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Core Report of the Electric Power Utility Efficiency Improvement Study

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CORE REPORT

OF THE

ELECTRIC POWER UTILITY

EFFICIENCY IMPROVEMENT STUDY

Prepared by

Central Project Team
Energy Development Division (IENED)
The World Bank

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Acronyms

APA	- Asia, the Pacific, and the Americas
BMZ	- Bundesministerium für Wirtschaftliche Zusammenarbeit (Germany)
BPPE	- Best Practice Plant Efficiency
CODOP	- Central Operations Department, Operations Policy Unit (World Bank)
CPT	- Central Project Team
DANIDA	- Department of International Development Cooperation (Denmark)
EIRR	- Economic Rate of Return
EPUES	- Electric Power Utility Efficiency Improvement Study
ESMAP	- Energy Sector Management Assistance Program
FINNIDA	- Finnish International Development Agency (Finland)
FIRR	- Financial Rate of Return
GLA	- General Licensing Agreement
GTZ	- Deutsche Gesellschaft für Technische Zusammenarbeit (Germany)
IDEAS	- Institutional Development Advisory Services
IDGTE	- Institute for Diesel and Gas Turbine Engineers (UK)
IENED	- Industry and Energy, Energy Development Division
ILO	- International Labor Organization
INUWS	- Infrastructure and Urban Water & Sanitation Division (World Bank)
ISO	- International Standards Organization
KfW	- Kreditanstalt für Wiederaufbau (Germany)
LRMC	- Long-run Marginal Costs
MIS	- Management Information System
NPA	- National Power Authority (Sierra Leone)
NPC	- National Power Corporation (Philippines)
NPV	- Net Present Value
ODA	- Overseas Development Administration (UK)
OMS	- Operation Manual Statement (World Bank)
UNDP	- United Nations Development Program
USAID	- U.S. Agency for International Development
ZOPP	- Zielorientierte Projekt-planung (objectives-oriented planning)

Abbreviations

GWh	- gigawatt hour = 10^6 kWh
kV	- kilovolt
kVA	- kilovolt-ampere
kW	- kilowatt
kWh	- kilowatt hour
MW	- megawatt = 10^3kW
MWh	- megawatt hour = 10^3 kWh

The following countries participated in this study and were visited by EPUES missions. In the report they are referred to as countries A through CC. Nearly 90 utilities and power plants in these countries were studied.

Angola
Barbados
Benin
Botswana
Burkina Faso
Central African Republic
Cote d'Ivoire
Ecuador
Equatorial Guinea
Ethiopia
Ghana
Guatemala
Guinea
Guinea-Bissau
Haiti
Indonesia
Liberia
Mali
Mauritania
Mauritus
Mozambique
Niger
Nigeria
Peru
Philippines
Senegal
Sierra Leone
Somalia
Sudan
Swaziland
Tanzania
The Gambia
Togo
USA
Zaire
Zambia
Zimbabwe

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FOREWORD

During the past ten years, multilateral development banks have financed $34.6 billion in power projects. According to a World Bank review of lending for electric power, installed capacity grew at an average annual rate of about 8 percent in 51 developing countries. But other measures of progress in the sector showed disturbing signs of inefficiency. Network losses increased, economic rates of return declined, receivables increased, and debt service ratios dropped [Munasinghe, et al.]. Performance was especially poor in Africa, where many power plants required rehabilitation after just a few years of operation. Poor performance was also observed by many bilateral donor agencies.

Motivated by these disturbing findings, financial and technical assistance agencies from Germany, Finland, the United Kingdom, the World Bank, UNDP, and the United States agreed in September 1988 to fund an investigation of power sector performance. For this purpose, the Electric Power Utility Efficiency Improvement Study (EPUES) was organized, and was in full swing by January 1989.[1] A Steering Committee comprising of one member from each supporting agency set the objectives and work agenda. The Steering Committee meets biannually to discuss progress and is informed monthly by newsletter *(EPUES Update)* on Study activities. The Energy Development Division (IENED) of the World Bank manages the study, with day-to-day activities controlled by a Central Project Team (CPT) within IENED.

The objective of the Study is threefold: (1) to determine the underlying causes of poor power plant performance in developing countries; (2) to measure the economic and financial costs of poor performance to utilities, power users, and the economy as a whole; and (3) to prepare programs to remedy shortcomings, and guidelines for improving performance. The central hypothesis is that poor performance is caused not only by visible deficiencies, or by external factors such as lack of spare parts or foreign exchange but also, and principally, by institutional and human constraints, both within and outside of the organization. The main conclusions, likewise, are that the problems of electric power utilities involve four pivotal issues: lack of clear policies and goals set by the governments; the utilities' lack of independence, especially to establish tariffs based on economic principles, the utilities' inability to maintain institutional functions such as training; and inappropriate donor policies and procedures.

To investigate the hypothesis, EPUES sent mission teams to assess more than 60 diesel power plants. EPUES limited the investigation to diesel plants, rather than evaluating a variety of plants of differing sizes, technical characteristics, and organizational structures, because diesel generating sets are similar all over the world. Therefore, extraneous technological factors played only a minor role in the interpretation of performance records.[2]

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1 Denmark's technical assistance agency, DANIDA, joined EPUES in December 1989.

2 Diesel power plants are generally smaller than other thermal plants, which made the investigation of a few hundred employees and their functions more feasible than it would have been to investigate the thousands typical of larger operations. Also, the operational performance of diesel plants is generally worse than other types of equipment. Diesel technology, although basically robust and reliable, is unforgiving if proper operating procedures and maintenance are neglected. Hence, technical failures quickly result from human failures.

The recommendations generally relate to the management needs of small integral utilities in isolated areas. These are the utilities that tend to be dominated by diesel plants--whereas larger, more centralized utilities have a variety of plant types on their systems. Some recommendations may not apply to utility organizations that use large interconnected plants.

As of the date of this report, the missions have completed their assignments in 17 countries and collected information from 20 others. Based on these mission reports, World Bank reports, information from equipment manufacturers and the Institute for Diesel and Gas Turbine Engineers (IDGTE), and reports provided by financial and technical assistance agencies that support EPUES, the CPT has developed a general technical and nontechnical data base reflecting the overall operations of more than 60 diesel power plants worldwide.[3] The analysis of these diesel power plants provided a clear view of some of the most important functions of the utilities operating them. In this Report, the reader should understand that the lessons learned apply to diesel plants and only to utilities when it was clear that problems identified at diesel plants clearly reflected problems at the utility level. The reader will also discover from the Report that most problems at the utility level have direct and observable effects on the operation of its diesel power plants.

This Report discusses the causes of poor performance and makes recommendations for improving performance and for further study of certain problems. The Executive Summary outlines the study's findings and lessons learned, and presents the recommendations in Chapter 10, Recommendations and Outstanding Questions. Chapters 1 through 10 present the findings, lessons learned, and recommendations for a specific area of inquiry. In all, the Report analyzes 10 essential factors contributing to a sustainable, efficient diesel power project: autonomy; clear, non-conflicting objectives; good top management; adequate human resources; institutionalized training; adequate technical resources; access to foreign exchange; financial transparency; sufficient revenues; and appropriate donor policies and procedures. EPUES analysis suggests that poor performance can be explained by deficiencies in any of these 10 factors. Most importantly, the identification and analysis of these 10 factors suggests strategies for improving the performance of specific diesel power plants.

The validity of EPUES analysis rests heavily on the reliability of data collected by the missions. In fact, EPUES found some data inconsistent, missing, or simply unacceptable. Although data problems do exist, much of the data was acceptable, and considerable effort has been made to ensure its accuracy.[4]

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3 The CPT has collected and analyzed more than 200 documents relating to diesel power plant efficiency and sustainable operation, which are organized as a library for the CPT, EPUES consultants, and other interested individuals.

4 For example, mission teams spot-checked monthly diesel power plant data collected at the powerhouse against daily logs. It was unusual for a mission to find uncompleted log sheets, although maintenance and outage records were often missing or incomplete, especially in developing countries in Africa. Data was collected by engine number over a multiyear period (usually three years), so that inconsistencies became apparent by looking carefully at the operating history of each machine. Cost and quantity data on fuel, lube oil,

The chapters refer to various plant and utility samples. Plant samples consist of sets of diesel power plant data for specified years. The data set consists of fourteen inputs such as plant location, year of operation, plant size, plant output, fuel consumption, and so forth. The largest sample contains data for 63 diesel plants in 27 countries over several years, and has more than 139 data sets. Unfortunately, not all data inputs are known for every plant, so plant samples vary throughout the Report depending on the issue under discussion. In Chapter 1, for example, the largest sample of diesel plants was restricted to include plant data only from developing countries and the years 1987 and 1988. Plant samples are defined in each chapter or an associated annex.

Utility samples also vary throughout the Report. Chapter 4 discusses total system power losses for a sample of 30 utilities. When data on nontechnical power losses are cited, however, the sample is reduced to those six utilities from which such loss data were available. Like plant samples, utility samples are defined in the chapters or associated annexes.

The missions also collected nontechnical information, which is stored in a separate database.[5] This information is derived from analysis of the human functions in each utility, such as management quality, autonomy of operation, and training. Again, EPUES's objective was to isolate factors that could explain the poor operation of the diesel plants. As noted in chapters 1 through 9, qualitative investigations of personnel and their functions in the utility led EPUES to identify the 10 explanatory factors listed above. Technical data allowed EPUES to assess the efficiency of the diesel plants, and qualitative information allowed EPUES to relate low efficiency to possible explanatory factors. In Chapter 1, for example, EPUES notes a strong correlation

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and spare parts were collected at utility headquarters and cross-checked with power plant data. Information on spare parts usage and costs was particularly sparse and difficult to check. Certain manufacturers were able to provide records of spare parts sold by engine number, but the teams could not ascertain whether the parts had been used. Maintenance costs were, in general, unrecorded and difficult to confirm because of poor or nonexistent cost accounting.

Cost of capital equipment and associated structures was also difficult to collect. EPUES had little luck separating out capital costs from utility investment budgets, which were often confusing or misleading due to poor accounting procedures, off-budget investments made with donor grants, and a widespread tendency for utilities to lump investments in diesel equipment with equipment of other types.

5 With respect to the collection of information on diesel utility management, training, and the other human-related functions, EPUES relied heavily on the judgment of mission team members. Each team used a standard set of yes/no questions but was encouraged to pursue problem areas or interesting lines of investigation. In some cases, local consultants were used, and utility counterparts were always part of the team. This approach provided a reasonably accurate impression of power plant operations and a reasonably uniform data base. The weakest investigation of human activities concerned consumers' attitudes toward the utility, which often have an impact on diesel power plant operation. EPUES was able to collect only anecdotal evidence on the beneficiary side of the power sector.

between inefficient operation and low autonomy, and concludes that a prerequisite to efficient operation is autonomy.

Chapter 10 synthesizes and expands upon the recommendations in chapters 1 through 9. The most important outstanding questions are also identified in Chapter 10.

The Report identifies the 28 African countries by the letters A through CC (there is no Country I). The 8 countries of Asia, the Pacific, and the Americas are identified by the letters DD through LL (there is no Country II).

EXECUTIVE SUMMARY

0.1 The Core Report summarizes a two-year study of the major problems found in diesel power plants in 17 developing countries, explores in some detail the causes of these problems, and suggests possible solutions. Of the 10 chapters, 1 addresses technical issues, 8 explore the human-related functions and policies needed for utility operation, and the final chapter summarizes the Report's recommendations. The Report focuses primarily on humans rather than technology, because very few problems with technology were encountered during the study. On the other hand, the study found substantial problems associated with the functions and policies controlled by government and utility personnel.

0.2 Using a measure called "Best Practices Plant Efficiency" (BPPE), EPUES found that diesel plant efficiency can be quantified, but not uniquely. BPPE quantifies efficiency using a set of technical inputs, their associated prices, and the plant's energy output. If a utility has more than one diesel plant, the utility's efficiency is the average of all its diesel plant efficiencies. EPUES has used BPPE as a tool to identify causes of inefficiency.

Major Problems

0.3 Compared with diesel power plants in industrialized countries, a typical diesel plant investigated during the study is characterized by low production, low revenues, high costs, and short engine lifetimes. Few of these plants were financially viable. Electricity tariffs were generally too low; often even operating costs of generation were not covered by revenues.[1] This problem was compounded by inefficient revenue collection systems. Government agencies often did not pay their bills, or they made payments very late.[2]

0.4 The quality of electricity output was often low. Many unscheduled power outages occurred, and unacceptable voltage fluctuations were common, forcing industrial users to provide their own electricity supply.[3]

0.5 In many instances, waste oil was dumped near the plants, causing local pollution problems and longer-term serious ground water contamination. In a few cases, chemically treated or contaminated cooling water contributed to the environmental degradation.[4]

0.6 Inputs to the power plant were frequently too high. The number of labor hours per unit of production was typically 10 to 15 hours per MWh, which compares poorly with 0.5 to 4.0 hours per MWh in the UK and the US. The number of unskilled workers was especially high.[5]

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1 See Chapter 3, Economic and Financial Issues. From a representative sample of the 22 countries investigated, the average tariff (total billings divided by total kWh sold) was \$0.070/kWh (constant 1989 US\$), whereas the total operating cost, including fixed capital costs, was \$0.147/kWh (constant 1989 US\$).

2 See Chapter 4, Financial Management.

3 See Chapter 7, Technical Issues.

4 See Chapter 8, Environmental Issues.

5 See Chapter 5, Manpower.

0.7 Engine efficiency with respect to both fuel oil and lube oil consumption was often lower than manufacturers' expectations. Fuel consumption was 30 to 40 percent higher than anticipated. Engine maintenance was usually poor, making engine efficiency heavily dependent on age. Nonstandardization also caused maintenance problems.[6] In some cases, computed efficiencies were so poor that theft of fuel and lube oil were the only plausible explanation. Low fuel efficiency seriously damaged the plant's financial performance, because the fuel cost is typically 70 percent of the total variable cost of operation.

0.8 In many instances, engines lasted only a fraction of their normal lifetime, which greatly increased the plant's capital cost per unit of production. In several countries, average lifetimes were as low as 5 to 10 years.[7]

0.9 The typical power plant production cost, including capital costs, was $0.147 (1989 $) per kWh. By percentages, fuel, lube oil, labor, materials, and capital costs were 49.7, 3.7, 6.3, 5.4, and 35 percent, respectively. If only variable costs are considered, then fuel, lube oil, labor, and materials costs were 67.1, 5.0, 8.5, and 7.3 percent, respectively.

Identifying Possible Causes of Major Problems

0.10 Utility operating problems arise from deep-seated causes. Some are easily recognized--lack of foreign exchange to buy spare parts, for example--but are difficult to address nonetheless. Others, such as lack of autonomy, are less obvious. Many of the causes appear interdependent. The methodology of the study was chosen to help identify causes of major problems quantitatively by correlating sets of possible causal factors with power plant efficiency. A general efficiency measure was devised that allowed comparison of diesel plant operation intra- and inter-country. The initial choice of possible causal factors was based on qualitative analysis of the many mission reports and other documents relating to the study. Four broad problem areas were analyzed: (1) government-utility relationships, (2) internal utility institutional and management problems, (3) power plant operating problems, and (4) donor agency policies and procedures.[8]

0.11 With respect to government-utility relationships, the conclusion was that autonomy is a key factor in determining a utility's operating efficiency.[9] Many developing countries have foreign exchange restrictions that interfere with the timely ordering of spare parts. This problem can severely impair operating efficiency. Many governments impose contradictory objectives, such as low tariffs and a simultaneous requirement to be profitable. They also set noncompetitive wage scales, interfere in hiring decisions, and intervene in the utility's daily operations. The study focused on nine attributes of the government-utility relationship to determine the degree to which a utility is operating autonomously.

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6 See Chapter 7, Technical Issues.

7 See Chapter 3, Economic and Financial Issues.

8 Throughout the Core Report, the phrase "donor agency" refers to the technical assistance or financial aid agencies of developed countries.

9 See Chapter 1, Institutional Issues: Government and Utility Interactions.

0.12 With respect to utility and plant management, the study found few institutionalized training programs, many unstructured on-the-job training programs, an almost total lack of training for middle managers, and a host of other training problems. There were also other associated problems. Revenue collection was generally poorly organized and monitored. Turnover of skilled manpower was too high. Manpower planning was often weak. Planning, with the exception of new project construction, was nearly nonexistent.

0.13 Utility managers, especially at the middle-management and diesel plant levels, have not set up adequate information systems. This problem is pervasive: (a) many plants have inadequate records,[10] (b) labor input is not adequately monitored, (c) billing and collection systems are inadequate, (d) inventory information is nonexistent, and (e) financial information is usually not available at the plant level and is often not available in a coherent form at the utility level. Current cost accounting is not generally used, and historical cost accounting is useless in many countries because of rapid inflation.

0.14 With respect to donor policies and procedures, the study found weaknesses in project appraisals. It appeared that manpower and training functions, utility autonomy, management controls, and other basic human-related activities were not thoroughly appraised before projects were funded. However, the study based its observations on donor-funded projects and did not investigate agency project appraisal documents directly. It was very clear that donors often made over optimistic assumptions about load growth. Tied-aid resulted in a lack of standardization in many diesel plants, which in turn resulted in operational and economic inefficiencies. Donor appraisal teams often did not include the costs of nonstandardization in their project appraisals.[11] Finally, the study found little evidence of project monitoring by donor agencies. Donor agencies focused primarily on the installation of hardware and the construction of appurtenant structures, on training during the construction and commissioning periods, and on other short-term programs. In general, assistance programs were not geared to give utility managers clear signals about maintaining the value of capital equipment.

0.15 The study has identified ten causal human factors of poor diesel plant performance: (1) lack of autonomy, (2) conflicting utility objectives, (3) lack of management accountability, (4) insufficient training, (5) unavailability of internal utility resources, (6) poor management quality, (7) lack of financial transparency, (8) insufficient revenues, (9) lack of timely access to foreign exchange, and (10) inappropriate donor policies and procedures. In the Report, qualitative and semi-quantitative arguments are made for labeling these 10 factors as explanatory variables in varying degrees of poor diesel plant performance, and of poor power plant performance in general. It should be noted that in diesel plants, technology itself is not a cause of poor performance.

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10 Technical operating records were usually good. Maintenance records and cost records were often incomplete.

11 See Chapter 7, Technical Issues, paragraph 7.17.

Recommendations

0.16 EPUES has concluded that government interference in all utility operations must be eliminated before efficient and sustainable performance is possible. This conclusion is based on the analysis in Chapter 1, which strongly suggests that increasing autonomy increases efficiency. One could take this suggestion to the extreme and recommend that all utilities be privatized. However, the national utilities studied by EPUES are monopolies; and, if these utilities are privatized, then governments must become efficient regulators. Thus, although EPUES recommends that governments and utilities focus primary attention on increasing autonomy, it stresses that it is equally important for governments to hold utilities accountable for their performance. Donors appraising all diesel power projects should evaluate autonomy and should tie aid to the precondition of increasing autonomy where that is necessary.[12]

0.17 On the basis of this diesel study, EPUES recommends that national utilities work out nonconflicting objectives with their governments. The most frequent conflict noted in this study arose from governments demanding that their utilities use their diesel plants to carry out socially desirable but highly unprofitable rural electrification programs, while also expecting those utilities to operate profitably. EPUES noted that tariffs were frequently too low to cross-subsidize such programs, and the study found little evidence that government mechanisms designed to reimburse utilities for losses actually did so. EPUES did not consider possibly more cost-effective rural electrification programs, including those using other types of plants, but recommends that utilities and donors seriously address this issue.

0.18 EPUES also concluded that a major problem for most utilities was the lack of hard currency. Donors have tried to ameliorate this problem through several innovative programs.[13] For most utilities, the problem remains urgent and often forces diesel plants to operate continually in a crisis mode. Insufficient access to foreign exchange especially hurts maintenance, which depends on the timely procurement of spare parts. EPUES recommends that donors initiate programs facilitating the timely procurement of spare parts.[14]

0.19 Lack of foreign exchange often induces governments and utilities to create complex procedures for equitably disbursing foreign exchange. These procedures themselves create uncertainty, decrease planning capabilities, and result in utility inefficiency. Utilities should simplify these procedures internally as much as possible, or at least make existing procedures transparent. Donors should appraise the complexity of the procurement process and support improvements when necessary. If the system is essentially opaque, then donors and utilities should set up alternative procurement procedures.

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12 A rough methodology for appraising autonomy is given in Chapter 1. EPUES is now developing this methodology in more detail.

13 See Chapter 4, Financial Management.

14 See Chapter 4, Financial Management, for a discussion of this problem.

0.20 Because EPUES found that many utility managers do not appreciate the capital value of diesel equipment, it recommends that donor agencies require governments to on-lend aid for power projects.[15] EPUES also recommends that utilities require sufficient information from all types of power plants to determine their technical and financial status. This recommendation implies that at the power plant level, cost-based accounting systems should be used. It is also very important for utility management to maintain an active feedback system, which gives plant managers the technical and financial information they need to properly assess their performance.

0.21 EPUES found training programs to be inadequate for diesel machine operators through the middle management level. EPUES has concluded that utilities must have an institutionalized training program. Because local institutionalized training may be economically infeasible in smaller countries, EPUES recommends an investigation of alternative structures such as regional training programs.[16] EPUES also recommends that donors fully appraise existing training programs and allocate funding in aid projects specifically for institutionalized training.[17]

0.22 EPUES recommends the institutionalization of manpower planning. Donors should appraise manpower planning programs and incorporate funding into aid projects that is specifically for institutionalizing manpower planning.

0.23 Finally, EPUES recommends that donors include the costs of nonstandardization and environment controls in their appraisals of all diesel power projects, and that they realistically estimate equipment lifetimes, operating costs, capital costs, and other financial variables.

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15 See Chapter 3, Economic and Financial Issues, and Chapter 9, Donor Policies and Procedures, for discussions of on-lending issues.

16 See Chapter 6, Annex 1 for a discussion of regional training.

17 EPUES is working on guidelines for appraising training programs. See Chapter 6, Training, for further discussion.

CHAPTER 1. INSTITUTIONAL ISSUES: GOVERNMENT AND UTILITY INTERACTIONS.

1.1 In its missions to 60 diesel electric power plants in 17 developing countries, EPUES found 10 variables affecting sustainable and efficient plant operations. One of the most critical had to do with institutional issues between government agencies and national utilities. This chapter discusses the impact of institutional issues on the efficient long-term operation of diesel power plants.

Findings

1.2. Most power utilities in developing countries are state-owned enterprises (SOEs); of the more than 20 utilities EPUES studied in detail, all but one are state-owned in whole or in part. These utilities are not autonomous or have limited autonomy, and few are accountable for the quality of their operations. Most have defined objectives, but frequently these objectives conflict with each other.

1.3 The World Bank has already explored SOE management and reform in some detail [Shirley, 1983, 1989], and has identified five conditions that can help improve the efficiency of SOE operations. Government must: (a) set clear and attainable objectives linked to performance, (b) maintain control without undue interference, (c) hold managers accountable for results, (d) appoint capable managers or assure that managers with appropriate skills are available, and (e) reward managers for good performance and sanction them for poor performance. Conditions (a) through (c) enable the SOEs to be more autonomous while remaining under government control; conditions (d) and (e) are criteria for imposing efficiency in an autonomous environment.

1.4 The EPUES team also found two other conditions necessary for autonomy. First, a utility must have timely access to foreign exchange in order to buy critical parts and materials for its diesel plants. The operations of many utilities in this study suffer because of their inability to acquire and spend foreign exchange.

1.5 Second, all but one of the utilities operate under tariffs set by government. EPUES found that when a tariff is too low, a utility can neither carry on its business in local currency, since it lacks cash flow, nor buy foreign currency with the local currency it has earned. Thus, government tariff policy imposes a very strong restriction on a utility's autonomy.[1]

1 This problem has been extensively discussed in World Bank appraisal and evaluation reports on all types of power sector loans.

Table 1: Questions that Can Determine a Utility's Level of Autonomy.

1.	OBJ:	Does the utility have clear objectives?
2.	BOD:	Does the utility have a Board of Directors with nongovernmental members?
3.	SAL:	Does the utility control its employees' salaries?
4.	H&F:	Can the utility independently hire and fire employees?
5.	INC:	Can the utility initiate incentives for its employees?
6.	CTRL:	Are daily operations of the utility insulated from external political pressures?
7.	ACCT:	Is management held accountable for its performance?
8.	FX:	Does the utility have sufficient foreign exchange to buy spare parts when they are needed?
9.	$:	Are tariffs sufficient to produce revenues greater than or equal to operating costs?

Note: See paragraphs 1.9 to 1.15 for explanation of questions.

1.6 These two additional conditions can be stated as: (f) access to adequate foreign exchange,[2] and (g) a tariff policy that provides sufficient cash flow to cover operating costs on a continuous basis.[3,4]

1.7 The EPUES missions reported that many utilities are autonomous in some ways and not in others. EPUES has developed a way to measure overall autonomy with the set of nine yes/no questions shown in Table 1. Nine "yes" answers indicate that the autonomy of the utility is very high. If all answers are "no," the utility's autonomy is very low. Private utilities ranked as most autonomous. These questions were derived from the seven conditions (a-g) above. Table 1 expands on condition (b), which specifically addresses whether a manager can make operating decisions without government intervention. These decisions concern issues in which government has varying levels of interest. Some managers have autonomy to hire and fire staff as well as to make daily operating decisions; others do not have autonomy even in daily operating decisions. The levels of autonomy ratings for 16 utilities are listed in Table 2.

1.8 All utilities are legally SOEs except utilities A and B in Country GG and Utility A in Country LL. Utility A in Country D is legally a parastatal but is unique in that it is half owned by the private sector and is not controlled by the national utility. Of the 15 utilities ranked for level of autonomy, the 3 private utilities and the mixed-ownership utility are the most autonomous, with

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2 Condition (f) does not imply that electric utilities require a special mechanism for foreign exchange. Most utilities in the sample used the same procedure for foreign exchange as other SOEs.

3 Condition (g) does not imply that governments should not subsidize electrical rates. EPUES has strong indications, however, that efficiency is very poor in utilities where revenues are insufficient to cover operating costs. Condition (g) assumes that the technical and commercial operations of the utility are reasonably efficient, but this is not always the case. For example, the tariff in Country A was sufficient to provide a reasonable rate of return, but the commercial operation of the national utility was so poor that it suffered heavy losses.

4 The question of capital recovery is covered in Chapter 3, Economic and Financial Issues.

ranks of 9, 9, 8, and 8, respectively. Countries E, F, and G rank the lowest (1, 1, and 0). The utilities in countries H and CC also rank very low (2 and 2).

1.9 The relationship of autonomy to efficiency for the 15 utilities is shown in Table 2.[5] The measure of efficiency, "Best Practices Plant Efficiency," (BPPE), quantifies efficiency using a set of technical inputs, their associated prices, and the plant's energy output. If a utility has more than one diesel power plant, the utility's efficiency is taken to be the average of its power plant efficiencies. (BPPE is explained in detail in Annex 2.)

TABLE 2: A Comparison of Level of Autonomy with Best Practices Plant Efficiency (BPPE).

Utility	Country	Level of Autonomy	BPPE
A	H	2	0.13
A	M	3	0.29[2]
A	E	1	0.43
A	F	1	0.46
B	D	4	0.46
A	CC	2	0.47
A	LL	8	0.50
A	J	5	0.52
B	LL	3	0.54
A	DD	3	0.61[1]
A	D	8	0.62
A	L	5	0.63[2]
B	GG	9	0.67
A	A	6	0.79
A	GG	9	1.00

1 One power plant. Efficiencies at three others are similar.
2 Average of two power plant efficiencies.

5 Many of the "yes/no" answers that make up the autonomy ratings in Table 2 require further research to reconcile conflicting information. These answers apply to the time of the mission or the years just before it. In some cases, a utility was in the process of rehabilitating equipment and personnel at its diesel plant(s). In countries A and E, completely new management systems had just been or were about to be instituted. Table 2 is therefore clearly time-dependent. A comparison of mission reports and Bank Staff Appraisal Reports suggests that most governments have moved toward giving their parastatals more autonomy. Given the political shifts in Eastern Europe and the obvious impact of such changes on African governments, it seems likely that parastatal utilities will have greater autonomy in the future.

1.10 The rankings in Table 2 are based on actual utility operations. For the question concerning objectives (OBJ), EPUES missions asked utility and diesel power plant managers whether they had clearly defined and nonconflicting objectives. Most managers said their objectives were clear but conflicting. A common example was a mandate to set a rate of return on investment, and at the same time to promote unprofitable rural electrification programs (i.e., Country DD).

1.11 The question on salaries (SAL) classifies the utilities according to whether employee salaries are set by a national civil service salary scale. If the utility must adhere to such a scale, then the answer is "no," the utility does not control its employees' salaries (i.e., the national utility in Country D). Even when employees are not considered civil servants, management must sometimes ask the national government to approve salary adjustments (i.e., Country A). In these cases, the answer is also "no."

1.12 A similar situation exists for hiring and firing (H&F). Many EPUES missions found that utilities are heavily overstaffed (especially with unskilled workers), which indicates that the utility does not control its own hiring and firing. This function is often in principle (even legally) under the purview of utility management, but in reality is politically controlled (i.e., countries E, H, M, CC, and LL).

1.13 Government intervention in the daily affairs of the utility (CTRL) is the most costly form of interference. Several EPUES missions saw diesel engines that had been destroyed because of political pressure on managers to continue operating engines that were damaged, (i.e., countries A, D, and G).

1.14 Accountability is shown in the "ACCT" column. EPUES found that managers of private utilities were accountable to utility shareholders. Managers of Utility A in Country A were accountable under a performance contract to the government. The managers of the parastatal utility in Country D were accountable only to the private owners.

1.15 The FX column concerns a diesel plant manager's access to foreign exchange; a "no" answer means access is insufficient. Complaints about the lack of foreign exchange for spare parts is not sufficient for a "no" answer.

1.16 Finally, the "$" column, which asks whether revenues are sufficient to cover operating costs, evaluates government tariff policy. If revenues are low because of poor commercial operations, and the utility's tariff is sufficient to cover costs, the answer will be "yes." A complete list of level of autonomy indicators is in Annex 1.

1.17 EPUES assumes, based on existing evidence, that the efficiency of a utility correlates strongly with its autonomy.[6] Like autonomy, efficiency is not uniquely defined but depends on a spectrum of technical, economic, and financial performance measures. Partial indicators, such as cost per kilowatt-hour of production or day's receivables, can be quantified, but they can be quite misleading. EPUES has used BPPE as an indication of utility efficiency.

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6 EPUES is in the process of correlating efficiency with such specific variables as autonomy, good management, and incentive systems.

1.18 Table 2 compares Level of Autonomy wi h BPPE for the 15-utility sample. All Level of Autonomy and BPPE ratings are for 1987 or 1988.

1.19 Utility A in Country GG, a small, privately owned and operated diesel utility that has the highest relative efficiency, is the first comparator. It has no major problems with autonomy, management, training, spare parts, fuel availability, or availability of hard currency.

1.20 Utility B in Country GG, the second comparator, is an isolated rural diesel plant. It has some problems with availability of qualified maintenance personnel and fuel, but its efficiency is low primarily because of high fuel costs and older, less efficient equipment.

1.21 The very low efficiency in Country M is caused by the under use of new machines, lack of autonomy, and lack of trained personnel. On-site expatriate technicians do much to keep the diesel plants functioning.[7] One plant manager has been jailed several times for attempting to force payments from government agencies by disconnecting their electricity.

1.22 The utility in Country A has relatively high efficiency. It was managed for five years by expatriates who took over line management positions in 1983. Efficiency then increased dramatically but fell somewhat in 1989 after their departure. The two EPUES missions to this utility clearly saw the difficulties the expatriates faced in isolating the utility from government interference and saw a clear increase in government controls after their departure. Despite a performance contract, this utility suffered severely from lack of good management.

1.23 Levels of autonomy and associated efficiencies shown in Table 2 have a reasonably high degree of correlation, even though other critical explanatory variables, such as management quality, have not yet been included.[8] The efficiency ratings suggest that utilities with very low autonomy are much less efficient than utilities with very high autonomy. More importantly, no utility with low autonomy has a high efficiency.

Lessons Learned

1.24 EPUES has concluded that (a) state owned utilities in the sample have low levels of autonomy, and (b) utilities with low autonomy have low efficiency. Both are the rule in developing countries. EPUES is now in the process of demonstrating quantitively that autonomy is an important explanatory variable of efficiency.

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7 The expatriates have left the plants recently due to political unrest and associated safety problems.

