel, lube oil and water testing;

(i) providing a workshop for instruments;

(j) providing an electrical workshop;

(k) extending the mechanical workshop;

(l) creating a stock control and storekeeping system for spare parts;

(m) improving storage facilities for spares;

(n) repairing and improving the ventilation of the powerhouse;

(o) providing a lubricating oil storage system; and

(p) introducing a safety program.

Operation and Maintenance Personnel

5.10 Skilled personnel to operate and maintain the generating plants would best be provided through an operation and maintenance contract with a competent firm. Such a contract would fix LEC's operating and maintenance costs for the contract period and would enable it to reorganize and train the necessary staff at the same time. The contract should specify clearly the responsibilities of each party, LEC and the contractor, and should state explicitly what spare parts are covered. 16/

5.11 Since one of LEC's problems is overstaffing, the use of an operation and maintenance company under contract would enable LEC to restructure its work force at its plants. Personnel considered suitable for training, either by virtue of long experience or by having the necessary educational background could be selected from the present staff for intensive training by the contracted company. Redundant staff should be adequately compensated and discharged, to reduce staff to levels consistent with industry standards. 17/

16/ "Accidents" involving high cost parts such as a crankshaft, for example, would normally be excluded from the maintenance contract and would be covered by standard machinery insurance.

17/ Reducing the number of staff employed to provide enough properly trained and adequately compensated personnel to operate and maintain the plant is essential, and requires the support of the Government in its implementation.

5.12 After selecting appropriate staff for training, LEC should regrade the positions to which they will be appointed when the training is complete to provide adequate salaries and working conditions to retain the trained staff.

5.13 The staff to be provided by the contractor would include a power station superintendent, shift charge engineers, control room operators, engine drivers, maintenance foremen, mechanics, electricians, fitters, a storekeeper, a chemist, an instrument mechanic and a training and safety specialist. The details are listed in Table 5.1. Laborers would be hired locally from LEC's existing staff and trained by the expatriate firm.

Fuel Quality Control

5.14 Simple procedures and kits are available to test fuel for incompatibility and the pressure of catalytic fines. These are the two problems that have most affected LEC's operation. An arrangement should be made with the refinery to permit the necessary tests to be done before each batch of fuel is delivered to LEC's tanks. There is no alternative but to remove the contaminated fuel which was in the tanks during the missions's visit.

5.15 Terms of Reference for the above work are provided in Annex 3. Detailed cost estimates and cost benefit analyses for the recommended plant modifications are provided in Annex 4.

VI. GENERATION EXPANSION AND REHABILITATION OPTIONS

Introduction

6.1 The urgent measures required to restore the Luke Diesel Plant to its rated capacity were described in Chapter V. In addition to this plant there are other technically feasible opportunities for rehabilitating and upgrading the plant. These opportunities normally would be screened for economic feasibility using the long run marginal costs of energy and capacity (LRMC). However, since a long range least cost generation expansion plan was not available, the rehabilitation opportunities are evaluated here as alternatives to new plant in a preliminary system expansion study.

6.2 The basic objective of a "least cost" generation expansion study is to define a sequence of generating plant additions/modifications which will satisfy the load forecast while maintaining a specified level of system reliability at minimum cost. The objective is extended in this case to include capacity additions or plant modifications which may not be necessary to meet the reliability criterion but which lead, through fuel substitution or improved efficiency, to a lower overall cost of generation.

6.3 An important peculiarity of the Liberian power system is the seasonal dependence of the generation. In the dry season the output of the hydroelectric plant, which is run-of-the-river, is almost negligible, whereas in the wet season it can satisfy most of the demand. Thus the dry season conditions (December to June) determine plant additions. Sufficient thermal plant must be provided to cover demand and reserve requirements in the dry season.

6.4 The expansion is studied with the assistance of computer programs which calculate the system risk level (LOLE) and simulate the system operation to determine production costs. The capital cost and operating cost of the system for each alternative expansion pattern are combined and discounted to obtain the net present value of total costs. This section summarizes the main findings of the preliminary expansion study and presents a description of the recommended rehabilitation options. Input assumptions and main results of the calculations for the generation expansion study are included in Annex 5.

Main Conclusions

6.5 The most economic options for expanding the power system in Liberia are a mixture of rehabilitation and addition of thermal and hydro units. The proposed Via storage project is not recommended under any of the scenarios considered here because of its high cost and the fact that

it would not provide substantial additional capacity during the dry season (see paras. 6.12 - 6.13).

6.6 In all scenarios considered by the mission the rehabilitation of the Luke low speed diesel units and Mt. Coffee (up to 64 MW) is warranted. In the lower load growth scenario (i.e., 1% per annum) 5 MW diesel units would have to be installed in the Bushrod station, two of them commissioned by 1989 and the four remaining ones by 1992. In the higher load growth scenario (i.e., 3% per annum) the commissioning date of some of these units would have to be accelerated (i.e., five 5 MW diesel units commissioned by 1989), and the rehabilitation of the Bushrod gas turbine (unit #4) would be warranted. In addition to these, several thermal units would have to be commissioned by 1992 and 1994, and the Mt. Coffee hydro station would have to be upgraded by 16 MW for 1993. 18/

6.7 The total cost of the rehabilitation component of the expansion program is about US$6.3 million. Upgrading Mt. Coffee by 16 MW would cost an additional US$8.6 million. These costs exclude the investment in new capacity, which would be about US$17.5 million in the low growth scenario, and about US$60.1 million in the high growth scenario. 19/ Terms of Reference for the rehabilitation work are included in Annexes 3 and 4. A summary of costs is presented in Table 6.1.

Table 6.1: GENERATING PLANTS
SUMMARY OF REHABILITATION AND MANAGEMENT

Plant Name	Unit Type (No)	Current Plant Rating	Program Cost
		(MW)	(US million)
Mount Coffee	Hydro (4)	64	
- Rehabilitation			2.2
Luke	Diesel (3)	39	4.1 a/
Bushrod	Diesel (2)	3	
TOTAL			6.3

a/ These costs are already included in Chapter IV.
b/ No rehabilitation recommended by the Mission.

Source: Mission estimates.

18/ The thermal units to be installed are: one 15 MW diesel unit, one 5 MW diesel unit and two 15 MW gas turbine units would have to be commissioned by 1992; and one 15 MW diesel unit would have to be commissioned by 1994.

19/ All figures are estimated in 1986 dollars.

Alternative Expansion Scenarios

6.8 The analysis of future generating requirements is based on two general types of expansion:

(a) development of the Via storage project and additions to hydroelectric capacity supplemented by thermal plant for dry season capacity; or

(b) thermal plant expansion without immediate development of Via storage.

6.9 These two basic options reflect the peculiarities of Liberia's power system. As mentioned above, hydro plant availability during the dry months is limited. As a result, adding storage capacity (i.e., Via storage project) to the hydro plants is an option for increasing hydro plant availability during the dry season, with the objective of reducing total operating costs during the year. The shortfall of capacity (if any) during the dry season would have to be made up by existing or additional thermal units.

6.10 A close examination of the hydrological conditions (see Annex 5) and the characteristics of this alternative show that the Via storage project would allow an additional 16.1 MW of base load capacity during the dry season (i.e., about 25% of peak demand). However, during the wet season, the Via storage would not contribute to additional capacity. 20/

6.11 The second general alternative for expansion can be divided into two subgroups. The first subgroup is a purely thermal expansion (i.e., rehabilitation and addition of thermal units only), and the second subgroup would be a mixed alternative, that is, rehabilitation and addition both of thermal and hydro units, without the development of the Via Storage project. In this case, new hydroelectric units would provide additional energy during the wet season while thermal units would operate during the dry season.

Via Development

6.12 There are no cases which favor developing Via at the present time. At 1% load growth, the total present worth of costs was $159,249,000 (Case 1-1A) with Via as compared with $109,890,000 (Case 2-1A) without Via. At 3% growth the total present worth of the costs was $198,590,000 with Via and $148,355,000 without. The reason Via does not prove to be economically viable is because it adds little to base-load

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20/ The data used to develop monthly hydro capabilities was obtained from: "VIA Storage Project and Expansion of Mt. Coffee Power Plant, Stage 1 Report", Harza Engineering Co. International, June 1984.

generation during the dry season, so additional thermal plants would still be required to meet load growth.

Table 6.2: NET PRESENT VALUE OF GENERATION EXPANSION ALTERNATIVES

General Alternative No.	Specific Case No.	Description a/	Cumulative Present Worth at 12%
			(US$000)
1-1		Via included, load growth = 1%	
	1-1A	Via-1993, Mt. Coffee 80 MW-1987	159,249
	1-1B	Via-1990, Mt. Coffee 80 MW-1987	176,137
	1-1C	Via-1993, Mt. Coffee 80 MW-1993	156,557
1-2		Via included, load growth = 3%	
	1-2A	Via-1990, Mt. Coffee 80 MW-1987	198,592
	1-2B	Via-1990, Mt. Coffee 80 MW-1990	196,072
2-1		Via not included, load growth = 1%	
	2-1A	Gas Turbine (#4) refurbished	109,890
	2-1B	Gas Turbine not refurbished	107,852
2-2		Via not included, load growth = 3%	
	2-2A	Mt. Coffee 80 MW-1987	148,355
	2-2B	Mt. Coffee 80 MW-1990	146,042
	2-2C	Mt. Coffee 80 MW-1993	144,473

a/ Thermal plant additions and retirements associated with each case not described in this listing.

Source: Mission estimates.

6.13 Simulation with a 5% load growth also indicates that Via would not be the preferred option: total discounted costs would be about US$151.5 million with Via, and about US$107.3 million without it. 21/ The most economic option in this case would be to advance the upgrading of the Mt. Coffee plant to 1990, and install a series of thermal plants (110 MW) between 1989 and 1997.

21/ These figures are not comparable to the 1% and 3% load growth scenarios because they do not include fuel, operation and maintenance costs prior to 1990.

Upgrading Mt. Coffee to 80 MW

6.14 It would be best to delay the upgrading of Mt. Coffee under conditions of 1% growth rate. Only a higher growth rate (e.g. 3-5%) would justify the upgrading, which in any case would not reduce required thermal plants.

Gas Turbine Capacity

6.15 The simulation indicated a strong requirement for gas turbine capacity, as would be expected with a system having the need for seasonal thermal peaking capacity. The difference in net present worth with ($109,890,000 (Case 2-1A)) or without ($107,852,000 (Case 2-1B)) rehabilitation of the gas turbine Unit #4 is relatively small. Given the expected lower operating costs (if the unit is repaired) and the fact that the presence of gas turbine plants is required through the period under analysis, rehabilitation of Unit #4 is recommended.

Least-Cost Solution

6.16 At 1% load growth the least cost expansion plan is Case 2-1B, which does not include the upgrading of Mt. Coffee, the refurbishment of the Bushrod gas turbine (Unit #4) or the Via reservoir. Expansion consists of rehabilitating the Luke plant and Mt. Coffee, installating six 5 MW diesels to be housed at the existing Bushrod building and one 15 MW gas turbine. The NPV of the option is $107,852,000.

6.17 At 3% load growth a mixed hydro and thermal alternative is the least-cost solution (Case 2-2C) consisting of six 5 MW diesels, two 15 MW diesels and two 15 MW gas turbines, and upgrading of Mt. Coffee by 16 MW. The NPV was $144,473,000. Annex 5 summarizes the characteristics of each preferred alternative, and the remainder of this chapter outlines the recommended rehabilitation work.

Rehabilitation Projects

Mount Coffee Station

6.18 The Mount Coffee station consists of two 15 MW and two 17 MW units. They are all in need of repair and could be upgraded to 20 MW each through the changes in the turbines, generators, transformers, instruments, etc. As a result of these improvements, the plant's rated capacity could be increased from 64 MW to 80 MW. The differential capacity is equivalent to adding a new unit of approximately the same size as the others. This program would still leave space in the existing plant facilities to add the two other 20 MW units planned for in the design of the station. The 80 MW plant rating would increase hydro-

electric energy production, introduce 16 MW (25%) of reserve to the LEC system during the wet season which would permit LEC to meet peak loads without resorting to operating the thermal units.

6.19 The rehabilitation work would involve a complete overhaul of the plant's common facilities--installing a new trash rake system, repairing the unit isolating valves, the spillway gate drive controls and telemetry, upgrading the air and water cooling systems, etc. The work would also include a survey to check the the building's settling, in relation to the turbine alignment problems. Details of these tasks are outlined in the Terms of Reference in Annex 3. For the upgrading of the station, in addition to the general repairs to the units, alloy turbine runners should be installed, the generators should be rewound with Class F insulation, and the transformers should be replaced. These steps would permit each of the units to attain a capacity of 20 MW. Details on these tasks are addressed in the Terms of Reference in Annex 3.

The Diesel Stations Feeding into the LEC System

6.20 The Bushrod Station. This diesel plant is 24 years old and its original capacity was 13.2 MW (three units of 1.9 MW each and three units of 2.5 MW). Presently only two units are in operation and they are in bad condition. These gasoil fired units cannot produce more than 1.5 MW. Overhauling these units would cost about $250,000 each, including new radiators, air filters, a generator overhaul, new instrumentation and controls, etc. In view of their age, their old design (which cannot be updated), the high fuel consumption (net production 11 kWh per US gallon) and the fact that production of this engine model was discontinued in 1978, it is recommended to retire the units.

6.21 The building, however, is in good condition. If the existing engines were removed and the foundations customized, six generating sets on a steel subframe could be installed. Because of building size, each unit would have to have a maximum power of 5 MW.

6.22 The Luke Station. This station was commissioned at the end of 1980. It has three 13.6 MW ten cylinder slow-speed units. Units 1 and 2 were commissioned in 1980, Unit 3 in 1982. All burn heavy oil.

6.23 Of all the thermal plants in the LEC system this plant has the best fuel economy and serves as base load unit in the dry season when almost no hydropower is available. As mentioned in Chapter IV, the engines have suffered considerably from the use of a very poor grade of fuel, lack of maintenance and shortcomings in the design of the auxiliary systems. These problems have resulted in poor availability and excessive maintenance cost.

6.24 To save the plant from further deterioration or complete breakdown the mission has recommended a program of rehabilitation

together with a management contract for operating and maintaining the plant by an expatriate team for a period of two years. During this time, permanent personnel will be selected and trained.

6.25 Bushrod Gas Turbine Plant. This station comprises 2 x 15 MW and 2 x 19.1 MW gas-oil fired gas turbine units. Although they were intended for service as peaking and standby units when they were installed (1969 through 1973), they are now operated as medium-load units during the dry season.

6.26 LEC now considers the Mount Coffee firm capacity in the dry season as zero. During the dry season, after reaching full capacity on the Luke diesel units, it is necessary to place the gas turbines in service to satisfy the load demand over 40 MW, or shed load if the gas turbines are not available.

6.27 LEC already has begun a program of rehabilitating the gas turbine units and is presently (July, 1985) overhauling Units 2 and 3. Unit 1 already has been rehabilitated.

6.28 The fourth unit has been out of service since January 1983, and is currently scheduled for rehabilitation around January, 1986. The cost of this work is quoted at US$1.5 million in 1985 prices. This unit will be 14 years old in 1987 and has an expected remaining life of six years. The repairs include a complete reblading of the gas turbine stationary blades, and replacement of the hot gas casing with a new alloy casing design.

VII. TRANSMISSION AND DISTRIBUTION OPERATIONS

Overview

7.1 LEC's transmission and distribution systems are relatively new and voltage levels and regulation seem acceptable in most areas. 22/ Technical losses, although clearly higher than optimum, are not excessive. There are, however, deficiencies in the planning, operation and maintenance of the distribution system which will lead to poor quality and costly service in the future unless prompt action is taken to correct them.

7.2 In defining the deficiencies and suggesting remedies the mission uses the performance of a typical well-run North American utility as a benchmark. The usual argument against this approach is that a utility in a developing country does not have the resources, skilled personnel, technology or availability of spare parts to attain the same standard of operation as a utility in an industrialized country. However, because of the adverse impact of poor quality electricity service on the economy, it is crucial that a utility in a developing country aim for high standards and be given the necessary resources to achieve them. A simple example shows the benefits of improving the management of the distribution system. LEC at present does not practice transformer load management and suffers at least 75 burnt-out transformers per year costing over US$60,000 for the replacements. 23/ A transformer load management system would cost about US$75,000 to set up and would eliminate most of the burn-outs.

7.3 Some of the reasons why LEC is not attaining the required high standards of operations are:

(a) there is a shortage of skilled staff and the existing staff has to devote its time mainly to solving urgent day-to-day problems;

(b) the organization and work responsibilities are not well-defined, leading to underemployment of the available skilled staff;

22/ Customer complaints about quality of service stem mainly from outages caused by generating plant failures.

23/ There is also a significant cost associated with changing these transformers under emergency conditions rather than during scheduled work.

(c) the utility is restricted by general government pay and benefit scales from adequately rewarding initiative and hard work;

(d) there is a high level of overstaffing leading to situations where the number of people involved in an activity become a hindrance to its efficient completion; and

(e) there is not enough awareness of the tools and techniques available to improve operations. 24/

7.4 LEC has an excellent opportunity at this stage of its development to utilize the most modern technology available since it has to completely rebuild its distribution system data base. For example, by digitizing its system maps and by linking customer account numbers to distribution transformers, which in turn are linked to feeders, the vast array of information in the billing system can be accessed and used for transformer load management, feeder load control and expansion planning.

7.5 The following paragraphs describe some of the most obvious deficiencies in the present operation of LEC's transmission and distribution systems and propose possible improvements.

Deficiencies

7.6 Among the most obvious deficiencies:

(a) there are no reliable system drawings, so switching is done from memory by a few knowledgeable individuals--a procedure which is dangerous both to human life and equipment;

(b) the protective system is not routinely checked and recalibrated, resulting in spurious outages;

(c) post fault analysis to identify defects in specific components or procedures and avoid repeats is not done rigorously;

(d) there is no organized maintenance program for the 69 and 12 kV lines; 25/

24/ This applies especially to distribution operations where the availability of low cost computers has revolutionized the way distribution systems are planned, managed and operated.

25/ A good maintenance program would include routine pole and line inspections, tree trimming, replacement of rotted poles, rusted hardware, cracked insulators, etc.

(e) substation switchboard instruments and meters are not maintained regularly;

(f) there is no central control room for distribution operations;

(g) the execution of construction work is not well planned, leading to many inefficiencies;

(h) there is no power factor correction; and

(i) the transport fleet is for the most part broken down, making inefficient use of staff.

Proposed Improvements

7.7 The deficiencies noted above can be improved in two ways: (a) by making technical improvements including standards, guidelines, and a system to manage the distribution network; and (b) by improving organization, work methods and support services.