8 The R value from a standard regression analysis is 0.81.

1.25 Utilities can have high autonomy and low efficiency because of poor management, lack of proper training, poor employee incentives, and so forth. It is probably also true that utilities with high efficiency will be highly autonomous, but it is not yet possible quantitatively to draw this conclusion from the findings. Nevertheless, based on semi-quantitative analysis, EPUES believes that private power utilities are significantly more efficient than public power utilities in developing countries.[9]

1.26 An important lesson is that problems that appea. .e caused by lack of spare parts and poor maintenance most often originate from a fundamental lack of autonomy. Compare, for example, the cost factors that compose the total cost of operation per MWh for the very efficient private Utility A in Country GG and the central diesel plant in Country F, as shown in Table 3. Clearly, the fuel and capital factors are far more costly in Country F.[10] Although both utilities pay comparable prices for fuel and equipment, the EPUES mission reported that the fuel efficiency of the diesels in Country F is very low and that the generating equipment is being destroyed by bad maintenance. The principal problem is not the unavailability of trained maintenance staff or lack of spare parts but rather government salary restrictions and hiring policies that prevent the utility from hiring qualified staff.[11]

Table 3: A Comparison of Cost Factors for Country GG*and Country F.

Cost Factor	Cost ($MWH)		Percentage	
	Country GG	Country F	Country GG	Country F
Fuel	$40.60	$ 91.49	62.4%	52.0%
Lube	$ 0.55	$ 3.88	0.8%	2.2%
Labor	$ 6.24	$ 9.69	9.6%	5.5%
Materials	$ 5.50	$ 11.49	8.4%	6.5%
Capital	$11.90	$ 59.32	18.3%	33.7%
Total	**$65.09**	**$175.87**	**100%**	**100%**

* Utility A (private).

9 EPUES has compared efficiency ratings for 32 utilities in developing and industrialized countries. On average, the private and highly autonomous utilities are more efficient than state-owned utilities, but some private utilities have efficiency ratings below those of some state-owned utilities.

10 Each cost factor except capital cost is calculated by multiplying a quantity by an associated price. The fuel factor, for example, is computed by multiplying annual per liter cost of fuel by the annual fuel consumption per MWh of the plant's diesel engines. The capital cost factor accounts for the annual interest costs and depreciation of diesel equipment.

11 These comparisons can be very informative. For example, in other comparisons of this type, the labor component was excessively high, strongly suggesting the existence of a patronage system. In several cases, the lube oil component was very high, indicating the existence of a black market in lube oil.

Recommendations

1.27 The most critical outstanding question is: How can utility autonomy be increased? It is a question for financing and technical assistance agencies, for governments, and for the utilities themselves. Increasing the level of autonomy often involves structural adjustments throughout the government and such associated macroeconomic issues as restructuring salary levels throughout the government. Why, for example, should the government of Country D allow its national utility to set its own salaries, when more than 100 other parastatals in the country cannot? Some ways to increase autonomy may be management contracting, leasing, performance contracts, and full privatization.

1.28 EPUES makes two recommendations. First, donors should assess during project appraisal the level of autonomy of the recipient utility; and second, if the utility has a low level of autonomy, donors should attempt to increase the utility's autonomy before providing assistance. Annex 3 contains more discussion of strategies for increasing autonomy.

CHAPTER 2. INSTITUTIONAL ISSUES: INTERNAL RELATIONS.

2.1 EPUES mission studies of diesel plants have clearly shown that the relationship between an individual power plant and its parent utility is determined by the role the power plant plays in the supply of power. Where diesel generation is important to overall supply, diesel plants are closely integrated into the utility; where they make only a marginal contribution, however, or are mainly stand-alone systems serving small towns or rural areas, they tend to operate in an institutional vacuum. The plant's importance within the utility system determines whether it will get an equitable share of the utility's financial, human, and material resources.

2.2 Relations between utilities and all types of power plants cover a range of issues, such as manpower and spare parts management. These issues, as they relate to diesel plants, are discussed in more detail in other chapters. This section will identify ways in which distinct institutional arrangements can affect any plant's operational efficiency and sustainability.

Findings

2.3 A consistent trend in many EPUES mission studies is that even where diesel plants are critical to national power supply, they had a lower priority than other sources of power. In Country M prior to the ongoing rehabilitation program, for example, even though diesel was the primary source of power, the oil-fired steam plant in the capital received more attention and scarce resources than two more rapidly deteriorating units. In Country D, although rural towns and villages were totally dependent on diesel, few resources were allocated to the diesel stations, and utility managers saw the diesel plants as a necessary evil.

2.4 Despite the fact that in many countries diesel power is the most cost-effective way to meet short- and medium-term increases in demand and to develop rural electricity supplies, utilities gave diesel plants low priority when planning power supplies. Corporate and project planning departments tended to focus on larger scale investments such as new hydro and steam plants, perceived as more likely to get financial aid from multilateral agencies. Furthermore, because job satisfaction, working conditions, and living arrangements were more favorable in the larger thermal and hydro power stations, experienced power engineers tended to view diesel plants as lower in status in terms of career development, and they preferred to be stationed at major hydro or thermal plants. This was not true, however, for small private diesel plants, where job satisfaction and working conditions were better than at government-run plants.

Organizational Relationships

2.5 Diesel plants tend to be organized differently from plants that have higher status within the utility.

2.6 Activities in most utilities were divided into two main categories: technical, which incorporated generation, transmission, and distribution; and nontechnical, which covered finance, administration, and personnel. There were variations in the detailed organizational structure depending on the size of the utility, but in the technical function, most utilities had generation or production departments responsible for the supply of power, with separate transmission and distribution departments. A diesel plant that made a significant contribution to overall supply was likely to be linked with the utility through the utility's generation department. This was the case in

Country L, for example, where the power station manager reported to the generation manager, and the generation department had overall responsibility for the power stations.

2.7 Where a diesel plant was marginal, however--a standby or peak load facility connected to a grid, or a plant in a rural area unconnected to a grid--it was likely to be linked to the utility either through distribution or a separate rural electrification department. In Country D, for example, while the hydro station managers reported to the head office production manager, diesel plants fell under a central directorate, and the managers of those plants were responsible to regional and zonal distribution managers. In Country M, the diesel plants outside the capital were part of a rural electrification division and had little contact with the production department at head office. Moreover, because of inadequate staffing at the division, the diesel plants operated almost as independent utilities.

2.8 In many developing countries, EPUES found that the distances between the diesel power plants and the utility's head office were vast and communications poor, resulting in only minimal technical supervision from the head office. In Country M, for example, one plant was more than 500 kilometers from the capital, and if not for the expatriate technician's radio link, there would have been no communication.

Technical Relationships

2.9 EPUES found that power stations linked to utility generation departments have greater access to technical supervision, a higher priority for manpower, and more spare parts and other resources. Major construction or rehabilitation of large hydro or thermal stations was commonly overseen by the utility's projects department, which had engineers experienced in project design and management. Projects departments rarely became involved in diesel projects, however. In Country M, for example, the utility's project department was only marginally involved in two diesel projects, since they were projects of the rural electrification department. This department provided most of the required work force for civil and electromechanical construction. In Country D, despite the fact that a multimillion dollar rehabilitation project covered eleven diesel stations, the projects department was only marginally involved.

2.10 Any organization that carries out a range of activities in different locations has problems with local management, supervision, and control. A utility cannot station senior management personnel at every location; and when a plant is part of a regional structure, or is too small to justify a full complement of managerial and technical personnel, it will inevitably have local managers who may not have the necessary technical background.

2.11 EPUES found that many diesel plants were inadequately staffed at all levels. The utilities could partially compensate for this by providing regular technical supervision. In most utilities this did not happen, however, and the diesel plants suffered not only from an absence of adequate staff to operate and maintain them but also from neglect by the utilities' head offices. In Country D, although there were more than 20 diesel power plants, the diesel generation section of the production department was staffed with only three engineers, who rarely visited the plants. The same situation existed in Country M, where the diesel plants were rarely inspected.

2.12 The diesel power stations were hurt over the long term by the absence of regular technical inspections, checks to ensure proper maintenance, and training of staff. Managers were left very much on their own to operate and maintain plants, resulting in even newly-commissioned plants deteriorating rapidly and requiring rehabilitation within five to six years. That is what happened in Country D, for example.

2.13 This neglect also affected the morale and interest of diesel plant management and staff, who responded to the perceived lack of concern on the part of the utility management by making little effort to write conscientious technical reports. These reports are intended to cover the main power plant operations: fuel and oil consumption, power supplied, breakdowns, maintenance activity, and so on. In some cases, the manner of reporting and the forms to fill out had not changed for more than 20 years.

2.14 Even where these technical reports were completed conscientiously by plant managers, the reports were rarely analyzed (or even filed properly) at the utility's head office, and the managers received little or no feedback. This further demoralized the managers, who in some cases no longer even bothered to complete their reports.

2.15 EPUES missions often found that technical information either was not available at the diesel plant or was written in a language not understood by the personnel. In Country CC, for example, the manufacturers' operational manuals were written in English and German, which the staff did not understand They therefore used drawings in spare parts catalogues to identify problems and carry out maintenance. This was a typical problem. Although responsibility for providing appropriate manuals, operating instructions, and maintenance schedules rested with plant manufacturers and suppliers, the utilities should have ensured that the power plants were supplied with appropriate guides for operation and maintenance.

2.16 It is clear from the EPUES studies that routine and preventative maintenance is the key to long-term operational efficiency of diesel power plants. If maintenance were part of the operational philosophy, and if it were preplanned and prescheduled, the need for parts could be anticipated. At the parastatal in Country D, for example, some of the diesel units have operated for more than 20 years without serious problems because of the mine's maintenance schedules. EPUES found very few cases, however, where a utility had annual maintenance schedules for diesel plants. Diesel plants were also given a very low priority in the allocation of spare parts. Requests for spares had to be funneled through the regional and distribution structure, across to the generation department, and then to the stores section within the finance directorate. In some cases, it took 6 to 12 months before a plant could obtain even the most basic spares, such as a filter.

2.17 It is unlikely, however, that adequate spare parts will make a significant impact on diesel plant efficiency until the utilities come to acknowledge the critical role of maintenance in the long-term sustainability of these plants.

Financial Relationships

2.18 Most of the diesel plants were located in predominantly rural areas, where the cost of generation was subsidized because power was thought to improve the quality of life. In most countries, the utility provided the subsidy, even though it operated under statutes providing for cost recovery. None of the utilities was free to establish its own tariffs, and no power plant had the authority to impose a differential tariff based on the cost of generation. Moreover, few if any diesel plant managers were aware of the cost of generation, or cared whether or not the plant was financially viable. In practice, therefore, financial considerations were by and large irrelevant, beyond the need for enough funds to keep the plant running.

2.19 Excluding Country L, the utilities were in dire financial straits and consequently subjected their diesel plants to tight budgetary control In addition to difficulties caused by national tariff and foreign exchange policies, some of the utility's own financial management practices, such as lack of comprehensive financial management, budgeting, and accounting procedures, at both the utility and diesel plant level, contributed to its decline. This, in turn, affected the operation of the diesel plants.

2.20 Few of the diesel plants had budgetary control systems that provided for either recurring costs or capital expenditures. EPUES found it nearly impossible to obtain financial information on operation and maintenance because most utilities did not have a cost center system of budgeting and expenditure control. Consequently, diesel plant managers had no idea what it cost to operate their plants and were working on the basis of month-to-month expenditure.

2.21 Few diesel plant managers had access to their own bank accounts, and had to request funds from regional or head offices. This often caused essential maintenance work to be abandoned. Even where local managers did have authority to spend funds, the limits were so low as to make this authority meaningless. The same limitations applied to purchase orders and requisitions, which had to be checked and counter-authorized by more senior management.

2.22 One reason for centralized financial control is to limit the potential for misappropriation and other illegalities. In a few of the countries, however, the diesel plant was also the administrative center for a local distribution system, responsible for both generation and distribution, and therefore had control of its own finances. This was the case in Country M, for example, where two diesel plants were totally self-sufficient and financially independent of the utility. They were required to meet all their own recurrent costs, including fuel supplies.

2.23 This arrangement, however, was the exception, and derived from a fully funded, integrated diesel generation/distribution project. Moreover, three years after the project was commissioned, it continued to benefit from expatriate technical assistance. Even here, however, the plants did not use proper budgets and expenditure estimates, and also had cash flow problems. Nearly every month, the managers had to mount a collection drive among consumers to raise money for fuel.

2.24 Despite the critical financial state of most utilities, many had huge amounts outstanding in accounts receivable. Debts exceeding 100 and even 200 days were the norm rather than the exception, which caused serious cash flow problems in local currency on top of the shortage of foreign exchange. Consequently, the diesel plants were continually cash starved, and in some cases had difficulties meeting such basic expenditures as wages and salaries. Thus, when minor repairs or preventive maintenance were needed, local managers could not buy cleaning materials or replace tools.

Manpower Relationships

2.25 Manning and staffing issues are addressed in detail in the Manpower chapter, which identifies lack of appropriate staffing as a critical factor in the operational inefficiency and physical decline of diesel power plants. However, staffing and personnel issues are usually beyond the control of all types of power plants; like financial matters, manpower and personnel issues are highly centralized in most utilities. EPUES found that not only were local diesel plant managers unable to determine remuneration, but their ability to hire, fire, promote, discipline, and train staff was severely limited. Their lack of authority to either reward or punish affected their ability to control their staff. Moreover, few utilities operated with manpower budgets, or had a systematic way to determine optimal staffing levels according to the requirements of particular diesel plants.

2.26 The high unemployment in most developing countries made it difficult for diesel plant managers not to carry more employees than they need as a social service. Moreover, where the manager's own pay was linked to the number of people he supervised, he had no incentive to reduce staff. In fact, local managers often tried to boost their salary grade by building up their workforce.

2.27 When a utility lacked a comprehensive manpower management system, such technically qualified personnel as mechanical and electrical engineers were reluctant to move to diesel plants, which tended to be outside the mainstream of the utility's activities. They feared that once posted to a diesel plant, they would lose promotion opportunities available at head office or in other types of plants.

2.28 EPUES missions have found a general lack of appreciation of the complexity of diesel technology, reflected not only in staffing, but also in the absence of training for diesel operators and maintenance personnel. In Country D, Utility B's technical training institution provided training courses for hydro operators and transmission and distribution personnel, but not for diesel operators. On the other hand, its private Utility A did provide special courses for diesel operators and maintenance staff. Here, an operator was not allowed to supervise a shift until he had passed a two-year comprehensive theoretical and practical training course.

Power Plant/Community Relationships

2.29 EPUES collected little information on relations between diesel power plants in general and the communities they serve. As noted in Chapter 1, the national utilities are dominated by government interests.

2.30 EPUES recommends in this Report that utility management policies should be broadened to include a wider range of interests, and should allow greater community participation in the energy sector. There is now minimal community involvement even at the power plant level; there are few efforts to involve local communities in an advisory role or even provide them with information.

2.31 This situation does not seem to be deliberate, but probably derives from the fact that no utility or plant manager understands the benefits of community involvement. In Country M, community advisory committees were established at two diesel plants at the initiative of the Finnish consultants. At one of these plants, the committee has helped established a disconnection policy, has educated consumers about the need to pay their accounts promptly, and has provided guidance fc- load shedding in establishing priority consumers. At the other, the committee has had minimal involvement with the diesel power station and exists in name only.

2.32 In general, initiatives for involving plant and utility representatives come from regional political or administrative development committees rather than from the utility. These committees enable managers to disseminate information and get feedback from the community, but can expose managers to community pressure. In Country D, where regional managers sit on development committees, for example, they are under great pressure to expand distribution and ensure continuity of supply even when doing so could result in damage to overburdened plants.

Power Plant/Donor Relationships

2.33 Close donor involvement in various types of power plant projects has had mixed results. Involvement during the project phase has normally contributed to successful implementation, and to the establishment or rehabilitation of the plant. Such projects were usually carried out on a turnkey basis, and depended heavily on expatriate technical and supervisory expertise. The donor agency was usually involved in monitoring progress and was able to bring pressure to bear on the utility or the national government, where such pressure was necessary to resolve problems and overcome delays. Donor involvement thus resulted in projects being completed on time and within budget.

2.34 The drawback to donor supervision and management of projects has generally been that it inhibited the involvement of the utility, where managers were often happy to allow the donor and external contractors to do everything, including provide manpower and resources. Since donor agencies and expatriate consultants were able to put greater pressure on government agencies, the managers simply waited for project to be completed.

2.35 The donors' immediate objective of completing projects as soon as possible therefore contributed to serious long-term problems with sustainability and operational efficiency of many plants. Diesel power plants often were not fully integrated into utility generation systems (the cause of other problems) precisely because the utilities had minimal involvement when the plants were being built.

Lessons Learned

2.36 EPUES has learned several lessons about the institutional relationship between power plants and the utility:

2.37 The level of productivity and efficiency depends heavily on the amount of support a plant receives from utility headquarters for institutional integration, technical supervision, and other financial and nonfinancial resources. When national economic policies constrain the resources available to a utility, the utility tends to reallocate its resources to a preferred group of plants, usually those which represent large investments or which provide power to major urban centers. The allocation of resources is in most instances not equitable. Diesel plants that represent small scale investments and are located in remote rural areas are often shortchanged.

2.38 EPUES found that the preferred plants, which are usually grouped and tightly supervised by a utility's generation department, are likely to operate more efficiently than plants indirectly linked to the utility through its distribution or rural electrification department.

2.39 National economic policies that constrain a utility's ability to hire and fire, and to control salaries and other personnel issues, also affect individual plants.

2.40 Without comprehensive manpower development policies, qualified utility staff will continue to concentrate on the preferred group of plants, since other plants are perceived as career dead-ends.

2.41 As long as electricity is regarded as a free good for improving the quality of life rather than as a catalyst for economic development, electric power generation will continue to be subsidized, and the objective of cost recovery will be difficult to accomplish. Cost center accounting, which was not used by any of the plants in this study, can help make subsidies and expenditures more transparent. This is a prerequisite to the effective implementation of cost recovery programs.

2.42 EPUES has collected little information about how community involvement in power plant operations and administration can help operational efficiency, but believes that such involvement has positive benefits.

2.43 Utilities have often restricted their participation during project planning and construction, to facilitate completion of the project on time and within budget using expatriates. Such arrangements have proved detrimental in the long term, since this lack of involvement often results in the project or plant not being an integral part of a utility's generation system.

Recommendations

2.44 Donors should assess the low priority given to diesel power plants at the utility management level. Specifically, the management status of the person responsible for diesel power at headquarters should be reconsidered.

2.45 Donors should also assess the availability of technical staff at headquarters, and the procedures used by headquarters to evaluate power plant operation and feed back advice to the plant manager. It is especially important to determine whether the accounting and technical information systems used by the plant manager are sufficient to give headquarters a complete understanding of the power plants' financial and technical performance.

2.46 Utilities should assess the effect of local and informal institutions on the overall performance of the power plant.

2.47 Governments requiring rural electrification projects should ensure that the utility provides sufficient human, technical, and financial resources for the sustainable operation of these systems.

CHAPTER 3. ECONOMIC AND FINANCIAL ISSUES.

3.1 This chapter reviews EPUES findings concerning the economic and financial performance of diesel generating stations. The main areas of inquiry were: (a) the quality of financial and economic performance; (b) the variables affecting that performance; and, (c) given a certain set of outputs, who pays for power station operation?

3.2 The annexes to this chapter look in turn at diesel capital costs and lifetimes, plant utilization, operating costs, and measures of financial and economic benefits. These are the variables that affect financial and economic performance, the distribution of benefits, and the distribution of costs.

Findings

3.3 The financial performance of utilities has generally been very poor. If tariff revenues exactly equal long run marginal cost (LRMC) at a given load factor, then investments will realize a financial rate of return (FIRR) equal to the discount rate; the net present value (NPV) will be zero; and no subsidy will be required. If the tariff falls below that level, the FIRR will also fall. The NPV will become negative and subsidies will be required, initially to cover depreciation. If tariff revenues fall below operating costs, both FIRR and NPV will be substantially negative, and operations will need to be subsidized. The subsidy can take the form of a direct government transfer of funds, or be indirect, such as allowing the utility not to pay its fuel bills.

3.4 EPUES found a few instances where tariff levels were sufficient. In some cases, however, they were below LRMC, and often below total operating costs. Tariffs sometimes covered less than 75 percent of the fuel bill. Although EPUES has not attempted to recalculate FIRRs for the diesel plants in this study, it is safe to conclude that in many cases they are negative. Subsidies are generally required for depreciation and capital costs, and often for daily operations.

3.5 The failure to cover costs means that plants and utilities operated in a crisis management situation. A great urgency was attached to cash income to cover costs, and since cash was often acquired at a premium rate, this created continuing shortages for other needs such as maintenance.

3.6 EPUES found this situation particularly acute for isolated diesel generators, since costs were higher than for grids incorporating larger thermal or hydro units. Most isolated diesel stations charged the national tariff, which meant such tariffs were particularly inadequate for isolated diesels. The only exceptions were essentially captive private plants, and a small private utility in Guatemala.

3.7 In several African countries, rapid depreciation of the currency put pressure on the tariff, since 80 to 90 percent of plant costs involved imported products. The real cost of power relates closely to currency depreciation, and failure to adjust the tariff to reflect depreciation meant its real value was falling despite substantial increases in domestic prices.

3.8 Tariff revenue is a function of tariff level, system losses, and performance on billing and collection. The tariff level alone cannot offset these other deficiencies. EPUES found that system losses and billing and collection were so poor that the tariff would have had to be well above the cost of alternative energy sources (small captive generation or kerosene lighting) to realize a positive FIRR.

3.9 Losses in many countries were over 20 percent, and in some cases over 40 percent. This severely affected financial performance. Data on billing and collection were not always available, but the accumulation of unpaid bills (accounts receivable) showed that these also reached high levels.

3.10 In almost all countries, the public sector owed more to the utility than the private sector, with local administration substantially worse than the national government. This reflected political influence over the utility and difficulty disconnecting government consumers.

3.11 Country L demonstrates that performance can improve if the political will exists. Nonpaying customers there pay a 5 percent surcharge after 20 days and are subsequently disconnected. In 1989, the utility disconnected 12 percent of its consumers, including a number of government departments.

3.12 The economic internal rate of return (EIRR) will generally be higher than the FIRR. Benefit measures include the savings that result from switching to electricity from more expensive energy sources. As demand for electricity increases, customers may be willing to pay more than the tariff. Costs may also need adjustment to reflect economic prices. In general this would improve the EIRR, except when fuel costs are subsidized, as costs are adjusted downwards once they are net of taxes and duties.

3.13 Measures of economic benefit vary accorded to consumer groups. Residential consumers were the largest group served by diesel plants in the EPUES sample, followed by the public sector (government offices, urban administration, street lighting, etc). Industrial consumption was variable (many production facilities have their own generators), and agricultural consumption was minor.

3.14 The main economic benefit to residential consumers was the substitution of electric for kerosene lighting. Because electric lighting is cheaper and more efficient, it also benefitted commercial consumers.

3.15 Electric power creates new demands. A DANIDA evaluation in Country K found that, after lighting, men most value a television set. Women value refrigerators and washing machines, which substitute for female labor. Some consumers sold their possessions to buy these new appliances.

3.16 Small- and medium-size industry will also benefit from the increases in productivity associated with better lighting and new appliances. In Country M, EPUES found a noticeable move to electric equipment by small- and medium-scale industry (e.g. brick makers and engineering repair shops). In Country K, tailors reported a 150 percent increase in productivity when they switched from pedal to electric sewing machines. The efficiency of electric welding machines led to a rapid increase in the number of iron workshops.

3.17 Although larger industry often has captive generating capacity, it will use grid supply as it becomes available because grid supply is typically sold for less than its cost of production. EPUES found several cases of major industry moving away from captive power and expanding operations as grid supply became available.

3.18 The financial benefits of subsidized power to industry are evident. Benefits to the national economy will depend on the relative costs of captive private generation and generation within the grid. The economies of scale in both capital and operating costs imply that substantial economic benefits will result from replacing small captive capacity with grid supply.

3.19 In practice, however, EPUES missions found that low reliability of public supply means these benefits on capacity costs often go unrealized, since industry is obliged to retain standby capacity. Economies of scale also go unrealized because of the inefficiency of grid supply. In general there will still be economic benefits from switching to grid supply, although EPUES identified some instances where the operating costs of grid supply exceeded operating costs of captive supply. In these cases, the customers who switch would be doing so because of the financial subsidy in the tariff, and economic benefits would be negative.

3.20 Grid supply also has a social impact. EPUES identified instances of schools holding evening classes and street lighting improving safety at night. The DANIDA evaluation in Country K, however, found that problems in hospitals continued to be pressing in spite of electricity providing lighting, and in some cases, air conditioning.

3.21 A number of missions reported heightened economic activity in response to the new or more reliable power supply. These findings, however, are anecdotal, and do not allow electrification to be compared with other infrastructure investments such as transport or communications, which also facilitate economic expansion. EPUES missions did not collect sufficient data to compute EIRRs or to make other quantitative economic comparisons.

3.22 Given the usual failure to cover costs, there is a subsidy to power consumers. The application of a national tariff to isolated diesels means this subsidy is particularly marked for consumers in backward or rural areas, where isolated diesels are located. Tariff structures usually favored residential consumers, and often incorporated a particular subsidy to those using 100-200 kWh a month.

3.23 The welfare arguments for this practice appear to be weak. Those connected to the grid generally do not need a subsidy to realize the benefits from substituting electric for kerosene lighting, although they may require assistance (for example through credit) for connection costs. Consumers of power are generally affluent rather than poor; energy consumption by those connected to the grid is directly related to income. Subsidies to consumers below 100-200 kWh a month will favor poorer over richer consumers, but these groups are still far from the poorest.

3.24 The second major consumer group is government, including central, regional, and local administrations. EPUES found that these groups do not usually receive as favorable a tariff as residential consumers, but realize greater financial benefits because of their poor performance paying their bills. There may be welfare arguments for subsidizing certain government activities, but direct subsidies to specific activities are preferable to indirect subsidies through the power sector.

3.25 Increased productivity in small- and medium-scale industry is not dependent on subsidized power. Subsidized power might lead large industry to abandon its own more efficient source of supply.

3.26 Another group benefitting from grid power is consumers of free, stolen power. In some cases this is the largest single consumer group. EPUES missions did not produce data on the losses resulting from power theft.

3.27 Where the diesel plants fail to cover costs, such costs must be met by a direct or indirect subsidy from government. The burden then will fall either on taxpayers or on the marginal beneficiaries of public expenditure, from whom those expenditures will be cut.

3.28 Donors sometimes directly subsidized the power sector by financing capital costs with no requirements that these be on-lent. EPUES found that in these cases, the burden of the subsidy was borne by beneficiaries of marginal aid projects which then were not financed.

3.29 On-lending terms for the utilities EPUES studied typically incorporated a grace period of several years. The missions found cases where the burden of debt repayment became such that another subsidy was required.

3.30 EPUES also looked at how financial performance is affected by some of the major inefficiencies identified during the missions. This was done by building a simple model of diesel plant costs and operations, then examining the impact of variations in key parameters.

3.31 EPUES missions identified a number of cases of investment in overcapacity. In one extreme example, both ODA and KfW had separately financed a 10 MW expansion of installed capacity at a single location that has since reached 3 MW peak demand.

3.32 The mission to Country DD concluded that with projected load growth, the FIRR might be positive at one of four sites. Given higher valuations of economic benefits, the EIRR could be positive (and above 20 percent) in two of the four sites. In general, overcapacity is reflected in initial low capacity factors, and will sharply reduce financial and economic rates of return. To some extent this can be offset by subsequent load growth. However, if a plant starts with a very low capacity factor, then the effect of discounting is to create growth. Thus, adequate capacity factors several years in the future cannot produce an adequate FIRR.

3.33 The EPUES missions also identified major problems with maintenance and overhaul. In some cases this led to diesel engines ceasing operations after little more than 20,000 hours.

3.34 The impact of shortened lifetimes depends on how the machine would have been used with a longer lifetime. Some analysts assume a target lifetime of 80,000 hours over 15 years. EPUES' own analysis suggested that low load factors in systems dominated by evening lighting peaks prevented such high utilization, and that 80,000 hours might be stretched over 25 years if the diesel plant could be kept operating for that length of time.

3.35 Given these assumptions, a drastically shortened life (20,000 to 40,000 hours) has a major impact on the FIRR. Given the effect of discounting, however, extending lifetime beyond, say, 50,000 to 60,000 hours has much less effect. Of course, once a machine approaches that many hours, the effect of discounting will be removed, so this conclusion does not affect the financial and economic case for undertaking maintenance in any given period.

3.36 EPUES found that poor maintenance often affects fuel consumption. At an extreme, fuel consumption in Country F was more than 50 percent above the average, although this most likely included pilferage as well as machine consumption. Given the great importance of fuel to total operating costs, variation in fuel efficiencies has a major impact on the FIRR. In the EPUES financial model, roughly a 30 percent increase in unit consumption (or fuel price) was sufficient to reduce the FIRR from 12 percent to zero. Smaller increases also had a significant impact.

3.37 EPUES found the FIRR also to be reasonably sensitive to variations in capital costs. The other components of cost, lube oil, materials, and labor, have less impact on the FIRR.

Lessons Learned

3.38 EPUES has learned a number of lessons that are of importance to maximizing the financial and economic returns from diesel generation investment:

3.39 Donors should not undertake projects without first reviewing demand forecasts and verifying any unusual features of the forecast through site visits. The greatest weakness in demand forecasts appears to be where a few discrete industrial investments form the basis of the prediction. Such forecasts should be closely reviewed, and donors should consider phasing in new capacity so the project will not be vulnerable to a few industrial investment decisions. Donors should consult with the utility and other donors to ensure that their efforts are not being duplicated.

3.40 Residential lighting is an important benefit of isolated diesel stations. Residential consumers prefer low cost to high reliability. Where industrial consumption is also important, these consumers value reliability of supply much more than cost, since their economic benefits are reduced when reliability is low.

3.41 Both utilities and donors should consider the optimum supply and reserve margins appropriate to isolated diesels, and relate reserve margins to willingness to pay. The willingness to pay is likely to vary according to the consumer mix. Donors generally accept the utility's policy on reserve margins, or use the standards of Western countries. In some cases, investments in high reserve margins are encouraged by the donor's failure to apply on-lending terms for aid. If such aid is passed on by government as an increase in equity, the utility may treat it as free, and not take it into account when calculating costs. EPUES found evidence that failure to enforce on-lending terms encourages overexpansion of capacity and use of high reserve margins as an (expensive) way of avoiding maintenance expenditures. The costs of failing to enforce on-lending are a lower level of revenue and a consequent reduction in government expenditure at the margin. Donors and governments should routinely implement and monitor on-lending terms for aid to the power sector.

3.42 Mission reviews of operating costs in a number of diesel plants confirmed that spending for maintenance was suboptimal. The costs of delayed maintenance in terms of higher outages and shorter lifetimes are not given sufficient weight at diesel plants not covering operating costs, since those plants attach great importance to present cash income, including increases in income from avoiding maintenance expenditures.

3.43 The enforcement of on-lending terms for capital aid would help ensure a better balance between new capacity and maintenance expenditures. However, for utilities that maintain a short-term planning horizon as a result of continued financial crisis, non-concessional loans may be more attractive than immediate cash payments for maintenance. On-lending terms usually include a grace period, and even if interest is fully capitalized at commercial rates during this grace period, the fact that repayment is delayed for several years may be sufficient to make such terms attractive to a hard-pressed utility.

3.44 Inadequate maintenance has a very damaging effect on financial and economic performance. Financial signals must therefore be found that will influence the utility to alter the balance of expenditure in favor of increased maintenance. The diesel plant spare parts fund, described in Chapter 4, Financial Management, is one way to achieve this.

3.45 The financial rate of return is often inadequate because tariffs fail to reflect LRMC. Utilities must continue to demand real increases in tariffs from their governments. This is particularly important in many African countries, where utilities depend on rapidly depreciating currency to purchase many of their production inputs. Governments need to develop internal capacity to review and adjust tariffs.

Recommendations

3.46 Donors should require, and governments should agree, that all power sector loans will be on-lent to the utilities. Donors should monitor on-lending terms for aid to the power sector, including technical assistance.

3.47 Tariffs should cover long-run marginal cost. All donors, the utility, and the government in a specific country should determine and agree to the long-run marginal cost. The World Bank computes this cost in most developing countries, and could provide the basis for a common agreement among donors on country-specific tariff targets.

3.48 One variable that affects financial and economic performance is the cost of expatriate consultants. EPUES missions did not collect sufficient information to adequately estimate these costs and recommends further study of this issue.

CHAPTER 4. FINANCIAL MANAGEMENT.

4.1 Financial management of a utility consists of generating revenues through metering, billing, collection, and the procurement of spare parts, all of which enable the utility to sustain its operations. The main impediments to adequate revenue generation are: (a) electricity consumed without the knowledge of the utility (nontechnical loss); (b) delays in payment or outright nonpayment (high accounts receivable); and (c) power plant breakdown due to difficulty procuring spare parts. Proper management of a utility's metering, billing, and collection functions is fundamental to controlling nontechnical loss. Losses due to breakdowns of all types of plants can be prevented by simplifying the procurement process, including lessening government controls on foreign exchange expenditures.

4.2 The findings in this chapter regarding nontechnical loss and accounts receivable are based on EPUES reports, and on World Bank and ESMAP reports from 1980 through 1989 covering 30 electric power utilities in 23 African countries and 4 countries in Asia, the Pacific, and the Americas. The findings regarding spare parts procurement are based on EPUES investigations of 15 utilities which have had problems buying spare parts for their diesel plants in an environment with limited foreign exchange--a problem as critical for donors as it is for utilities.

Findings: Nontechnical Loss

4.3. For 26 of the 30 power utilities in the sample, total system loss averaged 18.9 percent a year between 1980 and 1989, ranging from a maximum of 47 percent for the utility in Country G in 1988 to a minimum of 4.1 percent for the utility in Country AA in 1981 (see Annex 1). Nontechnical loss averaged 11.3 percent for the same period, for a 6-country sample, with a maximum of 20 percent for Country N in 1983 and a minimum of 1 percent for Country M in 1982. Nontechnical loss, that is, averaged 46 percent of total system loss. It reached a maximum of 70.9 percent of total system loss for Country A in 1989, and a minimum of 5.6 percent for Country M in 1982 (see Annex 2).

4.4. EPUES investigated the causes of these nontechnical losses and the utilities' effort to rectify them.

Metering

4.5. Metering involves five sets of issues: (a) physical status of meters, (b) performance of meter readers, (c) consumer pilferage, (d) utility control, and (e) meter landlords.

Status of Meters

4.6. Of the 30 utilities in the sample, 5 reported a shortage of meters and 7 reported a substantial number of faulty meters. Faulty meters result from lack of spare parts, inadequate maintenance, and poor technical design. The World Bank has financed several programs for meter connection and replacement, and facilities for meter calibration and repair.

Performance of Meter Readers

4.7. Apart from Country A, where meter readers are not trained to accurately record meter readings (e.g. they displace decimal points). EPUES found that meter readers at seven utilities were negligent in reading and recording data. In Countries K, M, R, and X, for example, meters often go unread over long periods, and consumption figures are based not on readings but on rough estimates. Such negligence may be attributed to low wages, as in Country M. In Country X, negligence is fostered by the utility's not paying for the full cost of meter readers' visits.

4.8. Besides negligence, EPUES found four utilities--in countries M, N, R, and CC--at which staff collude with customers to record low readings. In Country CC, sources outside the utility informed the EPUES mission that some customers are not billed at all, due to bargaining between meter readers and consumers. In Country R, managers are attempting to remedy the problem by experimenting with employee incentives. Countries M and N have undertaken remedial action, including dismissing employees who have participated in defrauding the utilities.

Consumer Pilferage

4.9. In addition to this collusion, EPUES found seven utilities that suffered other forms of consumer pilferage. As reported by one utility's task force on system loss reduction, electricity may be pilfered in one or a combination of the following ways: (a) direct connection, (b) use of jumper, (c) meter substitution, (d) destroying the meter, (e) removable tampering device, (f) substitution of recording demand chart; and (g) use of reversing transformer. Consumers are assisted in the use of these techniques by local electricians who are often current or former utility employees. The pilfering is usually not counteracted by disconnection.

4.10. In Country N, EPUES found evidence that consumers deliberately destroy their meters, since the utility allows them to pay the minimum monthly charge when meters are faulty. Illegal connections are another problem. They occur not only in low-income households, but also in middle- and high-income groups and among large commercial consumers.

4.11. Some utilities have tried to detect and prevent consumer pilferage by increasing surveillance by independent fraud squads within the utility. The energy monitoring unit in Country N, and the inspection division of Utility A in Country EE, are such fraud squads. Country N has special crews which review electricity connections block by block to detect illegal connections, verify that each legal connection has an accurate meter, and ensure that the connection is in the utility's records. Country J also has such crews. Other utilities are increasing the number meter readers and inspection crews. Country H is experimenting with rotating meter reader districts every month.

Utility Control

4.12. Control over illegal consumption is constrained by the utilities' own policies and by lack of government support. Some utilities, such as Utility A in Country R, do not have a policy of prosecuting illegal consumers; others, such as in Country G, do have that policy, but seldom enforce it.

4.13. In many countries, such as Country N, lack of government support for prosecuting pilferers leaves utilities vulnerable to fraud. In Country EE, there are laws against electricity pilferage, but cumbersome legal procedures hamper prosecution, and in any case, since pilferage is only a misdemeanor, the penalties are light and do not serve as deterrents. In some instances, government actually works against efforts to decrease nontechnical losses. In Country J, for example, public buildings and public lighting are not metered. In Country H, the utility is pressured to give preferred treatment to privileged private sector consumers, and to maintain connections even if bills are not paid. For some consumers invoices are not issued.

4.14. Utility A in Country EE and the utility in Country N are trying to get support to prosecute consumers suspected of illegal connections. In the absence of such support, many utilities are implementing disconnections and other penalties. In Country N, customers with faulty meters are now billed for their estimated consumption rather than the minimum charge. In Country A, if a meter is faulty, the consumer is billed on the basis of the highest reading of the previous three months.

Meter Landlords

4.15. A particular feature of the market for electricity in the main urban centers of countries T and DD, is the existence of "meter landlords" who unofficially supply power from the public system through their own metered or unmetered connections. These landlords can abuse the system by charging higher rates than the utility. But they perform a useful service by reducing distribution and billing costs, and by making electricity affordable to many consumers who cannot afford the utility's connection charges.

Billing

4.16. Nontechnical loss can also be reduced by better billing procedures. These procedures can be improved through (a) computerization and management information systems (MIS); and (b) management.

Computerization and MIS

4.17. EPUES found nine utilities with inaccurate and unreliable billing data, due mostly to computer programming errors, nonstandard systems, and hardware and software shortages. In countries H and K, for example, many consumers are not billed because the utility does not have an up-to-date consumer list. The utility in Country CC has no uniform way of billing its customers; some districts are still billing manually.

4.18. Six utilities had billing delays caused by computer and office automation problems. Hardware malfunctions frequently occurred at in countries A, M, and T, and at Utility B in Country D. In Country A, bills were prepared by outdated bookkeeping machines. In Country M, the utility used old, inefficient data processing equipment for billing and accounting.

4.19. Many power projects include provision for improved computerization. Fourteen utilities, or 46 percent of the sample, used some form of computerization assistance between 1980 and 1989. This assistance usually included hardware and software additions or upgrades, technical assistance, and training. Other office technologies were also included. In Country J, the utility got accounting machines to keep track of customers' accounts. In Country N, the Bank recommended providing the utility with cash registers which had direct access to consumer records.

4.20 GTZ has provided funds and technical assistance to Country A for an automated billing system. In Country W, the utility is in the process of computerizing and cleaning up its private customer portfolio.

Management

4.21 In addition to the technical barriers to efficient billing, EPUES found 11 utilities with management problems that affected billing practices. The main problems were general lack of staff authority, absence of effective controls, and inappropriate administrative arrangements. In Country F, the utility does not have a statistical department; there is no financial planning, no organization of work, and no qualified accounting personnel. In Country R, Utility A's revenue management function is generally weak, and responsibilities are not coordinated among the utility's commercial offices. In Country N, the utility's commercial department handles all metering and billing as well as disconnection and reconnection, thereby exposing itself to collusion and corruption. Data inconsistencies frequently arise in billing records and meter readings countries A, M, and N.

4.22 The lack of management control has in some cases resulted in billing fraud. In countries A and M, EPUES missions discovered significant underbillings. In Country H, invoices were often sent to disconnected consumers, since the number of administrative staff is based on the number of invoices; in 1987, its utility adopted administrative and control procedures to detect billing fraud. Utility A in Country EE continually investigates its erring employees. In countries A, M, and N, the utilities prevent fraud by imposing severe penalties on staff, including dismissal.

4.23 Utilities try to improve revenue management by increasing the number of senior management posts, or by reorganizing their commercial operations. In Country N, the utility increased the number of its area directors and assigned each director the responsibility for the accounts in his area. The utility in Country R recently appointed a senior revenue manager. In Country H, the utility adopted a plan in 1987 for complete reorganization. In Country J, a World Bank project in 1981 included a commercial specialist to help the utility reorganize its commercial department.

Logistics and Manpower

4.24 Billing delays are also caused by logistics and manpower problems. The national utility in Country D, for example, must process all bills from the regions at its central computer in the capital, and it can take two months before bills are distributed. In Country CC, one diesel plant is isolated for security reasons and can be reached only by air; since the plane does not fly regularly, the utility has difficulty sending billing information to the power plant. In Country X, the shortage of qualified staff is aggravated by rapid staff turnover at two critical revenue-producing areas.

4.25 To alleviate staff shortages, some utilities have implemented training and incentive programs, as discussed in Chapter 5, Manpower. To help solve its logistics problems, the national utility in Country D plans to install a computer at the parastatal to store meter data and receipts; the utility will then send disks to the main accounts office in the capital for processing. In Country EE, Utility A has been rehabilitating its communication system.

Findings: Accounts Receivable

4.26 Of the 30 utilities in the EPUES sample, 28 had accounts receivable averaging 6 months of sales for the combined public and private sector. The maximum was 18.2 months for Country K in 1986; the minimum was 1.4 months for Country DD in 1988 (see Annex 3). EPUES investigated the reasons for such inefficient billing and collection, and the ways the utilities have tried to correct these procedures.

Billing

4.27 Delays in billing are a major cause of high accounts receivable. In Country T, for example, billing takes two to three months. Country CC had a six month backlog of billings in 1985, and billing is delayed up to nine months after consumption. Billing problems have been reviewed in paragraphs 4.16 through 4.23.

Collection

4.28 Collection problems fall into five categories: (a) accounting and computerization, (b) collector-consumer collusion, (c) private sector performance, (d) public sector performance, and (e) utility write-offs.

Accounting and Computerization

4.29 The same computer and office automation problems that affect billing also affect the monitoring of accounts and collection of payments. In Country G, the utility is unable to monitor customer debts. In Country R, Utility A's efforts to recover receivables have been uncoordinated.

4.30 Accounts receivable are usually computerized along with billing. GTZ has been providing technical assistance for an integrated billing and collection system in Country A. In Country D, the national utility is also planning to computerize its accounts.

Collector-Consumer Collusion

4.31 Collusion between collectors and consumers is aggravated when the meter readers are also the collectors. To prevent collusion, countries A and M have discontinued their policy of allowing meter readers to collect cash. In Country LL, collections can be made by contractors and remitted to the utility's regional commercial offices, or customers can make payments at participating commercial banks.

Private Sector Performance

4.32 Private sector accounts receivable for 5 utilities averaged 4.2 months of sales between 1981 and 1989, with a maximum of 5.3 months of sales for Country G in 1989 and a minimum of 1 month of sale for Country Y in 1981 (see Annex 4). Private sector accounts receivable for 12 utilities averaged 53 percent of total accounts receivable for the same period.

4.33 Many utilities cannot effectively collect from private consumers because of inadequate or nonexistent policies regarding arrears. These utilities seldom disconnect their customers. In Country N, for example, many consumers pay only a fraction of their total bill; any payment is sufficient to keep the electricity connected. Furthermore, those who are disconnected often hire a local electrician to restore their connection illegally, since the utility does not have the authority to prosecute energy pilferers.

4.34 Ten utilities have implemented disconnection policies in order to decrease receivables and curtail delinquency. A World Bank mission to Country N has recommended that surcharges be levied for late payments and substantial security deposits be required for customers who are frequently delinquent.

Public Sector Performance

4.35 Public sector accounts receivable for 7 utilities averaged 12.3 months of sales between 1981 and 1989, with a maximum of 38.7 months for Country G in 1989 and a minimum of 1.8 months of sales for Country DD from 1985 to 1988. While sales to the public sector generally accounted for only 20 to 30 percent of total sales, public sector accounts receivable for 12 utilities averaged 47 percent of total receivables, with a maximum of 86 percent for Country Z for the period 1983-1989 (see Annex 5). Despite the lack of statistics on public sector receivables for other countries in the sample, EPUES found 20 utilities with problems collecting their public sector accounts.

4.36 In Country J in 1988, the government did not pay its electricity bills since the utility also had high debts to the government. The main reason for such public sector delinquency is that this sector is virtually immune to disconnection policies, as six utilities reported. In Country EE, for example Utility A's efforts to disconnect delinquent public sector establishments resulted in "adverse consequences." Such immunity may also extend to the private sector. In Country CC, middle- and high- (mainly industrial) tension consumers cannot be disconnected for political reasons, and the utility has been forced to give them preferential treatment.

4.37 Countries L and CC have tried, with some success, to reduce public sector receivables by disconnecting government customers to force them to pay their bills. In Country D, the national utility has recently been authorized by the government to disconnect most government agencies (excluding the water utility) that do not pay their bills within two months after they are issued.

4.38 Disconnection of public sector consumers is much less common than the debt-equity swap, an arrangement whereby a utility offsets its receivables against its debts to the government. While the clearing of cross-entity debts is usually done on an ad hoc basis, four utilities, one each in countries J and R and two in Country EE, use this approach regularly. In Country R in 1989, the government established a clearing system for monthly settlement of its mutual obligations with the electric utility, the water parastatal, and the electric parastatal. In Country J, state enterprises pay their electricity bills by means of entries in their compensation accounts with the government accounting agency. Credits to the utility's account are drawn from lump sums in the national and regional budgets. The credits are given periodically, based on annual estimates of consumption.

Utility Write-offs

4.39 Four of the utilities in the sample wrote off a portion of their receivables on an ad hoc basis. Write-offs averaged 12.7 percent of total utility accounts receivable between 1985 and 1988, with a maximum of 22.2 percent for SNE (Guinea) in 1986 and a minimum of 1.6 percent for ECG (Ghana) in 1988 (see Annex 6). EDM (Mozambique) has a policy of writing off debts after three years. In EDM (Mali), outstanding receivables are booked as losses after four years.

Findings: Spare Parts Procurement

4.40 EPUES found extreme scarcity of foreign exchange to be the root cause of most procurement problems. This scarcity tends to lead to complex procurement systems, resulting in long delays and uncertain procurement. EPUES has shown (Annex 7) that a strong correlation exists between complexity of procurement systems and the lack of foreign exchange in the least developed countries of Africa.[1] Local currency is used to buy fuel and lube oil, whose availability depends to large extent on utility cash flow.

4.41 EPUES missions found two common scenarios for the procurement of spare parts. Most often, the utility developed an annual budget which projected foreign exchange needs related to specific power plant projects. Since most utilities did not use foreign exchange to buy fuel or lube oil, the requests were primarily for capital improvements and spare parts. The budget was normally approved by the government. Once this approval was granted, the purchase of spare parts became, for some utilities, a straightforward procedure, and for others a complex jungle, depending on the scarcity of foreign exchange and the nature of the foreign exchange allocation process.

4.42 Where foreign exchange was very scare, allocation systems tended to be cumbersome, and resulted in long delays and great uncertainty as to whether foreign exchange would ever be allocated for specific transactions.

4.43 The second procurement scenario involved the donor agency furnishing spare parts to the utility. A number of World Bank Staff Appraisal Reports and EPUES mission reports noted that donors often financed spare parts as a component of a new power project. Spare parts were also included for some plants in operation or under rehabilitation. Normally, the parts were procured by the donor agency, which then ensured their delivery to the utility. While this process avoided foreign exchange bottlenecks, delivery of parts was nevertheless sometimes slow due to

1 One cannot conclude that reducing procurement complexities will make foreign exchange more available, but it will decrease uncertainty and make rational planning possible.

the donor's own procurement regulations. Distance, communications problems, and weak institutional links between utilities and aid agencies also complicated the process.

4.44 The financial magnitude of the procurement problem has been estimated in two ways. First, the cost of spares and consumables was estimated, for 11 utilities (16 plant-years) in industrialized countries (USA, UK, Australia) to be $16.00 per kilowatt of installed capacity annually. Second, the same estimate was made for 50 diesel power plants in Africa, Asia, the Pacific, and the Americas, and found to be about $22.00 per kilowatt of installed capacity annually. Significant variations occurred from year to year, especially in Africa, where many diesel plants are undergoing rehabilitation.

4.45 Evidence suggests that a solution to the problem of buying spare parts in a limited foreign exchange environment is to remove complexity from the procurement system. World Bank operating staff have tried to simplify procurement by designing financing mechanisms which make limited amounts of foreign exchange available through simple, transparent systems. In Country M, for example, where foreign exchange is *extremely* limited, the Bank has set up a monthly hard currency "Dutch" auction. Bidders are allowed one bid only. The auction begins at an exchange rate much higher than the official rate. If no parastatal bids for currency at that rate, the rate is lowered. If the parastatal has sufficient local currency and is desperate for hard currency, it will bid high. Any parastatal can buy foreign exchange at this auction. Bidders pay to enter the auction and must specify in advance the amount on which they intend to bid. Not all bidders are successful, since the foreign exchange is limited and the sale price may be too high. On the other hand, the lack of complexity in this system makes it clear to parastatal managers what they must do to get the hard currency they need. It facilitates strategic planning and gives managers an incentive to maximize their revenues.

4.46 A second example of such simplification is a licensing agreement between Country D and the Bank, which includes a list of critical spare parts for such government and parastatal operations as public transport, agriculture, electricity, and water. Each parastatal has a budget for buying spare parts from this list, and can procure the parts with a two-step process. At the time of the EPUES mission to Country D, Utility B had used the licensing agreement just once and the number of parts on the critical list was quite limited. Nevertheless, the process worked very well and the utility was petitioning to have additional spare parts included on the list.

Lessons Learned

4.47 EPUES has learned the following lessons about metering, billing, collection, and spare parts procurement:

Metering

4.48 All electricity sales must be metered. Meters must be designed to withstand potential damage caused by weather and other natural causes, and to prevent tampering. Meters should be adequately maintained and inspected. All utilities must have a sufficiently equipped meter calibration and repair facility, including hardware, spare parts, and qualified staff. Where individual metering is unfeasible, bulk metering can be used.

4.49 Meter readers should be adequately compensated and equipped, to ensure good morale and enable them to perform their jobs effectively. Sanctions must be in place to instill discipline and prevent collusion with consumers.

4.50 Financing of meter connection and replacement programs, and of meter calibration and repair facilities, has produced doubtful results due to lack of institutionalized measures to guarantee their sustainability.

4.51 EPUES found no comprehensive programs that guarantee a motivated and collusion-free workforce of meter readers. While some utilities are experimenting with incentives to increase meter reader productivity, and others are disciplining readers who collude with customers, there is no indication whether such actions have been effective.

4.52 Pilferage occurs among low-income, middle-income and high-income consumers. It also occurs in some commercial sectors, and is suspected in some industrial sectors.

4.53 The major obstacle utilities face in prosecuting pilferers is lack of government support. Utilities have been unsuccessful in lobbying for legislative protection, particularly in countries where they are expected to give preferred treatment to government agencies and privileged private sector consumers.

4.54 Meter landlords compensate for a utility's metering, billing, and collection deficiencies. The concrete costs and benefits of allowing meter landlords to operate within a consumer group have not yet been determined.

Billing and Collection

4.55 While the collection function has generally been decentralized, the trend is now toward centralization of billing, to overcome billing delays and discrepancies in accounts. Standardized country-wide computer billing is dependent on competent middle managers and staff, geographical and communication constraints, and checks and balances between utility headquarters and its satellites.

4.56 The general lack of staff authority, absence of effective controls, inconsistent administrative processes, inappropriate organizational set-up, and lack of qualified staff allow for fraud in the billing and collection process. Past courses of action, such as improving staff recruitment, training, incentives, and discipline and reconfiguring the organization, are theoretically acceptable. However, these may be ineffective or even detrimental if they are not adapted to the utility's culture, as mentioned in Chapter 5, Manpower.

4.57 While more utilities are beginning to disconnect consumers and implement surcharges and other penalties in response to nonpaymer private sector receivables will not be significantly reduced without the utility having legislative a. hority to prosecute pilferers.

4.58 The collection of payments from the public sector is more difficult than from the private sector, due to public sector immunity from utility disconnection policies; in some countries, attempts to disconnect public agencies have resulted in "adverse consequences." While a few governments have authorized utilities to disconnect public sector agencies, the more popular and less politically sensitive course of action is to settle debts between the utilities and public sector agencies through debt-equity swap programs. These ad hoc clearing house arrangements do not yield sustainable results.

Spare Parts Procurement

4.59 EPUES concluded that the availability of foreign exchange is closely related to a utility's spare parts ordering, financing, and delivery system. Complexity in procurement increases as a government attempts to control allocation of limited foreign exchange. These procurement problems create further inefficiency, which results in severe problems for plant managers.

4.60 Direct donor financing of specific spare parts bypasses the national banking system and other government controls (and sometimes utility controls) to remove inefficiencies in procurement. Donor's own procurement procedures, however, often complicate and delay such direct financing systems.

Recommendations

4.61 Utilities should establish adequate cost and revenue records on newly installed power plants. Cost center accounting should be introduced if new power plants are installed or if new generation units are added to existing plants. Technical assistance should be provided to install cost center accounting and to train staff in the correct accounting procedures.

4.62 Utilities should develop and implement standards for meters and meter installation. These standards must ensure a high degree of protection against pilferage and destruction.

4.63 Consultants should prepare a report at the end of the liability period for all newly installed power plants identifying requirements for further training, technical assistance, and support to meet recurrent cost of power generation. The report should also include a critical assessment of the project and provide recommendations for future investment projects. These recommendations should be collected in the form of lessons learned and provided to planners of future lending operations as a manual with continuous updates.

CHAPTER 5. MANPOWER.

5.1 Manpower is one of the most fundamental components of performance in every organization, profit or not-for-profit, whether in an industrialized or developing country. It is certainly fundamental in the electric power sector, where manpower can help a utility operate within a system of complex constraints, and adjust to the constantly changing needs of its customers.

5.2 There are a variety of problems and constraints that affect manpower planning. This chapter summarizes the manpower issues confronting 23 utilities in 22 African countries. Findings are based on EPUES and World Bank missions, and on research presented in the Bank's Staff Appraisal and ESMAP Energy Sector Reports from 1980 through 1989.

5.3 EPUES found that the number of staff at a diesel plant was determined by a utility's hiring and firing practices. These practices were influenced by labor market constraints outside the utility's control, constraints within the utility, and direct or indirect government intervention.

5.4 The lack of control and organization in hiring and firing caused skills mix problems, which were compounded by the lack of training and incentives, particularly salaries. Training helped improve skill levels and balance the mix of skills, while incentives affected the utility's and the diesel plant's capability to retain staff once skills were required.

5.5 The lack of training and incentives created problems with staff morale, which affected the ability of utilities to operate efficiently. Manpower planning and development is the key to maintain good morale. The table below, Profile of Manpower, summarizes these manpower issues.

5.6 The utilities were classified as either understaffed (Shortage), appropriately staffed (Appropriate), or overstaffed (Overstaffed). They were then analyzed under six problems areas: skills mix, hiring and firing, training, incentives, morale, and planning and development. The number of utilities reporting a particular problem is noted under "P," and the number planning or implementing a solution is noted under "A." These problems are discussed in Findings, below.

5.7 As Table 1 illustrates, over half the utilities were classified as overstaffed, four as understaffed, and only six as appropriately staffed. The overstaffed utilities' main concern was skills mix, followed by hiring and firing and low staff morale. Most remedial actions addressed planning and development and hiring and firing. While these are positive signs, problems of low staff morale also need attention, especially if they are not included in the planning and development strategies.

Table 1. Profile of Manpower.

Staff Numbers	Total No. of Utils.	Reported Skills Mix Problems	Hiring & Firing (P)	Hiring & Firing (A)	Training (P)	Training (A)	Incentives (P)	Incentives (A)	Staff Moral (P)	Staff Moral (A)	Manpower Planning & Dev't (P)	Manpower Planning & Dev't (A)
Shortage	4	4	2	3	2	4	0	2	0	0	2	3
Appropriate	6	4	1	3	2	5	1	3	2	0	0	0
Overstaffed	13	13	8	9	3	6	4	4	7	1	5	10
Total	23	21	11	15	7	15	5	9	9	1	7	13
Percent	100%	91%	48%	65%	30%	65%	22%	39%	39%	4%	30%	57%

5.8 The understaffed utilities were also concerned mainly with skills mix. They also had problems with hiring and firing, training, and planning and development. Most of their remedial actions seemed to be focused on training.

5.9 For the four appropriately staffed utilities, the main problem was also skills mix, with training and low staff morale problems also reported. Their efforts were concentrated on improving training and hiring and firing procedures, to alleviate the skills mix problem.

5.10 The main concern for all utilities, regardless of staffing condition, was problems associated with an imbalanced mix of skills. Ninety-one percent reported problems. The next biggest concern was hiring and firing, followed by problems in staff morale. All utilities are giving increased attention to training, hiring and firing procedures, and manpower planning and development, but not all have made these issues a high priority. A detailed manpower profile for each utility, on which the above table is based, appears in Annex 1.

Findings

5.11 EPUES identified five major problems that negatively affect manpower resources: (a) poor salary structures and lack of incentives, (b) overstaffing and understaffing, (c) the lack of skilled personnel, (d) hiring and firing problems; and (e) inadequate manpower planning and development programs.

Poor Salary Structure and Lack of Incentives

5.12 EPUES traced most of the problems related to manpower resources to a poor salary structure and the lack of incentives to motivate and retain qualified staff.

5.13 Because most utilities were civil service entities, their salaries were set by the government to conform to civil service pay scales, which were 50 percent or more below those offered by the private sector. This resulted in the utilities' inability to attract qualified staff especially for its low-prestige diesel plants, and to its losing skilled staff to the private sector, where wages were not strictly controlled. Turnover rates were highest among the younger, professional, and skilled staff.

5.14 In most cases, wages were too low to keep up with the cost of living. This forced many employees to supplement their income by working overtime or taking second jobs. These outside activities resulted in low morale; staff absenteeism; walking out during regular working hours; low productivity; insubordination; and the reluctance to adhere to operational procedures, maintenance practices, and safety regulations. The utilities also experienced theft of tools, pilferage of highly marketable fuel and lubricating oil, and other instances of corruption.

5.15 These disciplinary problems clearly indicated the lack of motivation and low level of employee morale. The lack of tangible rewards compounded the problem. In Country B, for example, utility staff were not motivated by promotion since it had no financial consequence. EPUES also noted that productivity and motivation at diesel plants were negatively affected by poor working conditions, including cramped, poorly lit, poorly ventilated, dirty, and noisy areas.

5.16 Some utilities provided incentives in order to compete with the private sector and supplement their employees' low wages. Such benefits as free milk, free or subsidized education, free or subsidized housing, free transportation, free electricity, and travel overseas helped these utilities decrease turnover and retain their senior professional staff. EPUES observed that these benefits appealed most to the older staff, while the younger staff, preferring more take-home pay, tended to leave to take jobs in the private sector.

5.17 At the parastatal Utility A in Country D, for example, although salaries were actually lower than for employees of the national utility, the parastatal had lower turnover among its experienced professional staff. Turnover, again, was more common among the younger staff, who valued pay over benefits.[1] Even at the national utility, turnover was not as high as at other utilities, and the professional staff stayed an average of 14 years. This, too, was attributed more to benefits than to salaries. In Country R, where the staff of the parastatal also received modest salaries, the utility has managed to motivate, attract, and retain staff without high monetary rewards because the staff sees the utility as a good source of career development and as a provider of their basic needs.

5.18 Although wages in all utilities were low, some were able to compete modestly with the private sector by providing incentives to supplement low wages. In these utilities, employees were more motivated and their morale was higher.

Overstaffing and Understaffing

5.19 While EPUES found a wide range of staffing conditions, the most prevalent one was overstaffing. Thirteen of the utilities were overstaffed, four had staff shortages, and only six had appropriate staffing levels. The manpower structure of most of the utilities, whether over- or understaffed, can be represented by a pyramid with a very broad base. There were shortages at

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1 See Chapter 5, Annex 2 for a more detailed discussion of the parastatal in Country D.

the management and professional levels, and a massive oversupply of semiskilled and unskilled workers.

5.20 Understaffing was caused mainly by the lack of skilled personnel to fill jobs, and by salaries insufficient to attract qualified applicants. In some cases, two semiskilled workers had to be hired to perform work that could have been done by one qualified worker. The parastatal in Country R, the utility in Country S, and both the national and parastatal utilities in Country D were generally able to fill top positions and hold on to senior, professional employees because of incentives and the availability of technically qualified support personnel. But Country AA reported a 40 percent vacancy in senior management, and Utility A in Country R reported that 50 percent of its professional positions were vacant.

The Lack of Skilled Personnel

5.21 EPUES found a lack of skilled staff and an unbalanced mix of skills in all utilities, regardless of staffing levels. These problems affected the utility at all levels, from management to technical, skilled, and semiskilled personnel.

5.22 Some utilities, with the help of donors, initiated training programs to improve skill levels of their staff, so they could operate and maintain the utilities efficiently. As discussed in Chapter 6, Training, however, many training programs were ineffective, due to several factors. In some countries, training was considered an adjunct activity and not a priority, and funds to support a fully-functioning, structured program were seldom adequate and often nonexistent. As a consequence, many training programs were either limited in scope or gave the wrong training to the wrong workers. In countries BB and Z, for example, supervisory employees were trained as technicians, not as managers, a critical error in utilities which need to improve the balance between skilled and unskilled employees.

5.23 EPUES found some training programs too theoretical and taught by staff with no practical experience. Other programs were unstructured and largely hands-on. But even where training programs were well structured, efforts were unproductive due to the trainees' low level of education. In Country A, for example, training was not as effective as expected because 50 percent of the utility's supervisory staff and 90 percent of its lower level staff were functionally illiterate. This condition, common to many of the utilities, posed a constraint to further technical training and upgrading that could not be rectified by even the most effective training programs.

5.24 To solve the literacy problem among workers who need technical training, some of the governments have initiated literacy programs. Although this will be a long-term process, it will help eliminate illiteracy as an obstacle to technical progress.

5.25 Chapter 6 offers a more detailed discussion of training and how it affects manpower resources.

Hiring and Firing Problems

5.26 EPUES identified several factors negatively affecting hiring and firing procedures. One major constraint was the lack of qualified candidates in the local labor markets, particularly in countries without educational institutions to provide the utilities with qualified graduates. In Country F, for example, there was only one high school and no accredited technical school. In Country T, the utility had difficulty hiring professionals due to the shortage of engineering and computer science graduates from the university. Technical schools and training centers also were unable to meet demand, either because graduates were inadequately trained or because qualified graduates were drawn to the private sector.

5.27 In many countries, national policy appeared to dominate hiring and firing procedures. As shown in Table 2, EPUES found many diesel plants overstaffed. The effects of this for 1988 are clearly reflected in the performance measure of hours worked per megawatt-hour of production. One rural diesel plant from APA is included as a comparator; the comparison clearly illustrates the extent to which overstaffing occurs in the other diesel plants listed in the table. EPUES and World Bank Staff Appraisal Reports have often attributed overstaffing to either patronage or to a national policy of providing jobs in the national utility as a kind of social service program.

5.28 The high correlation of h/MWh with BPPE (i.e. R is greater than .74) suggests that increases in staffing can significantly decrease overall plant efficiency.

Table 2. Manpower Performance Measures.