Technical Improvements

7.8 Technical improvements can be made by strengthening both the newly formed Corporate Planning Department and the Transmission and Distribution Departments. Technical assistance, computer facilities and software should be provided to the Planning Department to enable it to perform the following functions:

(a) establish a computerized data base for the transmission and distribution system;

(b) analyze the transmission and distribution systems with special emphasis on reactive power dispatch, transformer tap settings, capacitor placement, etc.;

(c) prepare and update, as required, settings for all protective devices on the system;

(d) analyze monthly statistical reports from the transmission and distribution department to determine system loading as a basis for forecasting;

(e) prepare estimates for line extensions;

(f) prepare annual budgets;

(g) analyze major outages to determine the cause;

(h) prepare a set of standards and guidelines for line construction, transformer installation, etc.; and

(i) prepare economic factors for use in evaluating distribution transformer purchases. 26/

7.9 The Transmission and Distribution Department should be reorganized and given the technical assistance and facilities to perform the following functions:

(a) transformer load management using the data base prepared by the planning department, supplemented by actual load measurements; 27/

(b) use of a work order system with links to asset records and accounts;

(c) analysis of the cost of line extensions, a physical audit of the completed work and comparison with the original estimates;

(d) regular maintenance of all substation gear including meters and instruments;

(e) regular maintenance of lines including tree trimming, replacement of poles, insulation, etc.;

(f) collection and analysis of fault data;

(g) analysis of reasons for low voltage complaints and the preparation of estimates to perform extensions where necessary to improve service;

(h) switching as necessary for fault isolation or system economy; and

(i) operation of a central control room for system switching.

7.10 The cost of the equipment, software and technical assistance is approximately US$2.9 million. This includes the use of foreign personnel for at least three years to establish the systems and supply the

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26/ Distribution transformers should be purchased on the basis of total life cycle cost, i.e., including the effect on iron and copper losses over their useful life.

27/ It is important to note that the systems required to maintain the data base (forms, flows of information, etc.) must be in place before a survey is done to establish the data base so that it is automatically kept up-to-date.

training. The work may be achieved in two ways, through the use of a consulting company with utility experience, or through a "twinning" arrangement with a qualified public utility.

7.11 In addition, the mission recommends the installation of approximately 13.5 MVAR of capacitors at a cost of about US$1.2 million. Installation of these capacitors will save about US$1.2 million per year in fuel and about US$90,000 per year in deferred capacity. Terms of Reference for the required work are given in Annex 6.

Improvements in Organization Work Methods and Support Services

7.12 Improvements in organization, work methods and support services include the following:

(a) reorganizing the planning, transmission and distribution departments with clear lines of responsibility and job definitions;

(b) reducing staff to levels necessary for the proposed functions;

(c) improving physical facilities at the offices, workshops and stores to permit good security and a proper work flow;

(d) introducing salary and benefit schemes which reflect the market value of the skills concerned and are responsive to performance;

(e) providing new line trucks, tools and equipment;

(f) streamlining crew strengths and skills to match the equipment for optimum performance;

(g) organizing work and stores procedures to maximize the useful time spent on the job;

(h) introducing elementary hotline techniques;

(i) introducing effective systems to manage fleet maintenance;

(j) providing a communication system separate from the general radio system which is overloaded because of the deficiencies of the telephones; and

(k) training linesmen and technicians.

7.13 The cost of the required equipment, software and technical assistance is about US$1.9 million, and Terms of Reference for the work are given in Annex 7.

VIII. ISOLATED DIESEL PLANTS

Overview

8.1 Since the mission's work focussed on the main interconnected power system, it visited only one of the rural isolated diesel power stations, at LEC's request, to assess the operation and suggest improvements. 28/ Based on its visit to the Gbarnga Power Station the mission recommends that a consulting firm be engaged to perform the following tasks:

(a) inspect all of the rural stations and estimate the cost of the work required to recover derated capacity, improve fuel efficiency and rehabilitate newer units;

(b) perform a cost/benefit analysis to determine how much of the rehabilitation/upgrading is economically justified;

(c) prepare a work plan and, upon LEC's approval, supervise the necessary work;

(d) prepare a standard instrumentation package to be included on future units and retrofitted on existing units; the instrumentation should monitor all parameters necessary to run the plant safely and efficiently, for example:

- energy generated (kWh)
- fuel consumed
- lubricating oil temperature pressure
- exhaust temperatures
- cooling water temperature;

(e) prepare a maintenance schedule for the plants including a routine for sending oil samples for spectrographic analysis;

(f) prepare an inventory control and retrieval system;

(g) train operators and maintenance staff;

(h) advise LEC on purchasing standard sizes and types of plants in future to minimize spare part inventories and the need for specific engine training for maintenance staff; and

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28/ To improve reliability, inadequate revenue collections, and reduce high costs, Liberia's National Energy Committee (NEC) has recommended to the Government the creation of locally owned Rural Electric Utilities to operate and manage isolated diesel stations.

(i) investigate and advise LEC on the logistics of using mobile plant to cover planned maintenance outages in the rural plants, thereby reducing the required reserve capacity in each plant (small gas turbines should be considered as alternatives for use as mobile plant where weight restrictions are important).

8.2 Phase one of the above work, the investigation, is estimated to cost about US$93,000. Annex 8 provides Terms of Reference for the work. The following paragraphs describe the mission's specific findings at Gbarnga and include some general recommendations.

Findings and Recommendations

8.3 The Gbarnga Power Station consists of one powerhouse with two old 605 kW medium-speed units and two modern 2,122 kW skid mounted units. All the engines are gasoil fired and radiator cooled. The old 605 kW engines have been partly dismantled because of bearing failures.

8.4 The modern 2,122 kW units were manufactured in 1978 and installed in 1982. Only one unit was available. The other was awaiting completion of a generator winding repair.

8.5 The medium speed units are beyond repair and should be scrapped except for a few items which could be salvaged, such as the control board instruments and the switchgear.

8.6 The 2,122 kW units appear to be well maintained. The running hour counters in the control board of Unit 2 indicated 878 overload hours and 2,523 normal load hours. Since maximum demand does not exceed 1,400 kW, the mission recommends that LEC check these instruments and the actual engine loading. Overloading of the units is not recommended. The control board does not have a kWh meter so actual energy production can only be estimated from fuel consumed or hours and average load run. This makes it difficult to monitor efficiency. LEC should install a kWh meter.

General Remarks about Rural Power Stations

8.7 Maintenance capabilities in small rural power stations are of necessity less than in large stations. This imposes the following requirements for the engines and auxiliaries in such stations:

(a) the fuel used should be gas oil. The cost of complications resulting from heavy fuel operation will outweigh the fuel price advantage in any plant with a capacity of less than about 10 MW;

(b) units should preferably be semi-transportable, i.e., of the skid mounted type enabling them to be relocated to other areas by the time load growth justifies larger units. The Gbarnga units meet these requirements;

(c) because their safety relies more on protective intrumentation than units in stations with more skilled operators, fail-safe protective systems should be used exclusively and protection system testing should be a routine preventive maintenance activity, preferably done in the presence of a travelling inspector;

(d) units should be moderately rated, both in terms of piston speed and bmep;

(e) critical maintenance operations should be carried out by or under supervision of expert personnel; and

(f) an engine condition monitoring program consisting of spectrographic analysis of lube oil samples, made monthly or depending on engine size, at 250 or 500 running hours would allow more logical maintenance schedules to be developed.

TERMS OF REFERENCE FOR RESTRUCTURING LEC

Summary of Requirements

The Government of Liberia is soliciting proposals for a consulting firm to assist in restructuring the Liberia Electricity Corporation (LEC). The final objective is to organize an efficient electric utility through the sale of LEC, a lease of the concession to generate and sell electricity, or a management contract to run the electricity service. Privatizing LEC operations, either completely or in stages, shall be considered in the restructuring. Any of the above options should be complemented with a well defined regulatory framework. This framework should ensure that high quality service is provided at minimum cost.

The work involves all that is required to negotiate and implement a contractual agreement between the Government of Liberia and a competent power utility for running the electricity service. This includes:

(a) identifying potential bidders for a sale, lease or a management contract;

(b) negotiating a contract with the interested firm (s). The contract should specify performance targets, fees, bonuses, rights and obligations of each party, etc.; and

(c) negotiating and agreeing on a regulatory and arbitration framework to protect the interests of all parties involved.

The firm shall also assist the Government in the process of:

(a) implementing a financial strategy for settling LEC's liabilities and defining options to deal with outstanding arrears from its customers; and

(b) negotiating a solution to the problem of excess staff.

The solution to these problems may be negotiated as part of the contract agreement between the interested firm (s) and the Government of Liberia.

In the following discussion the work is refered to as the "Program" and the entity submitting a proposal as the "Firm". The cost of the work is estimated at US$334,000 consisting of US$210,000 in professional services, US$94,000 in travel and subsistence, and the remainer in contingencies and overhead costs. The program is financed by _____. The executing agency is _____.

Background

LEC is a statutory government corporation responsible for the generation, transmission and distribution of electricity in Liberia. During the past years its finances and service reliability have deteriorated to the point where, if action is not taken, the utility will no longer be able to operate. To arrest this trend, a joint UNDP/World Bank loss reduction mission has recommended the restructuring of the utility. The report of the mission is part of these Terms of Reference. In addition, the Government of Liberia and the World Bank have agreed to undertake a strategic study of the public enterprise sector. The findings and recommendations of this study are also part of these Terms of Reference.

Scope of Work

The work is to be performed by a core team of three experts: one utility management specialist, one financial analyst and one legal adviser. The participation of other specialists may be required to assist in the activities of the core team. The team will work in close coordination with the Bureau of State Enterprises (BSE). The BSE is an autonomous Government agency responsible for advising the Government on policies towards public enterprises, assisting in improving the performance and financial situation of state enterprises, and reforming ownership/management arrangements.

The first tasks of the team will be to:

(a) assist in defining, together with the BSE, the new corporate structure of LEC and the most suitable form(s) of contract for running the power system. The initial proposals should be flexible enough to be able to incorporate suggestions/preferences of firms interested in taking the contract.

(b) on the basis of the above, identify and approach potential bidders, discuss proposed suggestions/modifications to the proposed form(s) of contract and short-list candidates for negotiation.

The division of responsibilities within the team of external experts is as follows. The utility management specialist will:

(a) review the existing staff levels and negotiate with the bidder(s) the actual number and qualification of staff required for the restructuring and for normal operational practice. This should include staff levels in each department, qualifications required for each position and the distribution between local and expatriate staff;

(b) examine the training needs and agree with the bidder(s) on a training program to gradually increase the use of local management; and

(c) negotiate a set of performance targets to be built into the management or lease contract.

The financial analyst will:

(a) evaluate the financial situation of LEC;

(b) prepare a strategy to settle the liabilities to and from LEC. Transfering part (or all) the liabilities may be subject to negotiations with the potential bidder(s);

(c) assist the Government in defining and implementing an adequate compensation scheme for personnel made redundant;

(d) participate in the evaluation of the financial aspects of the contract with the interested firm(s), including the preparation of proposals for fees, bonus payments, etc.

The legal advisor will:

(a) draft the necessary legal documents for the establishment of a new entity. This should include but not necessarily be limited to the preparation of a charter, statutory code, and the definition of rights and responsibilities of the new management firm;

(b) draft the necessary legal documents for the establishment of a regulatory framework to determine changes in tariffs, and to monitor standards of service, required rate of return of the utility, and any expansion plans proposed by the new management; and

(c) draft a legal document outlining the provisions for arbitration in case of conflict between the Government and the managers/ owners of the new corporate entity.

All the above tar's may be defined during the negotiation with the potential bidder(s).

In addition to the responsibilities identified above, the core team shall participate in all activities related to the negotiation of a contract and assist the Government of Liberia until this is finalized.

Division of Labor and Responsibilities

The Firm will be fully responsible for managing the identification, negotiation and finalization of a lease or management contract between the Government of Liberia and a competent utility. The Government of Liberia will provide: (a) access to documents and data; (b) counterpart staff as required; (c) office space; and (d) secretarial services.

Guidelines for the Proposal

The proposal of Firm should provide comprehensive details of the following:

(a) a work plan in accordance with these Terms of Reference;

(b) the nature of the organization and previous experience in related work in other countries;

(c) curricula vitae of staff to be assigned for the work; and

(d) a preliminary estimation of hours per person required for the work.

Structure and Schedule of Payments

The structure and schedule of payment for services rendered during the contract period will be negotiated with the Government of Liberia. These payments will be based on a fixed fees plus bonuses tied to performance targets.

TERMS OF REFERENCE

FOR

IMPROVEMENT OF LEC'S COMMERCIAL OPERATIONS

Summary of Requirements

The Liberia Electricity Corporation is soliciting proposals for a company to reorganize and manage its commercial department, initially for two years. The objective is to minimize non-technical energy losses and to significantly improve LEC's collection performance. To achieve these objectives the company will have to completely restructure the department, introduce modern utility billing, metering and customer service systems and re-establish the customer data base.

The company will be responsible for staffing the commercial department but must train Liberian staff who will eventually take over the operation.

Main Functions

The main functions of the commercial department are:

(a) billing, from meter reading to delivery of bills;

(b) collections;

(c) installation of new services;

(d) disconnections and reconnections; and

(e) public relations.

The estimated expatriate manpower requirements are:

(a) a five person management team consisting of commercial manager, metering supervisor, billing supervisor, customer service supervisor, and computer manager;

(b) a meter engineer and two meter technicians;

(c) two organization specialists to install and train staff in the necessary metering and billing systems; and

(d) one manager and thirty-two technical supervisors for establishing the data base.

Equipment Requirements

The estimated equipment requirements are:

(a) "turnkey" computer software for billing, meter maintenance and debt management with optional modules for accounting, payroll, purchasing, inventory control, work order management, transformer load management and distribution analysis;

(b) computer hardware including digitizing equipment to facilitate the formation of the customer database and use of the software in (a);

(c) meter test equipment;

(d) vehicles and tools to equip service crews;

(e) kilowatt hour meters, service wire and related hardware; and

(f) modifications to the offices to allow secure operation of the commercial department.

The estimated cost of the program to establish the necessary systems and manage the operation for two years is US$9.4 million, consisting of about US$8 million in technical services and US$1.4 million in equipment. A breakdown of project costs by activity is given in Table 1.

Background

Two major deficiences inhibit the efficient operation of LEC's Commercial Department and threaten the Corporation's financial viability: (a) failure to bill a large portion of active customers correctly; and (b) poor collection of revenues owed to LEC.

Generation and sales data show that of 363.52 GWh generated for sale in Liberia in 1983/84 only 63% of this total was actually billed, indicating a revenue loss of US$20 million. Moreover, of the 229.23 GWh billed at a total value of US$34.4 million, only US$23.7 million were collected, resulting in the loss of an additional US$10.7 million in revenues.

A joint UNDP/World Bank mission visited Liberia in June 1985, studied the reasons for LEC's problems and suggested solutions. The report of the mission forms a part of these Terms of Reference.

Table 1: ESTIMATE OF COSTS FOR IMPROVING COMMERCIAL OPERATION

I. Overall Management	
Professional Services a/	800,000
Travel & Subsistence	150,000
Contingencies	88,000
Overhead/Profit	88,000
	1,126,000
II. Establishment of Data Base	
Professional Services b/	3,840,000
Travel & Subsistence	950,000
Contingencies	618,000
Overhead/Profit	634,000
Equipment c/	1,350,000
Local Costs d/	403,200
	7,795,200
III. Metering System Improvements	
Professional Services e/	260,000
Travel & Subsistence	40,000
Contingencies	30,000
Overhead/Profit	30,000
	360,000
IV. Billing System Improvements	
Professional Services	70,000
Travel & Subsistence	30,000
Contingencies	10,000
Overhead/Profit	10,000
	120,000

a/ Management team of five professionals to reorganize and run commercial operations for two years.

b/ A team of one professional (80,000 p.a.) to manage the mapping exercise for two years; eight (65,000 p.a.) mapping crew supervisors and twenty-four (55,000 p.a.) line crew foremen for a period of two years.

c/ Includes vehicles, computer hardware and software, 12,000 meters and sockets, conductors and accessories and service conductors.

d/ Includes costs of 16 helpers for crew supervisors and 48 line crew members for two years.

e/ One manager and one meter technician to reorganize the department for a period of two years.

Source: Mission estimates.

Scope of Services

The company will do everything necessary to achieve the objectives outlined in the Summary of Requirements and may proposed alternative approaches. Some of the specific tasks are:

Reorganize the Commercial Department

The company will restructure the commercial department consistent with modern utility operating practices. It will determine the functions of staff, prepare job descriptions, prepare procedures and implement them. The company will determine the computer software and hardware needs to operate the various functions of the department.

Reestablish Customer Data Base

This will require a visit to each customer connected (legally or illegally) to the LEC system. The opportunity will be used to locate each customer on a map and to assign a unique account number linked to the transformer from which the service is supplied. The transformer must also be numbered uniquely. A suggested approach to the task is as follows:

(a) Digitize the geographical maps for the area using a digitizing table and appropriate computer software.

(b) Issue a map section produced on a plotter to a mapping supervisor.

(c) The mapping supervisor along with one or two assistants should go to the field, locate the distribution lines on the map section and check each customer connected to the line.

(d) If the customer is legally connected (has a valid account number on the old system and is not in arrears) the supervisor should assign an account number according to a prearranged scheme, and locate and number the transformer from which the service is supplied.

(e) A service crew should remove the meter install a new one and bring the old meter in for testing, recalibration and return to stock.

(f) If the customer is illegally connected the supervisor should prepare a service contract, receive payment and have the service crew immediately install a service. If the customer is unable to pay immediately, the illegal service should be removed and noted pending a request for service from the customer.

(g) If the area requires major strengthening, e.g., extension of the High Tension lines or the installation of a new transformer, this should be noted by the supervisor and a work order sent to the Distribution department.

(h) At the end of the day, the information should be brought in and entered (by a second shift) in the computer using the digitizer.

It is important that all of the procedures for updating and maintaining the system be in place before the actual survey and clean-up starts to ensure that if new services are installed in an area being surveyed they are entered properly to maintain the integrity of the data base.

A second survey should be made about 6 months after the process described above to ensure that customers have not illegally reconnected themselves.

Computer Software and Hardware

The computer software used should be a standard utility package which allows on-line access to customer accounts. A number of "turn-key" packages are available and the firm should select one that is capable of doing all of the accounting functions, e.g., general ledger, payroll, etc. The software chosen should also be capable of sharing its data base with technical analysis programs to be used by the planning and distribution operations departments. Under no circumstances should the company develop custom software.

The existing computer hardware should be replaced if necessary to accommodate the chosen software. In selecting hardware sufficient redundancy should be included to allow for typical maintenance response times.

Metering System

The company will organize the meter section to adequately test meters, keep records of the movement of meters on the distribution system and control meter sealing. It should ensure that meters of an adequate quality are purchased and that LEC's name is clearly marked on the meter to reduce fraud.

Inspections

The company will organize an effective inspection section to follow up and check suspected theft and fraud, and to respond to customer's request for meter test, etc.

Customer Services

The company should organize an efficient customer service section to deal with customers promptly and efficiently. It should establish and publish norms for response to various customer requests. Efficient operation of this section will require on-line customer records that can be accessed by service personnel.

Division of Labor and Responsibilities

The expatriate management team will be fully responsible for the operation of the Commercial Department during the contract period. LEC will provide: (a) access to documents and data; (b) counterpart staff as required; (c) office space; (d) secretarial services; and (e) prompt response by other departments interfacing with the commercial department.