Power Plant	Country	Hours/MWh[1]	BPPE[2]
A	H	45.2	0.14
A	M	78.4	0.32
B	M	23.4	0.52
A	J	3.2	0.60
A	CC	34.5	0.60
D	D	9.3	0.61
A	F	6.2	0.62
E	D	13.6	0.63
B	L	10.4	0.69
A	LL	13.0	0.70
A	G	23.9	0.73
A	D	4.0	0.84
A	A	8.8	0.91
A	L	3.0	1.00
B	GG	0.8	1.00

1 The number of employee hours per megawatt-hour of electricity produced.
2 Best Practices Plant Efficiency.

5.29 In Country T, staffing problems were compounded by government pressure to hire more lower level staff than the utility needed. Meanwhile, the utility had difficulty hiring the professionals it needed because the government assigned local university graduates to various industries and agencies according to priorities established by a national planning committee. In Country J, the government's emphasis on expanding higher education, its policy of guaranteed employment, and its practice of assigning graduates to the utility without regard to its needs, resulted in the utility having a high proportion of young, inexperienced professional staff. In Country D, because of a no-firing rule enforced by the government, the national utility became so overstaffed that even after the government finally allowed it to discharge 1,300 employees in 1985, it was still overstaffed.

5.30 In some countries, labor unions directly affected hiring and firing through the negotiation of annual contracts. Arbitration procedures were sometimes long and complicated and directly affected the efficient operation of the utility.

5.31 National policies affecting utility headquarters also directly affected local plants. EPUES found that diesel plant managers had little authority to hire local people as meter readers or bill collectors, but could only make requests and recommendations. Local managers also had little authority to honor requests from local officials who favored certain candidates for positions in the diesel plant. Often managers had to accept unneeded and unwanted additional staff assigned by headquarters.

5.32 Several missions raised interesting cultural questions. For example, while Westerners might frown on responding to pressure from local officials, conditions in many developing countries are quite different. The success of any effort in these countries depends on cooperation with local political authorities. Many political officials are respected not only because of their office, but because of their age or position in society, and managers need to have good working relationships with them to function in the local environment. As a result of their lack of authority, and the utility's lack of understanding of local political conditions, local diesel plant managers often found themselves unable to cooperate effectively with local officials.

5.33 All of these negative factors have contributed to the utilities' need for continued technical assistance to compensate for their inability to recruit and retain a productive workforce. To fill this need, many utilities have, with donor assistance, resorted to hiring expatriates to train local plant staff or to fill line management and operational positions.

Inadequate Manpower Planning and Development Programs

5.34 Every one of these manpower problems could have been alleviated by a sound manpower development program that addressed all aspects of recruitment, dismissal, promotions, salaries, benefits, and training. Such a program needs the support of local diesel plant managers, and of the local and national governments.

5.35 EPUES found that manpower development programs were either weak or nonexistent in all surveyed countries. This was due to centralized authority and to the lack of managers capable of carrying out such programs. Where managers were capable of developing and implementing such programs, they did not have the financing or autonomy to do so. A centralized but weak manpower planning and development structure often resulted in vague areas of responsibility, confusing or weak chains of command, and frustration among local diesel plant managers and supervisors.

5.36 Manpower planning was generally ad hoc. There were no objectives linked to short-, medium-, or long-term goals, and issues of organization, jurisdiction, unit function, job descriptions, career paths, job qualifications, work regulations, and labor arbitration procedures were often undefined. Even when they were defined, they were often disregarded because of internal or external pressure. Regulations were either nonexistent or weakly enforced, enabling management, or committees within the utility or the government, to decide on temporary solutions to case-specific problems. In many cases, these solutions were not compatible with existing personnel policies.

5.37 The overall result of the lack of manpower planning and development has been a chaotic recruitment process, a salary structure not in tune with reality, and a group of unmotivated and frustrated plant managers who supervise employees without skills, motivation, morale, discipline, or direction.

5.38 Efforts by the World Bank, local governments, utilities, and consulting agencies to improve manpower development programs have not produced noticeable results. Where EPUES did find improvements, they were minimal, and the possibility of continued improvement remains questionable.

5.39 The importance of manpower planning and development has been underestimated in most instances. In a typical project appraisal, manpower issues are not addressed with the same rigor as a financial or economic analysis. Problems are often "solved," rather, with ready-made pseudo solutions, such as hiring consultants, training, fellowships, etc. Even the World Bank's attempts at comprehensive manpower planning and development lack clear procedures, strategies, targets, and monitoring indicators. Where such specifics exist, they have low priority or are not enforced, and are not linked to strategies that lead to long-term objectives.

5.40 A comprehensive manpower planning and development program can illuminate an inventory of needs. It can also serve as a basis to persuade government to implement more favorable policies or to grant the utility more autonomy, with all the corresponding benefits.

Lessons Learned

Utility Level

5.41 The examination of manpower issues yielded the following lessons:

5.42 A central lesson in this chapter is that most utilities do not have, and critically need, institutionalized manpower planning and development programs. The absence of such programs negatively affects a utility's productivity and efficiency. Where it is not the extant practice of the utility, a condition of aid should be that Management Information Systems be established to enable performance objectives to be set and progress toward those objectives monitored.

5.43 A second important lesson is that utilities must establish salary and benefit packages competitive with the private sector. Job performance, motivation, and morale are directly linked to salaries, incentives, working conditions, and the recognition of merit through promotions. Job performance and utility reliability, for example, were notably better in utilities where low wages were ameliorated by fringe benefits.

5.44 Where utilities cannot compete with private sector salaries, they can supplement employees' income with fringe benefits, which help the utilities retain older professional staff.[2] Where high staff turnover is a problem for the utility, every effort should be made to provide staff, recruited and trained for the power station project, with a reward package adequate to ensure their retention.

5.45 EPUES found that the lack of autonomy among diesel plant managers to develop policies suited to their local circumstances creates an environment in which they cannot resolve local manpower problems.

Plant Level

5.46 When new plants of any type are constructed and staffed, and where the existing operational and maintenance practices are considered inadequate, a working group of the design consultant, the plant manufacturer, an experienced operations and maintenance manager, and a representative of the utility's management should develop a manual for the new plant's operation.[3]

Recommendations

5.47 Utilities should develop institutionalized manpower planning and development programs.

5.48 Utilities should establish salary and benefit packages competitive with the private sector. If salaries are government controlled, then benefit packages should be strengthened to make the combined salary and benefits competitive with the private sector.

5.49 EPUES recommends investigation of what non-monetary measures can be established to increase productivity, raise morale, promote a sense of belonging, instill pride in the work, and develop a sense of career direction.

5.50 EPUES also recommends further study of cultural factors which may affect a utility's ability to operate efficiently. In this regard, consideration should be given to analysis of the effects of local and informal institutions on the efficiency of the utility and its power plants.

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2 The parastatal in Country D is a case in point. See Chapter 5, Annex 2.

3 See Chapter 3, Annex 3, for a detailed discussion of this manual.

CHAPTER 6. TRAINING.

6.1 Training issues are inextricably linked with a number of management, institutional, financial, and technological factors. It is often difficult to tell which manpower problems can be resolved through training, and which are symptomatic of more deep-seated problems. Some of the diesel plants EPUES studied were totally dysfunctional in all major areas: management, institutional structure, government interference, finances, equipment, parts, and personnel. The training programs in such utilities merely reflected this condition. As suggested in Chapter 1, Institutional Issues, time and money spent on training is largely wasted if such overriding institutional issues as operational autonomy and appropriate tariffs are not first resolved. This chapter presents information on training from EPUES mission reports, from documents on training in related fields, and from discussions with training experts.

Findings

6.2 With a few exceptions, the EPUES missions found ineffective or nonexistent training programs and significant unmet training needs in the 12 countries in which training was studied. Most utilities had severe mismatches between manpower needs and employee skills. The most serious skill shortages were in middle management and technical specialties, such as power plant operators and mechanics. Many of these problems have been repeatedly discussed in the World Bank's Staff Appraisal Reports, but Bank and donor agency attempts to address these problems have met with little success. Two APA countries, DD and EE, were the main exceptions; both had ongoing training programs that, while not without problems, did a fairly good job of training staff. The biggest problem in Country DD was that there were more staff than training slots, which prevented most operators and mechanics from participating in the program.

6.3 EPUES found the lack of adequately trained operators and mechanics to be a major factor in the poor performance and short life of diesel plants in developing countries, plants, contributing to the need for early plant rehabilitation or replacement. These plants, in fact, operated much less reliably, for shorter periods of time, and at higher costs than projected. While some breakdowns were caused by the politically-forced operation of malfunctioning equipment or by lack of spare parts, EPUES found clear evidence that relatively modest training programs would enable utilities to operate diesel power plants at higher levels of reliability, availability, and longevity.

6.4 Table 1 indicates that in 11 of the 12 countries, training was not supported with sufficient resources by nearly all relevant parties, including donor countries, development banks, and utilities. Power project grants and loans often included insufficient funds for training, and donor or lender teams sent to conduct feasibility or cost-benefit analyses often did not include training or manpower specialists, despite past experience with failed training efforts. Utilities themselves also accorded training too little importance, often because budget constraints and a general atmosphere of crisis made it difficult for them to give consideration to long-term human resource development. Some utilities expected donors to support training, and so made no training efforts of their own.

6.5 Most training-related problems, such as a shortage of skills, are not unique to electric utilities. The World Bank has found the same problems in other sectors. Several broad reviews of the Bank's experience with vocational and technical training in other sectors are discussed in Annex 5.

6.6 The economic stagnation, hard currency shortages, educational shortcomings, and general bureaucratic morass in many of the countries also contributed to training and manpower difficulties.

6.7 EPUES missions found 12 common problems regarding utility training: (a) insufficient fiscal and human resources devoted to training; (b) lack of executive attention to long-term training plans or comprehensive needs assessment; (c) short-term, intensive training courses; (d) unstructured, ad hoc on-the-job training; (e) insufficient educational background of trainees; (f) lack of qualified local trainers, and the perception that training is a low esteem career; (g) inability to retain staff with valuable skills due to higher salaries in the private sector; (h) lack of standardized equipment, which increases training needs and complicates specific training; (i) lack of appropriate training materials and operating manuals in the languages of the operators and mechanics; (j) the utility's inability to perceive the advantages of training; (k) the low priority given diesel training compared to training in other technologies; and (l) insufficient training for diesel power plant managers and supervisors.

6.8 Table 1 lists 14 utilities in 12 developing countries where EPUES identified ten of these problems. A rural diesel utility in Country GG is included as a comparator. An "X" indicates that the utility has the problem identified by the column heading. No "X" means the problem either does not exist or has not been discovered. These findings are discussed below. Training programs common to developed and developing countries are discussed in Annex 4. Table 1 in Annex 4 shows the types of training offered in the subject countries.

Common Training Problems

Insufficient Resources

6.9 As Table 1 indicates, the missions found that nearly all the utilities devoted insufficient resources to training. The only clear exception was the parastatal in Country D, which supported extensive long-term training and education, including a high-quality apprenticeship program.

Table 1. Training Problems at Twelve Diesel Power Plants.

Country	Resource	Short	Unstruct	Education	Trainers	Retain	Equip	Materials	UtIcen	DiesPrior
GG			x			x				
E	x	x	x	x			x			
A	x									
LL	x	x	x	x		x				
LL2										
J	x			x	x		x	x	x	
F	x	x	x	x				x		
DD	x	x	x		x		x	x		
H	x	x	x	x			x		x	x
L										
CC		x						x		x
G		x			x		x			
M	x		x	x	x	x		x		
D	x		x			x				x
D2										
DONORS	x	x				x	x		x	x
(overseas)										
DONORS	x	x	x		x*		x	x	x	
(in country)										

* Time constraints/other duties, sometimes training expertise problems; diesel knowledge usually good.

** Donor Incentive Problems, not utility incentive problems.

"Resource" refers to lack of resources devoted to training.
"Short" refers to training being too short-term in nature.
"Unstruck" refers to training being too unstrucured.
"Education" refers to insufficient educational background of trainees.
"Trainers" refers to poor quality or unmotivated trainers, or trainers with other primary duties and insufficient time to train.
"Retain" refers to problems retaining trained staff.
"Equip" refers to problems stemming from equipment factors, such the number of different makes and models, or inappropriately complex equipment.
"Materials" refers to insufficient training materials and equipment manuals, and tne lack of materials in local language.
"UtIncen" refers to utility not perceiving incentive to support training.
"DiesPrior" refers to diesel technology being given lower priority in training than other generation technologies.
LL2 refers to a small private utility.
D2 refers to parastatal.
Donors (Overseas) refers to donor training programs in donor countries.
Donors (In Country) [illegible] to donor programs in host country.

Lack of a Long-Term, Integrated Approach to Training

6.10 The most frequently identified problem was that donors usually did not require utilities to institutionalize diesel training programs or address training issues in a comprehensive, strategic fashion. This was true, to some extent, in every utility except the parastatal in Country D. Most other problems derived from this ad hoc approach to training.

6.11 Trainees were often expected to master subjects in much less time than trainees in Europe or North America, even though many students were much less well-prepared academically. This situation was due to funding constraints, inability or unwillingness to spare staff (trainees or trainers) from normal duties, overestimation of what trainees could learn in a short time, and underestimation of training needs. It is clear from the investigation of diesel training programs for power plants in developed countries and for ship engines that operators and fitters need three-year structured apprenticeships to become qualified. EPUES found that the intensive pace of the training programs and the lack of a hands-on component prevented trainees from assimilating what they had studied.

6.12 Training was often handled as an adjunct to construction, commissioning, and operation of the diesel plants. Such training can be useful if the staff are already well-trained and only need instruction about specific equipment. If staff do not have knowledge or skills, however, such an informal approach cannot produce positive results. In the diesel plants EPUES studied, expatriate supervisors were often expected to perform on-the-job training in addition to their primary operational duties. Out of necessity, they gave little emphasis to training.

6.13 The use of expatriate advisors in line positions can result in conflicts between immediate and long-term needs. While the expatriate personnel are essential in some cases, continued dependence on such assistance reduces the utility management's incentive to train its own diesel operators and mechanics.

Low Education Levels of Trainees

6.14 The low education level of trainees was a problem particularly in Sub-Saharan Africa. The poor education of trainees was due in some countries to inadequate education systems, and in other countries to salary levels too low to attract qualified staff. Countries A and M were examples of the former situation; Country D was an example of the latter.

Staff Turnover

6.15 The high turnover of employees was caused by salary differentials between utilities and the private sector, especially for scarce technical skills; and by the fact that the extremely low salaries of the civil servants and parastatal employees were in some cases only a fraction of the cost of living. Improved benefits packages designed to compensate for low salaries, as at the parastatal in Country D, (housing, electricity, health care, education, etc.) appealed to older staff who had families, although the younger staff placed greater emphasis on cash earnings. There are drawbacks to improved benefits packages in lieu of increased salaries. Where employees are entitled to housing, for example, there might not be enough housing to go around, and employees who do not receive housing often are not compensated in any other fashion.[1] Employees of the national utility in Country D suffered from this problem.

Technology Factors: Lack of Standardization and Appropriateness

6.16 In some countries, the variety of makes and models of diesel equipment caused more training problems than equipment inappropriateness or complexity. The problems resulting from this lack of standardization are discussed in Chapter 7, Technical Issues. The selection of diesel equipment is often driven by grant or loan availability, which in the case of bilateral assistance dictates the equipment's country of origin. Many utilities operate equipment from a number of manufacturers, often at the same site. In Country H, for example, there were 40 diesel generator sets from 17 different manufacturers; and in Country DD, EPUES found a powerhouse with diesel engines from five different manufacturers, which complicated the learning and retention of engine-specific information and procedures. The complexity of the technology can also increase training needs. Larger, more complex diesel generators are often chosen for their ability to use heavy oil, which can lower operating costs. But these machines require more highly trained operators and mechanics.

Lack of Appropriate Training Materials and Manuals

6.17 EPUES visited many diesel plants which lacked training materials and operating manuals, or had materials in a language the operators could not understand. This made troubleshooting almost impossible, and frustrated the staff in Country DD, where employees were well-motivated and interested in self education.

Utilities' Interest in Training Staff

6.18 In many utilities, the position of diesel trainer was considered a dead-end career to be avoided by high-quality personnel. Few senior utility executives had responsibility for diesel training, and their unwillingness to invest in training programs to support preventive maintenance was often due to their expectations of donor support for specific plants. Certain utilities did not invest in maintenance training because they expected donors to replace or rehabilitate damaged diesel equipment. In some cases, a diesel plant was so identified with a specific donor that the utility was unwilling to take any responsibility for its operation (i.e. Country H).

Lack of Emphasis on Diesel Training Programs

6.19 EPUES missions found instances (countries D, CC, and DD) where high quality training programs neglected diesel in favor of other technologies. Some gave lower priority to the diesel component of their generation system because of the scarcity of resources and the assumption that diesel would be phased out. This assumption has led to the undermining of diesel performance and reliability. In Country CC, for example, the utility has devoted many resources

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1 David L. Lindauer, Oey Astra Meesook, and Parita Suebsaeng, "Government Wage Policy in Africa: Some Findings and Policy Issues," pp. 7, 18, 19, 23.; and *The World Bank Research Observer*, Vol. 3, No. 1, Jan. 1988, pp. 1-24.

to its training center, which provides good job training staff in generation, transmission, and distribution. Generation training, however, focuses on hydro and large thermal plants, and there has been no training for diesel operators and mechanics. Such training is currently being planned.

Lack of Training for Power Plant Managers and Middle Managers

6.20 Diesel power plant managers were rarely trained in the wide range of technical, organizational, accounting, and human relation functions for which they were responsible. The burden on managers was greatest in isolated diesel plants, which received little support from headquarters. EPUES also found middle management staff to be poorly trained and lacking necessary skills and experience.

Lessons Learned

6.21 In regard to training issues and programs, EPUES has identified two basic lessons: (a) an *institutionalized* training program is an essential component of an efficient and sustainable power operation; and (b) for donors, a comprehensive training needs analysis should be a prerequisite for, or integral part of, any power sector project.

6.22 An institutionalized training program requires high quality management and staff, long-term funding, and strategic planning. It must include training for all aspects of power plant operations, including commercial operations and middle management, and the training of trainers.

6.23 Institutionalized training is expensive, and many utilities, especially in smaller African nations, cannot afford a comprehensive long-term program. As a result, EPUES has concluded that serious consideration should be given to establishing regional training centers, cooperatively supported by participating utilities and financial and technical assistance agencies. Another approach worthy of serious consideration is the twinning of utilities in developing countries with utilities in industrialized countries. Twinning arrangements provide a mechanism for transfering technical and managerial knowledge from one utility to another one.

6.24 A comprehensive training needs analysis will identify instances where proposed plants cannot be supported by current utility staff, are not feasible, or are sustainable only with the long-term assistance of expatriate managers and consultants and with significant training interventions. Identifying in advance the need for expatriate assistance or training interventions will help project planners more realistically assess total project costs. Finally, assessment of training needs can be the utility's first step toward developing an official training policy and comprehensive training plan.

6.25 Where training needs have been chronically underestimated, such an assessment will illuminate the need for significant training interventions. Increasing the training component will increase the initial and projected costs of various power systems, but the hidden costs resulting from insufficient training will be much lower. Higher cost estimates may result in some marginal projects being rejected, but adequate training at the beginning of future projects will help prevent future unplanned costs for early rehabilitation and technical assistance.

Recommendations

6.26 EPUES recommends that guidelines be written to assist utilities and donors with the appraisal of existing training needs.

6.27 The organization, finance, and operation of regional training facilities should be studied. As an alternative, utility twinning arrangements should be investigated.

6.28 EPUES recommends further investigation of the content and design of training programs, including certification requirements, advanced teaching techniques, and so forth. See Annexes 1 through 3 for a more detailed discussion.

CHAPTER 7. TECHNICAL ISSUES.

Findings

Diesel Power Plant Design

Basic Design Criteria

7.1 In many of the diesel plants studied,[1] EPUES found that reliability of supply was inadequate and that total collapses of the electrical system (blackouts) occurred with unacceptable regularity. The two main plant-based causes were: inadequate capacity available to meet peak loads, and the failure to operate a "spinning reserve" policy (see Annex 1).

7.2 In Country D, EPUES noted that diesel engines on the interconnected electrical system could not be operated in parallel, thus restricting the available capacity to meet peak demand. There were also instances, such as in Country DD, where industrial loads with rapid fluctuations resulted in unacceptable voltage and frequency variations in the public supply systems. These "dirty" loads arose, for example, from supplies to arc furnaces or radio transmitters, both industrial applications involving frequent starts of large electric loads. In other instances, such as at diesel plant B in Country L, low reliability was due to the fact that the plant had diesel engines of unproven prototype design.

Prime Mover Selection and Auxiliary Systems

7.3 In all cases where EPUES reviewed diesel engine selection after the engine had been operating for several years, the team concluded that the selection was correct in the terms of the technology available at the time the decision was made. This aspect of design therefore appears to be adequately covered by conventional appraisals.

7.4 Some missions reported inappropriate sizing of diesel engines because of (a) over-optimistic projections of both demand and peak load growth, (b) failure to identify the full extent of the interconnected network, or (c) inadequate consideration of supply reliability objectives.

7.5 In the majority of cases, the choice of which diesel engine to use was not made on a lowest cost basis. Where capacity was insufficient to meet the load, cost was irrelevant. Where capacity was adequate, however, EPUES found that the diesel plant manager often did not have the necessary information to dispatch engines on a least cost basis. In many cases, the engines were too large to operate on spinning reserve without high cost on long periods of underloading.

7.6 The utility in Country DD made a practice of degrading the nominal output of its diesel engines by 2.5 percent per annum. This practice was based on experience that available output falls over time when other operational parameter limits (i.e. exhaust temperature and maximum firing pressure) are observed.

7.7 In general, essential engine auxiliaries were not considered significant causes of diesel plant outage. Loss of capacity in countries F and K, and in one plant in Country DD, was attributed, however, to fouling or inadequate design of the cooling systems. In some cases, the cooling tower packing had collapsed. Several instances were also noted of loss of cooling capacity

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1 i.e. in countries F, G, J, M, CC, and DD.

of radiators due to fouling of the finning by dead insects (countries A and DD). In one instance (Country H), this was aggravated by the designer failing to take into account the direction of the prevailing winds, which caused hot discharge air from the cooling radiators to be recirculated into the air intakes. In addition, EPUES noted several instances of severe leakage of lubricating oil from radiators, which caused extensive areas of oil-soaked ground. In plants in countries A, DD, and KK, the radiators were all of a common design and manufacture.

7.8 Many of the diesel systems EPUES reviewed were subject to frequent blackouts.[2] Although there were many causes, the missions found that between 66 and 75 percent resulted from distribution system faults and electrical storms of short duration. The typical sequence of events leading to a blackout was that a short-duration fault on the distribution system created a voltage reduction outside normal limits, which caused the protection on the electrical auxiliary equipment to trip. The resultant loss of cooling water, fuel, and in some cases lubricating oil then activated the engines' protection system, which initiated a cascade trip and a system blackout. Staff informed the missions that the main protection continued to operate after the causative fault on the distribution system had cleared.

7.9 In several cases, EPUES noted that restarting took an excessively long time following a blackout, due to inadequate design consideration of the need for black start capability. Some new diesel plants had no such capability,[3] and operators had to restart them by switching on the distribution system to isolated load centers. Then they had to start a small (black start capable) engine at a remote plant to supply electricity to a plant capable of carrying the system load to restart the diesel plant, which would then re-energize the distribution equipment. In countries G and K, this practice led to excessively long blackouts, and to running diesel engines below capacity for long periods in order to conserve starting air.

Plant Layout

7.10 EPUES found most of the diesel plants to be well laid out, a judgement in which the operations and maintenance staff concurred. In some instances, both in Africa and APA, additional engines had been installed in plants not designed to accommodate them. The problems which resulted from this were: (a) obstruction of the area where components were taken for maintenance; (b) obstruction of the areas for use of tools, which increased maintenance time and made the task more difficult; and (c) because of these obstructions, the need to dismantle components (e.g. heat exchanger tube stacks, auxiliary drive electric motors) that had to be taken outside the plant for repair.

7.11 EPUES observed two problems in connection with overhead electric travelling cranes in diesel plants. (a) While equipment requiring cranage for maintenance was sited within the crane rails, the crane hoist could not locate vertically above the equipment because it was too close to the rails and outside the travel of the hoist carriage. And (b) on V-form diesel engines, where pistons pull out at an angle, the barrel of the crane hoist in some plants was at right angles to the axis of the cylinder line, causing the hoist ropes to ride over the hoist barrel, which damaged both rope and barrel.

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2 Eight in Africa, one in APA.

3 Five plants in Country DD.

7.12 In several diesel plants in Country DD, EPUES observed that the area between engines was used to accommodate an engine control panel. This restricted access for maintenance and obstructed the area in which equipment was dismantled and rebuilt.

7.13 The missions saw many instances of valve and other gauges positioned in such a way as to make the operation of diesel engines unnecessarily difficult. In other cases, personnel had no means to access tank manholes, vents, or drains for operation or maintenance.

Standardization

7.14 Most public diesel plants had engines of at least two different makes. This resulted in such problems as: (a) the need for increased variety of spare parts, with consequent cost implications; (b) the need for more special tools; (c) decreased interchangeability of auxiliary equipment; and (d) different procedures for operating and maintaining each machine, with the consequent need for more training and supervision of staff.

7.15 Many privately-operated diesel power plants in Africa, APA, and the UK, by contrast, have engines from one manufacturer with interchangeable spare parts and auxiliary equipment. Where more than one type of engine is used in private diesel plants, it is usually due to the fact that the plant needs a larger unit than originally planned, or that the original equipment is obsolete.

7.16 If the drawbacks indicated in para. 7.14 are valid, then operating costs are likely to increase as a result of different engines in the same diesel plant. This increase can be calculated as follows. Using data from Diewert's draft report, the measure VCi[4] data points are plotted against the number of different engine types installed in the diesel plant [Diewert, E.]. Similar engine types are defined as those with identical bore and stroke. Diesel engines which run fewer than 500 hours a year are excluded if they did not contribute significantly to plant output and are believed to be black start units.[5] The linear regression line through these points indicates that the cost of operation does increase in direct relation to the number of diesel engine types. [6] See Figure 1 below.

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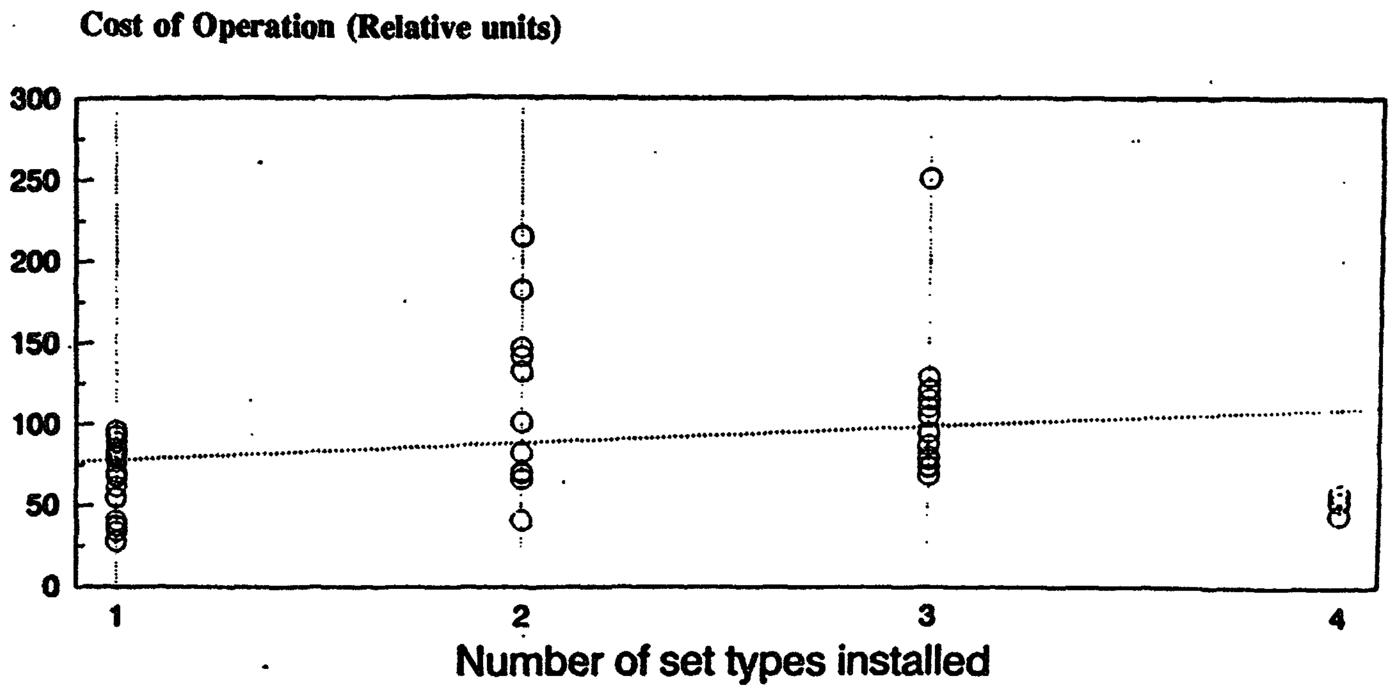
4 VCi is variable unit cost (in US$/MWh) excluding capital contribution. A similar result is obtained plotting Ei points against the number of set types installed in the plant.

5 Only data points for which plant configurations are known (those published in IDGTE Working Cost Reports) have been used, as complete plant configuration data were not available at the time of writing.

6 It should be borne in mind that the data sample was very small, and since all the diesel plants concerned were able to report operating statistics to IDGTE, they may well not have been representative of the operational and maintenance standards often found in diesel plants in developing countries.

Cost of Operation vs. Number of Set Types

Figure 1



Number of set types based on different bore or stroke: Engines which run less than 500 hours/a have been ignored.

Electrical Distribution/Transmission System

7.17 The reliability of supply at the diesel plants was reduced or not protected in many cases by inadequate design consideration of the transient and dynamic stability of the electrical system. In many instances,[7] excessive technical losses were caused by inadequate design and poor construction of distribution systems, incorrectly sized transformers, and the operation of underloaded engines for long periods. EPUES found few diesel systems with adequate meter test, calibration, and repair facilities; and also found many station batteries in a poor state of maintenance.

Building and Civil Works

7.18 EPUES found several instances[8] of faulty engine foundations, which caused misalignment and ultimately failure of the bearings or crankshaft. This required additional maintenance and increased operating costs. The faulty foundations were due to poor construction and design, aggravated in some cases by the staff failing to recognize symptoms or to contain the problem before it got worse. No international standards or code of practice covers the design and construction of diesel engine foundations.

Noise and Vibration

7.19 Noise levels in most diesel plants were excessive. This created a risk of hearing impairment to personnel with long exposure, and reduced their effectiveness due to noise fatigue and communication difficulty. Residents in the vicinity of these plants also complained of noise and vibration.

Ventilation

7.20 Several missions, notably the mission to a diesel plant in Country DD, found that natural draft ventilation systems were inadequate to maintain an acceptable working environment in generator houses. Dust ingress was also a problem in some diesel plants, e.g. in countries H and K.

Fire Protection[9]

7.21 In many diesel plants, the only means of fire fighting were portable fire extinguishers, often inadequate in both size and quantity. In plants with installed fire fighting systems, the fire pumps, particularly engine driven pumps, were in poor condition or inoperable. Enclosures protected by CO_2 had their access doors fixed open, which in any case rendered the system ineffective.

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7 In four African and two APA countries.

8 In countries D, K, and DD.

9 All types of thermal power plants pose a significant fire risk, since fuel is stored in large quantities and is often pumped under high pressure, in close proximity to high temperature surfaces, and at temperatures in excess of its flash point. Fire damage to the plant, equipment, and cabling can be considerable and cause prolonged outages.

Offices, Control Rooms, and Electrical Equipment Areas

7.22 EPUES found poor environmental conditions in diesel plant control rooms and equipment areas (high noise, temperature, humidity), which significantly reduced the efficiency of the operators who spent long periods in these areas. Office accommodations were often inadequate in size, environment (high noise, temperature, humidity), and equipment (not enough desks, file cabinets, or bookshelves for technical literature). Workshops often had inadequate storage facilities for tools, lifting and access equipment, floor area for laying down components during maintenance, machine tool facilities, lifting and handling equipment, and lighting. Buildings used to store spare parts had inadequate storage racks and bins for spare parts; and, inadequate access, lifting and handling facilities for heavier components, and ventilation. Poor ventilation led to condensation on spare parts, and consequent rusting.

General Safety Hazards

7.23 Many of the diesel plants the teams visited had safety hazards which could result in injuries to the staff. The most frequent hazards were open pipe and cable trenches.[10] Many missions reported poor standards of housekeeping (slippery, oily floors; electric leads and compressed air pipes trailing across floors; piles of waste and scrap materials obstructing personnel access). Some reported that personnel protection equipment (e.g. ear defenders, safety glasses) was available but was not used by the staff.