Guidelines for the Proposal

The Company's proposal should provide comprehensive details of the following:

(a) a work plan in accordance with these Terms of Reference;

(b) the nature of the organization and previous experience in related work in other countries;

(c) curricula vitae of staff to be assigned for the work;

(d) details of equipment to be procured to execute the work plan;

(e) a detailed proposal for training of LEC personnel during the contract period; and

(f) a preliminary estimation of hours per person required for the work.

Form of Contract

The contract which will be awarded to the successful firm will be part of an overall program of restructuring. It is expected that firms will bid for award of the total program, which will take the form of a management contract or a lease of the conversion to generate and sell electricity.

Schedule of Payments

The amounts and schedule of payment for services rendered during the contract period will be negotiated with the LEC. These payments will be based on a fixed fee plus bonuses tied to performance targets. The Company should make a proposal which will be used as a basis for the negotiation.

TERMS OF REFERENCE

FOR

PLANT REHABILITATION OPERATION AND MAINTENANCE

Summary of Requirements

Liberia Electricity Corporation (LEC) is soliciting proposals for a consulting firm or public utility to:

(a) organize and manage the rehabilitation of three diesel-electric power generating units and the upgrading of the auxiliaries at the Luke generating plant;

(b) organize and manage the rehabilitation of four hydro-electric power generating units at the Mount Coffee generating plant;

(c) define and specify the work necessary to upgrade the capacity and efficiency of the four hydro-electric power generating units at the Mount Coffee generating plant;

(d) prepare, negotiate and manage an operation maintenance and training contract for all the generating plants.

The objective of the rehabilitation work in the diesel and hydro plants and upgrading the auxiliaries at the diesel plant is to restore the design capacity and efficiency of the units and improve their availability. The specifications for upgrading the hydro-electric plant will be used when demand growth warrants this work. The operation, maintenance and training contract is to provide reliable operation and maintenance services in the short-term while local staff is trained to run the plants efficiently and safely.

In the followng discussion the work is referred to as the "Program" and the entity submitting a proposal to do the work is referred to as the "Firm". The cost of the rehabilitation work at the Luke generating plant is estimated at US$4.1 million. The cost of the rehabilitation work at the hydro-electric station is estimated at US$2.2 million, and the cost of the operation, maintenance and training contract for two years is estimated at US$10.1 million. Cost estimates are attached. The Program is financed by _____. The executing agency is _____.

Background

LEC is a statutory government corporation responsible for generating, transmitting and distributing electricity in Liberia. Its two main generating plants are the Luke plant consisting of 3 x 13.3 MW slow speed diesel engines; and the Mount Coffee plant consisting of 2 x 15 MW and 2 x 17 MW hydro-electric units.

The generating units at both plants require rehabilitation. There also is scope for increasing the capacity and efficiency of the existing hydro-electric plants. Operation and maintenance services are required to improve the availability of the plants along with a structured program to train local staff for these functions.

This work is part of the restructuring proposal for the Liberian utility by a joint UNDP/World Banks mission which visited Liberia in June 1985. The mission's report which describes the power system, examines its problems and proposes solutions is a part of these Terms of Reference. A brief description of the two plants follows:

Luke Plant

The Luke Plant is the major diesel driven electricity generating station. Its diesel engines are three 10 cylinder slow-speed engines (model 10 K 67-GS) designed by Burmeister and Wain, Copenhagen, Denmark and built by Gotaverken, Goteborg, Sweden. The two bearing generators are designed and manufactured by Asea, Sweden. Each unit is rated 13.6 MW at the generator terminals, 13.8 kV, 60 Hertz. Cooling of the engines is through shell and tube heat exchangers to intermediate fresh cooling water which is cooled by seawater in plate type heat exchangers located in a pumping/ cooling station at the seashore about one mile away from the powerstation.

The power house has natural ventilation through louvres in walls and roof and the engines take air from inside the power house through standard built-on filters on the turbo-chargers. The engines run on heavy fuel and the station is manned whenever engines run.

Units 1 and 2 were commissioned in January, 1980, Unit 3 in December, 1982. They are required to operate between 4,000 and 5,000 hours per year, mainly in the dry season (December through June). Major maintenance work is normally scheduled in the wet season, when hydropower is available to the grid.

The engines and auxiliaries have deteriorated as a result of using incompatible fuels containing high concentrations of catalitic fines, insufficient maintenance and from the absence or inadequacy of a number of auxiliaries and services.

Mount Coffee Plant

The Mount Coffee plant consists of two 15 MW and two 17 MW run-of-the-river hydro-electric units. They are all in need of repair. In addition there is potential for upgrading them to about 20 MW each through the use of new runners, generators and transformers. The station also has provision for an additional unit.

Scope of Work

The work should be done in two phases:

Phase I:

(a) Inspect the plants with specific attention to (but not limited to) the items described in the following paragraphs. The inspection shall be done in sufficient detail to arrive at a detailed specification of the required rehabilitation and upgrading, its cost and the time frame in which the work will be done.

(b) Specify the number, level and job descriptions for operations and maintenance staff both for ex-patriates and local staff.

(c) Prepare bid documents for the required services and equipment.

(d) Assist in evaluating bids and negotiating the contracts.

Phase 2

(a) Procure, expedite, and manage the implementation. This includes testing and commissioning new materials and equipment, construction work, repairing existing equipment and operation of plants until a final takeover certificate has been issued by LEC for all the work that has been done.

(b) Supervise training to ensure that LEC operating staff is technically competent to run the system and achieve the envisaged performance.

(c) Advise and assist LEC in any guarantee matters that may arise.

Specific Tasks

Although in the following pages several work elements are specified in detail and some solutions to problems are indicated, it should be noted that these are to be used for guidance only. The Firm is fully responsible to do all that is necessary to achieve the objectives of the program stated in the Summary of Requirements. The work elements

are presented in the order: Luke plant improvements, Hydro plant rehabilitation, Hydro plant upgrading, and Management of the generating plants.

LUKE PLANT

Program: Upgrading of Luke Power Station

Project: Reconditioning of Diesel Engines

Objective:

To restore the diesel engines to a condition that provides normal dependability and normal fuel and lubricating oil consumption; to enable pressures, temperatures and other engine paramaters to be held within safe limits; and to improve the ease of operation and maintainability of the engines.

Scope of Services/Equipment:

Inspect engines and engine records with particular reference to the fact that (a) the engines have been operating with fuel containing extremely high contents of catalytic fines; (b) the occurrence of frequent piston ring fractures (some leading to turbine damage) may indicate the presence of high cylinder wear nearing service limits; 1/ (c) pistons and piston rings show signs of scuffing; and (d) the white metal of some crosshead guide shoes has worn severely, causing insufficient guidance of the piston rods, which in turn has caused heavy wear of the stuffing boxes.

Arrange for and supervise the reconditioning of the units in a time frame that leaves the engines available through the dry season.

Note 1: The engine of Unit 3 is in the process of being repaired after major damage to the front half of the crankshaft, the front half of the base plate and the front half of the frame. This opportunity is being used for doing some overhaul work.

Since this engine has less operating hours (11,041) than Units 1 and 2 (20,000 hours each) and has not been using fuel with excessively high incompatibility and catalytic fines content, it is assumed that the cost for parts and labor for overhauling unit 3 will only be 50% of the cost for Unit 1 or 2.

Note 2: Overhaul of instrumentation is covered in a separate work element, as is the overhaul of the fuel separator units and the fuel end heating/viscosity control units.

1/ Max wear measured November 1983, unit 3: 3.7 mm.

Program: Upgrading of Luke Power Station

Project: Recondition and improve instrumentation in the entire power station

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Objective:

To prevent engine damage due to insufficient information on machinery performance and machinery conditions, or due to malfunctioning of the protection system.

Scope of Services/Equipment:

The scope of work includes:

(a) Clean, inspect, repair, recalibrate all instruments, both electrical and mechanical (gauges, sensors, transmitters, swtiches, controls for pressure, temperature, flow, rpm, vibration level, current, voltage, electric power, etc.)

(b) Provide gauges with labels showing instrument code used to identify instrument in P&I diagrams.

(c) Where applicable provide all gauges with colored bands showing maximum and/or minimum ranges for safe operation.

(d) Recondition the master frequency control unit.

(e) Relocate instruments if necessary for better reading or better accessibility.

(f) Devise and implement an Inspection/Maintenance Record card system for instruments.

(g) Pay special attention to the reverse power protection system. On a number of occasions, the generator circuit breaker has failed to open, in one case leading to severe crankshaft and bearing damage resulting in 10 months of outage for Unit 2.

(h) Check and readjust if necessary the settings of protective relays to reduce the occurrence of station blackouts due to faults on the transmission and distribution systems.

Program: Upgrading of Luke Power Station

Project: Provide a fire extinguishing system for the power station

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Objective:

To protect the station from damage due to fire.

Scope of Services/Equipment:

The scope of work includes:

(a) Provide and install a diesel engine driven fire fighting pump 350 m^3/h 90 m head. Including jockey pump, control system, etc.

(b) Provide a 3500 m^3 water pond, to be kept to level, from the existing water mains 2 x 100 mm diameter.

(c) Provide and install a sprinkler system over the diesel engines and the mechanical auxilliary equipment.

(d) Provide and install a CO_2 system in the switch gear room.

(e) Provide, install and connect fire fighting cabinets at all power house levels.

(f) Provide two foam carts with hoses, branch pipe, foam, etc.

Program: Upgrading of Luke Power Station

Project: Recondition and Modification of the Fuel System

Objective:

To improve the quality of the fuel at the diesel engine inlet, and to make the system less sensitive to operation and maintenance quality.

Scope of Service/Equipment:

The scope of work includes:

(a) Recondition the existing Alfa Laval Separator Module 2 x WHPX 513 (including replacement of 50% of all gauges, recalibration of the other 50%, renewing of insulation, and replacement of gaskets/seals).

(b) Install a third Alfa Laval Separator module type Alcap FOPX 613.

(c) Replace existing built-on separator feed pumps by electrically driven feed pumps 6000 l/h each, including piping, insulation, suction filters, valves, etc.; to feed all 3 separators.

(d) Provide a soaking tank for soaking separator disk packs in VECOM B 85 cleaning fluid (VECOM B.V. P.O. Box 27, 3140 AA Maassluis, The Netherlands) or equivalent.

(e) Provide an ultrasonic cleaning unit for fuel filter cores and fuel injectors, Lake BRANSON (Branson Cleaning Equipment Comp., Connecticut 06484, USA) or equivalent.

(f) Recondition the unit for fuel oil viscosity control and final fuel filtration. This includes cleaning and adjusting the viscometer, replacing 50% of all gauges, calibrating other gages, cleaning all components, and replacing all gaskets and insulation.

(g) Install a wash basin in the fuel treatment area.

(h) Modify the funnels under the water drain outlets of the heavy fuel daily service tanks so that any water in the drained fuel can be seen. 1/

1/ It is assumed that LEC will implement their plan to modify separators into model Alcap FOPX 613.

Program: Upgrading of Luke Power Station

Project: Increase the capacity and reliability of the intermediate cooling water to sea water heat exchange system.

Objective:

To keep engine operating temperatures within maximum permissible values

Scope of Services/Equipment:

The scope of work includes:

(a) Increase heat exchanging surface of the three plate type heat exchangers Alfa Laval type A 30 HBM (AL).

(b) Increase capacity of the four sea water pumps by 15 to 20%.

(c) Replace the cast iron sea water pump housings by bronze housings to reduce corrosion and cavitation.

(d) Modify the pump bearings to reduce shaft vibration and increase pump bearing life.

(e) Replace the electric motors and contactors of the sea water pumps with motors and contractors of a higher rating.

Program: Upgrading of Luke Power Station

Project: Provide a softener for the make-up water used for the jacket water system, the injection water system and the boiler system

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Objective:

To avoid scaling and subsequent overheating of engine components and to avoid output loss of the boilers.

Scope of Services/Equipment:

The scope of work includes:

(a) Supply and install two ion exchange units 1000 l/h each including piping, valves, etc., and including a 10 m^3 capacity glass fiber storage tank. 1/

1/ Depending on the condition of the existing make-up water tanks FAI and FAII the 10 m^3 glass fiber storage tank may be omitted.

Program: Upgrading of Luke Power Station

Project: Improve the power station disposal system for leaked oil, water, used oil, sludge and solid waste

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Objective:

To stop pollution of the power station and the surrounding area and to improve working conditions in and around the power station.

Scope of Services/Equipment:

The scope of work includes:

(a) Install 2 incinerators capable of burning 100 litres of sludge per hour each and capable of burning solid waste. This installation could include a gas oil feed pump, a sludge feed pump (taking sludge from existing used oil and sludge tank) and associated piping and cabling.

(b) Remove the existing sludge pump from the oil/water separator basin in the power station drainage system and replace it with duplex sludge pumps (Houttuin, Beverwijk, The Netherlands or equivalent) with a capacity of 5 m^3/h each. The pumps and associated piping, valves, cabling and contractors should be located under a shed near the oil/water separator. The pumps should be connected through existing piping to the existing used oil and sludge tank. The float mechanism that operates the contactor should be replaced by one of a more rugged design.

(c) Provide a concrete trough to receive water and sludge drained daily from the two heavy fuel settling tanks outside the power station.

(d) Provide a sludge pump to pump the contents of the trough into the used oil and sludge tank.

(e) Provide the existing sludge and water draining nozzles of the settling tanks with valves, replacing the blind flanges that presently cover the nozzles.

(f) Provide an electrically driven scavenge pump with suction hose and a 200 litre tank mounted on a trolley to be used for cleaning drip trays under tanks, filters, separator modules, fuel heating modules, etc., in the power station (since floors underneath the trays are of concrete, it is not possible to install drain piping in a retrofit).

(g) Provide 20 power sockets for connecting the mobile equipment for cleaning and other work in the power station.

(h) Provide bins for rubbish and rags. Provide and attach to the walls signs encouraging good housekeeping.

Program: Upgrading of Luke Power Station

Project: Recondition the laboratory for fuel, lube oil and water

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Objective:

To establish analysis facilities to enable quality control of operating fluids used in the power station.

Scope of Services/Equipment:

The scope of work includes:

(a) Clean room and the equipment that is in workable condition.

(b) Recondition the existing ASTM D88 Saybolt viscosimeter (manufactured by Sommer & Runge, Berling-Friedenau, W. Germany).

(c) Recondition the electronic balance (manufactured by Sartorius - type 212, Gottingen, W. Germany).

(d) Recondition the existing potentiograph (manufactured by Metrohm A.G., Herisau, Switzerland) to be used for measuring in concentration of hydrogen sulphide in fuel. This instrument could be used for pH measurements and quantitative analyses of ions in cooling water and of metals in lube oil. The procedures however are too complicated for day to day use. Other methods should therefore be used for these routine measurements.

(e) Provide test kits for:

(i) cooling water (pH, hardness, Cl content, nitrite content)

(ii) fuel oil (asphaltene stability, water content)

(iii) lube oil (viscosity, water content, dispersancy, suspended solids, total base number, total acid number, blotter spot)

(iv) provide new glass ware

Program: Upgrading of Luke Power Station

Project: Provide a workshop and space for cleaning, repairing, calibrating and storing mechanical and mechanical-electrical instruments (pressure gauges, pressure switches, pressure transducers, thermocouples, resistance thermometers, temperature switches, control valve components, etc.).

Objective:

To prevent engine damage due to lack of information on engine performance and engine condition because of faulty instruments.

Scope of Services/Equipment:

The scope of work includes:

(a) Provide workshop with minimum dimensions of 4 metres x 6 metres in an existing building at Bushrod (not in Luke Plant building, where there is no space available).

(b) Design details should include provisions for:
- Air conditioning
- Washbasin
- Hand-held foam fire extinguisher
- Good lighting, single phase outlets

(c) The shop should house:
- Workbench
- Portable pneumatic pressure source for calibrating and adjusting pressure gauges, pressure switches, pressure transducers, etc. both in-situ and in the workshop
- Portable temperature block for testing and calibrating thermocouples, resistance thermometers, temperature switches, etc. both in-situ and in the workshop
- Test manometers
- Multimeter
- Hand tools
- Cupboard to store tools, fluids for cleaning, calibrating, etc.
- Desk
- Manuals
- Instrument history record file

Program: Upgrading of Luke Power Station

Project: Provide an electrical workshop

Objective:

To provide a facility for testing, repairing and calibrating electrical instruments (relays, dial instruments, transmitters, contactors, circuit breakers, coils, etc.) for the Bushrod Gas Turbine Plant, the Luke Diesel plants and the Mount Coffee Hydro Plant.

Scope of Services/Equipment:

The scope of work includes:

(a) Provide a room of about 3 metres by 4 metres in one of the available buildings at the Bushrod site. The room should have air conditining, good lighting, sockets, etc.

(b) Provide the following equipment:
- Two multimeters
- One adjustable ac current and voltage source, 0-25 amps and 0-500 V
- One adjustable dc current and coltage source 0-20 mA and 0-10 mA for current and 0-1000 mV and 0-250 for voltage
- One megger testing set
- One phase rotation meter
- Two sets hand tools
- Soldering equipment
- One set wiring and cabling materials
- Two sets of insulated gloves
- Cabinets for storing instruments, materials, manuals and an equipment history file
- One equipment history record file

Program: Upgrading of Luke Power Station

Project: Extend Mechanical Workshop

Objective:

To provide better servicing and storage facilities for high pressure fuel injection equipment and equipment requiring comparable work standards.

Scope of Services/Equipment:

The scope of work includes:

(a) Erect a shop for cleaning, repairing, testing and storage of fuel injection equipment.
- Dimensions: 4 metres by 6 metres
- Location: Near or attached to the existing Mechanical Workshop

(b) Design details should include:
- Wallcrane for lifting fuel pumps off trolley into soaking bath, onto workbench and test bench and onto storage shelf
- Extraction fan in wall over pump and injector test bench
- Adjustable louvre in wall opposite to fan, near floor level
- Air conditioning
- Washbasin
- Hand-held foam fire extinguisher

(c) The building should house:
- Soaking tank with drainage and flushing pump
- Workbench for work on pumps and injectors 1/
- Injector test bench 1/
- Pump test bench 1/
- Injector needle grinding machine 1/
- Storage rack for spare fuel pumps
- Storage rack for spare fuel injectors
- Cupboard for tools and measuring instruments and for spare parts for pumps, injectors and tools
- Desk and file for pump and injector service history cards and manuals

(d) Erect shop for steamcleaning engine components:
- Dimension: 4 metres by 6 metres
- Location: Near or attached to existing Mechanical Workshop

1/ To be relocated from existing mechanical workshop.

(e) Design details should include:
- Tackle for lifting components from trolley (2 tons)
- Extraction fan in roof
- Louvres in lower end of walls
- Drainage system with small hand-cleaned oil/water separator pit
- Washbasin
- Waterproof lighting and waterproof socket for mobile steam cleaner and tackle

(f) The building should house:
- Steam cleaner
- Cupboard for solvents, tools and ancillary equipment for the cleaner
- Cupboard for special clothing, gloves, etc.

Program: Upgrading of Luke Power Station

Project: Devise and implement a stock control and store keeping system for the Luke Station, centralize Bushrod, Luke and Mt. Coffee stores and bring the spare stock up to requirements.