Waste Disposal

7.24 Many teams reported that oil saturation of the ground adjacent to the diesel plants was the result of inadequate consideration having been given to disposal of waste oil at the design stage. Other teams reported leaking radiators as a cause of ground pollution. Other diesel plant wastes which commonly present disposal problems are the solid scrapings from centrifuge bowls, used oil filters, and worn or damaged engine components.

Site Security

7.25 The teams found that security standards varied from fully fenced plant sites with alert full-time security guards monitoring access and egress, to unfenced sites with strangers wandering through the plant. No consistent pattern could be established between site security and other operational parameters, except where significant theft of fuel or lubricating oil increased operating costs. In the diesel power stations in countries F, G, and H, the teams found that consumption of oil and fuel appeared excessive because of theft. At other sites, maintenance work was difficult because hand tools supplied by the contractor had "disappeared."

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10 Counties F, J, O, CC, and Y.

Operation and Maintenance

Power Station Staff

7.26 Problems of overstaffing, inappropriate skills, unsuitable education and training, and manpower planning are discussed in other chapters. In the area of maintenance, diesel plant managers were often frustrated by: (a) lack of spare parts, tools, and miscellaneous maintenance materials; (b) lack of authority to initiate maintenance and corrective actions; (c) lack of general technical information, plant drawings, or the manufacturer's operation and maintenance manuals; (d) lack of operational cost data in cases where the plant manager is responsible for engine dispatch; (e) high staff turnover, (f) inadequate training or experience; and (g) poor communication with supervisors.

7.27 Reliability, availability, and housekeeping standards were noticeably better in private diesel plants,[11] where the above conditions did not apply.

7.28 The teams in countries P and U reported that high housekeeping levels were linked with the long-term presence of one or more expatriates. The standard of housekeeping of different diesel plants under the same utility and of the same age and design varied significantly.[12] The most significant factor in maintaining housekeeping standards appeared to be the motivation of the plant manager.

Operational Monitoring

7.29 The teams found that the quality and quantity of performance data varied from good to nonexistent. The utilities with the least amount of management information were generally those with the greatest shortage of qualified or experienced personnel, e.g. countries M, Y, and CC. Credible, regular, and timely management information was available to diesel power stations from the parastatal in Country L and a cooperative in Country EE, and from Country FF.

7.30 In most plants, the teams found that operational log sheets were kept on a regular basis, usually hourly while the engine was operating. Plant managers in countries L and DD, and at the parastatal in Country D, reviewed and analyzed the log sheets daily, and investigated or initiated corrective action if discrepancies were identified. These diesel plants also had a defect reporting system, and two of the three had well-trained, experienced operators who could handle abnormal situations. In plants where defect reporting was routine, recurrent defects were identified and minor modifications made to the diesel equipment to eliminate them.

7.31 A number of the teams noted that the data being logged were not plausible. Meters were misread or defective; the same readings were recorded month after month; log sheets were not reviewed by a supervisor; and operational staff did not report or were unable to recognize abnormal readings, sights, sounds, or smells. There were also many missing, broken, or miscalibrated engine monitoring instruments, and many protective devices were missing. The mission team at the national utility in Country D reported that when regular logging of operational parameters was

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11 e.g. in countries D, L, and DD.

12 Five plants in Country DD.

replaced with supervisory monitoring equipment, the recorded performance of the plant deteriorated.

7.32 Very few of the diesel plants, either public or private, had any staff trained in the basic chemistry of water treatment. In some cases, proprietary water treatment chemicals had been provided by the construction contractor, but without the necessary test kits,[13] equipment, instructions, or training.

Plant Maintenance

7.33 The most common factor to adversely affect maintenance work in public diesel plants[14] was the nonavailability of spare parts, which in most cases resulted from a scarcity of foreign exchange for procurement, as discussed in Chapter 4, Financial Management. This constraint did not apply to the privately-operated diesel plants.

7.34 In many cases, diesel plant managers also had no budget or authority to procure needed materials locally. Most were required to requisition spare parts through a headquarters procurement office. Procurement office personnel often had no knowledge of diesel power plants, gave low priority to spare parts requisitions, or simply failed to process the requisition requests.

7.35 The mission teams identified five main problems in connection with diesel plant maintenance manuals and parts lists: (a) they were not available at the plant; (b) they were written in a language which the maintenance staff could not read; (c) they were not comprehensive in that many auxiliary items were not covered, or the manuals did not indicate which particular part was installed in the plant; (d) "as installed" schematic system diagrams necessary for fault finding were not provided by the contractor; and (e) there was little technical data to enable the user to establish whether or not a part was functioning correctly.

7.36 Maintenance planning was found to be poor or nonexistent at many diesel plants, due to: (a) lack of spare parts; (b) failure of management to appreciate the need for such planning; and (c) failure to release the plant from service for maintenance, particularly where demand exceeded available capacity. Where diesel power plants are adequately maintained, overhauled, and operated within their design parameters (e.g. in APA and the UK), they achieve engine lives well in excess of 100,000 running hours, whether operated by public utilities or private companies. In several instances, public plants required rehabilitation after only tens of thousands of hours, some without ever having been overhauled. It is reasonable to conclude that this was a consequence of the failure to carry out maintenance and overhaul. Where there were reasonable plant maintenance histories and component wear records, preventive maintenance was always carried out.

7.37 Safe working systems to ensure the safety of personnel were in use at only a minority of the plants.[15] Such systems are required by statute in most developed countries.

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13 These were simple "go/no go" tests to indicate the concentration of treatment chemicals in the system, or the presence of scaling or corrosive conditions.

14 In one APA and 10 African countries.

15 e.g. in countries O and P; one plant in Country K; and one plant in Country L.

Spare Parts and Storage

7.38 Where significant quantities of spare parts were supplied with the diesel plant,[16] a proportion of those parts had deteriorated in storage, and could no longer be used because of corrosion hardening of 'O' ring seals. At the plant in Country G, the spare parts were adequately protected for long-term storage, but deteriorated rapidly after plant personnel opened packages to identify the contents.

7.39 EPUES frequently found, in relation to storage conditions, that: (a) spare parts were not stored in racks or bins; (b) either there was no inventory of spare parts or the inventory was not replaced as parts were used; (c) stores often contained worn out and damaged parts in the same location as the new parts; and (d) storage was not secure, although none of team reports mentioned theft of large diesel engine components.

7.40 Where there were constraints on the supply of spare parts, it was common practice to 'cannibalize' plants to maintain similar units in service. This reduced the available capacity of the plant for long periods pending rehabilitation, and sometimes led to corrosion damage of the cannibalized units.

7.41 Most diesel engine manufacturers issue technical bulletins to advise plant operators of changes in design or recommended operating practices, and of possible abnormal operating conditions. These bulletins are based on the manufacturers' research and development programs and experience with problems[17] with similar engines at other locations. But the teams found no instance that technical bulletins recommending modification of spare parts stock had been received by the stores, procurement, or maintenance personnel who needed to know. In some cases, staff complained that they received outdated parts after the manufacturer had initiated a design change.

7.42 Diesel plant supervisors in developing countries often have no direct way to communicate with the original equipment manufacturer. As plants age and many items become obsolete or unavailable, these supervisors must find suitable alternative components or sources of supply.

7.43 The mission teams found few instances of stores staff or procurement personnel being technically qualified. In the main, they were unskilled and with poor basic levels of education.

7.44 The missions had little time to meaningfully assess the adequacy of stores inventory under the operational circumstances of each diesel plant. The missions noted, however, that in the public plants, only one in Africa and one in APA had their inventory data routinely reviewed by management at any level. And only in Country P did the storekeeper report directly to the financial director.

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16 e.g. in one APA and three African countries.

17 e.g. a batch of components found to have been manufactured from faulty material.

Lessons Learned

7.45 Few technical problems were observed in power plants designed, constructed, and maintained according to industry standards.

7.46 Operational problems, unreliability of supply, and increased cost can result from nonstandardization of equipment.

Power Plant Design

Basic Design Criteria

7.45 It is important to define a standard for electricity supply reliability which avoids the growth of autogeneration and the burdens of excess capacity installation. Detailed, short time increment (e.g. half hourly) data on daily load profiles should be established early in the design phase, and should include seasonal variations and the factors which influence them, such as weather and holidays.

7.46 A detailed analysis of existing engines should be a regular part of the planning process, to ensure that a new plant will be capable of satisfactory parallel operation. These engineering checks must be carried out early in the design process, before the construction contract is finalized. For diesel power plants, restricting purchases of engines and parts to those which have been in reliable service for five years will help avoid problems from newly-designed equipment.

7.47 For planning purposes, the manufacturer's recommendations should be viewed in the light of experience with similar engines under similar operating conditions with the same owner. Similarly, assessments of the outage times necessary to complete maintenance routines are best estimated by personnel who have experience with similar work under similar labor practices and site conditions.

Generator Plant Dispatch

7.48 The dispatch of available plant capacity to minimize operating cost and maximize system reliability was identified as a weakness in several smaller systems which do not have the expertise to operate a load dispatch center. In these circumstances, a simple PC-based model could assist the operator in optimizing dispatch.

7.49 EPUES observed many instances where diesel power plant managers and operators had to run and maintain their plants without access to current technical information. This situation prevents operational recommendations and the maintenance guidelines of manufacturers and technical institutions from being applied.

Recommendations

7.50 Inadequate reliability of supply often results in the growth of autogeneration, which has adverse economic effects; but the installation of excess capacity, which would forestall autogeneration, has adverse economic effects as well. The factors necessary to minimize autogeneration should be identified.

7.51 Utilities should develop general technical standards consistent with international standards and avoid mixing different equipment. The additional costs resulting from nonstandardization should be added to any tenders which would result in mixes of equipment.

7.52 Utilities should prepare a report at the end of the liability period for all types of newly-installed power plants, identifying the need for further training, technical assistance, and support to meet recurrent cost of power generation. The report should also include a critical assessment of the project and provide recommendations for future investment projects. These recommendations should be collected in the form of lessons learned and provided to planners of future lending operations as a manual with continuous updates.

7:53 Utilities should provide technical literature and training materials adequate to its needs in quality and quantity. Manufacturers should regularly provide technical literature to power plant supervisors and to headquarters staff in a language they can read.

7.54 Utilities should insist that a consultant or a representative of the manufacturer (or the turn-key contractor) participates in the management of all new power plants for at least six months after commissioning. The terms of reference for the consultant should require that he and the utility manager set up all necessary site-specific procedures for maintenance and operation, define job descriptions for plant personnel, and prepare manuals in the local language. Utilities should also cooperate with manufacturers and donors in preparing the manuals, and in providing technical information to power plant personnel, in the local language.

7.55 Utilities and donors should ensure that a spare part preservation system is applied by all manufacturers to reduce the amount of corroded spare parts. Utilities should also ensure that suitable storage and inventory systems are available.

7.56 Small utility systems do not usually have the necessary expertise to operate a load dispatch center. The feasibility of producing a generic small system plant dispatch optimization program, along with manuals and a training package, should be investigated.

7.57 Consideration should be given to developing of a technical and operational monitoring and advisory service which would provide power plant managers with current technical information, advise them on resolving technical and operational problems, and monitor plant performance.

CHAPTER 8. ENVIRONMENTAL ISSUES.

8.1 All EPUES missions reported environmental pollution by waste lube oil at diesel plant sites. Experience indicates that most likely all diesel power plants in developing countries have a negative impact on the immediate environment, mainly because of disposal of oil and oily wastes.

8.2 A serious assessment of a diesel plant's environmental impact must consider the site specific effects of dumping oily wastes directly into the environment. The disposal of sludge and oily filters may have less effect in hot dry regions than in tropical countries, where the pollution of agricultural land, ground water, rivers, and lakes can be devastating. Annex 1 presents excerpts from EPUES mission reports regarding pollution from diesel plants in different regions.

8.3 Some missions had little time to collect information on site; their reports contained no detailed environmental information, as environment assessment was not a priority.

8.4 The amount of waste lube oil a diesel plant produces varies according to such site specific circumstances as the size of the machines and the plant, the plant's policy regarding oil changes, and the frequency of repairs that require oil changes.

8.5 EPUES surveyed diesel power plants ranging from 500 kW to more than 25 MW of installed capacity. The smaller plants with high speed engines required frequent oil changes (at one 500 kW African plant (every 200 hours). The bigger machines often required only a regular topping up of the lube oil and careful maintenance of the oil treatment equipment. These engines burn most of the oil, and require oil changes only when major machine parts are damaged or when the oil is contaminated or not of the quality specified by the manufacturer.

8.6 Owners and operators of bigger diesel engines (> 1 MW) usually have several manufacturer-recommended options for replacing oil. The recommendation to change the oil after a certain number of operating hours ensures that oil quality is higher than actually required. This creates a safety margin for both the manufacturer and the plant owner, but also leads to higher operating costs and waste of resources. Intervals shorter than the manufacturer recommends are required when the oil does not fulfill manufacturer's specifications.

8.7 The alternative to changing the oil in diesel engines after a certain number of hours of operation is to regularly test the oil in the machines at prescribed intervals. Manufacturers provide kits for simple on-site tests which measure the most essential properties of the lubricant.

8.8 Diesel manufacturers also offer more thorough testing on oil samples sent in by the utilities. They can interpret test results to determine the quality of the oil and identify significant wear and tear of machine components. They can also recommend replacing or checking specific engine parts.

8.9 The diesel power plants that EPUES teams visited all changed their oil at the intervals recommended by the manufacturer, rather than following one of the accepted alternative procedures. In two APA countries, the oil in the larger engines was changed after 2000 operating hours. In Africa, it was changed at shorter intervals. This policy increased avoidable oil consumption and created unnecessary environmental burdens.

8.10 Many diesel plants opted for regular lube oil changes instead of testing because: (a) oil could be resold by power plant employees; (b) due to unreliable communication between the power plant, the utility, and the manufacturer, oil samples and test results could not be easily exchanged; (c) the lube oil specified by the manufacturer was not available and the manufacturer did not support use of other oil; (d) the utility could not meet the cost of testing; (e) plant managers were not aware of the manufacturer's testing service; and (f) managers were incapable of conducting regular tests, or could not interpret the results transmitted by the manufacturer, thus increasing the risk of damaging the machines.

8.11 Since reducing the environmental impact of waste oil disposal depends on reducing the amount of lube oil the diesel plants use, EPUES recommends that a Technical Operational Monitoring and Advisory Service be established to monitor this and other environmental issues. (See Chapter 7, Technical Issues). This service could also encourage preventive maintenance and reduce long-term operating costs of plants.

8.12 The disposal of unavoidable waste oil is the second step in reducing pollution caused by diesel plants, and requires more attention from both donor agencies and utilities. EPUES missions found that waste oil is either disposed of directly near the plant or sold to private customers who use it for a variety of purposes, most of them environmentally unsafe. Waste oil is used, for instance, in vehicle engines; as "medicine" for the external treatment of wounded animals; for impregnating fences, boats, and wooden structures; as fuel for household stoves; and as fuel for industrial production (steam boilers, bricks, etc.).

8.13 Missions reports contained no information about the extent to which waste oil is used for each purpose. This is of concern because the burning of waste lube oil contaminated with heavy metals and chemical additives creates health hazards. The hazards are especially severe if the lube oil was mixed with transformer oil containing PCB.

8.14 Country DD has prohibited the sale of waste lube oil because it was being filtered and resold as new oil to car owners. The mission learned, however, that the oil is still given to private customers, and is also sometimes transported back to the refineries or to steam power plants, where it is used as additional fuel.

8.15 Small diesel plants normally do not have any facilities for environmentally safe disposal of waste lube oil; this oil is usually dumped near the plant along with such oily wastes as filters, rags, and machine parts. The amount of this waste is relatively small and does not justify the installation of incinerators or other costly equipment.

8.16 Incinerators at diesel power plants in Country DD were not used to burn waste oil because the diesel fuel needed to run the incinerators would have added to the cost of power production. No other mission reports mentioned the use of incinerators. One mission recommended always installing incinerators in new diesel power plants, but EPUES recommends that this not be done without thoroughly analyzing site specific conditions.

Fuel

8.17 None of the missions reported major environmental problems with regard to fuel handling. All the diesel plants surveyed had some pollution in the fuel discharge area. The missions attributed leaky fuel lines in one country, and the widespread pollution of the powerhouse in Country G mainly to poor management. The storage tanks in most facilities were equipped with sufficient containments to prevent significant pollution if a tank leaked. EPUES did not analyze many heavy fuel power plants, which may cause more problems than diesel fuel plants.

8.18 The missions did not assess fuel transport chains or the environmental impact of transporting fuel to diesel power plants.

Emissions

8.19 None of the missions reported on gaseous emissions. Diesel plants in remote areas with little air pollution do not seriously affect the environment, but in population centers, special precautionary measures may be required to reduce air pollution caused by these power plants. The British Institution of Diesel and Gas Turbine Engineers is currently developing emission standards for diesel power plants which could be used for future diesel power projects. Whatever emissions there are would be reduced by improving engine efficiency, which EPUES recommends as a general environmental practicefor all types of power plants. This could be accomplished in all cases with improved maintenance practices, better engine loading and dispatching, and loss reduction measures. (See Chapter 7, Technical Issues).

Cooling Water

8.20 The cooling water in diesel engines must be chemically treated to prevent corrosion in closed cooling systems. The cooling water was in most cases not treated, due to either lack of foreign exchange to buy the chemicals or to lack of management capabilities. The plant managers were in most cases aware of the need to treat the water. None of the mission reports cited pollution from chemically treated water as a problem, although the water in diesel engines must be replaced after major repairs.

Noise

8.21 The health consequences of unacceptable noise levels in the diesel powerhouse, and the consequences for operators in the plant, are discussed in Chapter 7, Technical Issues.

8.22 Only one diesel plant in Country DD had complaints from the inhabitants of nearby settlements; these inhabitants had settled there after the plant was installed.

Lessons Learned

8.23 Waste lube oil disposal is the most serious environmental problem associated with diesel plant operation. Uniform solutions are not effective, and remedies depend on site specific analyses.

8.24 Incinerators do not solve the waste lube oil problem. Project appraisals should assess methods of waste oil disposal, and proper disposal should be monitored.

8.25 The problem of disposing of PCB-laden diesel transformer oil has never been considered. At the least, repair shops should be equipped with facilities to collect the oil, which should be burned at a high temperature.

8.26 Noise abatement is mainly a design problem and should be part of the design specifications for new power plants.

8.27 The mission did not identify high emission levels as a problem associated with the operation of diesel plants.

Recommendations

8.28 Doncrs should conduct a study of two major aspects of waste lube oil disposal: (a) the range of technical options, and (b) the specific conditions for each site.

8.29 The first part of the study should compile information for distribution to diesel project planners and the utilities. The information should cover the following issues: (a) the use of waste lube oil in industrial high temperature processes in, for example, the cement and asphalt industries[1]; (b) incineration at low and high temperatures using makeshift equipment; (c) mixing filtered waste lube oil with diesel to burn in diesel engines; (d) central collection of transport sector waste oil at the plant to make disposal more economical; (e) recycling; and (f) alternative uses, such as dust binding on roads, impregnating distribution line poles, and so on. The study should result in a report detailing the advantages and disadvantages of the various options, their costs and benefits, and their managerial requirements.[2]

8.30 The study should be followed by a pilot project to apply these findings. The project could undertake environmental assessments as an integral part of new power plant investments, or, financed out of bilateral funds, could plan, design, and implement environmental protection measures in diesel plants that have already been financed by donor agencies. A suggested outline for such a study is included in Annex 2 to this chapter.

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1 See World Bank Technical Paper 93, Vol. III.

2 *The Environmental Manual for Power Sector Projects*, currently under preparation as part of a joint research project of several financing and technical assistance institutions, will address these issues in greater detail.

CHAPTER 9. DONOR POLICIES AND PROCEDURES.

9.1 This chapter addresses the effects of donor[1] policies and procedures on power sector projects and utility operations. Donor policies encompass such decisions as which components of the power sector to support and how to support them; whether proof of a project's economic viability should be a condition of assistance; and whether such assistance should be short-term or long-term. Donor support includes overseeing project planning and implementation; and establishing procedures for procurement, monitoring, and evaluation.

9.2 This chapter is not based on a formal evaluation of donor programs and policies. Donor agencies were not consulted or interviewed, and no donor policy or procedure documents were examined. On-site EPUES mission teams examined how donor actions affected diesel power plants, and how government and utility executives responded to donor actions and policies (real, perceived, or anticipated). The findings, and lessons learned, in this chapter were *inferred* from direct observation of power plants, utilities, and government agencies in EPUES mission countries.

9.3 EPUES realizes that donor agencies have different mandates, objectives, and policies which reflect explicit national policies and government directives. No one set of recommendations can respond to the needs of different donors. Even if there are commercial interests at stake, however, all donor agencies are or should be concerned with the long-term viability of the projects they support.

9.4 The findings and lessons learned about donor practices often involve broad issues, and are based on recurring patterns of problems, as discussed in the first eight chapters of this Report and in other reviews of power sector assistance.[2] Some of the issues in this chapter involve basic philosophical questions of donors' motivation for offering development assistance, of what types of assistance they should offer, and of their responsibilities for the impact of their projects on the populations they are trying to assist. More than the other chapters, this one raises broad questions and suggests changes in policies that can improve project and sector performance, but might go against the perceived self-interest of some donor organizations, such as preset disbursement targets or political objectives.

9.5 Certain inappropriate policies, actions, and omissions of donor agencies seem to contribute to the poor performance of diesel power plants specifically and utilities in general. Many problems seem related to donors' preference for financing capital projects and their lack of long-term involvement in the power sector of recipient countries. The focus of donors should be the lifecycle of the power plant and cover all aspects of operation and maintenance on a long-term basis.

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1 The term "donors" in the context of the Core Report refers to all multi- and bilateral financing and technical assistance agencies.

2 In particular, *A Review of World Bank Lending for Electric Power*, by Mohan Munasinghe, Joseph Gilling, and Melody Mason, Industry and Energy Department Working Paper, Energy Series Paper No. 2, March 1988.

9.6 Another problem is the poor quality and excessive optimism of project economic assessments. The World Bank has, in fact, been engaged in a thorough review of its project assessment practices and methodologies, including the specific problem areas of risk assessment, cost of capital, sustainability, and inadequacy of resources devoted to the economic analysis of projects.[3] These are some areas in which EPUES found donors to be deficient.

Findings

Donor Over-Optimism

9.7 Donors are often overly optimistic in appraising power projects, because they rely on unrealistically optimistic demand projections.[4] This leads to investment in unneeded capacity. Donors also assume optimistic projections of improved loss reduction and billing; and they overestimate the economic benefits of projects by overestimating plant and system reliability, or by estimating benefits based on the subsidized cost of power. These issues are discussed in detail in Chapter 3, Economic and Financial Issues, Annex 2, paragraph 5, and Annex 5, paragraphs 22-23, 3.39, and 3.47. Figures 1 and 2 illustrate a series of optimistic projections of system loss reductions in one African and one APA country, and show comparisons with actual experience.

9.8 Donors and recipient utilities often underestimate training requirements, leading on the one hand to underestimation of project costs, and on the other hand to an overly optimistic estimate of project reliability and sustainability, based on an assumption of capable management, maintenance, and operations staff.[5]

9.9 For all types of power projects, the World Bank Review [Munasinghe, et. al.] found that both the Bank and its borrowers were often too optimistic in predicting of a wide range of factors, including growth in demand, loss reductions, project implementation schedules, financial viability, and others.

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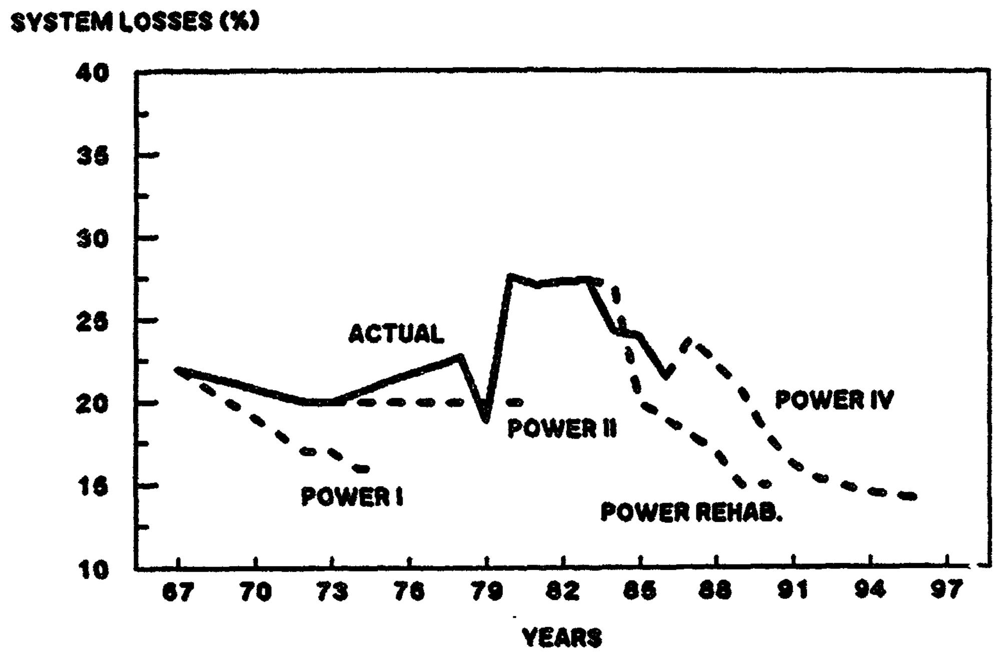
3 See World Bank memoranda, "Economic Analysis of Projects," Randolph L.P. Harris, CODOP, November 2, 1990; "Economic Analysis Project Appraisal," G. Beier, February 1990; "Some Bank Concerns Regarding the Economic Analysis of Projects" and "Economic Analysis of Projects: Follow-up Steps," P.K. Mitra; "Economic Appraisal of Projects: Review of World Bank Guidelines," D. Newbery, April 1990; "Projects vs. Policy Reform," R. Kanbur, April 1990; and "Project Appraisal and Planning Twenty Years On," I.M.D. Little and J.A. Mirrlees, April 1990.

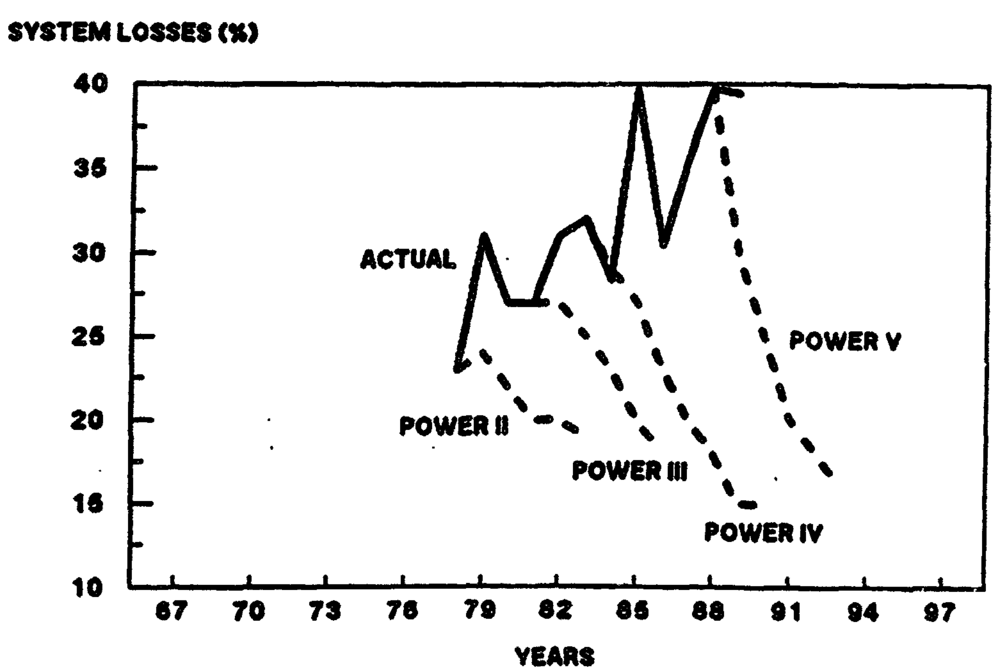
4 Chapter 3, Annex 2, paragraph 5.

5 See Chapter 6, Training.

Figure 1. System Losses - Actual and Forecasts.
Sudan - Blue Nile Grid.



Haiti - Port au Prince.



Weak Project Risk Analysis

9.10 It appears that donors may be insufficiently rigorous in assessing risks for all types of power projects, although they are often aware of the risks posed by institutional, financial, and manpower problems. EPUES found that many diesel projects did incorporate components explicitly intended to address these problems, but what often seemed to be lacking was any explicit assessment of the chances these measures had for success, or consideration of how the amelioration of a specific problem might affect overall project risk. Staff appraisal reports should refer to problems with similar projects in the same sector and country, and indicate how these problems will be avoided in future projects. Evaluation reports should be also considered, when a discussion of risks is part of the appraisal reports.

9.11 It is unclear when donors were genuinely too optimistic, and when they merely accepted predictions at face value while being privately sceptical. Donor personnel routinely work with utilities beset by tremendous institutional, economic, and manpower problems. Given these problems, and the uncertain economic, political, and policy environments in many recipient countries, it is natural for donor staff to accept the fact that projections become goals that are often unmet, that things generally do not work out as intended, and that these are simply realities that they must accept, particularly when confronted with pressures from senior management to disperse funds and export equipment. This pessimistic realism is common in all sectors of development assistance. Where it exists, however, it might be more profitably expressed during the project design and approval process, when it could help improve project design and weed out marginal power projects.

Project Conditionalities

9.12 Donors have a long history of supporting generation projects even though utilities suffer severe financial, institutional, managerial, and manpower difficulties. EPUES found that without adequate tariff structures and institutional arrangements, a utility will probably not be able to operate in an efficient, sustainable fashion.[6] Experience with aid conditionality is mixed, and is particularly poor in the area of tariff reform and financial targets.[7] Conditionality often has not delayed projects pending institution of reforms, but rather has required that countries agree to implement reforms during the project. Donors have financed projects when utility revenues, tariffs, billing, and collections were all clearly not conducive to sustainability of the project.[8]

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6 See Chapter 1, Institutional Issues: Utility/Government Interactions.

7 In addition to EPUES observations, this was also addressed in *Review of World Bank Lending for Electric Power*, pp. 20-24, 90-92. In addition, the World Bank Industry and Energy Department (IENED) is preparing a detailed study of the success of financial conditionality in power sector lending.

8 See, for example, Chapter 3, Economic and Financial Issues, paragraph 3.4.

Incomplete Project Assessments

9.13 EPUES found that a range of institutional, economic, and manpower factors critical to project viability and sustainability often received cursory treatment or were completely left out of project analysis and design. These factors included utility and plant autonomy, plant finances and revenue, manpower and training needs, spare parts financing and procurement, billing and collections, accounting systems at the plant level, and environmental impacts. Institutional appraisal was often insufficient or nonexistent.

9.14 Donors often did not perform comprehensive training needs assessments as part of the project design process, even though diesel power plants usually had poor reliability and longevity records where trained operators and mechanics were unavailable.[9]

9.15 Extreme scarcity of foreign exchange was the root cause of most parts procurement problems in countries the EPUES teams visited. The measures that host governments commonly used to contend with this scarcity led to complex procurement systems, which resulted in long delays.[10] Donor procurement, the other common response to this scarcity, was also complex and inefficient. Bilateral aid agencies also had complex procurement regulations which delayed procurement transactions; distance, communications problems, and weak institutional links between utilities and the agencies all complicated the ordering process.

Hardware Focus

9.16 Donors generally support spending for hardware, with some concentrating on generation hardware, at the expense of plant rehabilitation, transmission and distribution system maintenance, parts procurement, institutional development, effective training, and policy reform. The focus on hardware may be related in some cases to the donors' goal of using aid to promote capital goods exports, which results in donors competing to provide financing and in lack of equipment standardization. In other cases, the focus on generation projects may be a matter of habit, or be due to the fact that such projects are discrete and conceptually simple, and have significant hard currency requirements.

9.17 The focus on hardware, particularly if it is related to export goals, is also partly responsible for donors not learning from past mistakes and not being concerned with the sustainability of the project or financial health of the utility.

Tied Aid and Lack of Standardization

9.18 The severe problems caused by lack of equipment standardization, which in turn is largely due to donors' tied-aid practices, are well documented in other chapters.[11] This lack of standardization creates costly problems for plant operations, maintenance and repair, training, and

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9 See, Chapter 6, Training, Table 1.