Objective:

To make sufficient spare parts available at all times and at lowest possible cost.

Scope of Services/Equipment:

The scope of work includes:

(a) Establish consumption pattern of all spares and materials as can be expected on the basis of an agreed operating pattern of the engines throughout the year.

(b) Prepare spare parts order to be placed by LEC to obtain spare parts level commensurate with engine operating and maintenance pattern.

(c) Devise a stock control and store keeping system commensurate with the spare consumption to be expected.

(d) Prepare an implementation program.

(e) Supervise implementation

Program: Upgrading of Luke Power Station

Project: Improving storage facilities for electrical and mechanical spare parts and miscellaneous materials

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Objective:

To provide for easy access and clear arrangement of spares and materials.

Scope of Services/Equipment:

The scope of work includes:

(a) Remove all electrical spares and materials from cabinets on the basement floor level in the Luke Powerhouse.

(b) Arrange for about 100m shelf length in a suitable space in one of the other buildings on the Bushrod site.

(c) Extend the existing storage capacity for mechanical spare parts for the Luke engines in the Luke Power House using the cabinets that now store the electrical spares and materials. Lighting in all spares areas must be improved. Existing racks need some repair and new racks must be added. Total shelf length required is estimated at 700 meters.

(d) A spare cylinder liner, piston, pistonrod, cross head, connecting rod, cylinder head, exhaust valve and housing and two exhaust valves should be stored in preserved condition in the assigned area in the loading bay within reach of the power house crane.

Program: Upgrading of Luke Power Station

Project: Various structural and civil modifications and repairs to the Power Station.

Objective:

To bring safety and comfort of personnel to an acceptable level.

Scope of Service Equipment:

The scope of work includes:

(a) Repair steel stairways in the engine room. One stairway is missing most of its steps; other stairways have damaged steps caused by abuse from transportation of heavy engine parts.

(b) Extend the tackle rail over fuel separators so that separator disc packs can be put into a soaking bath for cleaning or on a trolley for maintenance.

(c) Modify the door between engine room and station superintendent's office to reduce the noise level in the office.

(d) Add one more windowpane to the sound insulating window between engine room and station superintendent. Both acoustic measures should reduce the noise level to below 65 db(A) with three engines running. At present the level with only engine one running is 68 db(A); with three engines running it is expected to be between 73 and 80 db(A).

(e) Improve ventilation of the engine room. With one engine running the air temperature at turbo charger outlet was measured 40°, which is equal to the design level. Outside ambient temperature was 29°C. 1/

(f) The sheet steel wall panels at the 20.5 metre level in the four power station walls above the windows should be removed temporarily to determine if the air temperature falls to design level. If the test is successful the plating should be replaced by louvres. If this is inadequate and the engines really do require cooler air, a system for forced ventilation has to be added to the Power Station. The cost of a forced

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1/ At present with the average day maximum outside temperature in the dry season of 32°C and with three engines running suction temperature at turbocharger inlet is 5 to 10°C above design value.

ventilation system has not been estimated since it is expected that increased natural ventilation will suffice.

Program: Upgrading of Luke Power Station

Project: Provide a Lube Oil Storage System

Objective:

To avoid dangerous transport and handling of barrels inside the Engine Room.

Scope of Services/Equipment:

The scope of work includes:

(a) Supply and install 2 horizontal storage tanks 20,000 l capacity each outside the power station for storage of lubricating oil. The installation should include two loading pumps and associated piping.

Program: Upgrading of Luke Power Station

Project: Introduce a Maintenance Safety Program

Objective:

To provide safety against personal injuries and damage to equipment during maintenance and repair work.

Safety Program: There is a requirement within the entire LEC system to implement a maintenance safety (tagging) system which will forbid the operation of any piece of equipment without following proper safety procedures. This program should be designed primarily for the plant but should be expandible to encompass all the facets of the LEC system including transmission and distribution equipment and systems.

The Firm should submit an outline of the program to LEC and subsequently supply the necessary materials for the program. It should then train the LEC personnel in the implementation of the program. It should also participate in the selection and training of an LEC Safety Officer(s) to manage and monitor the program. The Firm should supply Job Descriptions of the duties of the key positions of the Safety Department.

HYDRO PLANT REHABILITATION

The rehabilitation program is to include the maintenance work required to restore the Mount Coffee hydro-electric units to their design rating and efficiency.

Units 1 and 2 are each currently rated at 15,000 KW each and were installed in 1966. The turbines are Francis design and were furnished by The Allis Chalmers Co. The generators were supplied by the General Electric Co. as were the 20,000 kVA transformers.

Units 3 and 4 are rated at 17,500 KW each and were installed in 1972. These Allis Chalmers turbines are identical to units 1 and 2. The generators were supplied by Brown Boveri Corp. of Brazil. The transformers are also 20,000 kVA and are also Brown Boveri.

Turbines: The turbine equipment is to be overhauled and put into good operating condition including the instrumentation, the bearing cooling system and any other systems or equipment needing repair or upgrading.

Trash Rakes: The existing plant trash rakes are in poor condition and need replacing. Additionally, a large amount of debris has settled in front of the trash bars at the inlet to the penstocks.

The Firm shall have the debris cleaned out of the penstock inlet area and install trash rakes of modern design to maintain a clear area at the penstock. A suitable trash removal system shall be included.

Alignment of Generating Units: There have been several problems with the alignment of the units which have created bearing and turbine runner ring wear problems. It is suspected that the plant building may be settling.

The Firm shall survey the building as required, to identify and define the problem. It shall also report on the degree of settling as well as recommend (a) a program which will arrest this problem and (b) implement a second program to realign the units to the vertical position.

Controls and Instrumentation (C&I): A general overhaul of the hydro units and plant control systems including the repair or installation of devices to monitor unit efficiency is required.

Balance of Plant: The Firm shall inspect the entire Mount Coffee plant site, including the dam, spillways, penstocks, tailrace, etc., to determine any other rehabilitation work required to bring this plant up to peak performance and reliability. This additional work shall be tendered as a separate work element(s) over and above the work specified herein.

Project Estimate: Upon identifying the scope of work in detail as a result of the site inspections and investigations, the Firm shall estimate the cost of the rehabilitation program by categories of work elements, and submit the results of the estimate, with their recommendations, to LEC for its review and approval.

The report shall include the benefits to be achieved in terms of additional capacity and energy generated to determine the cost to benefit ratio. LEC shall advise of the values of new capacity ($/kW) and replacement energy ($/KWh) to be used for the evaluation.

HYDRO PLANT UPGRADING

The upgrading program is to ensure rerating of the units to produce a gross output of 20,000 KW each.

Turbines: The base turbine design is to be reviewed by a competent equipment design firm to determine if the runners can be upgraded to operate safely and consistently at 20,000 kW output. The gross design head is to be taken as 78 feet.

In the event this is not feasible, then new design runners are to be installed in the same turbine casing to generate at 20,000 kW as required. Suitable materials shall be used to minimize cavitation and wear damage.

The balance of the turbine equipment is to be inpected, although it is expected that it would be in good condition after the implementation of the rehabilitation program.

Generators: The two General Electric and two Brown Boveri generators are to be inspected and upgraded as necessary to permit continuous operation at 20,000 kW. The Firm shall arrange for the general repair of these units, including the cooling systems and instrumentation.

The Firm shall implement the work necessary for rewinding the stator and pole coils (if necessary) with a Class F insulated wire in order to achieve the new 20,000 kW rating.

Any other repairs or upgrading (e.g., the generator bus) that are required to complete the rerating of these generators shall be included in the Firm's scope of services.

Transformers: The four units' main transformers are each rated 20,0000 kVA which may not be sufficient to service the upgraded units' output. The Firm shall evaluate, and then implement the work necessary to operate these units at 20,000 kW. If this is not possible the transformers should be replaced.

Circuit Breakers: The Firm shall study the impact the upgraded unit outputs will have on the circuit breaker fault levels. In the event it becomes necessary to replace these devices, the Firm shall include this work in its scope of services.

Balance of Plant: The Firm shall inspect the entire Mount Coffee plant site, including the dam, spillways, penstocks, tailrace, etc., to determine any other complementary work required to increase the power rating of this plant up 80 MW. This additional work shall be tendered as a separate work element(s) over and above the work specified herein.

Project Estimate: Upon identifying the scope of work in detail as a result of the site inspections and investigations, the

Firm shall estimate the cost of the rehabilitation program by categories of work elements, and submit the results of the estimate, with their recommendations, to LEC for their review and approval.

MANAGEMENT OF PLANTS

Program: Management of Power Stations

Project: Providing of ex-patriate crew for managing, operating and maintaining the Power Stations initially for a period of two (2) years

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Objective:

To manage this activity and to train staff in plant operation and maintenance during a period in which LEC is reorganized.

Scope of Services:

The scope of services includes:

(a) To provide a crew of competent personnel, capable of operating and maintaining the power plants including:

- stock control and store keeping
- operating the workshop
- hiring outside services for repair work, etc.
- selecting and training capable LEC personnel that will take over Management, Operating and Maintenance positions after the contract has expired

(b) To provide spare parts for a period of five years.

(c) To help LEC prepare job descriptions and adequate compensation packages.

(d) To help LEC determine adequate compensation for staff made redundant by the reorganization.

Division of Labour and Responsibilities

The Firm will be fully responsible for the execution of the program. It will provide all of the services required to ensure its success.

LEC will provide the folloiwng:

(a) Access to the plants, to documents and to any data required to carry out the work.

(b) All surface business transportation in Liberia.

(c) Counterpart staff as required.

(d) Office space.

(e) Secretarial services.

Guidelines for Proposal

The proposal should provide comprehensive details of the following:

(a) A work plan in accordance with these Terms of Reference.

(b) A preliminary estimate of the hours, by discipline, required to complete the work and the location where each phase of the work will be carried out.

(c) The nature of the organization and previous experience in related work in developing countries.

(d) Curricula vitae (CV) of staff who will be assigned for the study as well as CV's of support staff at Headquarters.

(e) Staff and period to be assigned for establishment of the systems and training of LEC personnel inclusive of full CV's and previous experience.

(f) Project Organization chart with candidate names indicated.

(g) Quotation of the costs of each of the work elements specified in these Terms of Reference.

A sealed envelope should be enclosed with the proposal, indicating the cost estimate of this work based on a system of fixed professional fees which should also be determined in relation to the actual hours of work.

The Firm may suggest alternative schemes for attaining the objectives outlined in the Terms of Reference. Any alternative scheme should be clearly identified as such, and separate work schedules and costs should be provided for each.

Forms of Contract

The contract which will be awarded to the successful firm will be based on the International Model Form of Agreement Between Client and Consulting Engineer No. IGRA 1979 D&S - Produced and issued by the International Federation of Consulting Engineers (FIDIC).

Schedule of Payments

The schedule of payments will be negotiated. The Firm should propose a schedule in a Tender which will tie payments to clear performance targets.

COST ESTIMATES FOR GENERATING PLANT REHABILITATION

Summary of Cost Estimates (US$)
Estimate of Costs US$ 1/

Work Element	Professional Services	Travel and Subsistence	Furnish and Install	Local Costs
Program Management	266,000	56,000	---	7,500
Diesel Engine Overhaul	43,000	123,900	514,000	7,500
Recond./Mod. Instrumentation	19,800	14,400	39,200	600
Fire Extinguishing System	44,200	47,200	147,400	11,000
Recond./Mod. of Fuel System	61,600	44,160	420,400	10,000
Increase Cooling Capacity	28,600	11,400	58,200	1,000
Water Softener	22,000	12,150	32,600	1,000
Disposal System	61,600	42,600	157,500	1,500
Recond. Laboratory	30,800	9,240	19,400	3,200
Instrument Workshop	70,400	21,000	130,000	15,000
Electrical Workshop	70,300	13,800	38,800	15,000
Mechanical Workshop	48,400	25,800	91,400	11,000
Stock Control & Store Keeping	66,000	15,600	9,800	1,000
Improving Spares Store	30,800	10,500	32,000	1,500
Recond./Mod. P.S. Building	37,400	35,700	44,800	4,000
Lube Oil Storage System	30,800	10,100	93,200	1,000
Safety Program	40,000	6,000	3,000	-----
Ex-Pat Crew O&M	30,600	16,980	-----	-----
Total Cost	1,002,300	516,530	1,831,900	91,800

Total Foreign Cost	3,340,730
Total Local Cost	91,800
Contingencies (10%)	334,000
Profit & Overhead (10%)	334,000
Total	4,100,530

1/ Costs are based on Professional Services and Expatriate Services at a rate of US$400/day.
Air travel costs are based on US$1,500/trip (return).
Subsistence costs (hotel and Meals) are based on US$120/day.

Program Management
Estimate of Costs US$ 1/

Work Element	Professional Services	Travel and Subsistence	Equipment Costs	Installation Costs
	(Man months)	(Man months)		(Man months)
Phase 1: Pre-installation work				
Head Office Management				
Team including:				
Program Manager	60,000 (6)	11,000 (4 trips)		
Engineering Design	(in technical estimates)			
Scheduling	9,000 (2)			
Expediting	17,000 (2)			
Phase 1 Total	86,000 (10)	11,000		
Phase 2: Field Work				
Works Manager	60,000 (6)	15,000		
Mechanical	60,000 (6)	15,000		
Electrical	60,000 (6)	15,000		
LEC Personnel	7,500	---		
Phase 2 Total	180,000 (18)	45,000		
Total Costs	266,000 (28)	56,000		
Local Costs	7,500 (36)			

1/ Costs are based on Professional Services and Expatriate Services at a rate of US$400/day.
Air travel costs are based on US$1,500/trip (return)
Subsistence costs (hotel and meals) are based on US$120/day.

Overhaul of Diesel Engines and Auxiliaries
Estimate of Costs US$ 1/

Work Element	Professional Services	Travel and Subsistence	Equipment Costs	Installation Costs
	(Man months)	(Man months)		(Man months)
Phase 1				
- Inspect condition of engines and auxiliaries	8,800 (1)	5,100 (1)		
- Specify scope of work	8,800 (1)			
- Evaluate bids	8,800 (1)			
Total Phase 1	26,400 (3)			
Phase 2				
- Award contract				
- Overhaul		118,800 (30)	250,000	264,000 (30)
- Monitor contract	17,600 (2)			7,500 (LEC)
Total Phase 2	17,600 (2)	118,800 (30)	250,000	264,000
Phases 1 & 2	43,000 (5)	123,900 (31)	250,000	264,000 (30)
Local				7,500 (LEC)

1/ Costs are based on Professional Services and Expatriate Services at a rate of US$400/day.
Air travel costs are based on US$1,500/trip (return)
Subsistence costs (hotel and meals) are based on US$120/day.

Reconditioning and Improvement of Instrumentation
Estimate of Costs US$ 1/

Work Element	Professional Services	Travel and Subsistence	Equipment Costs	Installation Costs
	(Man months)	(Man months)		(Man months)
Phase 1				
- Inspect plant and define work scope	4,400 (.5)	1,800 (travel cost covered in work element overhaul diesel engines)		
- Issue specification	8,800 (1)			
- Evaluate bids				
Total Phase 1	13,200 (1.5)	1,800 (.5)		
Phase 2				
- Remove, repair and recondition		8,400 (1.5)	5,000	13,200 (1.5)
- New instruments			20,000	
- Implementing record system training	6,600 (.75)	4,200 (.75)	2,000	600 (LEC)
Total Phase 2	6,600 (.75)	12,600 (2)	26,000	13,200 (1.5)
Phases 1 & 2	19,800 (2.25)	14,400 (2.5)	26,000	13,200 (1.5)
Local				600

1/ Costs are based on Professional Services and Expatriate Services at a rate of US$400/day.
Air travel costs are based on US$1,500/trip (return)
Subsistence costs (hotel and meals) are based on US$120/day.

Provision of Fire Extinguishing System
Estimate of Costs US$ 1/

Work Element	Professional Services	Travel and Subsistence	Equipment Costs	Installation Costs
	(Man months)	(Man months)		(Man months)
Phase 1				
- Inspect plant and define scope of work	6,600 (.75)	4,200 (.75)		
- Issue specification	8,800 (1)			
- Evaluate bids	8,800 (1)			
- Monitor contract	8,800 (1)			
Total Phase 1	31,000 (3.75)	4,200 (.75)		
Phase 2				
- Install fire fighting pump		10,700 (2)	20,000	17,600 (2) 1,000 (LEC)
- Make pond		6,900 (1.5)	8,000	13,200 (1.5) 7,500 (LEC)
- Install piping and and sprinkler system	13,200 (1.5)	10,700 (2)	20,000	17,600 (2) 1,000 (LEC)
- Install CO_2 system		3,600 (1)	15,000	8,800 (1)
- Install fire fighting cabinets		6,900 (1.5)	8,000	13,200 (1.5) 500 (LEC)
- Foam Charts			6,000	
- Training				
Total Phase 2	13,200 (1.5)	38,800 (8)	77,000	70,400 (8)
Phase 1 and 2	44,200 (5.25)	47,200 (8.75)	77,000	70,400 (8)
Local				11,000 (LEC)

1/ Costs are based on Professional Services and Expatriate Services at a rate of US$400/day.
Air travel costs are based on US$1,500/trip (return)
Subsistence costs (hotel and meals) are based on US$120/day.

Reconditioning and Modification of the Fuel System
Estimate of Costs US$ 1/

Work Element	Professional Services	Travel and Subsistence	Equipment Costs	Installation Costs
	(Man months)	(Man months)		(Man months)
Phase 1				
- Inspect system and define scope of work	8,800 (1)	4,260 (1)		
- Specify work	17,600 (2)			
- Evaluate bids	8,800 (2)			
- Monitor contract	8,800 (1)			
Total Phase 1	44,000 (5)	4,260 (1)		
Phase 2				
- Installation/ Reconditioning	8,800 (1)	34,800 (8)	350,000	70,400 (8)
- Training	8,800 (1)	5,100		10,000 (LEC)
Total Phase 2	17,600 (2)	39,900 (8)	350,000	70,400 (8)
Phases 1 & 2	61,600 (7)	44,160 (8)	350,000	70,400 (8)
Local				10,000

1/ Costs are based on Professional Services and Expatriate Services at a rate of US$400/day.
Air travel costs are based on US$1,500/trip (return)
Subsistence costs (hotel and meals) are based on US$120/day.

Increase Cooling Capacity
Estimate of Costs US$ 1/

Work Element	Professional Services	Travel and Subsistence	Equipment Costs	Installation Costs
	(Man months)	(Man months)		(Man months)
Phase 1				
- Investigate present situation	6,600 (.75)	2,850 (.75)		
- Make specification	8,800 (1)	---		
- Evaluate bids	6,600 (.75)			
Total Phase 1	22,000 (2.5)	2,850 (.75)		
Phase 2				
- Modification of pumps and coolers	6,600 (.75)	8,550 (2.25)	45,000	13,200 (1.5)
				1,000 (LEC)
Total Phase 2	6,600 (.75)	8,550 (2.25)	45,000	13,200 (1.5)
Phases 1 & 2	28,600 (3.25)	11,400 (3)	45,000	13,200 (1.5)
Local				1,000

1/ Costs are based on Professional Services and Expatriate Services at a rate of US$400/day.
Air travel costs are based on US$1,500/trip (return)
Subsistence costs (hotel and meals) are based on US$120/day.