10 See Chapter 4, Financial Management, paragraphs 4.60-4.62, and Annex 2.

11 See in particular, Chapter 7, Technical Issues, paragraphs 7.15-7.17.

stores financing and management; and the solutions depend more on the donors than on the recipients. Because of tied aid practices, utilities are often forced to operate equipment from many different manufacturers, often at the same site. An EPUES team visited one diesel powerhouse in an APA country which had engines from five different manufacturers. And one country in Africa had 40 diesel generation sets from 17 different manufacturers.

9.19 Tied aid is not the only reason for lack of standardization. Conversely, the system of open tender/lowest bidder used by the World Bank and donors can have the same result. The lowest bidder might supply equipment different from that already in place, and subsequent tenders might be won by yet another vendor. The donor practice of not allowing recipients to specify the make and model of equipment also works against standardization. At the least, a penalty for introducing nonstandardized equipment should be introduced in the evaluation of bidding documents to compensate for higher long-term operation and maintenance cost.

Sustainability: Structure of Donor Financing

9.20 Donors often have a short-term approach to power sector assistance, rather than a longer-term investment perspective. This short-term approach involves discrete interventions such as constructing a power plant; it does not focus on ways to ensure a reliable and efficient power system. In many cases, patterns of donor assistance have encouraged utilities to neglect plant maintenance and to place a low value on plant longevity. Often assistance is not structured to give utility managers clear signals about the value of capital equipment. Certain utilities expect donors to pay for rehabilitating or replacing damaged equipment, and therefore do not invest their own resources in spare parts, maintenance, or training. Several utility officials said they had no incentive to buy spare parts because they knew or believed that donors would rehabilitate or replace equipment when it failed.[12]

9.21 Financing packages were often so beneficial, with such a high grant component, that they undermined a utility's incentive to do maintenance and repair. Since donors often do not demand that financing be on-lent, utilities do not get a clear signal that the plant has a value which must be safeguarded.[13]

9.22 As discussed in Chapter 3, financial rates of return have generally been low or negative, with most plants operating at a loss if cost of capital is included. For many plants, the tariffs are insufficient even to cover operating costs.[14]

Sustainability: Expatriate Staff

9.23 Donors should take care that their policies do not increase a utility's dependence on expatriate advisors. Such dependence may facilitate plant construction, but it can reduce the

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12 See Chapter 7, Technical Issues.

13 See Chapter 3, Economic and Financial Issues, paragraphs 3.41-3.43 for further discussion of on-lending.

14 See Chapter 3, Annex 6, paragraphs 1 and 2.

utility's sense of ownership of the plant and its willingness to invest in spare parts, maintenance, and training. In many cases, the presence of expatriates is essential for productivity; the reasons for this situation should be examined.

Project Planning and Design

9.24 In general, EPUES found few problems with the technical aspects of diesel project planning and design, although a few plants did have design shortcomings. At one diesel plant in Africa, for example, spare parts were financed but the plant had no parts storage area. Plants often lacked training facilities, the result of the project design not including a training needs analysis.

Evaluation

9.25 Both donors and utilities often failed to evaluate or learn from past projects. Cost and performance assessments were in any case hindered by lack of information on capital outlays, cost of spare parts and rehabilitation, and cost of expatriate consultants. This lack of information was due to poor in-plant accounting systems, which often were not reviewed as part of the project assessment. Such accounting systems made subsequent project evaluation impossible.

Donor Coordination

9.26 Competition between or lack of coordination among donors resulted in less efficient use of donor resources. EPUES found several cases of different donors simultaneously funding similar activities, and at least one case of donors funding redundant diesel power plants. This lack of coordination led to duplication of efforts, and prevented donors from effectively applying pressure for the reforms that would led to effective plant operation. Competition to supply power generation hardware led to poor equipment selection, lack of standardization, overinvestment in hardware, and underinvestment in human resources. Donor coordination in specific projects should be complemented by more intensive coordination in policy development to reduce the burden on developing countries that have to meet a large variety of donor-specific requirements.

Environmental Impact

9.27 EPUES found little consideration of environmental impact in diesel project designs or assessments. The possibility of lube oil and coolant contamination of water supplies was never considered, and few plants had lube oil recycling or safe disposal systems. The one environmental improvement was that newer diesel plants tended to be much quieter, and to offer a better work environment for staff.

Lessons Learned

9.28 Many of the lessons EPUES learned about diesel power plants are applicable to a wider class of power plants and to general utility operations. This point seems particularly relevant to donor policies and procedures.

9.29 Donors are often too optimistic in their economic appraisal of proposed power projects, because they rely on optimistic projections of demand, loss reductions, and a wide range of financial and administrative performance measures. Donors are also overly optimistic in assessing risk, or do not incorporate risk explicitly into assistance decision making.

9.30 Project appraisals are often incomplete and do not incorporate the many institutional, economic, and manpower issues vital to determining whether a project is sustainable.

9.31 Experience with conditionality in tariffs and financial targets has been poor. Donors often proceed with projects before reforms are undertaken, although such reforms could be prerequisites for successful projects.

9.32 Donors should give utilities clear signals about the value of equipment, by requiring on-lending or capital recovery accounts.

9.33 Excessive focus on hardware results in lack of attention to manpower and other components necessary for a successful project.

9.34 Donors are largely responsible for lack of equipment standardization, which has severe negative impacts. Lack of standardization is related to tied-aid financing and international competitive bidding requirements. Rigid insistence on open tender procurement, where the utility is not allowed to specify equipment make and model, can also cause lack of standardization.

9.35 Donors often prefer short-term discrete interventions to longer-term engagement, and often view assistance more as a gift or loan than as a long-term investment.

9.36 The natural tendency of donors to concentrate on a project's technical and hardware components is due to the fact that such components are relatively simple to design, and that results seem to be realized in a short period of time. Thus, the "cost-per-unit-produced" is low. Donors often neglect the institutional components of a project due to their complexity, particularly when they are confronted with host country sensitivities and resistance. Furthermore, results are realized over a much longer period of time, making "cost-per-unit-produced" much higher.

9.37 Based on the analysis in Chapter 1, Government/Utility Interactions, sustainable, efficient operation is more likely in autonomous utilities, which suggests strongly that donors should encourage recipient governments to increase their utilities' autonomy, or, even better, to privatize them.

9.38 EPUES encourages donors to appraise projects rigorously and realistically. If the EIRR is below the opportunity cost of capital, projects should not be undertaken. For isolated diesels, both utilities and donors should consider the optimum supply and reserve margins, and relate reserve margins to willingness to pay.

9.39 The enforcement of on-lending terms for capital aid can help ensure a better balance between new capacity and maintenance expenditures. Donors and governments should routinely implement and monitor on-lending terms for aid to the power sector.

9.40 Governments need to develop internal capacity to review and adjust tariffs. Donors should assist this effort.

9.41 High losses and poor financial management have a crippling effect on FIRRs. Donors' increasing focus on strengthening institutions, reducing losses, and improving billing and collection should be continued. The achievements of some countries show that political will can improve financial performance, although the public sector's poor performance in paying power bills means this will often does not exist. There are no welfare arguments for a subsidy to public sector consumers; and donors should closely examine proposals for capacity expansion when outstanding bills are high.

9.42 Donors should link the financing of new generation facilities with loss reduction programs if the appraisal mission identified high technical and nontechnical losses. Whether or not losses are acceptable is country specific and should be determined by the appraisal mission. Lending should be suspended if the utilities do not carry out loss reduction programs.

9.43 Donors should consult with the utility and other donors to ensure that their efforts are not duplicated. In some cases, donors optimistically assume an improvement in performance even though performance is clearly deteriorating. Donors may also overstate the economic benefits of power projects by relating consumer surplus measures to the (subsidized) price of power rather than to its economic cost. This conclusion is described in detail in Chapter 3, Annex 6. Estimates of the consumer surplus attaching to industrial power consumption may need particularly close scrutiny.

9.44 EPUES suggests that donors look carefully at procurement systems before funding power projects. If a procurement system has more than a few well-defined steps, then the donor and utility should design a separate mechanism for funding spare parts procurement. Donors should also encourage simple, transparent foreign exchange allocation systems from a reliable source.

9.45 In cases where limited foreign exchange is available to the utility, donors should make adequate provisions to alleviate the operational problems caused by delayed spare part ordering and supply. Possible arrangements could be the installation of spare part funds or an extended commitment to finance spare parts over several years of power plant operation.

9.46 EPUES has suggested a way to set up donor financing systems that are simple and can respond rapidly to utility requests. These would be hard currency accounts by donors in the country where spare parts might be purchased. This proposal is examined in Chapter 4, Annex 9.

9.47 Another strategy is to decrease the need for foreign exchange by manufacturing spare parts locally. Diesel manufacturers have indicated interest in such an approach, and many EPUES countries appear capable of manufacturing certain parts, particularly consumables such as filters. EPUES believes that such a strategy should be developed for producing spare parts, especially in the African regions.

9.48 The issue of tied-aid has long been controversial, and has been under discussion within the Organization for Economic Cooperation and Development (OECD). EPUES recommends further study to determine whether there are ways to reduce the negative impact of tied aid on the power sector, particularly in the area of equipment standardization; and also recommends an analysis of the costs of nonstandardization.

9.49 As noted above, the World Bank has been reviewing its economic assessment guidelines and practices. Given the weaknesses in project appraisals, EPUES recommends building on the recent World Bank work by developing guidelines and associated support documents.

9.50 EPUES found that the total cost of power from diesel plants was far greater than projected. This was also true for transmission and distribution costs of rural electrification.[15] Since significant improvement is often impossible because of political conditions or scarcity of resources, EPUES recommends further study of the most efficient ways to provide electric power, including a cost comparison between diesel grid power and such alternatives as dispersed generation, both fossil and renewable, and autogeneration.

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15 "Rural Electrification: A Review of World Bank and USAID Financed Projects," background paper, Melody Mason, April 1990.

CHAPTER 10. RECOMMENDATIONS AND OUTSTANDING QUESTIONS

10.1 The recommendations in this chapter summarize and, expand upon the recommendations in the first nine chapters. The recommendations are divided into three parts: (a) recommendations for governments, utilities, and donors; (b) recommendations for improving appraisal missions and preparing appraisal reports; and (c) operational recommendations. Outstanding questions are issues that have been raised but not answered by the EPUES study.

A. Recommendations for Governments, Utilities, and Donors.

10.2 EPUES has concluded that government interference in utility operations must be eliminated before efficient and sustainable performance is possible. This conclusion is based on the analysis in Chapter 1, Government/Utility Interactions, which strongly suggests that utilities with high efficiency are highly autonomous. EPUES considered recommending privatization of utilities. However, the national utilities in the study are monopolies; and, if these utilities are privatized, then governments must become effective regulators. Thus, while EPUES recommends to governments and utilities that primary attention be focused on increasing autonomy, it is equally important for governments to become effective regulators.[1]

10.3 Donors should assess whether government interference in the management of utilities and power plants causes poor performance. Based on the results of the assessment, donors should prepare country specific recommendations for regulatory and institutional changes.

10.4 EPUES recommends that national utilities work out nonconflicting objectives with their governments. The most frequent conflict arose from governments demanding that their utilities carry out socially desirable but highly unprofitable rural electrification programs, while also expecting the utilities to operate profitably. EPUES noted that tariffs were frequently too low to cross-subsidize such programs, and found little evidence that government mechanisms designed to reimburse utilities for losses actually did so. EPUES did not consider alternative, and possibly more cost-effective, rural electrification programs, but recommends that utilities and donors seriously address this issue.

10.5 EPUES concluded that a major problem for most utilities was the lack of hard currency. Donors have tried to ameliorate this problem through several innovative programs.[2] For most utilities, the problem remains urgent and often forces diesel power plants to continually operate in a crisis mode. Insufficient access to foreign exchange especially hurts maintenance, which depends on the timely procurement of spare parts. EPUES recommends that donors initiate programs facilitating the timely procurement of spare parts.[3] For example, donors could insist that

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1 Chapter 1 presents a rough methodology for appraising autonomy. EPUES is now developing this methodology in more detail.

2 See Chapter 4, Financial Management.

3 See Chapter 4, Financial Management, for a discussion of this problem.

a certain percentage of a project's initial investment value be deposited by the government into a foreign exchange account solely for the import of spare parts.

10.6 If no foreign exchange is provided, donors should make adequate provisions to alleviate the operational problems caused by delayed spare part ordering and supply. Possible arrangements could be the installation of a spare parts funds or an extended commitment to finance spare parts over several years of plant operation.

10.7 EPUES concluded that all outstanding receivables from government institutions should be paid to the utility as a precondition to aid. Customers with outstanding payments of more than three months should be disconnected before any disbursement is made. A monitoring system with effective procedures should be designed to prevent the recurrence of delinquencies.

10.8 Donors should require, and governments should agree, that all power sector loans will be on-lent to the utilities. Donors should monitor on-lending terms for aid to the power sector, including technical assistance.

10.9 Tariffs should cover long-run marginal cost. All donors, the utility, and the government in a specific country should determine and agree to cost. The World Bank computes this cost in most developing countries, and could provide the basis for a common agreement among donors on optimum country specific tariffs.

10.10 Donors should insist that utilities and expatriates consultants keep adequate cost and revenue records on newly installed power plants. Cost center accounting should be introduced if new power plants are installed or if new generation units are added to existing plants. Donors should provide or arrange for technical assistance to install cost center accounting and train staff in the correct accounting procedures. Cost and revenue monitoring should be required for a certain period.

10.11 Donors should always link the financing of any type of new generation facility with a loss reduction program, if the appraisal mission identified high technical and nontechnical losses. Lending should be suspended if to utilities, that do not carry out loss reduction programs.

10.12 Donors should insist that utilities develop and implement standards for meters and meter installation. These standards must ensure a high degree of protection against pilferage and destruction.

10.13 Utilities should prepare a report at the end of the liability period for all types of newly installed power plants which identify the need for further training, technical assistance, and support to meet recurrent cost of power generation. The report should also include a critical assessment of the project and recommend future investment projects. These recommendations should be collected in the form of lessons learned and given to planners of future lending operations as a manual. The manual should be continuously updated.

10.14 Donors should insist that salaries for electric utility staff be sufficiently attractive to reduce high turnover rates. Such incentives, as performance-oriented payment and clear career ladders, should be established before donors make a decision on financing a power plant or training courses.[4]

10.15 Job descriptions for employees in all types of power plants should preferably exist before the plant starts operation, or be prepared by the plant management in consultation with the manufacturer's representative no later than six months after commissioning. All job descriptions should be approved and signed by the utility's generation manager.

10.16 Training programs are only sustainable and efficient if institutionalized. Short-term training courses might result in temporary relief, but are not suited to reduce the shortage of trained staff in the long term. Since the cost of institutionalizing training is prohibitive to many of the smaller utilities, donors should coordinate to provide funding for the initial design of long-term programs, and should commit themselves to long-term support of training activities.

10.17 In addition to technical training courses, more attention should be paid to training middle level managers.

10.18 Utilities and donor agencies should explore novel approaches to training, such as twinning arrangements and regional training programs for all types of plants.

10.19 Donors should support standardization policies formulated by utilities in developing countries, and should assess the possibility of financing equipment of the same type and origin as already installed in the various types of plants. In the case of tied loans, an analysis of the additional cost of introducing equipment of different type and origin is required.

10.20 Utilities should establish reserve margins to account for overhauls and repairs of all types of essential power plant equipment. Donors should appraise utility standards and policies. An excess of power generation may cause relaxed maintenance and discourage utilities from increasing the efficiency of spare parts supply.

10.21 Specifically for diesel power plants, EPUES recommends that utilities and donors prepare and extend a list of the most important design specifications. This list should serve as a standardized control instrument to ensure completeness of future tender specifications.

10.22 EPUES suggests that donors look carefully at procurement systems before funding for all types of power projects. If the procurement system has more than a few well-defined steps, then the donor and utility should design a separate mechanism for funding spare parts procurement. Donors should also encourage simple, transparent foreign exchange allocation systems from a reliable source.

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4 EPUES found that mechanisms such as career ladders, which are used as incentives in many developed countries, might not be viewed as incentives, and, in fact, might be counterproductive. Thus, it is important to promote productivity through mechanisms that are culturally acceptable.

10.23 Donors should support utilities by providing information on the ways, means, and costs of avoiding environmental damage.

10.24 The evaluation departments of donor institutions should be strengthened. Lessons learned from evaluations should be documented and made accessible to project officers planning new projects.

10.25 Donors should reach an agreement about the imposition of conditionalities on utilities and governments prior to funding any type of power projects. Donor responses to breeches in conditionality should be coordinated.

B. Recommendations for Improving Appraisal Missions and the Preparation of Appraisal Reports.

10.26 A central objective of the second phase of the EPUES project is to prepare guidelines for improving appraisal of all types of power projects. During the next six months, many of the recommendations below will be expanded to included methodologies for completing them.

10.27 Autonomy is a critical factor in sustainable, efficient power utility operations. Project appraisal missions should judge a utility's degree of autonomy, and should tie aid to preconditions design to increase autonomy, where that is necessary.

10.28 Appraisals of utility autonomy should consider the following points:

(1) The objectives under which the utility operates should be stated in a clear and unambiguous manner without any contradictions.

(2) Some members of the utility's board of directors should be independent from government institutions, and preferably should represent the utility's nongovernmental customers.

(3) No government institution should interfere in the utility's daily operations.

(4) The utility should be authorized to set employee salaries and to include performance incentives in the salary structure.

(5) Utility managers should be responsible for recruitment, hiring, and firing. Recruitment should be performance oriented.

(6) Management should be held accountable for its performance. Performance targets, as well as the consequences for meeting or not meeting the targets, should be determined on an annual basis. Whether losses are acceptable is country specific and should be determined by appraisal missions.

(7) The government should make foreign exchange for the purchase of spare parts available to the utility without significant delays, through a transparent and simple system.

(8) Utilities should propose to their governments tariffs that are based on long-run marginal cost of power supply; and governments should set the tariffs accordingly. Under no circumstances should the tariff be lower than a utility's operating costs.

(9) Any unprofitable operation of the electric utility undertaken for political reasons (rural electrification) should be priced, and the government should transfer adequate funds to cover the losses to utility accounts.

10.29 An assessment of institutional structures must be part of the appraisal of all types of power projects. Responsibilities for decisionmaking in the utility must be clearly defined. Power generation and distribution facilities must be treated as profit centers, and must have appropriate cost center accounting systems. Appraisal reports should comment on the following:

(1) Especially in the case of rural electrification programs, project design should ensure that outlying operations receive sufficient support from utility headquarters to achieve a sustainable operation.

(2) Responsibility for decentralized spare parts stores should be with the manager of the associated power plant.

(3) A division of the utility, or selected managers in utility headquarters, should be responsible and accountable for specific operations in outlying areas.

(4) Division and power plant managers should have their own accounts with sufficient funds to purchase consumables and minor spare parts without consent from headquarters. Account limits, items eligible for purchase, and the limit per purchase must be clearly defined.

(5) There should be a reliable communications system between all types of power plants and the managers at headquarters responsible for power generation.

(6) For diesel power plants, regular technical inspections should be undertaken by supervisory staff from utility headquarters. The inspection report should recommend remedial actions to eliminate deficiencies; and follow-up missions should ensure that such actions were taken.

(7) Utilities should regularly provide diesel power plant managers with technical information issued by manufacturers. Manufacturers should upgrade their efforts to give adequate technical and other information to plant managers.

(8) Utilities should prepare manpower development programs. A manpower assessment should be carried out in parallel with, and with the same thoroughness as, the financial and technical assessments of new power plant investments. New plants of any type should be financed only if the positions created to operate it are clearly defined and included in the utility salary structure.

10.30 Staff appraisal reports should refer to problems identified in earlier projects in the same sector and country, and should comment on how these problems will be avoided.

10.31 Appraisal missions should check the cost and revenue records of similar power plants, and based on these data, should forecast expected costs and revenues of the power project.

They also should comment on the quality of data and recommend any necessary changes in accounting procedures.

10.32 Appraisal missions should visit all sites where investment in any new power generation facility is planned, and assess any unusual features of the demand forecast. Forecasts of growth rates based on a few discrete industrial investments should be closely reviewed.

10.33 For all types of power generation, an extensive training component should be mandatory. Appraisal reports should contain a section reporting on the needs and expected shortcomings due to the unavailal.lity of trained manpower. Appraisal reports should answer the following questions:

(1) Is the existing training program institutionalized?

(2) Is adequate training provided for upper management? middle management? operators and fitters? accounting staff? other administrative staff?

(3) Is on-the-job training structured?

(4) How are trainers trained?

(5) Is the trainer's job considered a dead-end position or a step towards higher level jobs?

(6) Does the utility have adequate financial resources and adequate materials (i.e. classrooms, technical materials, etc.) for its training program?

(7) Are the existing training programs short term?

(8) Do trainees have educational backgrounds that enable them to benefit fully from the training program?

(9) Does the utility provide an incentive for its employees to participate in training?

10.34 Characteristic for diesel engines is that, because of extreme high velocities and termperatures in the exhaust gases, actual emissions in the ambient air are relatively low, in spite of the very low stack heights. Nevertheless, when such engines are combined together as power plants of more than 10 - 15 MW, the emissions of $N0_x$ and SO_2 (in case of heavy fuel) may be of such a magnitutde, that a comprehensive study of dispersions has to be conducted. With traditional stacks of about 12m or less, the concentrations of NO_x and SO_2 may exceed the limits given by e.g., WHO.

10.35 All project appraisals should include an assessment of the environmental impacts of new power plants. The reports should also propose how to reduce the negative impacts of construction and operation, and should estimate the cost of environmental protection.

10.36 For diesel plants, donors should conduct a study of two major aspects of waste lube oil disposal: (a) the range of technical options, and (b) the specific conditions for each site.

C. Operational Recommendations.

10.37 This section includes recommendations for the design of all types of power projects, and for the operation of diesel power plants and electric utilities. They are not politically related, but oriented towards creating a sustainable and efficient utility operation by improving project design and utility infrastructure.

10.38 The low level of basic education in many developing countries should be considered during the preparation of job descriptions for power plant personnel and the design of training programs.

10.39 Utilities should provide technical literature and training materials adequate to its needs in quality and quantity. Manufacturers should provide technical literature regularly to power plant supervisors as well as to headquarters staff in a language which they can read.

10.40 Utilities should insist that a consultant or a representative of the manufacturer (or the turnkey contractor) participate in the management of all new power plants for at least six months after commissioning. The terms of reference for the temporary manager should include working with the utility manager to set up all necessary site-specific procedures for maintenance and operation, defining job descriptions for the plant personnel, and preparing a Generation Plant Operation Manual, preferably in the local language.[5]

10.41 The specifications for all types of new power plants should include sufficient and adequate rooms for personnel accommodation, washing and toilet facilities, a mess room for one full shift, a maintenance engineer's office, an operations engineer's office, and sufficient furniture for technical literature and manuals.

10.42 Utilities and donors should ensure that a spare parts preservation system is applied by all manufacturers to reduce the amount of corroded spare parts.[6]

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5 See Annex 3, Chapter 5 for a detailed discussion of Generation Plant Operation Manuals.

6 For example, one manufacturer delivers all spare parts in air tight plastic coatings. This system greatly extends the shelf life of spare parts.

ANNEXES

CHAPTERS 1 - 8

Chapter 1. Institutional Issues: Government and Utility Interactions.

Annex 1. Autonomy rankings for 15 utilities.[1]

CO/UTIL	OBJ	BOD	SAL	H&F	INC	CTRL	ACCT	FX	$	TOT
G/A	N	N	N	N	N?	N	N	N	N	0
E/A	N[2]	N	N	Y?	N	N	N	N	N	1
F/A	N?	Y?	N	N	N	N	N	N	N	1
H/A	Y	N	N	Y	N?	N	N	N	N?	2
LL/A	Y?	Y?	N	N	N	N	N	N	N	2
LL/B	Y	N	N	Y	N?	N	N	N	N?	2
M/A	Y	N	N	Y	N	Y	N	N	N	3
D/B	Y	N	N	Y	Y	N	Y	N	N	4
L/A	Y	N	N	Y?	Y?	Y	Y?	N	N	5
J/A	Y	Y	Y	N	N?	Y	N	N	N	5
A/A	Y	N	N	Y	Y	N	Y	Y?	Y	6
DD/A	N	Y	N	Y	N	Y	Y	Y	Y	6
D/A	Y	Y	N	Y	Y	Y	Y	Y	Y	8
LL/A	Y	Y	Y	Y	Y	Y	Y?	N	Y	8
GG/B	Y	Y	Y	Y	Y	Y	Y	Y	Y	9

1 See 1.8 for utility locations and 1.9 for definitions of column headings.
2 "?" indicates that the available information was not conclusive.

Annex 2. Data Summary and Best Practice Plant Efficiency (BPPE).

1. Table 1 shows the general characteristics of the diesel power plants EPUES investigated. The largest plant in the sample is located in Country L (71.8 MW), the smallest in Country H (640 kW). The largest output was at the Country L plant, the lowest at a plant in Country M. Quantity factors are computed per MWh of net production, where net production is defined as gross production of all generating units minus powerhouse consumption. Materials quantities would normally refer to quantities of spare parts and consumables. However, it was not possible to get detailed information on spare parts and consumables used.[1] Fortunately, the total cost of materials per MWh was obtainable for many plants. Thus, the price factor for materials is actually the total cost of materials at the power plant per MWh.

2. The quantity factors for fuel oil, lube oil, and labor are familiar efficiency factors that plant managers track to determine the efficiency of the diesel plant's equipment and labor force. These factors are referred to as "input efficiency factors."

3. Prices in Table 1 for fuel and lube oil appear distorted at the low end, reflecting subsidization. The highest fuel and lube oil prices reflect the high cost of transport to western Tanzania. EPUES has assumed that the initial capital cost of diesel plants using light fuel is $1000/kW, and that diesel plants using heavy fuel cost $1400/kW. This assumption is supported by actual capital costs of a few plants. However, as noted in Chapter 3, Economic and Financial Issues, much work on determining capital costs needs to be done. The wide variation in materials costs reflects to some extent the lumpiness of maintenance expenditures. The low expenditure of $0.61/MWh, at a plant in Country LL, clearly reflects minimal maintenance costs such as filters and cleaning materials; whereas the $48.19/MWh at the plant in Country M during its first year of operation suggests that the plant underwent repairs.

4. Quantity and price factors have been used to compute the costs of diesel plant operation. These costs include capital utilization, which is based on initial plant cost, plant depreciation, and interest. Table 1 shows these factors as a percentage of total cost. A "typical" diesel plant will expend 49.7 percent of its costs for fuel, 3.7 percent for lube oil, 6.3 percent for labor, 5.4 percent for materials, and 35.0 percent for capital. If, as is often the case, the cost of capital is not taken into account, then the percentage costs of fuel, lube oil, labor, and materials increase to 76.3 percent, 5.7 percent, 9.7 percent, and 8.3 percent, respectively. The total cost of operation, the sum of fuel, lube oil, labor, materials, and capital cost, varies from $0.068/kWh at a plant in Country JJ to $0.253/kWh at a plant in Country D. The total cost of operation at the plant in Country H, $1.315/kWh, was not included in the average because it was extraordinarily high. Local currencies have been converted into dollars using exchange rates from the IMF quarterly index of exchange rates.

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1 Materials quantities can be estimated by constructing a representative basket of materials used per MWh. EPUES has not yet gathered sufficient information to construct a representative basket.

Table 1. Summary of EPUES Technical Data (constant 1989 US$).

Plant Characteristics	Typical	Low	High
Plant Sizes (MW)	16.28	0.64	71.80
Plant Output (MWh)	39,347	223	208,589
Quantity Factors	**Typical**	**Low**	**High**
Fuel (1/MWh)	282	197	391
Lube Oil (1/MWh)	3.74	1.3	9.25
Labor (h/MWh)	13.32	0.25	105.43
Prices	**Typical**	**Low**	**High**
Fuel ($/1)	0.26	0.11	0.60
Lube Oil ($1/)	1.49	0.12	3.27
Labor ($/h)	2.61	0.15	11.29
Materials ($/MWh)	8.13	0.61	48.19
Capital ($/kW)	1,444	1,000	1,400
Operating Costs	**Typical**	**Low**	**High**
Fuel (%)	49.7	20.5	70.5
Lube Oil	3.7	0.2	7.2
Materials (%)	5.4	0.4	21.1
Capital (%)	35.0	10.7	59.0
Total Operating Cost	**Typical**	**Low**	**High**
Cost ($/kWh)	0.147	0.068	0.253

5. BPPE can in principle be applied for all types of plants. Given the quantity factors (input efficiencies) and prices at each plant, it is possible to compute a relative efficiency measure. This measure has frequently been used to help determine causal factors of poor performance. The calculation of BPPE has 3 steps: First, a table is constructed in which the total cost of operation of the each plant is computed using its prices and input efficiency factors, and the input efficiency factors of all other plants in a sample. Thus, each column in the table is a set of costs for a specific plant. For example, the (n,m) position in the table is the cost of plant n based on the prices for plant n but the input efficiency factors for plant m. One then searches the table for the least cost plant. In one of the largest diesel plant samples that EPUES considered, the least cost plant was in Country GG. This plant was included in the sample as a comparator against which less efficient diesel plants could be assessed.

6. Second, the input efficiency factors for the lowest cost plant are used to compute the total costs for each plant in the sample, using the prices each plant faces. This calculation tells us what the costs for each plant would have been if its input efficiencies were as good as the best plant.

7. Finally, dividing the cost of operation of each plant, computed using the best efficiency factors, by the cost of operation, using each plants own efficiency factors, gives the relative efficiency of each plant. For the least cost plant, the cost of operation was $68.63/MWh; since it had the best set of efficient factors, its relative efficiency was 1.00. A diesel plant in Country F, on the other hand, had an operating cost of $66.53, using the set of efficiency factors for the costs at both plants. Country F plant's total cost using its own set of efficiency factors was $144.67. Therefore, its relative efficiency was 46 percent ($66.53/$144.67). This relative efficiency is the called "Best Practice Plant Efficiency."

Annex 3. Increasing Autonomy and Efficiency.

1. An important EPUES objective is to guide donor agencies in increasing the sustainability of the power plants they finance. One aspect of sustainability is autonomy. World Bank documents and research by EPUES missions leave little doubt that governments throughout the developing world, especially in Africa, are adopting policies to give their utilities greater autonomy, because of evidence that greater autonomy leads to greater efficiency. There have been many efforts to define those policy changes which can promote independence in state-owned enterprises [Nellis, 1986]. The implementation of new policies is a political and country-specific matter. Nevertheless, utility inefficiency is so great a problem that many countries are now implementing new strategies. Four of these strategies are discussed below.

Expatriate Contract Strategy

2. Three countries in Africa have tried to improve efficiency by using expatriates as line managers. The theory is that experienced expatriate line managers with no connection to the government are more likely to act autonomously. Expatriate line managers are usually contracted for three to five years and are obligated to train counterparts to take over management of the utility when their own contracts expire.

3. EPUES investigated this approach in Country A, a European technical assistance agency financed expatriate engineers to run the utility for five years, and to remain as technical assistants to their counterparts for two additional years. While the expatriate engineers were less susceptible to government intervention, they still experienced problems related to government policies. They had difficulties getting fuel and establishing a workable disconnection policy for nonpaying consumers. Nevertheless, operating data during their tenure clearly shows that efficiency improved. The utility made a profit for the first time in its history.

4. Unfortunately, the improvements instituted by the expatriates were not sustainable. Just two years after the end of the program, EPUES could find no strong evidence of the program at the utility's diesel plants. The principal diesel plant was at almost a complete stop. Only one engine was operable, and bills had not been sent to residential customers for nearly three months. The utility management was weak and heavily influenced by government directives.

5. In Country M, an expatriate management program is currently underway as part of a major rehabilitation of the utility; it is too soon to evaluate whether the program will have a sustainable effect. One should be cautious about predicting the effects of this program based on the experience in Country A, since the reasons for failure in Country A may not exist in Country M.

6. The expatriate manager approach seems to be favored by financing and technical assistance agencies without much basis, and should be more closely evaluated.

Fee Contracts

7. Fee contracts are the least problematic of the strategies to increase autonomy because they require few government policy changes.

8. The private APA utility, used as a comparator in this paper, is a small, isolated utility which operates under many of the same constraints as utilities in developing countries, i.e. a

limited manpower resource base, no training facilities, difficulties obtaining fuel and spare parts, and so forth. On the other hand, the manager has access to foreign exchange and to highly trained mechanics. The utility has improved its efficiency using a fee contract for meter reading. Although the fee contract was not a matter of autonomy, this example demonstrates that such contracts can increase a utility's autonomy because the government cannot as easily control the way a private service is provided.