Providing Water Softener
Estimate of Costs US$ 1/

Work Element	Professional Services	Travel and Subsistence	Equipment Costs	Installation Costs
	(Man months)	(Man months)		(Man months)
Phase 1				
- Inspect situation and define location	4,400 (.5)	1,950 (.5)		
- Make specification	4,400 (.5)			
- Evaluate bids	4,400 (.5)			
- Monitor contract	4,400 (.5)			
Total Phase 1	17,600 (2)	1,950 (.5)		
Phase 2				
- Install and test training	4,400 (.5)	10,200 (2)	15,000	17,600 (2)
				1,000 (LEC)
Total Phase 2	4,400 (.5)	10,200 (2)	15,000	17,600 (2)
Phases 1 & 2	22,000 (2.5)	12,150 (2.5)	15,000	17,600 (2)
Local				1,000

1/ Costs are based on Professional Services and Expatriate Services at a rate of US$400/day.
Air travel costs are based on US$1,500/trip (return)
Subsistence costs (hotel and meals) are based on US$120/day.

Improving P.S. Disposal System
Estimate of Costs US$ 1/

Work Element	Professional Services	Travel and Subsistence	Equipment Costs	Installation Costs
	(Man months)	(Man months)		(Man months)
Phase 1				
- Obtain info and inspect system	6,600 (.75)	3,300 (.5)		
- Issue spec. for work & mat.	8,800 (1)			
- Evaluate bids	6,600 (.75)			
- Monitor Contract	13,200 (1.5)			
Total Phase 1	35,200 (4)	3,300 (.5)		
Phase 2				
- Install incinerators & assoc. equipment	8,800 (1)	15,300 (3)	85,000	17,600 (2) 1,000 (LEC)
- Civil Works	8,800 (1)	10,200 (2)	3,000	8,800 (10
- Install sludge pumps	4,400 (.5)	6,900 (1.5)	12,000	8,800 (1) 500 (LEC)
- Electrical work	4,400 (.5)	6,900 (1.5)	3,000	8,800 (1)
- Loose equipment and materials			10,500	
Total Phase 2	26,400 (3)	39,300 (8)	113,500	44,000 (5)
Phases 1 & 2	61,600 (7)	42,600 (8.5)	113,500	44,000 (5)
Local				1,500

1/ Costs are based on Professional Services and Expatriate Services at a rate of US$400/day.
Air travel costs are based on US$1,500/trip (return)
Subsistence costs (hotel and meals) are based on US$120/day.

Reconditioning of Laboratory
Estimate of Costs US$ 1/

Work Element	Professional Services	Travel and Subsistence	Equipment Costs	Installation Costs
	(Man months)	(Man months)		(Man months)
Phase 1				
- Inspect existing equipment	2,200 (.25)	840 (.25)	travelling costs	incided in 5
- Issue specification for repair and purchasing	8,800 (1)			
- Evaluate bids	2,200 (.25)			
- Monitor contract	4,400 (.5)			
Total Phase 1	17,600 (2)	840 (.25)		
Phase 2				
- Refurbish room	8,800 (1)	5,100 (1)		1,000 (LEC)
- Install and test equipment and				4,400 (.5)
train chemist	4,400 (.5)	3,300 (.5)	15,000	2,200 (LEC)
Total Phase 2	13,200 (3.5)	8,400 (1)	15,000	4,400
Phases 1 & 2	30,800 (3.5)	9,240 (1.75)	15,000	4,400 (.5)
Local				3,200

1/ Costs are based on Professional Services and Expatriate Services at a rate of US$400/day.
Air travel costs are based on US$1,500/trip (return)
Subsistence costs (hotel and meals) are based on US$120/day.

Bushrod Instrument Shop 2/
Estimate of Costs US$ 1/

Work Element	Professional Services	Travel and Subsistence	Equipment Costs	Installation Costs
	(Man months)	(Man months)		(Man months)
Phase 1: Pre-installation work				
- Design shop layout and equipment requried	17,500 (2)			
- Specify equipment supply	8,800 (1)		40,000	
- Specify repair parts	8,800 (1)		75,000	
- Evaluate bids	8,800 (1)			
- Prepare training program	8,800 (1)			
Phase 1 Total	52,800 (6)		115,000	
Phase 2: Field Work				
- Renovation of Bushrod building for workshop			5,000	10,000 (LCL)
- Install equipment				10,000 (1)
- Training program	17,600 (2)	21,000		5,000 (LCL)
Phase 2 Total	17,600	21,000	5,000	10,000
Total Costs	70,400	21,000	120,000	10,000
Local Costs				15,000

1/ Costs are based on Professional Services and Expatriate Services at a rate of US$400/day.
Air travel costs are based on US$1,500/trip (return)
Subsistence costs (hotel and meals) are based on US$120/day.

2/ This workshop should be located in the existing stores building adjacent to the gas turbine plant. It is intended to be used for repair and testing of mechanical and electrical instruments at all the LEC generation stations, i.e. Luke diesel, Bushrod gas turbines and MLount Coffee hydro plants.

Providing Electrical Workshop
Estimate of Costs US$ 1/

Work Element	Professional Services	Travel and Subsistence	Equipment Costs	Installation Costs
	(Man months)	(Man months)		(Man months)
Phase 1				
- Design shop lay-out	17,500 (2)			
- Specify equipment	8,800 (1)			
- Specify repair parts	8,800 (1)			
- Evaluate bids	8,800 (1)			
- Prepare training program	8,800 (1)			
Total Phase 1	72,700 (6)			
Phase 2				
- Renovation of building			10,000	10,000 (LEC)
- Installation of equipment		5,100 (1)	20,000	8,800 (1)
- Training	17,600 (2)	8,700 (2)		5,000 (LEC)
Total Phase 2	17,600	13,800	30,000	8,800 (1)
Phases 1 & 2	70,300 (8)	13,800 (3)	30,000	8,800 (1)
Local				15,000 (LEC)

1/ Costs are based on Professional Services and Expatriate Services at a rate of US$400/day.
Air travel costs are based on US$1,500/trip (return)
Subsistence costs (hotel and meals) are based on US$120/day.

Extention of Mechanical Workshop
Estimate of Costs US$ 1/

Work Element	Professional Services	Travel and Subsistence	Equipment Costs	Installation Costs
	(Man months)	(Man months)		(Man months)
Phase 1				
- Inspect existing shop and define scope of work	4,400 (.5)	1,800 (.5)	Travel covered in work element instrument workshop	
- Specify equipment and services supply	8,800 (1)			
- Evaluate bids	8,800 (1)			
- Monitor contract	8,800 (1)			
Total Phase 1	30,800 (3.5)	1,800 (.5)		
Phase 2				
- Erect buildings	8,800 (1)	20,400 (4)	20,000	26,400 (3) 10,000 (LEC)
- Install equipment and train personnel	18,800 (1)	3,600 (1)	45,000	1,000 (LEC)
Total Phase 2	17,6000 (2)	24,000 (5)	65,000	26,400 (3)
Phases 1 & 2	48,400 (5.5)	25,800 (5.5)	65,000	26,400 (3)
Local				11,000

1/ Costs are based on Professional Services and Expatriate Services at a rate of US$400/day.
Air travel costs are based on US$1,500/trip (return)
Subsistence costs (hotel and meals) are based on US$120/day.

Devising and Implementing Stock Control & Store Keeping System
Estimate of Costs US$ 1/

Work Element	Professional Services	Travel and Subsistence	Equipment Costs	Installation Costs
	(Man months)	(Man months)		(Man months)
Phase 1				
- Field survey, including determining of actual and required spares level	8,800 (1)	5,100 (1)		
- Obtaining spare parts quotations	8,800 (1)			
- Issue specification of control and storage system, determine space required	8,800 (1)			
- Evaluate bids	6,600 (.75)			
- Order spares after spec and on acc. of LEC	6,600 (.75)			
Total Phase 1	39,600 (4.5)	5,100 (1)		
Phase 2				
- Monitor spares contr.	13,200 (1.5)			
- Implement stock contr. & store keeping system				8,800 (1)
including training	13,200 (1.5)	10,500 (2.5)	1,000	1,000 (LEC)
Total Phase 2	26,400 (3)	10,500 (2.5)	1,000	8,800 (1)
Phases 1 & 2	66,000 (7.5)	15,600 (3.5)	1,000	8,800 (1)
Local				1,000 (LEC)

1/ Costs are based on Professional Services and Expatriate Services at a rate of US$400/day.
Air travel costs are based on US$1,500/trip (return)
Subsistence costs (hotel and meals) are based on US$120/day.

Improving Spare Parts Store
Estimate of Costs US$ 1/

Work Element	Professional Services	Travel and Subsistence	Equipment Costs	Installation Costs
	(Man months)	(Man months)		(Man months)
Phase 1				
- Field survey	Included in 11			
- Issue spec. of work and services	8,800 (1)			
- Evaluate bids	8,800 (1)			
- Monitor contract	8,800 (1)			
Total Phase 1	26,400 (3)			
Phase 2				
- Remove spares from existing area				500 (LEC)
- Refurbish area and fit up exissting racks	4,400 (.5)	6,900 (1.5)	10,000	13,200 (1.5)
				1,000 (LEC)
- Put spares back in and add new spares		3,600 (1)		8,800 (1)
				500 (LEC)
Total Phase 2	4,400 (.5)	10,500 (2.5)	10,000	22,000 (2.5)
Phases 1 & 2	30,800 (3.5)	10,500 (2.5)	10,000	22,000 (2.5)
Local				1,500

1/ Costs are based on Professional Services and Expatriate Services at a rate of US$400/day.
Air travel costs are based on US$1,500/trip (return)
Subsistence costs (hotel and meals) are based on US$120/day.

Modifications and Repairs to P.S. Building
Estimate of Costs US$ 1/

Work Element	Professional Services	Travel and Subsistence	Equipment Costs	Installation Costs
	(Man months)	(Man months)		(Man months)
Phase 1				
- Inspect building	4,400 (.5)	3,300 (.5)		
- Obtain acoustics advise	6,600 (.75)	2,400 (.25)		
- Issue specification of work and services	4,400 (.5)			
- Monitor contract	8,800			
Total Phase 1	24,200 (2.75)	5,700 (.75)		
Phase 2				
- Repair stairways, extend tackle rail h.f. separators		5,100 (1)	1,500	8,800 (1) 1,000 (LEC)
- Improvement of ventilation	8,800 (1)	15,300 (3)	12,000	17,600 (2) 3,000 (LEC)
- Accoustics improvement	4,400 (.5)	9,600 (1)	500	4,400 (.5)
Total Phase 2	13,200 (1.5)	30,000 (5)	14,000	30,800 (3.5)
Phases 1 & 2	37,400 (4.25)	35,700 (5.75)	14,000	30,800 (3.5)
Local				4,000 (LEC)

1/ Costs are based on Professional Services and Expatriate Services at a rate of US$400/day.
Air travel costs are based on US$1,500/trip (return)
Subsistence costs (hotel and meals) are based on US$120/day.

Providing Lube Oil Storage System
Estimate of Costs US$ 1/

Work Element	Professional Services	Travel and Subsistence	Equipment Costs	Installation Costs
	(Man months)	(Man months)		(Man months)
Phase 1				
- Inspect system and define scope of work	4,400 (.5)	1,800 (.5)	(travel included in 1)	
- Specify work	8,800 (1)			
- Evaluate bids	4,400 (.5)			
- Monitor contract	8,800 (1)			
Total Phase 1	26,400 (3)	1,800 (.5)		
Phase 2				
- Installation and testing	4,400 (.5)	8,300 (2)	80,000	13,200 (1.5)
				1,000 (LEC)
Total Phase 2	4,400 (.5)	8,300 (2)	80,000	13,200
Phases 1 & 2	30,800 (3.5)	10,100 (2.5)	80,000	13,200
Local				1,000

1/ Costs are based on Professional Services and Expatriate Services at a rate of US$400/day.
Air travel costs are based on US$1,500/trip (return)
Subsistence costs (hotel and meals) are based on US$120/day.

Safety Program
Estimate of Cost US$ 1/

Work Element	Professional Services	Travel and Subsistence	Equipment Costs	Installation Costs
	(Man months)	(Man months)		(Man months)
Phase 1: Pre-installation work				
- Prepare program	20,000 (3)			
Phase 1 Total	20,000			
Phase 2:				
- Present Program (2 courses)	20,000 (2)	6,500	3,000	
Phase 2 Total	20,000	6,500	3,000	
Total Cost	40,000	6,500	3,000	
Local Cost	Nil			

1/ Costs are based on Professional Services and Expatriate Services at a rate of US$400/day.
Air travel costs are based on US$1,500/trip (return)
Subsistence costs (hotel and meals) are based on US$120/day.

Providing Expatriate Crews
Estimte of Costs US$ 1/

Work Element	Professional Services	Travel and Subsistence	Equipment Costs	Installation Costs
	(Man months)	(Man months)		(Man months)
Phase 1				
- Inspect plant and specify required manning	4,400 (.5)	3,300 (.5)		
- Estimate together with LEC conditions that will govern contract with Operating/Maintenance Company to be invited for bidding	4,400 (.5)	1,800 (.5)		
- Prepare Request for Quotation	4,400 (.5)			
- Evaluate bids	6,600 (.75)			
Total Phase 1	19,800 (2.25)	5,100 (1)		
Phase 2				
- Award contract				
- Cost of team for 2 years				
- Monitor contract during 2 year period	10,800 (34)	11,800 (1) 2/		
Total Phase 2	10,800 (3)	11,800 (1)		
Phases 1 & 2	30,600 (5.25)	16,980 (2)		

1/ Costs are based on Professional Services and Expatriate Services at a rate of US$400/day.
Air travel costs are based on US$1,500/trip (return)
Subsistence costs (hotel and meals) are based on US$120/day.

2/ Six meetings in Liberia, four days each. Balance of three months spent at the Engineer's office.

Estimate of Annual Cost of Expatriate Personnel for Operation and Maintenance

		Each Year
	Operation	
1.	One power station superintendent	100,000
2.	Four shift charge engineers	340,000
3.	Four control room operators	320,000
4.	Twelve engine drivers	720,000
	Sub-total	1,480,000
	Maintenance	
5.	Two foremen (mechanical and electrical)	160,000
6.	Three mechanics	210,000
7.	Two electricians	140,000
8.	Two fitters	120,000
	Sub-total	630,000
	General	
9.	One storekeeper	70,000
10.	One chemist	85,000
11.	One instrument mechanic	80,000
12.	One training and safety specialist	85,000
	Sub-total	320,000
	TOTAL	2,430,000
	Two years	4,860,000
	Overhead and profit of O&M Company - 15%	729,000
	TOTAL	5,589,000

LUKE STATION REHABILITATION PROGRAM

Schedule

Season	Dry						Wet						Dry					
Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Activity																		
- Site inspection and define work scope	-----																	
- Engineer and issue specifications		---	-------															
- Evaluate bids and award contracts			---------															
- Overhaul engines						----------												
- Recondition fuel system						----------												
- Increase cooling capacity						----------												
- Install water softener						----------												
- Recondition and modify P.S. building						----------												
- Install disposal system					----------													
- Recondition laboratory					----------													
- Install instrument workshop					----------													
- Install electrical workshop					----------													
- Extend mechanical workshop					----------													
- Provide stock control and store keeping system					----------													
- Provide spares store					----------													
- Provide lubricating oil storage system					----------													
- Provide tagging and safety procedures					----------													

These activities can only be started after the dry season, but must be completed before the dry season starts.

These activities should start as early as possible. They can be done at during the dry season and should be finished before the second dry season.

UPGRADING PROGRAM

Turbine Rehabilitation
Estimate of Costs US$ 1/

Work Element	Professional Services	Travel and Subsistence	Equipment Costs	Installation Costs
	(Man months)	(Man months)		(Man months)
Phase I: Pre-Installation Work				
Inspect plant and define work scope	20,800 (2MM)	3,500	--	--
Issue specification	26,400 (3MM)	--	--	--
Evaluate bids and award contract	52,800 (6MM)	--	--	--
Phase I total	100,000	3,500		
Phase 2:				
Field work including new test devices check alignment, repair worn wickets, guide vanes, valves, coolers, etc.		67,500	900,000	500,000 (57 MM)
				20,000 (LCL)
Phase 2 total		67,500	900,000	500,000
Total Cost	100,000	71,000	900,000	500,000
Local Cost				20,000
Contingencies				157,000

1/ Costs are based on Professional Services and Expatriate Services at a rate of US$400/day.
Air travel costs are based on US$1,500/trip (return)
Subsistence costs (hotel and meals) are based on US$120/day.

Trash Handling System
Estimate of Costs US$ 1/

Work Element	Professional Services	Travel and Subsistence	Equipment Costs	Installation Costs
	(Man months)	(Man months)		(Man months)
Phase 1: Pre Installation Work				
Inspect and define work scope	4,400 (.5 MM)	1,800		
Specify trash rake	8,800 (1 MM)			
Contract with mobile crane operator	2,200 (.25 MM)			
Evaluate trash rake supply	8,800 (1 MM)		60,000	
Monitor trash rake contract	8,800 (1 MM)			
Phase 1 Total	33,000	1,800	60,000	
Phase 2:				
Field Work				
Install trash rake				8,000 (1 MM) 1,000 (LCC)
Remove debris in front of trash bars				5,000 (LCC)
Repair iso. gates			10,000	5,000 (LCC)
Phase 2 Total			10,000	8,000
Total Cost	33,000	1,800	70,000	8,000
Local Cost				11,000
Contingencies				12,000

1/ Costs are based on Professional Services and Expatriate Services at a rate of US$400/day.
Air travel costs are based on US$1,500/trip (return)
Subsistence costs (hotel and meals) are based on US$120/day.

Instrument Rehabilitation
Estimate of Costs US$ 1/

Work Element	Professional Services	Travel and Subsistence	Equipment Costs	Installation Costs
	(Man months)	(Man months)		(Man months)
Phase 1: Pre Installation Work				
Survey of scope of repair/rehabilitation work	4,400 (.5 MM)			
Phase 1 Total	4,400			
Phase 2:				
Field Work				
Repair work (Team of 3)	35,000 (4 MM)	20,000	50,000	100,000 (12 MM)
				15,000 (LCC)
Phase 2 Total	35,000	20,000	50,000	100,000
Total Cost	39,400	20,000	50,000	100,000
Local Cost				15,000
Contingencies				22,000

1/ Costs are based on Professional Services and Expatriate Services at a rate of US$400/day.
Air travel costs are based on US$1,500/trip (return)
Subsistence costs (hotel and meals) are based on US$120/day.

Building Survey
Estimate of Costs US$ 1/

Work Element	Professional Services	Travel and Subsistence	Equipment Costs	Installation Costs
	(Man months)	(Man months)		(Man months)
Phase 1: Pre Installation Work				
Field Survey	5,000 (.5 MM)	3,300		
Phase 1 Total	5,000	3,300		
Phase 2:				
Report findings and solutions with cost estimates	25,000 (3 MM)	———		
Phase 2 Total	25,000			
Total Cost	30,000	3,300		
Local Cost	Nil			

1/ Costs are based on Professional Services and Expatriate Services at a rate of US$400/day.
Air travel costs are based on US$1,500/trip (return)
Subsistence costs (hotel and meals) are based on US$120/day.

MOUNT COFFEE STATION REHABILITATION PROGRAM

Schedule

Season	Dry						Wet					Dry							Wet					
Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
ACTIVITY																								
Turb. Rehab																								
Site Inspection and define work scope	—																							
Engineer & Issue Spec		—	—	—																				
Bid, Eval. & Award					—																			
Fab & Ship						—	—	—	—	—	—	—												
Install												—	—	—	—									
Turb. Upgrading																								
Site Inspection	—																							
Engineer & Issue Spec		—	—	—																				
Bid, Eva. & Award					—	—																		
Design & Fab & Ship						—	—	—	—	—	—	—	—	—	—	—	—							
Install																—	—	—						

MOUNT COFFEE REHABILITATION PROGRAM

Schedule

Season	Dry						Wet					Dry							Wet					
Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
ACTIVITY																								
Generator Upgrading																								
Site Inspection and define scope of work	—																							
Engineer & Issue Spec		—	—	—																				
Bid, Eval. & Award					—																			
Fab & Ship							—	—	—															
Install												—	—	—	—	—	—	—						
Transformers																								
Site Inspection and define scope of work	—																							
Spec. work or supply		—	—	—																				
Bid, Eval. & Award				—	—																			
Design, Fab & Ship							—	—	—	—	—													
Install											—	—	—											

MOUNT COFFEE REHABILITATION PROGRAM

Schedule

Season	Dry						Wet					Dry							Wet					
Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
ACTIVITY																								
Circuit Breaker Study																								
Study at Site	—																							
Trash Handling System																								
Site inspection & define scope of work	—	—																						
Engineer & issue spec.		—	—	—																				
Bid, Eval., & Award					—																			
Fab & ship						—	—	—	—	—	—	—												
Install												—	—	—										
Instrument Rehab.																								
Site inspection & define scope of work	—																							
Engineer & issue Spec		—	—	—																				
Bid, Eval., & Award																								
Ship Parts				—	—																			
Rehabilitate												—	—	—										

MOUNT COFFEE REHABILITATION PROGRAM

Schedule

Season	Dry						Wet					Dry							Wet					
Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
ACTIVITY																								
Building Survey																								
Survey building	—																							
Report writing and submit		—	—	—	—	—																		
Safety Program																								
Define Program	—																							
LEC approval		—																						
Implement program					—	—	—																	
Instrument Shop																								
Design and layout shop facilities	—	—																						
Spec. Issue		—	—	—																				
Spare parts - Hydro				—	—	—																		
Eval., Bid & Award					—	—	—	—	—															
Ship									—	—	—	—	—	—										
Training												—	—											

UPGRADING PROGRAM

Turbine Upgrading
Estimate of Costs US$ 1/

Work Element	Professional Services	Travel and Subsistence	Equipment Costs	Installation Costs
	(Man months)	(Man monthso)		(Man months)
Phase 1: Pre Installation Work				
Inspect turbines and define scope of work	13,200 (1.5 MM)	3,500		
Issue specification	26,400 (3 MM)			
Evaluate bids and award contract	35,200 (4 MM)			
Monitor contract	8,800 (1 MM)			
Phase 1 Total	83,600	3,500		
Phase 2:				
Field Work				
Remove original runners			---	19,000 (2 MM)
New runners (install)		115,000	4,000,000	150,000 (18 MM)
Test unit performance	12,000 (1.5 MM)	3,500		
Phase 2 Total	12,000	118,500	4,000,000	169,000
Total Cost	95,600	122,000	4,000,000	169,000
Local Cost				20,000
Contingency				439,000

1/ Costs are based on Professional Services and Expatriate Services at a rate of US$400/day.
Air travel costs are based on US$1,500/trip (return)
Subsistence costs (hotel and meals) are based on US$120/day.

Generator Upgrading
Estimate of Costs US$ 1/

Work Element	Professional Services	Travel and Subsistence	Equipment Costs	Installation Costs
	(Man months)	(Man months)		(Man months)
Phase 1: Pre Installation Work				
Inspect generators and define scope of work	13,200 (1.5 MM)	3,500		
Issue specification	26,400 (3 MM)			
Evaluate bids and award contract	35,400 (4 MM)			
Phase 1 Total	75,000	3,500		
Phase 2				
Field Work				
remove rotor (a) for rewind				
Rewind stator				
Rewind rotor				
Repair other systems				
Reinstall rotor(s)	25,000 (3 MM)	125,000	1,260,000	840,000 (95 MM) 2/
Phase 2 Total	25,000	125,000	1,260,000	840,000
Total Cost	100,000	128,500	1,260,000	840,000
Local Cost				40,000
Contingencies				233,000

1/ Costs are based on Professional Services and Expatriate Services at a rate of US$400/day.
Air travel costs are based on US$1,500/trip (return)
Subsistence costs (hotel and meals) are based on US$120/day.

2/ The expatriot crew consists of 4 wirers and a supervisor for approximately five months per unit.

Transformers
Estimate of Costs US$ 1/

Work Element	Professional Services	Travel and Subsistence	Equipment Costs	Installation Costs
	(Man months)	(Man months)		(Man months)
Phase 1: Pre installation Work				
Inspect transformers and verify change out is required or just upgrading cooling system	(covered in generator work)			
Issue specification	6,000 (1 MM)			
Evaluate bids and award contract	6,000 (1 MM)		1,000,000 2/	
Phase 1 Total	12,000		1,000,000	
Phase 2:				
Field work				
Install transformers	--		--	10,000 (LCL)
Total Phase 2				10,000
Total Cost	12,000		1,000,000	
Local Cost				10,000
Contingencies				100,000

1/ Costs are based on Professional Services and Expatriate Services at a rate of US$400/day.
Air travel costs are based on US$1,500/trip (return)
Subsistence costs (hotel and meals) are based on US$120/day.

2/ This assumes new transformers will be required.

Circuit Breaker Study
Estimate of Costs US$ 1/

Work Element	Professional Services	Travel and Subsistence	Equipment Costs	Installation Costs
	(Man months)	(Man-months)		(Man months)
Phase 1: Pre Installation Work				
Review fault levels for verifying breaker rating w/20 MW units	4,400 (.5 MM)	1,800		
Phase 1 Total	4,400	1,800		
Phase 2:				
Field Work	---	---		
Total Cost	4,400	1,800		
Local Cost	Nil			

1/ Costs are based on Professional Services and Expatriate Services at a rate of US$400/day.
Air travel costs are based on US$1,500/trip (return)
Subsistence costs (hotel and meals) are based on US$120/day.

INPUT ASSUMPTIONS AND MAIN RESULTS FOR GENERATION EXPANSION ANALYSIS

Reliability Level

The study assumes a target Loss of Load Expectation (LOLE) of five days per year. This is usually reasonable for a developing country without a strong industrial base. The major industry in Liberia, iron ore production, has its own electricity supply and is not significantly affected by the public system. A study to determine the optimum LOLE may be justified in the future. 1/

Treatment of Hydroelectric Plant

The estimated monthly capacity and energy capability of the hydroelectric plant is an input to the risk calculation and production simulation programs. The programs use these values to modify the load before performing further calculations. A forced outage rate of the hydro plants of about 3% is simulated by derating the available capacity. These approximations are reasonable for Liberia since the hydroelectric plant is run-of-the-river and is used for base load. When assessing the expansion alternatives, the addition of a reservoir is simulated by changing the available energy and capacity in the dry season. River flow data has been obtained from the Horga/Stanley Ltd. Via Reservoir Report, 1984 (presented in Table 4). It is assumed that the hydroplant would continue to be used for base load in the dry season.

Generating Plant Data

The retirement date, available capacity, forced outage rate, fixed and variable operating and maintenance costs, fuel cost and heat rate are listed in Tables 1, 2 and 3 Table 1 lists these parameters for the existing plant in its existing condition, Table 2 for the existing plant if rehabilitated and Table 3 for possible new plants and reservoir additions. The fuel costs and heat rates listed in Table 1 for the diesels at the Luke plant reflect the use of diesel fuel rather than heavy fuel for which they are designed. In their present condition and with the present difficulty with heavy fuel quality this is a reasonable assumption.

Load Shape and Load Forecast

The daily loads over a four year period show little seasonal variation, with the peak varying from 61 MW in April to 57 MW in June. The 1982 loads for the Monrovia system are used to develop an hourly load

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1/ The optimum reliability level is that level at which the incremental cost of improving the reliability is equal to the cost to the economy of outages implied if the reliability is not improved.

model for the year based on 13 four week intervals. Each week comprises one typical peak day for average days and a weekend day. Other input information consists of monthly maximum demand ratios for an average day to a peak day and a weekend day to a peak day. The load shape derived by this approach is maintained through the study period.

Summary Results

The results obtained are derived from a simulation of the operation of the system with a 1% load growth rate per annum and a 3% load growth rate. The total costs of alternative plant configurations consistent with the target reliability level were calculated for a period of 15 years. Total costs for each year have been discounted using a 12% discount rate, and the net present value is used as the extention for selecting the least cost alternative for each growth rate scenario. The cash flow analysis and the plant composition of the two least cost alternatives are shown in Tables 5, 6, 7 and 8.

Table 1: SUMMARY OF GENERATING PLANT DATA FOR EXISTING PLANT

Type	Plant	Unit No.	Retirement Date	Available Capacity	F.O.R.	O & M Cost Fixed	O & M Cost Variable	Fuel Cost	Net Heat Rate
				(MW)	(%)	(US$/kW/year)	(US$/kW)	(US$/MBtu)	(Btu/kWh)
Hydro	Mt. Coffee	1	2014	15	5	5.17	.0039	---	---
		2	2014	15	5	5.17	.0039	---	---
		3	2022	17	5	5.17	.0039	---	---
		4	2022	17	5	5.17	.0039	---	---
				64					
LSD	Luke	1	2005	13.3	35	15.98	0.0055	6.51	8,418
		2	2005	13.3	35	15.98	0.0055	6.51	8,418
		3	2007	13.3	35	15.98	0.0055	6.51	8,418
				39.9					
GT	Bushrod	1	1990	15.0	16.5	20.00	.0024	5.73	13,400
		2	1990	15.0	16.5	20.00	.0024	5.73	13,400
		3	1993	19.1	16.5	20.00	.0024	5.73	13,400
		4	1993	----	16.5	20.00	.0024	5.73	18,250
				49.1					
MSD	Bushrod	5	1986 ?	1.5	40	31.50	.0080	5.73	8,418
		6	1986	1.5	40	31.50	.0080	5.73	8,418
				3.0					

Table 2: SUMMARY OF GENERATING PLANT DATA FOR EXISTING PLANT AFTER REHABILITATION

Type	Plant	Unit No.	Retirement Date	Available Capacity	F.O.R.	O & M Cost Fixed	O & M Cost Variable	Fuel Cost	Net Heat Rate
				(MW)	(%)	(US$/kW/year)	(US$/kWh)	(US$/MBtu)	(Btu/kWh)
Hydro	Mt. Coffee	1	2014	20	3	4.14	.0039	---	---
		2	2014	20	3	4.14	.0039	---	---
		3	2022	20	3	4.14	.0039	---	---
		4	2022	20	3	4.14	.0039	---	---
				80					
LSD	Luke	1	2005	13.3	5.0	15.98	0.0075	4.72	8,500
		2	2005	13.3	5.0	15.98	0.0075	4.72	8,500
		3	2007	13.3	5.0	15.98	0.0075	4.72	8,500
GT	Bushrod	1	1990	15.0	12.0	20.00	.0024	5.73	13,400
		2	1990	15.0	12.0	20.00	.0024	5.73	13,400
		3	1993	19.1	12.0	20.00	.0024	5.73	13,400
MSD	Bushrod	5	1986 ?	---	---	---	---	---	---
		6	1986	---	---	---	---	---	---

Table 3: SUMMARY OF GENERATING PLANT DATA FOR POSSIBLE NEW PLANTS

Type	Plant	Unit No.	Retirement Date	Available Capacity	F.O.R.	O & M Cost Fixed	O & M Cost Variable	Fuel Cost	Net Heat Rate
				(MW)	(%)	(US$/kW/year)	(US$/kWh)	(US$/MBtu)	(Btu/kWh)
	Mt. Coffee	5	(?)	20	3	3.79 a/	.0039	---	---
		6	(?)	20	3	3.55 a/	.0039	---	---
	Via Storage Reservoir b/			16	---	---	---	---	---
	Mt. Coffee	1	(1990)	20	3	4.76 c/	.0039	---	---
	(After Via)	2		20	3	4.76	.0039	---	---
		3		20	3	4.76	.0039	---	---
		4		20	3	4.76	.0039	---	---
Diesel	Bushrod Replacements Max 6: 5MW in same building @ $500/kW, Heavy Fuel			5	5	29.25	.0075	4.72	8,500
Diesel	As required @ $900/kW			15	5	18.00	.0075	4.72	8,500
	@ $900/kW			10	5	22.50	.0085	4.72	8,500
GT	As required @ $250/kW			15	12	20.00	.0024	5.73	13,400

a/ Average capacity for all plants.
b/ Available during dry season only. Costs included with Mt. Coffee hydro.
c/ Value shown is for four 20 MW units: for 5 units assume $4.29; for 6 units assumed $3.97 (includes Via Storage costs).

Table 4: VIA AND ST. PAUL AVERAGE RIVER FLOWS 1/
THROUGH NOVEMBER 1979-83, VIA STORAGE RESERVOIR

Month	Via Flow 2/	St. Paul Flow 2/	LEC Flow Requirements 2/	Via River Flow to Storage
May	63.75	173.56	563.64	NIL
June	92.79	252.46	548.27	NIL
July	223.91	609.60	503.86	223.91
August	579.61	1578.10	543.14	579.61
September	610.68	1662.50	570.47	610.68
October	360.00	980.29	606.34	134.10
November	192.84	524.10	589.26	9.24
			Total:	1557.84
			10% of Flow Required:	157.84
			Net to Storage:	1400 x 10^6 cm

Table 5: LIBERIAL ELECTRICITY CORPORATION GENERATION PLANNING STUDY, CAPITAL DISBURSEMENT
(Case 2-1B, 1% Annual Production Growth, Via NOT Included, Gas Turbine NOT Refurbished)

Year	Action	1985	1986	1987	1988	1989	1990	1991	1992	1993 - 1999	Total
1987	Rehabilitation Program										
	- Luke low speed diesels		5888	3000							8888
	- Bushrod gas turbine		0								0
	- Mt. Coffee 64 MW		1241	1058							2299
	Retire Bushrod MSD Plant										
1990	Retire 2 x 15 MW Gas Turbines										
	Install 2 x 5 MW MSD at Bushrod			1374	2750	1374					5498
1993	Retire 2 x 19 MW Gas Turbines										
	Install 1 x 15 MW Gas Turbine							1875	1875		3750
	Install 4 x 5 MW mSD at Bushrod						2061	4125	2064		8250
		0	7129	5432	2750	1374	2061	6000	3939	0	28685

Table 6: DISCOUNTED CASH FLOW ANALYSIS

(Case 2-1B)

Year	Capital Cost	Fuel Cost	O & M Cost	Total Cost	Present Worth at 12%
1985	0	8311	3517	11828	11828
1986	7129	8444	3536	19109	17062
1987	5432	7248	4028	16708	13320
1988	2750	7276	4055	14081	10023
1989	1374	7467	4066	12907	8203
1990	2061	7509	3832	13402	7605
1991	6000	7574	3854	17428	8830
1992	3939	7674	3879	15492	7008
1993	0	6943	4373	11316	4570
1994	0	7040	4399	11439	4125
1995	0	7129	4425	11554	3720
1996	0	7219	4451	11670	3355
1997	0	7304	4478	11782	3024
1998	0	7386	4505	11891	2725
1999	0	7469	4533	12002	2456
TOTAL	28685				107853

Table 7: LIBERIAL ELECTRICITY CORPORATION GENERATION PLANNING STUDY, CAPITAL DISBURSEMENT
(Case 2-2C, 3% Annual Production Growth, Via NOT Included, Upgrad Mt Coffee in 1993)

Year	Action	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995 - 1996	Total
1987	Rehabilitation Program												
	- Luke low speed diesels		5886	3000									8888
	- Bushrod gas turbine		1500										1500
	- Mt. Coffee 64 MW		1241	1058									2299
1990	Retire 2 x 15 MW Gas Turbines												
	Install 5 x 5 MW MSD at Bushrod			3435	6875	3440							13750
1993	Retire 2 x 19 MW Gas Turbines												
	Install 1 x 15 MW LSD						3375	6750	3375				13500
	Install 1 x 5 MW MSD at Bushrod						687	1375	688				2750
	Install 2 x 15 MW Gas Turbines							3750	3750				7500
	Mt. Coffee Upgraded to 80 MW								4551	4550			9101
1995	Install 1 x 15 MW LSD								3375	6750	3375		13500
	TOTAL CAPITAL EXPENDITURE	0	8629	7493	6875	3440	4062	11875	15739	11300	3375	0	72788

Table 8: DISCOUNTED CASH FLOW ANALYSIS
(Case 2-2C)

Year	Capital Cost	Fuel Cost	O & M Cost	Total Cost	Present Worth at 12%
1985	0	8553	3555	12108	12108
1986	7129	8926	3605	19660	17554
1987	5432	8282	4138	17852	14232
1988	6875	8766	4196	19837	14120
1989	3440	9094	4263	16797	10675
1990	4062	8246	4618	16926	9604
1991	11875	8736	4690	25301	12818
1992	15739	9115	4778	29632	13404
1993	11300	8704	5125	24329	9826
1994	3375	9017	5219	17611	6351
1995	0	9365	5584	14949	4813
1996	0	9686	5683	15369	4418
1997	0	10086	5787	15873	4074
1998	0	10364	5902	16266	3728
1999	0	10801	6022	16823	3442
TOTAL	72788				141168

TERMS OF REFERENCE

FOR

IMPROVEMENT OF TRANSMISSION AND DISTRIBUTION OPERATIONS

Summary of Requirements

Liberia Electricity Corporation (LEC) is soliciting proposals from a consulting firm to prepare and implement a program to strengthen and improve the operations of the Planning and Transmission and Distribution Departments. The work should be implemented as a completely coordinated program and is intended to:

(a) Reorganize the existing Planning Department establishing special sections within the Department to up-date technical information, organize data collection procedures, analyze losses in the existing system, provide the Commercial Department with the necessary technical data to classify customers using modern mapping techniques and prepare standards and guidelines for future expansion.

(b) Prepare technical specifications and equip the Transmission Department with a local dispatch center to remotely supervise available transmission routes during the two seasonal periods of the year.

(c) Establish a planned maintenance program for substations, transmission lines, and distribution lines providing adequate training to high ranked personnel on modern operation and maintenance practices.

(d) Equip the Metering Department with complete testing facilities.