9. EPUES found that diesel manufacturers would like to maintain their engines on a fee contract basis. EPUES believes such contracts are worthwhile. When an EPUES team in Country D inspected the records relating to the collapse of relatively new diesel engines, it found the engines had a design weakness which caused loss of oil pressure and other problems. Although the operators and fitters understood the problem, political pressure from city managers forced them to run the engines until they failed completely. A maintenance contract might have enabled the managers to have the engines repaired in spite of political pressure.

Performance Contracts

10. A more radical approach to increasing autonomy and efficiency is the performance contract, in which the government states its objectives for the utility, sets performance standards, establishes a system for monitoring and evaluating performance, and defines rewards and sanctions. Performance contracts give managers autonomy in daily operations but hold them accountable for performance. The best performance contracts meet all of the conditions for autonomy, except that government appoints qualified management.

11. A performance contract between the utility and the government of Country A was signed December 1987; it provides for an annual review of the utility by a quasi-regulatory body which monitors the performance of 17 SOEs. The first review, completed in 1989 for the utility's 1988 operating year, was quite negative. Under the evaluation system, the utility could earn 134 points if it successfully met all performance targets. If the score was over 67, the managers were eligible for bonuses. The score was 33. The utility argued that its seeming inability to meet the performance goals was due to the fact that all the goals were financial, and that technical goals, which would reflect the real improvements, should have been set instead.

12. This performance contract is the only one known to EPUES in the power sector.[2] Performance contracts have been more widely used in other sectors, however, where their success in improving efficiency has been spotty. One World Bank country officer, who had promoted the use of performance contracts in Africa, now says, "We've given up on performance contracts." Although theoretically they should be an excellent tool, they are not successful in practice. The reasons for this are unknown.

Privatization

13. Because most utilities in the EPUES study were established as a part of a nationalist movement, restructuring them as private enterprises has been politically difficult, and in some cases legally impossible. On the other hand, privatization is now evolving into a broader and more acceptable concept. Narrowly defined, privatization is the sale of an SOE's assets to the private sector. More broadly, it can exist in many forms [Shirley, 1989]. It can include contracting with

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2 Performance contracts have been negotiated recently in two more African countries, and may now be in effect.

the private sector for certain basic functions such as meter reading, billing, and collecting. It can also include management contracts where the government retains ownership of a utility but a private firm manages its assets; and it can include leasing assets to a private firm.

14. All forms of privatization are receiving increasing attention among developing countries. The most radical form, divestiture, has become an increasing part of Bank business. In 1988, 58 Bank projects in various sectors had major divestiture components [Shirley, 1989]. Six countries where divestiture is occurring (five in Africa, one in APA) are participating in EPUES. The use of management contracts and leasing arrangements is still too rare in the power sector to draw conclusions about their usefulness, but results in other sectors appear promising. In Country J, for example, the efficiency of the water utility improved dramatically after it was leased to a private firm [Triche, 1990].

Chapter 3. Economic and Financial Issues.

1. The annexes to Chapter 3 review capital costs and plant lifetimes, plant utilization, operating costs, and measures of the financial and economic benefits of power consumption as they relate to diesel plants. Since information is generally not sufficient to calculate financial and economic rates of return for individual diesel plants, EPUES has produced a model of a typical investment to use as a basis for investigating how poor maintenance, short lifetimes, low tariffs, and other problems affect financial and economic performance. The distribution of financial and economic benefits, the costs of subsidizing power, and the methods for appraising investments in diesel generation are also evaluated.

Annex 1. Capital Costs and Plant Lifetimes.

Plant Lifetimes

2. Diesel plant lifetimes vary considerably, with some exceeding manufacturers' expectations and others ceasing operations after less than 30,000 hours. A standard diesel plant lifetime is estimated at 80,000 hours. At 6,000 hours of operation a year, this implies a lifetime of 15 years. Lifetimes are considerably shortened by insufficient daily maintenance or periodic overhaul. Information on lifetimes is available from a number of EPUES mission reports.

Capital Costs

3. The EPUES study focused on the *operational* efficiency of diesel power plants. Because some were commissioned many years ago, information on capital costs is not complete. The estimate of current costs was based on a review of actual costs for a number of Caribbean utilities, and on discussions with a number of diesel manufacturers [Diewert]. Unit capital costs per kW of installed capacity, including construction and equipment for a new diesel plant, were about $1,000 if the plant uses distillate fuel, and $1,400 with heavy fuel oil.

4. EPUES mission data on costs per kW of installed capacity, cost breakdown, diesel plant lifetimes, and delay to commissioning are not extensive enough to alter conclusions derived from other sources. They do, however, illustrate the variation in unit costs according to project circumstances, and the existence of substantial economies of scale.

5. The resource costs of installed capacity are therefore highly variable, and the financial cost to the utility, on which it bases its investment decisions, is further influenced by on-lending terms for concessional aid. There is clear evidence that where concessionality is passed on, this distorts investment decisions in favor of additional (subsidized) capacity expansion. The financial costs of investment to a utility may differ according to the terms on which financial assistance is passed on. At an extreme, the cost of capital may be effectively zero, where the government finances capital investment by increasing the equity of the company, and donors make no on-lending requirements. This was the case for some donors in Country DD, where the government allowed the utility to treat new diesel plants as additions to equity rather than requiring them to cover debts at commercial rates. Where this was accepted by bilateral donors, and they did not impose on-lending requirements, capital costs to the utility were effectively free, other than any local cost contribution required.

6. Inevitably this distorts the balance between investment in new capacity and recurrent expenditure, and leads to investments in surplus capacity and high reserve margins which enable the system to bear prolonged outages due to lack of recurrent funds for maintenance and spare parts. Instances of this were indeed found by the EPUES mission to Country DD. The distortion is greatest where funds are passed on at no cost. But it is also apparent that the crisis management position of some utilities will lead to high discount rates for future costs. Thus on-lending terms for capital investment, *even if they are at commercial interest rates*, may be more attractive to utilities than cash payments for spares and maintenance. The EPUES mission report on Country CC describes a common position for power utilities:

> *"[The utility] is managing its working capital in a very short-term manner. The time horizon is about 2 months on basis of the budget control and its accounts payable....[The utility] in the past and at present lacks the funds to pay its bills. The utility reacts with either postponing its payments or asking for subsidies from the government."*

7. In such a situation, on-lending terms that incorporate a grace period for repayment of principal and interest may be readily accepted, as the burden of repayment is well outside the planning horizon. Other forms of aid, such as program aid for provision of spares and maintenance, may, however, require the utility to make an immediate cash payment, and so may not be acceptable.

Annex 2. Plant Utilization.

1. The economic and financial returns to investment in diesel generating capacity will vary according to operating hours and load. This section examines the approach to forecasting demand, the relation of investment in installed capacity to actual peak demand, and subsequent hours run. Since hours run is a function of both output demand and the engine's availability, the causes of outages in diesel plants are also reviewed.

2. The experience within the EPUES sample is varied. Some diesel engines within a grid functioned as standby capacity or covered peak load. In most cases, these machines operated in an isolated grid, and so met base load. In some cases, however, installed capacity was well below peak demand and the machines ran intensively, sometimes to the point that their lifetimes were shortened if maintenance was neglected.

3. A common experience as power is introduced into nonelectrified areas is that residential demand grows very rapidly, because of the lower cost and higher quality of electric compared to other forms of lighting. As residential demand grows, however, per capita consumption is likely to fall, as poorer customers with lower consumption are connected.

4. EPUES reviews frequently found over-optimistic demand forecasting. Some major errors in forecasting occurred in response to an anticipated industrial development or hotel expansion. Clearly, investing in expansion before industrial projects are firmly committed creates the risk of overcapacity. Another cause of overcapacity was ignorance of other investments in the sector. In one case, two donors each invested in approximately 10 MW of additional diesel capacity at the same site at the same time. As peak demand has since reached only 3 MW, the resulting overcapacity is considerable. Other studies have found similar problems. An ODA synthesis of six evaluation studies of diesel generation and associated power projects [(EV374, May 1985)] concluded:

> *"Overall demand forecasts were too optimistic for a variety of reasons. First, many of the forecasts were based on consumption trends prior to the oil price changes and subsequently failed to reflect fully either the price or income effects of those changes. Second, many of the components in anticipated demand were large and indivisible. Consequently, the non-appearance of final consumer investments e.g. by abandoning planned hotels, reflected backwards on electricity demand. Third, problems in the distribution system often caused the installation of private generating capacity which detracted from the growth of demand for public supply."*

5. The World Bank reached a similar conclusion in its "Review and Evaluation of Historic Electricity Forecasting Experience (1960-1985)." Although not specifically focused on diesel generation investments, this study concludes:

> *"On a worldwide basis, there has been a definite bias towards over-estimation in load forecasts. The mean percent deviation is always positive and increases from 9.1 percent in Year 3, to 12.7 percent in Year 7, to 15-20 percent by Year 10."*

6. Overcapacity is one explanation for low capacity factors in some diesel plants. A second cause is the peakiness of demand, which at many plants is caused by the dominance of residential demand for evening lighting. Subsidies to residential demand in general and to the lower levels of residential demand in particular (measured either by connected load or energy consumption) will increase this evening peak, as lighting comprises a higher proportion of electricity demand for low income consumers.

7. Regardless of demand, the utilization of the plant is significantly reduced in many cases due to low availability. Availability is defined as the proportion of total hours during which the plant could have been operated had there been a need. Allowing for minor servicing, adjustments, inspections, and, in most years, for a major servicing, availability in most months should be between 95 percent and 100 percent; but sustained 100 percent availability would indicate inadequate maintenance. Consistent monthly availability of less than 90 percent, even for older machines, should also raise doubts as to the quality of maintenance.

8. The missions considered two causes of nonavailability: (a) lack of fuel, or (b) a shutdown due to either poor maintenance or lack of foreign exchange for spares. Long delays in releasing foreign exchange and ordering parts meant that unplanned outages became more frequent, or of longer duration. Lack of fuel also led to unplanned outages, although not as often.

9. Frequent outages at some plants were due to minor overhead line faults, which caused the pumping of lubricating oil to cease and the generating set to trip on low lubricating oil pressure. Machines with electric motor driven pumps then need an incoming power supply to be restarted, which often prolongs the outages to over 30 minutes.

10. A number of the more isolated diesel plants suffered from difficulties of access and lack of storage capacity, which made them vulnerable to output disruptions from lack of fuel. The situation for individual African plants, according to the mission reports, was:

- Disturbance in truck transportation from the nearby port to plant area.
- Severe fuel problem, more than 100 hrs/month shutdown due to fuel shortage.
- Although there is a good railway connection from the captial, the fuel is reliably transported by BP trucks. Only few incidents during the last two years due to fuel shortages.
- Truck transportation from another plant; no severe fuel shortages.
- The fuel problem is alarming; 2 to 3 times per month the entire plant is forced to shut down despite the transportation of fuel by train.
- The fuel is transported by train wagons; no fuel shortages ever reported.
- The fuel is transported by train; frequently what arrives is too little to supply the plant. The team was told that missing train wagons cause these shortages.

- Sporadic truck transportation from another plant. The persistent fuel problem often results in standstill of the local textile mill.
- Fuel transportation from the capital by truck and rail. The cost of diesel fuel is more than twice the annual revenues from electricity supplies. In the coming years, [the plant] will be connected to the hydro power grid, which will cut fuel costs.

Annex 3. Operating Costs.

1. The principal components of operating costs for plants of all types are fuel, lubricating oil, labor, and maintenance (including spares and periodic overhauls). The available data on these components indicate a range of financial and economic costs, which EPUES used to analyze the performance of 60 diesel plants in Africa, Asia, the Pacific, and the Americas.

2. The variatior :· diesel plant performance was least for fuel consumption, which is surprising since fuel consum· 'on should be directly related to power production. The relation between production and lube oil consumption should also be direct, although poor maintenance can increase lube oil consumption. In both cases, the upper end of the range will reflect improper use of fuel and lubricating oil, varying from minor pilferage to theft and sale.

3. Estimated expenditures for labor were derived from plant records. Information on average wage rates was collected locally, or in some cases, from International Labor Organization (ILO) publications, an aggregate source which concealed possible local wage rate variations. The EPUES missions found that public sector wage rates were substantially below private sector levels. On the other hand, average public sector wages for skilled (and therefore mobile) labor appeared to be closer to international levels than for unskilled labor.

4. Variations in materials expenditure per MWh were uns... rising. Major overhaul expenditures were inherently lumpy, maintenance expenditures can be deferred, and maintenance costs were often not accurately recorded. EPUES also found that maintenance expenditures were substantially below desirable levels at many of the African plants, contributing to a suboptimum average expenditure.

5. In general, the EPUES missions did not go into sufficient detail to consider whether operating regimes were being optimized. In Country DD, however, the EPUES mission compared actual operation of the diesel generator sets on one system with an alternative optimized dispatch from the available sets of 23 percent to 100 percent. This reduced fuel consumption nearly 2 percent, and reduced total cylinder hours run from 1,096 to 940, with consequent maintenance savings. Clearly, if these savings could be duplicated in other diesel plants, the financial and economic benefits would be significant.

Annex 4. Financial Benefits of Power Consumption.

1. The EPUES missions produced some data on the financial benefits to the utility of selling power. In many cases revenues were below total costs, and in some cases below direct operating costs. The financial rate of return to many of these projects was therefore negative. The problems this poses for sustainability are discussed in Chapter 4, Financial Management.

2. To assess whether project investments were economically justified, and determine which parameters have the greatest impact on the economic rate of return, it is necessary to have an estimate of the economic value of the power outputs. The EPUES missions did not gather data specifically on the value of these outputs, but did collect information on the consumer mix and on distribution of benefits, which assisted in estimating the economic benefits. Economic benefits are discussed more fully in Annex 5.

3. The financial benefits of power depend on income from the sale of power. This in turn depends on the proportion of power which is sold (i.e. generation minus losses), on how many of those sales translate into financial revenue (i.e. billing and collection performance), and on the financial revenue per unit (i.e. tariff).

4. When tariffs rise sharply in cash terms but are offset by domestic inflation and compensating movements in the exchange rate, as in Country M, revenues will most likely fail to cover depreciation, or even cash flow needs, and financial benefits to the plant will be negative. The question then to consider is whether a higher economic than financial benefit can attach to consumption of the power. This question is discussed in Annex 5.

5. The level of losses by country is set out in Table 1 below. The figures are for total system losses, net of power station consumption. As they refer to national averages, they are in some cases different from the station/grid specific data gathered by the EPUES missions.

6. Total financial benefits depend on the translation of power sold (i.e. generation minus losses) into revenue. These benefits equal the generation sold times average tariff times the ratio of bills collected to sales registered. In addition, financial losses result from a delay to revenue. As most of the utilities operate under severe cash constraints, it is reasonable to regard the cost of one month's delay as being the interest payment on the sum involved.

Table 1. System Losses.

CC	(1985)	12%
LL	(1987)	16%
L	(1987)	17%
FF	(1987)	19%
K	(1986)	22%
H	(1987)	22%
A	(1987)	23%
D	(1987)	24%
F	(1989)	25%
M	(1987)	30%
J	(1984)	30%
E	(1988)	41%
G	(1987/88)	42%
Average		24.8%

Source: World Bank and EPES mission reports

7. The issues of financial management, and the steps necessary to convert sales into revenue--meter reading, issuing bills, collecting bills, and the registration of the cash collected in the utility's account were described in Chapter 4.

Annex 5. Economic Benefits of Power.

1. Electrification can bring a variety of benefits. The most simple to quantify are cost savings from the substitution of low cost electricity for kerosene in lighting, for diesel in agricultural pumping, for high cost small captive generating plants, and for a variety of other more expensive energy sources.

2. The lower cost of electricity and the higher quality of the end product mean that demand for these services--household lighting, agricultural pumping, power in industry, etc.--will rise. This brings economic benefits. EPUES suggestions for measuring these economic benefits are discussed in detail below.

3. At the same time electricity may bring less quantifiable benefits, such as better security at night from street and household lighting; and better health care and education. As incomes rise, a whole set of essentially new services (radio, television, air conditioning, etc.) depend on electricity. Benefits may also extend to new economic activity made possible by improved lighting in the home, and by small businesses having access to electric power. For many projects, stimulation of economic development was an explicit objective. Other broad objectives were regional development, integration of less developed areas into the national economy, and reducing migration from rural to urban areas.

4. Electricity is often seen as a precondition of economic development, and clearly a whole range of economic activities do depend upon power. This claim is, however, also made for other sectors, such as transportation and communications. If scarce capital is to be allocated between these and other competing sectors, more accurate measures of benefits are needed.

5. One argument is that electricity is a basic need which government must satisfy. This is clearly incorrect. In most countries in the EPUES study, only a low proportion of the total population (2 or 3 percent, in some cases) is connected to the public power supply, and those connected tend to be urban and affluent. Per capita consumption of power is also strongly related to income. As discussed in Annex 4, tariff revenue is in most cases insufficient to cover costs, and is therefore a financial subsidy to power consumers. Financing of the public power supply therefore constitutes a transfer from taxpayers to power consumers. As discussed below, this may well be a regressive transfer.

6. A more sophisticated case for power supply as a basic need is that it can improve the quality of health and education, and that for low income consumers, the substitution of electric for kerosene lighting can bring important financial benefits. This forms the rationale in some cases for subsidies to residential power consumption below a low threshold of energy consumption or connected load. It should be noted, however, that (a) financial benefits are realized without a subsidy, and (b) low income households connected to the power supply are not generally among the poorest in the society.

7. In the case of the two diesel stations in Country M, the objectives of the project were to promote economic development and slow migration of rural workers to an urban center. As the plants had been running for only two years, it was too early for evidence of economic response. In the case of plant A, however, there was a noticeable move by existing small and medium scale industry (e.g. brickmakers and engineering repair shops) to electrically powered

equipment. Productivity improved, and higher quality lighting stimulated evening trade. Security in residential areas around the plant was improved by the installation of 400 street lights, and the mission team also saw a significant improvement in health and education services. Because of improved lighting, the schools offered evening classes.

8. Power consumption at plant A was dominated by residential consumers. At the other plant, industry had a much larger share of consumption, and one industrial consumer accounted for 33 percent of billing. Consumer shares of total billings are shown in Table 1.

Table 1. Consumption by Consumer Category in Country M.

	Plant A	Plant B
Residential	57%	39%
Government and Municipal	36%	20.[illegible]%
Industrial	<1%	36%
Commercial	-	1.5%
Other	6%	-

9. Plant B was already more industrially developed than plant A, so impact was harder to identify. Much of the power went to large industrial consumers who were switching from captive capacity to public supply. Production in the fish and meat factories improved because of the increased power supply, and an additional 800 street lights were erected.

10. It should be noted that the supply of power at these two plants was highly subsidized, and that after allowing for losses and noncollection of bills, tariff revenues failed to cover operating costs. It is not surprising that industry should move to consuming publicly supplied power when it is sold for less than production costs. It is also likely that some expansion made possible by low cost power would not be economically viable if the costs of supply were properly reflected in the tariff. This is considered in greater detail below.

11. At a diesel power station in Country CC, one objective of public power supply was to substitute for captive generation, to enable industry to focus on commercial objectives and lower production costs. A particular target was the stimulation of such small to medium scale industries as textiles, sisal processing, soap, cooking oil, and a variety of agro-industries. Electricity supply was also expected to stimulate agricultural production (especially cotton), and commercial activity in the townships. A further environmental objective was the substitution of electricity for fuelwood in urban areas. The high cost of electrical appliances and energy for cooking, however, and the high proportion of low income households that use fuelwood for cooking, prevented this objective from being realized.

12. Small, isolated grids are typically dominated by residential consumers. High residential demand in turn leads to an evening peak in lighting demand, and so low load factors. This was true of some of the stations in Country DD, as shown in Table 2.

Table 2. Sales by Consumer Category in Country DD.

	Plant A	Plant B	Plant C
Residential	47.4%	65.0%	52%
Commercial	18.4%	10.0%	25%
Public Sector	9.5%	18.0%	10%
Industry	21.5%	7.0%	13%

13. Earlier World Bank missions found evidence of rural electrification generating completely new activities, such as ice making, photocopying, and beauty parlors. At the same time, a number of existing activities, such as commerce, poultry farming, and garment manufacturing, were expanded.

14. The EPUES mission and the 1984 ODA evaluation of electrification in Country DD both raised the issue of reliability. Setting reserve margins to meet a predetermined standard for reliability of supply imposes a capacity cost on consumers. One criticism of this practice was that inadequate attention had been paid to residential consumers' willingness to pay for higher reliability. In low income countries, willingness to pay will be lower than in high income countries, so reliability standards transferred from the developed world may be inappropriate.

15. The costs of low reliability to industry may be much higher in terms of lost production and damage to plant. In many cases reliability levels are so low that private producers retain their own captive capacity while connected to the public supply. The EPUES mission in Country DD concluded that tariffs were well below what industry would pay for *reliable* supply.

16. The DANIDA Evaluation of a diesel power project in Country K looked in depth at economic impact. The area served was not a major industrial center, due to distance from markets and cost of inputs. The main benefits were to residential and agricultural consumers.

17. For agricultural consumers, demand was complicated by subsidy arrangements. Diesel was subsidized but in short supply, although there was also a market supply of higher price diesel. Electricity was also supplied at roughly 50 percent of LRMC. In response to the lower costs of pumping, most farmers who switched from diesel to electric pumps had increased acreage and switched to higher value crops. The cultivation of summer crops was not worthwhile using diesel pumping, but became economic for the farmers at the lower cost of electric pumping. Some farmers sold their diesel engines when they switched, while others kept them as standby. Their choices related to variations in reliability of supply.

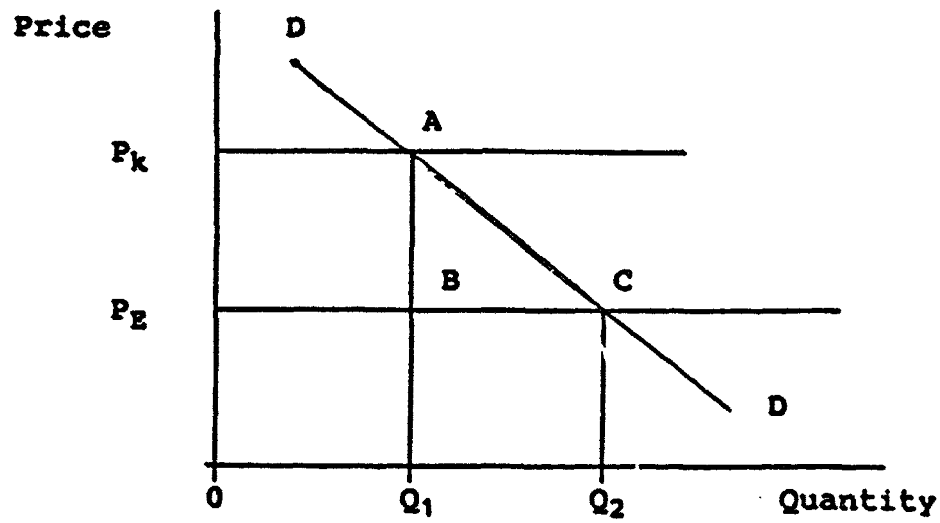
18. Small industry benefitted from a sharp increase in productivity. A tailor who switched from a pedal driven to an electric sewing machine reported he could now produce 10 shirts in the time it once took to make 4. Iron workshops that brought in electric welding machines following the public supply of power grew from 4 in 1983 to 60 in 1989. A power supply had already been available; small industry responded mainly to the increased reliability of the supply.

19. The social impact on the area was not as great. In hospitals, the overall quality of service did not improve. None had backup generators and one had to use hurricane lamps at night while the generator was switched off. Schools already operated on two or three shifts, although the quality of evening lighting rose sharply. None of the towns provided street lighting; however, electrification of the mosque's loudspeaker was considered a social benefit.

20. Given these results, how can economic benefits be quantified? The financial revenues from power sales are an inadequate measure of benefits if (a) they do not reflect the long run marginal cost of power, and if (b) there is evidence that the alternative project has significantly higher costs. Given the consumer mix in a number of countries, what conclusions can be reached on power economic benefits?

21. Many of the isolated diesel plants in the EPUES study will be supplying newly electrified consumers who will be substituting electricity for an alternative source of power, such as kerosene for lighting. In this situation, the consumer surplus attached to power consumption is used as an approximate measure of the welfare gains. Figure 1 illustrates the way consumer surplus is estimated.

Figure 1.



22. The demand curve DD illustrates demand for electricity. At the price of electricity set by equivalence to the cost of lighting fueled by kerosene (P_k), the level of demand is Q_1. At the actual price of electricity, the level of demand is Q_2. The financial benefits of power supply are sales times price, illustrated by the block OP_ECQ_2. In addition, there is a consumer surplus, represented by the area P_EP_kAC.

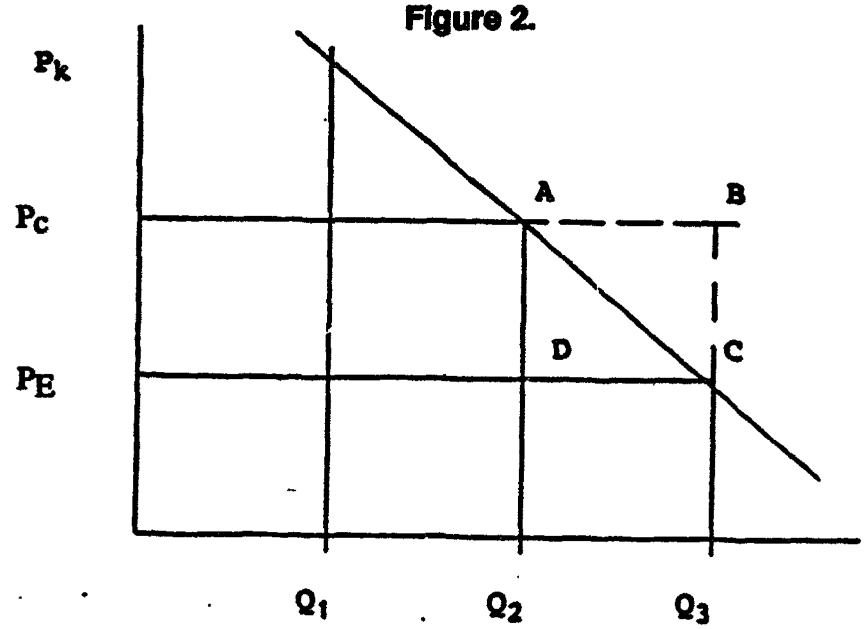
23. The consumer surplus is made up of two components. The "diverted market" represents the switch of existing demand from the more expensive to the cheaper energy source. The cost of the saved resource, in this case kerosene, is represented by the area P_EP_kAB. The "generated market" represents new energy consumption generated by the lower price, represented

by the triangle BAC. The economic value of generated consumption will depend on consumer's willingness to pay, which in turn will depend on the slope of the demand curve (elasticity of demand) and the relative prices of competing energies.

24. As the preceding section shows, the price of electricity is often set below its economic cost. This is true particularly for isolated diesel systems that charge a suboptimal national tariff despite considerably higher costs. The impact of this situation on the calculation of consumer surplus is illustrated below, again in comparison with kerosene for lighting. P_E is the financial price of electricity, while P_C is the long run marginal cost of producing electricity in the system.

25. At the low price of electricity, P_E, consumption is Q_3, while at the price P_c (=LRMC) consumption is Q_2. For the additional consumption [Q_3 - Q_2], however, consumer willingness to pay is below the cost of production. This generates disbenefits (measured by the triangle ABC), which offset the apparent consumer surplus due to a willingness to pay above the financial price of power (measured by the triangle ADC). The consumer surplus created by the switch from kerosene to electric lighting is therefore based only on the difference between the economic costs of kerosene and electricity. A measure of consumer surplus that looks only at the difference between kerosene costs and the (subsidized) electricity price, by contrast, will overstate benefits.

Figure 2.



26. The measurement of consumer surplus will therefore depend on how the electricity is used, and the alternative energy sources. An example of end-use analysis, taken from the Indonesia Urban Household Energy Strategy Study (ESMAP, 1990), is shown in Table 3. (The table includes data in electrified rural households in central Java in 1985.) The study demonstrated that:

"Electricity is widely used at all income levels, but, predictably, is consumed in much larger quantities by the rich. Thus, almost two-thirds of the households in the lowest income group use some electricity, but households in the highest income group use on average about ten times as much electricity a month as a poor household: 170 kWh as compared to 15 kWh. Even lighting, which accounts for about 50% of overall electricity use, increases by a factor of more than four across the income groups. Most of the increase, however, is the result of new uses of electricity, adopted as income rises. The only electric devices used by more than a quarter of the households in the lowest income group are lamps. As income rises, lamps are joined by television, ironing, refrigeration and, finally, water pumping. The order of importance of the different electricity uses is almost identical, with the exception of refrigeration which, due to its high per unit consumption, is the second most important appliance in terms of overall electricity use."

Table 3. Percentage of Urban Households Using Electricity by Income.

		<75	75-120	120-185	185-295	<295	ALL	Rural Electrified Households
	% Valid Household	27%	24%	23%	16%	10%	100%	
Electricity	86%	65%	85%	95%	97%	100%	85%	100%
Cooking	1%	0%	1%	3%	3%	14%	2%	-
Lighting	85%	63%	83%	94%	96%	98%	84%	100%
TV	40%	22%	47%	67%	73%	89%	52%	34%
Ironing	37%	16%	34%	57%	68%	80%	44%	34%
Refrigerator	7%	1%	3%	9%	21%	46%	11%	2%
Air Conditioning	0%	0%	0%	0%	1%	2%	0%	-
Pumping	6%	1%	3%	7%	16%	35%	9%	4%
Washing Machine	0%	0%	1%	0%	1%	11%	1%	-

27. Table 3 shows that in less developed rural areas, the consumption pattern was closer to the bottom end of the income range. All households used electricity for lighting, although in other respects electricity usage was lower than for urban households. Appliances with a high acquisition cost, such as TVs and refrigerators, were used less, making residential consumption of electricity in rural areas even more dominated by lighting demand. The measurement of consumer surplus for residential consumers in isolated grids has therefore focused on replacing kerosene with electricity for lighting.

28. Again, analysis of diesel power in Country DD illustrated the overall impact of this situation. Between 1981 and 1987, the percentage of electrified urban households grew from 47 percent to 74 percent. Kerosene consumption declined during the same period from 46 to 30 MJ/household/day. Of that, roughly 5 MJ can be attributed directly to the displacement of kerosene in lighting in newly electrified homes. In addition, rapid electrification may have been the main reason for the drop in charcoal use, as electric irons replaced household irons.

29. An analysis of lighting costs can be made in terms of equipment and energy costs for different approaches, along the lines presented below. The information, again, is from Country DD. Costs are in 1987 US$.

Table 4. Comparison of Lighting Costs.

	Kerosene Press. Lamp	Incandescent Lamp 60W	Flourescent Lamp 11W a/
Lamp			
equipment cost (US$)	25	0.93	11.76
lifetime (hr)	7300	1000	5000
lifetime (yr)	3.3	0.5	2.3
Ballast			
equipment cost	-	-	6.23
lifetime (hr)			25000
lifetime (yr)			11
Fuel			
fuel cost per unit	0.17/litre	0.09 $/kSh	0.09 $/kWh
consumption of fuel/month	18.3 litre	11.0 kWh	2.6 kWh
consumption of (kWh equivalent)	640 kWh	37 kWh	8.7 kWh
Lighting			
hours of lighting per day	6	6	6
luminous flux of lamp (lm)	400	730	930
nr. of lamps required to obtain same light level	2	1	1
total system light output (lm)	800	730	930
luminance relative to kerosene lamp		-0%	16%
Cost Overview			
annualized equipment costs	18.4	2.2	7.0
fuel cost	36.2	11.2	2.6
total costs for 1 year	54.6	13.4	9.6
total costs (per month)	4.5	1.1	0.8

a/ Electric load of lamp and ballast is 14.2 Watts.

30. The economic benefits of substituting electricity for kerosene can be estimated by comparing the demand for and costs of the two different energies. In the example above, if we assume that all substitution is between kerosene pressure lamps and incandescent electric lamps, the annual costs will be $54.6 for kerosene lighting and $13.4 for electric lighting. If we further assume that 15 percent of the demand for electric lighting is met from kerosene in the absence of electricity, and that the demand curve is a straight line between the kerosene equivalent price and the present price, an estimate of consumer surplus can be calculated.