(e) Analyze, plan and implement measures in the existing system to reduce technical losses and improve the quality of service. The measure may include the installation of capacitors for power factor improvement and improvement of operational practices to reduce power transformer losses.

The work will be done in two phases. Phase 1 will include familiarization with the system, reorganization of the various departments for immediate action, collection of system data, initiation of proper maintenance programs and training of LEC engineers to establish a distribution system data base. The latter is a prerequisite to the analysis and planning of future system expansion. A detailed study on the measures required to reduce technical losses should also be completed in this phase. This study shall result in the preparation of specifications for equipment and unified standards and guidelines. Phase

2 will include the installation and commissioning of equipment, the implementation of operating procedures and final training of LEC operating and maintenance staff.

The overall cost of the program, including local staff and facilities is estimated to be about US$3.0 million. The Phase 1 cost is estimated at US$924,000, consisting of US$525,000 in professional services, US$200,000 in expenses and US$105,000 in equipment. The Phase 2 cost is expected to be about US$1.9 million, consisting of US$200,000 in professional services, US$1.6 million in equipment and the remainder in expenses.

The program is financed by _____. The executing agency might be _____. In the following discussion the firm submitting a proposal to do the work is referred to as "the firm", and the work is referred to as the "program".

Background

The Liberia Electricity Corporation (LEC) was established by a Legislative Act in July 1973 as a subsidiary of the Public Utilities Authority. LEC became an autonomous corporation on the dissolution of the Public Utilities Authorities by an Act in February 1976. The corporation engages in the development, generation, transmission, distribution and sale of electrical energy.

This program to strengthen and improve the operations of LEC's Planning, Generation, Transmission and Distribution Departments is one of a group recommended by a World Bank Power Loss Reduction Mission. The mission's report, which describes the power system and outlines the work to be done, is part of these Terms of Reference.

Scope of Work

The program includes everything that is necessary to achieve the objectives listed in the Summary of Requirements. Some of the specific tasks are:

Phase 1

(a) Advise LEC on the quantity and qualifications of engineers and technicians and on the physical facilities required for the expansion of the present Planning Department.

(b) Assist and train LEC in the following:

(i) Operational data collection routines.

(ii) Technical data collection procedures.

(iii) Determination of existing system characteristics and loss levels.

(iv) Representations of the existing distribution system by suitable modes and line sections for the purpose of computerized system studies.

(v) Application of suitable load forecasting techniques.

(vi) Application of economic optimization techniques, particularly in the context of system losses.

(c) Supply a suitable computer system including CRT terminals, printers, digitizers for data entry of maps and drawings, and plotters for obtaining output in the form of maps and circuit diagrams.

(d) Supply a package of system analysis software suitable for load forecasting and distribution system studies. The output of these studies should provide load flows, voltage profiles and sectional and total losses. Programs are also required for transformer load management, single and three phase short circuit studies and (optionally) for transient stability studies.

(e) Prepare up-dated complete transmission and distribution one line diagrams including data on equipment installed (transformers, disconnects, regulators, etc.).

(f) Prepare a comprehensive set of distribution standards and guidelines.

(g) Review existing system protection and substation maintenance practices.

(h) List the existing protection equipment (relays, etc.) and instrumentation.

(i) Provide structure of organization required for maintenance of substations, protection systems, distribution and transmission lines and establish proper planned maintenance programs.

(j) Specify and prepare detailed cost estimates and equip the Transmission Department with a centralized load dispatch center with supervisory equipment to remotely control network breakers and loads.

(k) Prepare technical specifications and equip the Metering Department with complete meter testing facilities.

(1) Perform the necessary technical loss reduction studies once data on the complete system is available. Specify the equipment and work schedule required to implement specific loss reduction projects in the existing system.

Phase 2

(a) Procure, expedite and provide project management to implement specific projects developed in Phase 1. It is expected that Phase 2 will start before the end of Phase 1.

(b) Complement training so that LEC engineers will be competent to continue with the specific programs started in Phase 1.

Division of Labor and Responsibilities

The firm will be fully responsible for the implementation of the program. It will provide all of the required expatriate professional personnel and all the services required to ensure the success of the program. The LEC will provide:

(a) access to the plants, substations, documents and to any data required to carry out the work;

(b) counterpart staff as required;

(c) office space;

(d) secretarial services; and

(e) translation services if required.

Guidelines for Proposal

The proposal should provide comprehensive details of the following:

(a) a work plan in accordance with these Terms of Reference;

(b) a preliminary estimation of the hours per person required for the work and the place in which the work will be carried out;

(c) the nature of the organization and previous experience in related work in developing countries;

(d) curricula vitae of staff who will be assigned for the program as well as curricula vitae of support staff at Headquarters; and

(e) details of equipment offered or arranged for supply.

A sealed envelope should be enclosed with the proposal indicating the cost estimate of this work based on a system of fixed professional fees, which should also be related to the actual hours of work. The firm may suggest alternative schemes for attaining the objectives outlined in the Summary of Requirements. Any alternative scheme should be clearly outlined as such, and separate work schedules and costs should be provided for each.

Form of Contract

The contract which will be awarded to the successful firm will be part of an overall program of restructuring. It is expected that firms will bid for award of the total program, which will take the form of a management contract or a lease of the conversion to generate and sell electricity.

Schedule of Payments

The schedule of payments will be negotiated and the firm is invited to propose a schedule. However, LEC will tie the payments to clearly defined performance targets.

COST ESTIMATE

Program: Institutional Strengthening

Project: Strengthening of Planning Department

Objective:

To reorganize the Planning Department by establishing specialized sections to obtain information not available at present.

Scope of Services/Equipment:

Provide two planning engineers for two years and the necessary computer software and hardware to:

- Train LEC engineers on data collection procedures and prepare "as built" system drawings.
- Obtain detailed circuit data of the distribution network.
- Train LEC engineers on load forecasting and distribution expansion planning.
- Prepare a comprehensive set of construction standards and guidelines.
- Perform detailed loss reduction studies on the existing system and prepare work schedules to implement specific loss reduction projects.

Estimate of Cost (1986 US$):

	Professional Services	Travel and Subsistence	Equipment
Phase 1			
Professional services for two engineers for 2 years			
- Salary and benefits	420,000		
- Travel (self and family of 3)		24,000	
- Living expenses		144,000	
Minicomputer systems (3)			75,000
Software			30,000
Contingency 10%	42,000	16,800	10,500
Phase 1 Total	462,000	184,800	115,500

Total Phase 1: US$762,300
Total Phase 2: ----------
Total Project: US762,300

Note: This project is shown as a single activity. It provides the engineering input to other projects under this program.

Costs are based on professional services and expatriate services at a rate of US$400/day.

Air travel costs are based on US$1,500 (round trip).

Subsistence costs (hotel and Meals) are based on US$120/day.

COST ESTIMATE

Program: Institutional Strengthening

Project: Strengthening of the Transmission and Distribution Department

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Objective:

To establish a Load Dispatch Center and train LEC personnel on proper operation and maintenance routines.

Scope of Services/Equipment:

Phase 1: Provide specialists to assess and specify the required equipment to establish a Load Dispatch Center. Prepare maintenance programs for substations, generating stations, transmission lines and distribution lines.

Phase 2: Procure, install and commission the recommended equipment. Implement maintenance programs and training of LEC staff on proper operation and maintenance routines.

Estimate of Cost (1986 US$):

	Professional Services	Travel and Subsistence	Equipment Equipment
Phase 1			
Consulting services (12 man months)			
- Salary and benefits	105,000		
- Travel (self and family)		6,000	
- Living expenses		36,000	
Contingency (10%)	10,500	4,200	
Phase 1 Total	115,500	46,200	
Phase 2 (rough estimate for order of magnitude)			
Consulting services (12 man months)			
- Salary and benefits	105,000		
- Travel (self and family)		6,000	
- Living expenses		36,000	
Equipment			1,300,000
Contingency (10%)	10,500	4,200	130,000
Phase 2 Total	115,500	46,200	1,430,000

Total Phase 1: US$ 161,700
Total Phase 2: US$1,591,700
Total Project: US$1,753,400

Costs are based on professional services and expatriate services at a rate of US$400/day.

Air travel costs are based on US$1,500 (round trip).

Subsistence costs (hotel and meals) are based on US$120/day.

COST ESTIMATE

Program: Institutional Strengthening

Project: Strengthening of Metering Department

Objective:

To improve the meter testing facilities of the Metering Department.

Scope of Services/Equipment:

Phase 1: Provided by Planning Department.

Phase 2: Professional services to install the equipment and train LEC personnel in its use.

Estimate of Cost (1986 US$):

	Professional Services	Travel and Subsistence	Equipment
Phase 1: - Engineering services provided by Planning Department strengthening			
Phase 2 (Rough estimate for order of magnitude)			
Installation and training (3 man months)			
- Salary and benefits	26,000		
- Travel		1,500	
- Living expenses		10,800	
Equipment			100,000
Physical Contingency (10%)	2,600	1,230	10,000
Phase 2 Total	28,600	13,530	110,000

Total Phase 1: US$-------
Total Phase 2: US$152,130
Total Project: US$152,130

Costs are based on professional services and expatriate services at a rate of US$400/day.

Air travel costs are based on US$1,500 (round trip).

Subsistence costs (hotel and meals) are based on US$120/day.

COST ESTIMATE

Program: Institutional Strengthening

Project: Reduction of Technical Losses
(Note: Order of Magnitude Estimate only)

Objective:

To reduce technical losses by the installation of fixed and switched capacitors on distribution circuits to improve power factor.

Scope of Services/Equipment:

Installation of 13.5 MVAR of capacitors in 450 kVAR banks, 10 fixed banks and 20 switchable banks.

Note: The engineering and precise definition of this activity will be provided by the newly forced section of the Planning Department. This includes exact locations and size of capacitor banks to attain optimum loss levels.

Estimate of Cost (1986 US$):

	Professional Services	Travel and Subsistence	Equipment
Phase 1: Engineering provided by reorganized Planning Department.			
Phase 2			
Capacitors and accessories			120,000
Switches and controls			30,000
Project Management (12 man months)	65,000		
Contingency (10%)	6,500		15,000
Phase 2 Total	71,500		165,000

Erection (Local Cost): US$65,000

Total Phase 1: US$-------
Total Phase 2: US$301,500
Total Project: US$301,500

Costs are based on professional services and expatriate services at a rate of US$400/day.

Air travel are based on US$1,500 (round trip).

Subsistence costs (hotel and Meals) are based on US$120/day.

ESTIMATE OF BENEFITS

Program: Institutional Strengthening

Project: Reduction of Technical Losses

Scope of Services/Equipment:

Installation of 13.5 MVAR of capacitors in 450 kVAR banks, 10 fixed banks and 20 switchable banks.

Assumptions:

- Technical losses reduced by 16% of present level (estimated from sample calculations).
- Half of the total amount of capacitors is installed each year over a two year period.
- During the two year period the absolute value of losses related to power factor increases at the rate of load growth (3%).
- New addition to feeders are adequately compensated, outside the scope of the project, after the second year (benefits do not increase after the end of the project).
- Life of capacitors is 20 years.
- Discount rate 12%.
- Value of capacity savings US$52/kW.
- Value of energy savings US$0.16/kW.

Calculation of Savings:

Year	Loss Reduction Demand	Loss Reduction Energy	Savings (1985 US$) Demand	Savings (1985 US$) Energy	Total
	(MW)	(GWh)			
1	----	---	------	---------	---------
2	0.74	3.2	34,480	512,000	546,480
3	1.68	7.3	87,360	1,168,000	1,255,360
4-20	1.68	7.3	87,360	1,168,000	1,255,360

Total costs US$2.97 million assumed to be spent in equal parts during the first two years.

Net present value (at 12%): US$5.8 million.

EDR = 40.9%.

TERMS OF REFERENCE

FOR

STRENGTHENING OF SUPPORT SERVICES

Summary of Requirements

Liberia Electricity Corporation (LEC) is soliciting proposals from consulting firms or public utilities to prepare and implement a program to strengthen its support services and train line crews on the use of modern equipment and work methods. The proposed work is intended to: (a) streamline the operation of the motor vehicle transport section; (b) improve the established radio communication; (c) refurnish all line crews with modern equiment and tools; and (d) train line crews in modern line construction and maintenance methods. The main components of line program are:

(a) To determine the replacement or needs for new vehicles in the Commercial, Generation, Transmission, Planning and Distribution Departments.

(b) To improve present maintenance practices of the existing transport fleet, including the establishment of a computerized maintenance system.

(c) To improve the existing communication network between dispatchers, supervisors and line crews.

(d) To equip line construction and maintenance crews with modern working tools and utility-body vehicles.

(e) To train line crews on the use of modern heavy-duty mobile equipment.

The entire program should be completed in two years and training must be such that LEC will be able to continue to form and train new crews in the future.

The work will be done in two phases. Phase 1 will include familiarization with the system, detailed assessment of the costs and benefits of the various measures, preparation of specifications for equipment, preparation of training plans and some immediate training activities. Phase 2 will include the procurement, installation and commissioning of equipment, the implementation of operating procedures and final training of LEC operating and maintenance staff.

The overall cost of the program, excluding local staff and facilities, is estimated to be about US$1.9 million. The Phase 1 cost is

estimated at US$121,400, consisting of about US$86,700 in professional services, and US$34,700 in expenses. Phase 2 cost is expected to be about US$1.8 million, consisting of US$105,900 in professional services, US$1.6 million in equipment and the remainder in expenses.

The program if financed by _____. The executing agency might be _____. In the following discussion the firm submitting a proposal to do the work is referred to as "the firm", and the work is referred to as the "program".

Background

The Liberia Electricity Corporation (LEC) was established b a Legislative Act in July 1973 as a subsidiary of the Public Utilities Authority. LEC became an autonomous Corporation on the dissolution of the Public Utilities Authorities by an Act in February 1976. The Corporation engages in the development, generation, transmission, distribution and sale of electrical energy.

This program to strengthen LEC's support services is one of a group recommended by a UNDP/World Bank Power Loss Reduction Mission. The Mission's report, which describes the power systems and outlines the work to be done, is a part of these Terms of Reference.

Scope of Work

This program includes everything that is necessary to achieve the objectives listed in the Summary of Requirements. Some of the specific tasks are:

Phase 1

(a) Review the condition and requirements of the existing transport fleet.

(b) Review the condition of equipment and procedures used for maintaining LEC vehicles.

(c) Prepare specifications, detailed cost estimates and implementation schedules for the required maintenance facilities.

(d) Prepare specifications for the vehicles required to replace or supplement the existing fleet.

(e) Review the condition and requirements of the existing communication system used for generation, transmission and distribution facilities.

(f) Prepare specifications, detailed cost estimates and implementation schedules to upgrade the communication network.

(g) Review specific line construction and maintenance tools, heavy-duty mobile equipment and prepare detailed cost estimates and implementation schedules for revamping existing tools and line trucks.

Phase 2

(a) Procure, expedite, manage the installation and commission the maintenance facilities and vehicles specified in Phase 1.

(b) Procure, expedite, manage the installation and commission equipment specificed in Phase 1 for the communication system.

(c) Provide personnel to train LEC line crews in Monrovia on up-to-date work methods.

(d) Arrange training (actual hand-on not superficial classroom instruction) for LEC supervisors in a utility in a developed country.

Division of Labor and Responsibilities

The firm will be fully responsible for the implementation of the program. It will provide all of the services required to ensure the success of the program.

The LEC will provide the following:

(a) access to company sites, to documents, and to any data required to carry out the work;

(b) all transportation in Liberia;

(c) counterpart staff, as required, at the educational level specified by the firm to ensure success of the training;

(d) office space, standard office equipment and supplies;

(e) secretarial services; and

(f) translation services if required.

Guidelines for Proposal

The proposal should provide comprehensive details of the following:

(a) A work plan in accordance with these Terms of Reference.

(b) A preliminary estimation of the hours per person required for the work and the place in which the work will be carried out.

(c) The nature of the organization and previous experience in related work in developing countries.

(d) Curricula vitae of staff who will be assigned for the study as well as curricula vitae of support staff at Headquarters.

(e) Details of equipment offered or arranged for supply.

(f) Staff and period to be assigned for establishment of training of LEC personnel, inclusive of full curricula vitae and previous experience.

A sealed envelope should be enclosed with the proposal indicating the cost estimate of this work based on a system of fixed professional fees, which should also be determined in relations to the actual hours of work. The firm may suggest alternative schemes for attaining the objectives outlined in the Summary of Requirements. Any alternative scheme should be clearly identified as such, and separate work schedules and costs should be provided for each.

Once the proposals have been evaluated, LEC will proceed to negotiate the contract with the most qualified firm and, if they are unable to reach agreement during the negotiations, proceed to negotiate with the second best qualified firm. LEC may reject any or all of the offers received if none of them is satisfactor.

Form of Contract

The contract which will be awarded to the successful firm will be based on the International Model Form of Agreement between Client and Consulting Engineer No. ICRA 1980, P.M. P.I., produced and issued by the International Federation of Consulting Engineers.

Schedule of Payments

The schedule of payments will be negotiated, and the firm is invited to propose a schedule. However, the LEC will tie final payments to clear performance targets.

COST ESTIMATE

Program: Strengthening of Support Services

Project: Transport Fleet and Training of Line Crews

Objective:

To replace the vehicles in the existing fleet which are beyond economic repair, to supply new vehicles and line tools, train personnel on modern work methods and organize a vehicle maintenance shop.

Scope of Services/Equipment:

This project should be done in two phases. On Phase 1 an overseas public utility with experience in operating large fleets would be engaged to assess LEC's requirements for replacement vehicles, new vehicles, line maintenance equipment and spare parts. The firm will also review existing maintenance practices on the transport fleet and recommend equipment for the establishment of a new vehicle maintenance shop. On Phase 2 procurement of the equipment specified in Phase 1 will be completed and a training program for line crews will be carried out.

Estimate of Cost (US$):

	Professional Services	Travel and Subsistence	Equipment
Phase 1			
Consulting service to define vehicle needs and tools for line work (8 man months)	70,000		
Travel (2 round trips)		3,000	
Living expenses		24,000	
Contingency (10%)	7,000	2,700	
Sub-total	77,000	29,700	
Phase 2			
Consulting services to procure vehicles and train crews (8 man months)	70,000		
Travel (2 round trips)		3,000	
Living expenses		24,000	
Vehicles, tools and spares			1,400,000
Contingency (10%)	7,000	2,700	140,000
Sub-total	77,000	29,700	1,540,000

Total Phase 1: US$ 106,700
Total Phase 2: US$1,646,800
Total Project: US$1,753,400

COST ESTIMATE

Program: Strengthening of Support Services

Project: Communication Equipment

Objective:

To improve the existing radio communication system

Scope of Services/Equipment:

Phase 1: Professional services to specify the requirements of a complete radio network between dispatchers, supervisors and crews with selective calling.

Phase 2: Procure, expedite, manage the installation and commission the equipment.

Estimate of Cost (US$):

	Professional Services	Travel and Subsistence	Equipment
Phase 1			
Consulting services (1 man month)			
- Salary and benefits	8,800		
- Travel (1 round trip)		1,500	
- Living expenses		3,000	
Contingency (10%)	900	500	
Sub-total	9,700	5,000	
Phase 2 (rough estimate for order of magnitude)			
Consulting services (3 man months)			
- Salary and benefits	26,300		
- Travel		1,500	
- Living expenses		9,000	
Equipment			120,000
Contingency (10%)	2,600	1,000	12,000
Sub-total	28,900	11,500	132,000

Total Phase 1: US$ 14,700
Total Phase 2: US$172,400
Total Project: US$187,100

TERMS OF REFERENCE

FOR

STUDY ON IMPROVEMENT OF LEC'S ISOLATED DIESEL PLANTS

Summary of Requirements

The Liberia Electricity Corporation is soliciting proposals for a company to study its isolated diesel systems. The objective of the study is to present cost-effective proposals to rehabilitate the systems and to improve operation and maintenance practices.

The estimated cost of the program to establish the necessary systems and manage the operation for two years is US$92,600, consisting of about US$60,000 in technical services and the remainder in travel and subsistence.

The program is financed by _____. The executing agency is _____.

Background

A joint UNDP/World Bank mission visited Liberia in June 1985, and identified some problems with the operation of LEC's isolated diesel stations. The report of the mission forms a part of these Terms of Reference.

Scope of Services

The company will do everything necessary to achieve the objectives outlined in the Summary of Requirements and may propose alternative approaches. Some of the specific tasks are:

(a) inspect all of the rural stations and estimate the cost of the work required to recover derated capacity, improve fuel efficiency and rehabilitate newer units;

(b) perform a cost/benefit analysis to determine how much of the rehabilitation/upgrading is economically justified;

(c) prepare a work plan;

(d) prepare a standard instrumentation package to be included on future units and retrofitted on existing units; the instrumentation should monitor all parameters necessary to run the plant safely and efficiently, for example:

- energy generated (kWh);
- fuel consumed;
- lubricating oil temperature and pressure;
- exhaust temperatures;
- cooling water temperature;

(e) prepare a maintenance schedule for the plants including a routine for sending oil samples for spectrographic analysis;

(f) prepare an inventory control and retrieval system;

(g) train operators and maintenance staff;

(h) advise LEC on purchasing standard sizes and types of plants to minimize spare part inventories and the need for specific engine training for maintenance staff; and

(i) investigate and advise LEC on the logistics of using mobile plant to cover planned maintenance outages in the rural plants thereby reducing the required reserve capacity in each plant (small gas turbines should be considered as alternatives for use as mobile plant where weight restrictions are important).

Division of Labor and Responsibilities

The company will be fully responsible for achieving the objectives outlined in the Summary of Requirements. LEC will provide: (a) access to documents and data; (b) counterpart staff as required; (c) office space; and (d) secretarial services.

Guidelines for the Proposal

The Company's proposal should provide comprehensive details of the following:

(a) a work plan in accordance with these Terms of Reference;

(b) the nature of the organization and previous experience in related work in other countries;

(c) curricula vitae of staff to be assigned for the work;

(d) details of equipment to be procured to execute the work plan;

(e) a preliminary estimation of hours per person required for the work.

Form of Contract

The contract which will be awarded to the successful firm will be based on the International Model Form of Agreement Between Client and Consulting Engineer, No. IGRA 1979 P.I. -- produced and issued by the International Federation of Consulting Engineers (FIDIC).

Schedule of Payments

The amounts and schedule of payment for services rendered during the contract period will be negotiated with the LEC. These payments will be based on a fixed fee plus bonuses tied to performance targets. The Company should make a proposal which will be used as a basis for the negotiation.

ESTIMATE OF TECHNICAL LOSSES

Load Characteristics and Basic Data

System Configuration and Data. The mission found that information on the layout and composition of circuits is not well documented. The few maps available showing routes of overhead lines are outdated and need revision. To compensate for this lack of system data sample distribution circuits that appeared representative were selected as test cases. Typical feeders with exclusively industrial, commercial or residential type loading were chosen. Further details as to how calculations were made are given in paragraphs that follow.

Load and Loss Factor. The annual peak demand of 68 MW (October 29, 1984) is used for calculating peak time losses. An average load factor of 68% provided by LEC and a loss factor of 50% are applied for the calculation of all current-dependent loss components, except for sample studies of 12.5 kV and 400 volt feeders where the relevant loadings of those feeders are taken into account whenever they are available.

Power Factor. For step-up, step-down and distribution power transformers the actual value of 0.85 measured during the annual peak is applied. For the distribution system actual values measured during sample studies, which vary from 0.72 in industrial feeders to 0.95 in residential feeders, are used.

System Component Categories

Step-up Transformers at Generating Stations. The peak power losses are determined by adding the no-load and load losses of each generation power transformer using well-known formulas. MW outputs of all generating units were obtained from the LEC for a typical evening peak loading condition (wet season). For the determination of the energy losses, the no-load losses are integrated over the whole year, while the load losses are calculated using the overall system loss factor.

Since not all the units were in operation during the peak load hour that was analyzed, the results reflect typical unit availability. Results also show that of the total yearly energy losses in step-up transformers (5.9 GWh) about 50% (2.9 GWh) correspond to no-load losses of transformers which are connected to the grid but are not being used.

69 kV Transmission Network. Results of a sample study carried out on a particular day where all circuits were being fed radially from Mt. Coffee generating station are included. The calculation is done using a computer model of the circuits to be analyzed. The computer model requires data on circuit length, type and size of conductors, phase spacing, connected loads, and maximum demand, voltage, load factor and

power factor at the generating station. The computer allocates total feeder load along the circuit in proportion to the connected load. It then calculates the existing losses, percentage conductor loading and voltage drops along each section of the line.

Step-down Transformers at 69 kV Substations. The method of calculation is the same as for step-up transformers. Loading at each substation was measured at the same peak load hour as in the case of the step-up transformers. As in the case of generating plant, power transformers only about 22% of the total installed capacity in substations is being used. Yearly energy losses are high due to no-load losses of large transformers connected to the grid but with very small loads.

12.5 kV Primary Distribution Lines. Due to lack of circuit data an approximate assessment method is used. Only three typical feeders are analyzed in detail. One Industrial, one Commercial and one Residential. The methodology used is similar to the one used on the transmission network. Percentage losses are calculated for each type of circuit and then pro-rated on the total peak load of which 15% is assumed to be industrial, 35% commercial and 50% residential.

Low Voltage Secondary Network. This is the most difficult to calculate because of the extreme complexity of the low voltage network. A typical circuit connected to a 75 kVA fully loaded distribution transformer is analyzed in detail using the same program employed for the transmission network. Complete data including service drops, type of load connected, cable lengths, conductor sizes and number of customers connected was obtained in the field for this purpose. Some circuits have voltage drops as high as 15.7% at the end. Losses are close to 8% of peak demand.

Distribution Transformers. The method of calculation is the same as for step-up and step-down power transformers. Loadings, however, are determined by allocating the total system load proportionate to the capacity of each transformer. Some error is introduced because the exact number of each size of transformer is not known. No updated records have been kept by the LEC and figures used correspond to data for 1979 to which a fixed percentage increase per year is added.

PRIMARY LINE LOSSES IN TYPICAL INDUSTRIAL FEEDER

Feeder Name: Industrial Circuit
Substation: Bushrod

Feeder Data:

- Line to line voltage: 12.5 kV
- Line length: Main circuit: 12,431 feet
  Branches: 15,604 feet
- Load factor: 49.2%
- Loss factor: 27.1%
- Power factor at peak: 72%
- Type of conductor: 556 AAAC
- Distribution transformers: Quantity 99
  Connected kVA: 17,797
- Installed Capacitors: None
- Peak demand: 4,655 kVA

Calculated Losses:

	kVA	kW	kVAR	PF
Peak Demand	4,655	3,352	3,230	0.72
Losses	74.7	23.7	70.8	0.32

Estimated yearly energy losses: 56,300 kWh

Maximum voltage drops (%): 1.92
Maximum conductor loading (% of capacity): 32.1

	kW	kVAR
Losses without PF correction:	23.68	70.82
Losses with PF corrections: a/	12.89	38.57

Savings with PF correction: 10.7 kW
Yearly energy savings: 25,400 kWh

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a/ Changing PF to 0.95.

PRIMARY LINE LOSSES IN TYPICAL COMMERCIAL FEEDER

Feeder Name: Water and City Circuit
Substation: Krutown

Feeder Data:

- Line to line voltage: 12.5 kV
- Line length: Main circuit: 3,675 feet
  Branches: 7,957 feet
- Load factor: 57.2%
- Loss factor: 35.7%
- Power factor at peak: 89%
- Types of conductor: 266 AAAC (65%), 3/9 AAAC (34k%), 2 cu (1%)
- Distribution transformers: Quantity: 61
  Connected kVA: 3,1ƀ2
- Installed capacitors: None
- Peak demand: 1,025 kVA

Calculated Losses:

	kVA	kW	kVAR	PF
Peak Demand	1,025	912	467	0.89
Losses	1.9	1.02	1.57	0.55

Estimated yearly energy losses: 3,200 kWh

Maximum voltage drop (%): 19%
Maximum conductor loading (% of capacity): 11.3%

PRIMARY LINE LOSSES IN TYPICAL RESIDENTIAL FEEDER

Feeder Name: Paynesville Circuit
Substation: Congotown

Feeder Data:

- Line to line voltage: 12.5 kV
- Line length: Main circuit: 10,821 feet
  Branches: 19,517 feet
- Load factor: 70.8%
- Loss factor: 51.5%
- Power factor at peak: 95%
- Types of conductor: 266 AAAC (20%), 4/0 AAAC (18%), 3/0 AAAC (8%), 1/0 AAAC (24%), 4/0 cu (9%), 2 cu (16%), 6 cu (5%)
- Distribution transformers: Quantity: 121
  Connected kVA: 4,537.5
- Installed Capacitors: None
- Peak demand: 2,000 kVA

Calculated Losses:

	kVA	kW	kVAR	PF
Peak demand	2,000	1,900	625	0.95
Losses	14.5	7.61	12.38	0.52

Estimated yearly energy losses: 34,500 kWh

Maximum voltage drop (%): 7%
Maximum conductor loading (% of capacity): 22.0%

LOSSES IN TYPICAL RESIDENTIAL CIRCUIT SECONDARY LINES

Location: Residential Sector near Downtown Monrovia

Line Data:

- Capacity of transformer feeding circuit: 75 kVA
- Line to line voltage: 415 volts
- Line length: Secondary lines: 1,200 feet
  Service drops: 830 feet
- Number of customers: 102
- Load factor: 70%
- Loss factor: 52%
- Power factor at peak: 88%
- Types of conductors: Mains: 266 AAAC (25%), 4/0 AAAC (37%), #2 AAAC (25%), 1/0 AAAC (12%)
  Service drops: #6 cu (28%), #8 cu (42%), #10 cu (30%)
- Peak demand: 75 kVA

Calculated Losses:

	kVA	kW	kVAR	PF
Peak load	75	66	36	0.88
Losses	6.0	5.15	3.06	0.86

Maximum voltage drop (%): 15.7%
Maximum conductor loading (% of capacity): 75%

69 kV TRANSMISSION LINE LOSSES

Name: LEC Transmission Line Network

Line Data:

- Line to line voltage: 69 kV
- Line length: 394 kms
- Power factor at peak: 0.85
- Type of conductors: 266.8 AAAC, 3/0 AAAC
- Peak demand: 63 MW
- Loss factor: 0.50

Calculated Losses:

	MVA	MW	MVAR	PF
Peak Demand	74.1	63	39	0.85
Losses	5.7	2.6	5.0	0.45

Estimated yearly energy losses: 11.18 GWh

Maximum voltage drop (%): 8.5%
Maximum conductor loading (% of capacity): 53.1

GENERATOR TRANSFORMER DATA

Installed At	Make	MVA Rating	Percent Impedance	Voltage Rating
			(%)	(kV)
Old Diesel 2,3	A.C.	3 x 2.5	6.8	69/12.5
Old Diesel 4, 5, 6	A.C.	3 x 2.9	6.8	69/12.5
Gas Turbine 1	BBC	23	9.1	69/13.8
Gas Turbine 2	BBC	23	9.1	69/13.8
Gas Turbine 3	BBC	28	9.2	69/13.8
Gas Turbine 4	BBC	28	9.2	69/13.8
Mt. Coffee 1	G.E.	15/20	7.15	69/12
Mt. Coffee 2	G.E.	15/20	7.15	69/12
Mt. Coffee 3	BBC	15/20	9.65	69/12
Mt. Coffee 4	BBC	15/20	9.65	69/12
Slow Diesel 1	ASEA	12/16	7.3/9.7	69/13.8
Slow Diesel 2	ASEA	12/16	7.3/9.7	69/13.8
Slow Diesel 3	ASEA	12/16	7.3/9.7	69/13.8
TOTAL MVA: 246.2				

Source: LEC.

SUBSTATION TRANSFORMER DATA

No.	Installed At	Make	MVA Rating	Type	Percent Impedance	Voltage Rating
					(%)	(kV)
1.	Bushrod	---	2 x 3 x 3.125	----		
2.	Krutown	Pauwells	2 - 20	OLTC	7.35 - 9.8	12.47/66.96
3.	Capitol	Pauwells	2 - 20	OLTC	9.95 - 10.05	12.47/66.96
4.	Newport	Pauwells	2 - 20	OLTC	8.5 - 8.59	12.47/66.96
5.	Congotown	UNIAO	2 - 20	OLTC	9.275	12.47/66.96
6.	Paynesville	UNIAO	2 - 20	OLTC	9.275	12.47/66.96
7.	Gardnersville	UNIAO	2 - 20	OLTC	9.275	12.47/66.96
8.	Virginia	ASEA	5/6.3	OLTC	7.48	12.47/67
9.	Robertsfield	G.E.	5/6.25	OLTC	7.62	12.47/66.96
10.	Buchanan	G.E.	7.5/9.375	----	7.69	12.47/66.96
11.	Bong Mines	BBC	2 - 10	OLTC	7.7	6.9/69
12.	Kakata	G.E.	3 x 0.833	----	6.84	12/47/67
13.	Todee	A.C.	2 x 0.333	----	5.9	12.47/67
14.	Bonihills	G.E.	2 - 5	----	3.79	34.5/69
15.	Clay	G.E.	3 x 0.833	----	6.84	12.47/67
16.	Mt. Coffee	G.E.	2.5	----	6.88	12.47/69
TOTAL Installed MVA: 318.8						

Source: LEC.

TERMS OF REFERENCE

FOR

TARIFF STUDY

Summary of Requirements

LEC is soliciting proposals from a consulting firm to carry out a complete tariff study aimed at formulating an electricity pricing structure which would cover costs of meeting power demand and generate the revenue requirements of the utility. Related objectives also include the review of all other tariff measures financially acceptable to both LEC and its customers which may stimulate efficient use of power system capacity.

The study should formulate tariff proposals for a period of about five years, based on a reference load forecast and a reference expansion plan. In addition to devising a recommended pricing structure, the study should also establish a methodology which will allow continual tariff revisions in response to changing conditions.

The scope of work of the study should include, but not be limited to, the following:

(a) computation of the marginal economic costs;

(b) analysis of existing tariff structures;

(c) formulation of proposed tariff changes; and

(d) implementation plans.

Background

LEC was established by a Legislative Act in July 1973 as a subsidiary of the Public Utilities Authority. LEC became an autonomous corporation on the dissolution of the Public Authorities by an Act in February 1976. The corporation is engaged in the development, generation, transmission, distribution, and sale of electrical energy.

The Integrated National Energy Program for Liberia (INEPL) developed in 1985 by the National Energy Committee (NEC)--established with the mandate to assist the government in developing appropriate energy policies--includes among its recommendations a policy study on electricity pricing. The study's main objective should be the determination of tariffs of electricity supplied by public utilities in

both Monrovia and the rural areas so as to cover the long run costs of production.

The execution of this study is now highly recommended by the joint UNDP/World Bank ESMAP mission. The report of the mission is part of these Terms of Reference.

Scope of Work

The scope of work required to meet the above mentioned objectives includes, inter alia, the following:

(a) Calculation of marginal economic costs of generation, transmission, and distribution of electricity at the various voltage levels of the system, for different consumer categories, and over a certain specified timeframe.

(b) Analysis of the existing tariff structure and its comparison with the marginal cost structure to identify adjustments needed to cover future expansion plans.

(c) Formulation of a preliminary proposal for tariff changes based on updated marginal costs, load forecasts, and reference expansion plans.

(d) Modification of the preliminary proposal to:

(i) compensate for distortions in the pricing of electricity substitutes;

(ii) earn sufficient revenue for the utility to meet its financial objectives;

(iii) provide for income distribution objectives; and

(iv) ensure practicality and reasonable cost of administering the new tariffs.

(e) Preparation of an implementation plan in close consultation with the management of the utility.

In addition to the above, the study should give particular attention to the following current deficiencies in tariff form and structure:

(a) the application of minimum monthly charges;

(b) provision of a discount for high voltage consumers;

(c) provision of incentives for major consumers to use wet season supply who can accept interruptable supply in the dry season due to their own back-up plant;

(d) reduced rates, possibly with load limiters instead of meters for lights only supply;

(e) penalization for poor load factors; and

(f) incentives for prompt payment by Government and consumers.

Division of Labor and Responsibilities

The Consultant will be fully responsible for the completion of the study. It will provide all the services required to complete the study within the timeframe previously arranged.

LEC will provide the following:

(a) access to company sites, to documents, and to any data required for the study;

(b) all transportation in Liberia;

(c) office space, standard office equipment, and supplies; and

(d) secretarial services if required.

Guidelines for the Proposal

The proposal should provide comprehensive details of the following:

(a) a work plan in accordance with these Terms of Reference;

(b) the nature of the organization and previous experience related to work in other countries;

(c) curricula vitae of staff to be assigned for the work; and

(d) a preliminary estimation of the hours required for the work.

Form of Contract

The contract which will be awarded to the successful bidder will be based on the International Model Form of Agreement between Client and Consulting Engineer No. IGRA 1980, P.M. P.I., produced and issued by the International Federation of Consulting Engineers.

Structure and Schedule of Payments

The structure and schedule of payment for services rendered during the contract period will be negotiated with the Government of Liberia. These payments will be based on fixed fees plus bonuses tied to performance targets.

ENERGY SECTOR MANAGEMENT ASSISTANCE PROGRAM

Activities Completed

Country	Project	Date	Number
Energy Efficiency and Strategy			
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
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	Recommended Technical Assistance Projects	6/85	038/85
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 Given 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
Sudan	Power System Efficiency Study	6/84	018/84
	Management Assistance to the Ministry of Energy and Mining	5/83	003/83
Togo	Wood Recovery in the Nangbeto Lake	4/86	055/86
Uganda	Energy Efficiency in Tobacco Curing Industry	2/86	049/86
	Institutional Strengthening in the Energy Sector	1/85	029/85
Zambia	Energy Sector Institutional Review	11/86	060/86
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
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
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
Thailand	Accelerated Dissemination of Improved Stoves and Charcoal Kilns	9/87	079/87
	Rural Energy Issues and Options	9/85	044/85
Uganda	Fuelwood/Forestry Feasibility Study	3/86	053/86