31. Referring back to Figure 1, P_E is \$0.9/kWh. P_k, the kerosene equivalent price, is \$0.42/kWh, the price at which the two lighting options are equivalent. The resource cost savings/kWh (P_E P_k AB in Figure 1) are therefore US \$0.05 [0.15 x (0.42 - 0.09)]. The benefits of generated power, ABC in Figure 1 are \$0.14 [0.5 x 0.85 x (0.42 - 0.09)]. Total consumer surplus in this illustration would be \$0.19, and the economic benefit of power used for domestic lighting would be 61 percent greater than the financial benefits resulting from the actual sale price. As described above, this measure would, however, overstate consumer surplus if the price of electricity is below its economic cost.

32. The actual value ascribed to economic benefits of power for domestic lighting varies according to which numbers are used. More recent analysis in Country DD (IED, 1990) argues that consumer surplus measurements have substantially underestimated benefits by (a) underestimating the energy savings, since kerosene lamps may be considerably less efficient than assumed, and since many urban households use energy-efficient fluorescent lamps; and by (b) underestimating the extent to which better quality lighting generates a range of new activities not feasible under kerosene lighting.

33. An additional way to estimate consumer surplus in residential power consumption is to calculate the equivalent cost of small (50 kW) generating sets for household consumption. This approach can also be used to calculate the cost of supplying power to industry. Clearly the value of electric power may be extremely high to industry, since relatively small expenditures for electricity can be essential to the functioning of an entire plant. However, the benefits of specifically *public* supply of power will be limited by the costs of running captive capacity at the industrial plant. The benefits of public supply will therefore stem from the economies of scale vis-a-vis private supply. These economies relate both to initial capital costs and to subsequent operating costs.

34. This kind of calculation can be done using EPUES mission data on capital costs, cost of fuel and spares, and cost of labor for diesel plants. These costs were analyzed in preceding sections. It is assumed there is a minor overhead cost in labor charges, so that other variable costs per MWh are slightly higher for small captive capacity. Finally, capacity factors are assumed to be greater than for public plants.

Table 5. Substitution of Public for Private Generating Capacity.

	Private	Public
Unit Size (kw)	50	1500
Cost per (kw)	1800	100υ
Lifetime (years)	20	20
Test Discount Rate	12%	12%
Capacity Factor	20%	38%
Annual Charge/kw ($)	241	134
Charge/MWh ($)	138	40
Fuel Costs/MWh ($)	77	57
Spares Costs/MWh ($)	27	14
Other Variable Costs/MWh ($)	30	26
Total Costs/MWh ($)	272	137

35. In this situation, if the tariff for publicly suppl'ed electricity is 13.7 cents per kWh, it will generate some resource savings as existing industries switch from captive capacity to public supply. In addition, new consumption stimulated by the lower cost can be valued at half of the price differential between private and public power. On the assumption that 30 percent of industrial demand is diverted from existing captive capacity, and that 70 percent is new demand attributable to the lower price of public power, the economic benefits would equal $87/MWh, or 64 percent greater than the simple financial model of benefits. In practice, set size for public utilities could well be higher than this, so cost savings would be greater. However, the analysis omits incremental distribution costs.

Table 6. Estimated Operation of Autoproducers' Generating Plant in Country J, 1984.

Sector	Capacity (kVA)	Utilization Factor (%)	Hours of Utilization	Generation (MWh)
Domestic (50 villas x 15 kVA)	750	60	1hour/day	164
City 1	2,880	70	200 hours	403
City 2	500	70	250 hours	88
Total	4,130			655
General				
Embassies	1,200	60	3 hours/day	788
Hotels	2,060	75	2 hours/day	1,128
Others	250	60	1 hour/day	55
Total	3,510			1,971
Government	2,000	70	250 hours	350
Radio Station	350	70	300 hours	74
Hospitals	250	70	1 hour/day	64
Airport, etc.	250	70	1 hour/day	64
Total	2,850			522

36. EPUES found that a number of points bear on this conventional approach to measuring surplus for industrial consumers. The first point, which emerged in earlier studies, is that capacity benefits will be substantially reduced if the quality of public power supply is low.

37. Table 6, taken from the KfW mission report on Country J, shows the estimated operation of autogeneration in 1984. Clearly, reliability of supply was so poor at that time that most industries, hotels, government departments, and even housing complexes maintained a captive generating plant. In this circumstance, there would still be a capacity benefit from public supply if (a) the captive plant were more expensive per kW than public capacity, and (b) depreciation of private capacity was reduced by the provision of public supply. Capacity benefits would, however, be lower than in the analysis above.

38. The impact of varying assumptions on industrial consumer surplus is illustrated in an evaluation of electrification in Country DD, where it was assumed that industrial/commercial consumer surplus was commercial revenue times 0.75, based on the difference between the tariff and autogeneration costs. Many industrial/commercial consumers installed standby generators, and operated them for significant periods, due to the low reliability of power supply. The evaluation therefore set a minimum value based simply on energy savings from not running standby generators. This was calculated on the assumption that the economic cost of fuel in standby generators would have been the same as the cost of supplying these generators from the grid, with the higher unit consumption of small generators being offset by distribution losses.

39. The first phase of the evaluation was a time-slice analysis for system expansion. It was concluded that *"...The IERR of the system is calculated in constant prices as either -1.22% or 5.1% depending largely on what is assumed as the commercial/industrial consumer surplus."* This illustrates the impact of low quality public supply of power, which reduces the benefits from displacement of small and inefficient autogeneration. Diewert's analysis also shows the correlation between size and average efficiency (as defined in his paper "Efficiency Measures for Diesel Electric Power Plants"). Average efficiency increases dramatically in the move from plants of under 1 MW capacity to plants of over 10 MW capacity. The highest efficiency achieved for plants of 0-1 MW lies below average efficiencies for all other plants.

Table 7. Efficiencies by Size of Diesel Plant.

Installed Capacity	Average Efficiency	Minimum	Maximum	Coefficient of Variation	Number of Observations
0 - 1 MW	.352	.152	.521	.360	8
1 - 10 MW	.534	.214	.883	.283	32
10 - 50 MW	.708	.498	1.000	.184	32
50 - 100 MW	.747	.508	.922	.179	7

40. Another finding of the same study is the greater efficiency of diesel plants in private ownership. These figures are shown in Table 8.

Table 8. Diesel Plant Efficiency by Type of Ownership.

Type of Ownership	Average Efficiency	Minimum	Maximum	Coefficient of Variation	Number of Observations
Private	.745	.527	1.000	.172	26
Public	.540	.152	.850	.308	54

41. The relative variable operating costs of public and private diesel plants are also of interest; these figures are summarized in Table 9. The average costs for public plants are greatly increased by the very poor performance of two public plants in Country H. An adjusted average is therefore shown after these two exceptionally poor plants have been removed from the sample:

Table 9. Diesel Plant Variable Operating Costs ($MWh).

	Private Plant	Public Plant	Adjusted Public Plant
Mean for Sample	81.03	120.10	96.12
Maximum	182.25	958.01	250.59
Minimum	37.15	27.84	27.84

42. The implications of these two findings for consumer surplus in industrial power consumption will be contradictory. The much lower efficiency of small diesel plants will increase the benefits of substituting public capacity. (As Table 6 illustrates for Country J, much captive capacity was below 1 MW.) However, the greater efficiency of private plants will reduce the benefits of substituting by public supply. We return to these issues subsequently.

43. Isolated diesel generators may also serve a third major consumer category, agricultural consumers. In countries where there is a significant demand for irrigation, agricultural power consumption may well be dominated by water pumping. In this case, the surplus for agricultural consumers can be analyzed by comparing costs of diesel and electric pumping sets. An example of such a calculation is shown in Table 10.

Table 10. Estimated Break-Even Costs of Diesel and Electric Pumping.

	Electric	Diesel
Motor/Engine Size (H.P.)	5.0	7.0
Pump Lifetime (years)	15.0	10.0
Pump Capital Cost ($)	261.2	668.5
Annual Charge ($)	38.3	118.3
O & M Costs ($)	59.8	168.1
Costs of Diesel Fuel ($/hour)		0.52
Annual Diesel Costs ($, over 800 hours)		411.8
Cost of Electricity ($/kWh)	x	
Annual Electricity Costs	2,984 (x)	
Total Annual Cost	98.2 + 2984(x)	698.1
Break - Even Price (cents)	20.1/kWh	

44. The consumer surplus is again estimated on the basis of 50 percent of the differential between the agricultural tariff and the substitution point between diesel and electric power, $0.201/kWh. It should be noted, however, that agricultural power consumption was not a major element of power demand for most of the EPUES sample.

Annex 6. Financial and Economic Performance.

1. The EPUES missions focused on the operational efficiency of diesel plants over several years, but did not gather sufficient information on lifetime efficiency to calculate an ex-post rate of return. Despite this, the evidence is that financial rates of return fall below the test discount rate. Where tariff revenues are insufficient to cover both capital and variable costs, then by definition, the financial rate of return falls below the test discount rate. Where tariffs are insufficient to cover operating costs, the plant runs at loss, and a financial rate of return cannot be calculated. (An internal rate of return cannot be calculated if the sign of the cash flow does not change.)

2. As described above, most plants in the EPUES sample ran at a loss, once capital costs were included. For many plants, the tariff was set too low to cover operating costs, and these plants made a financial loss every year of operation, their loss rising directly in line with their utilization. Once allowance is made for failure to convert generated power into tariff revenue, the picture is even worse. At an extreme, some plants had average revenues that were insufficient to cover variable fuel costs, which were about 75 percent of total variable costs.

3. In order to examine the impact of different operational problems on diesel plant performance, EPUES built a rough model of ideal diesel plant performance, drawing on the data described in earlier annexes. This model was then used to examine the impact of over-investment, short lifetimes, and poor maintenance on the financial performance of diesel plants.

4. The key elements of the model were as follows:

(a) The plant was assumed to consist of 4 x 1.5 MW high speed units, with a unit cost of $1000 per kW of installed capacity.

(b) Annual hours run were assumed to total just over 80,000 hours over a 25 year life. The average capacity factor was 38 percent. Based on IDGTE data, capacity factors were initially assumed to be higher but to decline in later years.

(c) Based on the adjusted data for African diesel plants in Annex 3, fuel costs were assumed to be $72/MWh, labor costs $10/MWh, and lube oil costs $6/MWh. As actual expenditures on spares are clearly suboptimal, spares provision was increased in the model to $15/MWh. Allowing for capital costs at a 12 percent discount rate, total costs were $141/MWh.

(d) Gross system losses were set at 10 percent, and it was assumed that all bills were collected without excessive delays.

5. If the tariff in the model is now set at a level 10 percent above LRMC (i.e. a tariff of just under 16 cents/kWh), then the FIRR will be equivalent to the discount rate, and the Net Present Value (NPV) at a 12 percent discount rate will be zero. Revenue is then exactly sufficient to cover operating costs plus depreciation. This can be taken as our initial model of sustainable power plant development.

6. In general, however, tariffs are below this level. Table 1 shows the impact of tariff changes on our model investment.

Table 1. The Impact of Tariff Changes on the Model.

Tariff US cents/kWh)	FIRR	NPV @ 12%
15	10.7%	-0.4M
14	6.4%	-$1.8M
13	1.2%	-$3.2M
12	Negative	-$4.6M
11	Negative	-$6.0M
10	Negative	-$7.4M
5	Negative	-$14.3M

7. In all countries in the sample, national utilities charged the national tariff for power consumption in isolated grids, despite the higher costs of such grids. The only exception to this was the small private diesel power utility in Country LL. As a consequence, in many countries the financial performance of diesel plants was poor, with average tariffs substantially below operating costs. In Country DD, for example, the EPUES mission concluded that

> *"On the basis of the electricity supplied by the Mirrlees machines at the four sites examined, all operate at a financial loss.... This is the result of the low average tariff, system losses ranging from 21% to 31%, and the overcapacity at [two plants]. Even if a more realistic output is assumed over the lifetime of the plant (i.e. a 35% plant factor), none of the plants are financially profitable. At two of the sites...the average tariff revenue exceeds the operating costs (i.e. at current sales levels and excluding the capital element."*

8. EPUES analysis has shown that severe problems are likely to arise for all types of plants if operating revenues fall below operating expenses. Given the usual failure of governments and donors to set up overt subsidy mechanisms in such a situation, utilities then enter a severe cash crisis. Indirect subsidy mechanisms may come into effect, such as provision of fuel oil on credit. Utilities in this crisis usually adopt very short term planning horizons and cut back on provision for spares and maintenance.

9. A reduction in tariff revenues through an increase in system losses, failure to bill and collect recorded sales, or a combination of the two will have a similar effect on any plant's financial performance. One response to this in a number of African countries has been to increase the tariff to compensate for lost tariff revenue, effectively penalizing those paying for power for the costs of those not. Table 2 below illustrates this for our model investment by showing the break-even tariff needed to achieve a 12 percent rate of return, as gross system losses rise and billing performance deteriorates.

Table 2. Percentage of Sales Billed and Collected Gross System Losses. (In U.S. Cents)

Gross System Losses	100%	95%	90%	85%	80%
10%	15.5	16.2	17.1	18.1	19.2
15%	16.3	17.1	18.1	19.1	20.3
20%	17.3	18.2	19.2	20.3	21.6
25%	18.4	19.4	20.5	21.7	23.0
30%	19.7	20.8	21.9	23.2	24.7

10. Figures for losses and noncollection vary by country. If we allow an average of 24 percent gross system losses and assume that 95 percent of recorded sales are billed and collected, this would give reasonably typical figures. In order to maintain a 12 percent rate of return, the tariff would need to rise by nearly 4 cents. If the tariff were not adjusted to reflect this, then in our model investment the rate of return would become negative as revenues fell nearly to operating costs, and the NPV would fall to -$4M.

11. In some cases, diesel plant performance was much poorer. In Country J, 1986 losses were 35 percent, and only about half the sales were billed and collected. A tariff of 42 cents/kWh would have been required to realize a 12 percent rate of return, well in excess of the costs of capital power generation. The focus of many donors on strengthening institutions and improving billing and collection is clearly correct.

12. A further problem identified by the missions was frequent investment in excess capacity. In some cases, this will most likely continue for much of the project's life. In other cases, as demand grows and other investments are postponed, the capacity factor of the plant will rise. For the model investment we have looked at lifetime excess capacity, and also at the impact of initial overcapacity made good by subsequent load growth until capacity factors reach those in the base case. The findings are summarized in Table 3 below. As would be expected, the FIRR is negatively related to investments in overcapacity but positively related to load growth.

Table 3. Overcapacity and Load Growth for Diesel Power Plants.

	Stable Capacity Factor		5% PA Demand Growth	
Initial Capacity Factor	NPV	FIRR	FIRR	NPV
10%	-$4.0M	Negative	6.8%	-$2.2M
20%	-$2.7M	3.8%	9.2%	-$1.1M
30%	-$1.4M	8.1%	10.8%	-$0.5M

13. As Table 3 illustrates, the impact of initial investment in overcapacity can to an extent be offset by subsequent load growth. However, very low capacity factors in early years cannot be fully offset by growth in demand because future benefits will be reduced through discounting.

14. This Report has demonstrated the harmful effects of inadequate maintenance on various aspects of diesel plant performance. Financial performance is specifically affected by shortened lifetimes when plants are not overhauled; and by increased fuel consumption due to inadequate maintenance, oil filtering, or oil testing.

15. The impact of shortened lifetimes is set out in Table 4 below. It should be noted that our assumption of a reasonably low capacity factor over a long lifetime reduces the impact of a shortened lifetime, because of the effect of discounting.

Table 4. The Impact of Shortened Lifetimes on Financial Performance.

Lifetime	FIRR	NPV
5 Years (20,300 hours)	Negative	-$3.1M
10 Years (38,700 hours)	5.2%	-$1.3M
15 Years (55,000 hours)	10.4%	-$0.4M
20 Years (71,000 hours)	11.2%	-$0.2M
25 Years (83,750 hours)	12.0%	0

16. The average fuel consumption in Diewert's analysis was 253 litres/MWh. The maximum consumption of 391 litres/MWh was nearly 55 percent higher. The impact on the model of increased fuel consumption, whether due to price or higher specific consumption, is shown in Table 5.

Table 5. The Impact of Increased Fuel Consumption on Financial Performance.

Fuel Consumption/Price	FIRR	NPV
+30%	Negative	-$3.4M
+20%	3.5%	-$2.4M
+10%	7.6%	-$1.3M
-10%	14.5%	$1.1M
-20%	18.1%	$2.2M
-30%	21.0%	$3.3M

17. The impact of other variable costs is relatively slight. As the preceding discussion has shown, considerable scope exists for reducing manpower levels and total costs, although it

should be noted that a 50 percent reduction in manpower costs would raise the rate of return from 12 percent to only 14.1 percent.

18. The model diesel plant is less sensitive to variations in capital costs than to fuel costs, as capital costs form a lower proportion of total costs. The impact of capital cost variation is shown in Table 6.

Table 6. The Impact of Capital Cost Variation on Financial Performance.

Capital Costs	FIRR	NPV
+30%	8.2%	-$1.6M
+20%	9.3%	-$1.1M
+10%	10.5%	-$0.6M
-10%	13.6%	$0.1M
-20%	15.7%	$1.1M
-30%	18.3%	$1.6M

19. The impact of a one to two year delay in construction will reduce the FIRR to 10.9 percent. A delay of four years would reduce it to 9.1 percent.

20. The adjustments to convert this financial calculation to economic prices will vary substantially from country to country according to (a) the share of domestic inputs in capital and spares costs; (b) the degree of taxation or subsidy on capital and operating costs; (c) the share of different consumer groups in power consumption; and (d) the calculation of consumer surplus for different consumer groups. EPUES has data only on average *financial* prices. As the Central Team does not have sufficient information to recalculate these as average economic prices, there is no separate model for a plant's economic rate of return. There are, however, a number of general points that can be made on economic performance.

21. The EIRR will in almost all cases be above the FIRR, because in most cases capital and operating costs will be adjusted downwards while revenues will be adjusted upwards to reflect the consumer surplus. The only possible exception to this is where there is a major subsidy to a cost element. An example would be the subsidy to fuel costs in Venezuela, which could in theory produce power sector investments that were financially but not economically viable.

22. The largest adjustment in calculation of the EIRR is likely to be due to adjustment of revenues to reflect economic benefits. In the case of domestic lighting, the calculation of consumer surplus is reasonably robust, because of the large gap between costs for kerosene and electric lighting, and because of the higher quality of the latter.

23. Consumer surplus measures for industrial consumption of power are less robust, for two main reasons: (a) The capacity savings from avoiding industry investment in a captive generation will not be achieved if the reliability of public power supply is poor. Available evidence suggests that is often the case, and a range of industrial units are obliged to retain captive capacity. And (b) although there should be economies of scale from substituting public for private capacity, in practice these will be reduced because of the lower efficiency of public sector power generation.

24. There are clearly theoretical economies in switching from small-scale private captive generation to a grid supply, whether public or private. Unless all system peaks are coincident, load factors will be higher in the grid, realizing capacity savings. There are also economies of scale in capital and operating costs. In practice, however, a number of factors may reduce these economic benefits:

(a) In some cases of public supply there has been a marked tendency to over-investment; at an extreme, installed capacity reaches seven or eight times peak demand. This will offset the expected capacity savings from grid supply.

(b) The evidence bears out economies of scale in capital costs. In some cases, however, lifetimes of machines in the public grid are under 30,000 hours, sharply increasing the annualized cost of capacity. The poor quality of public supply means that private industry is obliged to retain standby capacity, so in most cases capacity cost savings are much reduced. The system ends up with high and inefficient reserve margins in the form of captive capacity to compensate for low reliability. It is even possible for this to happen when installed capacity in the grid is sufficient in relation to peak demand. And

(c) There are also economies of scale in operating costs. This is, however, on an average basis. In the case of poor public performers, operating costs may rise above the level of private supply.

25. Given the frequent practice of selling public power at below long-run marginal cost, it is not surprising that a number of EPUES reports show private industry switching to public supply as it becomes available, and in some cases increasing consumption. This clearly demonstrates that public supply is financially attractive to private consumers, but not that it is economically efficient.

26. The estimates of operating costs for public supply of power in African plants showed some operating at extremely high costs, with a peak of nearly $1/kWh at one unit. Several other diesel plants, although well below this extraordinary peak, showed operating costs well in excess of the cost for private capacity. It therefore appears that, at least in some cases, the inefficiencies of operating a public plant reduce the theoretical advantages of economies of scale.

27. In sum, if the public supply of power is expensive and unreliable but is sold cheaply, then the more expensive source of supply often will be used because of the financial subsidies attached to it. At extreme, the economic benefits for industrial power consumption may be negative.

28. There are two questions that arise from this conclusion. First (the overall justification for the EPUES project), how can the efficiency of grid supply be increased so that theoretical economies of scale can be realized in practice? Second, if subsidies are paid to private industrial consumers to switch to a more expensive public supply, who pays for this subsidy?

Annex 7. Distribution of Benefits.

1. The direct beneficiaries of power investment are the consumers of power. Indirect beneficiaries include consumers of services drawing on power, and employees whose jobs are generated by power investment.

2. The direct beneficiaries are mainly residential consumers, for whom the benefits of substituting electric for kerosene lighting are likely to be much greater than the costs. All households connected to the electricity supply will use electric lighting, although high incomes groups may consume up to four times a much electric lighting per household as low income groups (and up to 10 times as much total electricity). The value attached to this additional lighting, however, will be less than that attached to the initial substitution.

3. A second major consumer of electricity is central, regional, or municipal government administration. This demand is primarily for lighting, as is commercial demand.

4. The share of industry in total consumption is variable because the reliability of public supply is frequently too low to enable private industry to dispose of all of its captive capacity.

5. The power tariff for isolated diesel generating plants is usually below LRMC. This has two effects: (a) electricity brings substantial resource savings by substituting for other sources of energy, although the suboptimal tariff means that a greater share of these economic benefits will accrue to consumers and a lower share to the utility; and (b) contradictorily, the low price encourages power consumption above its economically optimal level. Consumers will use power for which they may not be willing to pay the actual cost of production. The tariff is generally structured to favor residential consumers, and in particular low-income consumers. A proportionately greater share of benefits will therefore accrue to these groups.

6. Particular benefits accrue to consumers who do not pay for power. In many countries, theft of power is high. Information is not available about who benefits from this theft.

Chapter 4. Financial Management.

Annex 1. Percentage of Total System Loss.

TOTAL SYSTEM LOSS (%)

COUNTRY	UTILITY	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	AVG	MAX	MIN
BB	A			18.0	21.2							19.6	21.2	18.0
S	A				11.0							11.0	11.0	11.0
B	A								28.0			28.0	28.0	28.0
T	A	9.0	13.0	10.0	9.0	17.0	16.0	16.0	15.0			13.1	17.0	9.0
A	A								23.0		26.8	24.9	26.8	23.0
R	A	15.0	13.0	24.0	9.0	10.0	13.0	21.0	22.0	21.0		16.4	24.0	9.0
LL	C	12.0	13.0	12.2	12.6	13.3	17.0	17.0	16.0			14.1	17.0	12.0
J	A					35.0				42.0		38.5	42.0	35.0
DD	A	19.1	18.7	19.1	20.8	20.6	19.8	19.6	18.7	16.9		19.3	20.8	16.9
Q	A	11.0	14.0	12.0	10.0	13.0	15.0	13.0	16.0			13.0	16.0	10.0
N	A	31.0	31.5	28.0	35.0							31.4	35.0	28.0
H	A	10.0	16.0	21.0	24.0	26.0	22.0	22.0	21.0			20.3	26.0	10.0
V	A	8.0	7.0	13.0								9.3	13.0	7.0
L	A	18.0	20.0	19.0	19.0	19.0	18.0	19.0	17.0			18.6	20.0	17.0
CC	A									18.2		18.2	18.2	18.2
W	A		14.0	12.0	9.0	12.0	10.0	9.0	14.0			11.4	14.0	9.0
X	A	17.0	20.0	19.0	23.0	20.0	14.0	18.0	17.0			18.5	23.0	14.0
FF	A	10.5	10.3	10.6	11.0	13.0		16.0	19.0			12.9	19.0	10.3
EE	A	18.0	20.0	21.0	20.0	19.0			21.0	18.0		19.6	21.0	18.0
Y	A	16.0	16.0	16.0	16.0	16.0	16.0	12.0	13.0			15.1	16.0	12.0
G	A	30.0	29.0	29.0	28.0	30.0	24.0	22.0	32.0	47.0	42.0	31.3	47.0	22.0
M	A	17.0	19.0	18.0	22.6	21.6	33.0	28.0	30.0			23.7	33.0	17.0
K	A	27.6	27.1	27.3	27.4	24.3	24.0	21.5				25.6	27.6	21.5
D	B	9.0	9.0	15.0	20.0	21.0	21.5	21.0	24.0			17.6	24.0	9.0
Z	A			13.0								13.0	13.0	13.0
AA	A	7.7	4.1	11.2	12.4	6.0	5.1	7.0				7.6	12.4	4.1
AVERAGE		15.9	16.6	17.5	18.0	18.7	17.9	17.6	20.4	27.2	34.4	18.9	22.5	15.5
MAXIMUM		31.0	31.5	29.0	35.0	35.0	33.0	28.0	32.0	47.0	42.0	38.5	47.0	35.0
MINIMUM		7.7	4.1	10.0	9.0	6.0	5.1	7.0	13.0	16.9	26.8	7.6	11.0	4.1

Annex 2. Percentage of Nontechnical Loss.

NON-TECHNICAL LOSS (%)														
COUNTRY	UTILITY	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	AVG	MAX	MIN
A	A								15.0		19.0	17.0	19.0	15.0
N	A	16.0	16.5	13.0	20.0							16.4	20.0	13.0
X	A	7.0	10.0	9.0	13.0	10.0	4.0	8.0	7.0			8.5	13.0	4.0
EE	A	8.0	10.0	11.0	10.0	9.0			11.0	8.0		9.6	11.0	8.0
M	A	1.0	2.0	1.0	5.6	4.6	14.9	12.4	13.0			6.8	14.9	1.0
K	A	11.6	11.1	11.3	11.5	8.1	6.2	8.1				9.7	11.6	6.2
AVERAGE		8.7	9.9	9.1	12.0	7.9	8.4	9.5	11.5	8.0	19.0	11.3	14.9	7.9
MAXIMUM		16.0	16.5	13.0	20.0	10.0	14.9	12.4	15.0	8.0	19.0	17.0	20.0	15.0
MINIMUM		1.0	2.0	1.0	5.6	4.6	4.0	8.0	7.0	8.0	19.0	6.8	11.0	1.0

Nontechnical Loss as Percentage of Total System Loss.

COUNTRY	UTILITY	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	AVG	MAX	MIN
A	A								65.2		70.9	68.1	70.9	65.2
N	A	51.6	52.4	46.4	57.1							51.9	57.1	46.4
X	A	41.2	50.0	47.4	56.5	50.0	28.6	44.4	41.2			44.9	56.5	28.6
EE	A	44.4	50.0	52.4	50.0	47.4			52.4	44.4		48.7	52.4	44.4
M	A	5.9	10.5	5.6	24.8	21.3	45.0	44.4	43.3			25.1	45.0	5.6
K	A	42.0	41.0	41.4	42.0	33.3	25.8	37.7				37.6	42.0	25.8
AVERAGE		37.0	40.8	38.6	46.1	38.0	33.1	42.2	50.5	44.4	70.9	46.0	54.0	36.0
MAXIMUM		51.6	52.4	52.4	57.1	50.0	45.0	44.4	65.2	44.4	70.9	68.1	70.9	65.2
MINIMUM		5.9	10.5	5.6	24.8	21.3	25.8	37.7	41.2	44.4	70.9	25.1	42.0	5.6

Annex 3. Accounts Receivable (Months of Sales).

COUNTRY	UTILITY	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	AVG	MAX	MIN
BB	B	7.7	6.9	6.0	6.5							6.8	7.7	6.0
	A	16.4	12.6	9.0	10.0	7.0						11.0	16.4	7.0
S	A			2.0								2.0	2.0	2.0
T	A						7.0					7.0	7.0	7.0
A	A				11.7	5.3				3.4		6.8	11.7	3.4
R	A	10.6	7.1	7.4	11.0	11.8	12.5	13.5	8.0	4.3		9.6	13.5	4.3
LL	B	4.1	4.2	6.8	6.3	4.9	3.0					4.9	6.8	3.0
	C	2.2	2.1	2.5	3.4	3.6	3.9					2.9	3.9	2.1
J	A				9.5	11.0	13.7	7.2	5.3		6.5	8.9	13.7	5.3
F	A							9.9		2.5		6.2	9.9	2.5
DD	A	2.2	2.5	2.2	2.3	1.8	1.7	1.6	1.6	1.4		1.9	2.5	1.4
N	A		4.2	5.4	3.6							4.4	5.4	3.6
H	A	6.4	4.6					4.7				5.2	6.4	4.6
V	A	8.0		15.0	12.0							11.7	15.0	8.0
L	A									1.8		1.8	1.8	1.8
CC	A					10.0		6.0		3.9	3.0	5.7	10.0	3.0
W	A				4.0	4.1	4.2	3.6				4.0	4.2	3.6
X	A		8.0		6.0			10.8				8.3	10.8	6.0
FF	A	3.0	3.0	3.9								3.3	3.9	3.0
EE	A					2.2	2.1	2.1	1.9			2.1	2.2	1.9
	B	3.7	3.7	2.6	4.1	2.0	2.6	3.5				3.2	4.1	2.0
Y	A			4.1	4.7	4.5	3.2					4.1	4.7	3.2
G	A	4.6	3.0	6.8								4.8	6.8	3.0
M	A					12.6	10.8	10.8				11.4	12.6	10.8
K	A	7.4	10.4	12.6	15.1	14.0		18.2				12.3	18.2	7.4
D	B	4.2	3.0	3.0			5.3					3.9	5.3	3.0
Z	A	8.0	7.4	5.2	6.0						9.0	7.1	9.0	5.2
AA	A	10.0	10.0	10.0	6.4	4.7	4.1					7.5	10.0	4.1
AVERAGE		6.6	5.8	6.1	7.2	6.6	5.7	7.7	4.2	2.9	6.2	6.0	8.1	4.2
MAXIMUM		16.4	12.6	15.0	15.1	14.0	13.7	18.2	8.0	4.3	9.0	12.9	18.2	10.8
MINIMUM		2.2	2.1	2.0	2.3	1.8	1.7	1.6	1.6	1.4	3.0	1.8	1.8	1.4

Annex 4. Accounts Receivables from Private Sector (Months of Sales).

COUNTRY	UTILITY	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	AVG	MAX	MIN
H	A						5.1	4.2	4.6			4.6	5.1	4.2
W	A							5.1				5.1	5.1	5.1
Y	A		1									1.0	1.0	1.0
G	A										5.3	5.3	5.3	5.3
M	A							5.0				5.0	5.0	5.0
AVERAGE			1.0				5.1	4.8	4.6		5.3	4.2	4.3	4.1
MAXIMUM			1.0				5.1	5.1	4.6		5.3	5.3	5.3	5.3
MINIMUM			1.0				5.1	4.2	4.6		5.3	1.0	1.0	1.0

Annex 5. Accounts Receivable from Public Sector (Months of Sales).

COUNTRY	UTILITY	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	AVG	MAX	MIN
DD	A		12.0	5.0	5.0		1.8	1.8	1.8	1.8		4.2	12.0	1.8
H	A						10.0	5.5	6.5			7.3	10.0	5.5
W	A							8.0				8.0	8.0	8.0
Y	A		12.0			12.0						12.0	12.0	12.0
G	A										38.7	38.7	38.7	38.7
M	A							14.0				14.0	14.0	14.0
D	B			2.0								2.0	2.0	2.0
AVERAGE			12.0	3.5	5.0	12.0	5.9	7.3	4.2	1.8	38.7	12.3	13.8	11.7
MAXIMUM			12.0	5.0	5.0	12.0	10.0	14.0	6.5	1.8	38.7	38.7	38.7	38.7
MINIMUM			12.0	2.0	5.0	12.0	1.8	1.8	1.8	1.8	38.7	2.0	2.0	1.8

Accounts Receivable from Public Sector as Percentage of Total Accounts Receivables.

COUNTRY	UTILITY	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	AVG	MAX	MIN
A	A				34.7	(24.4)						5.2	34.7	(24.4)
R	A				44.4							44.4	44.4	44.4
F	A								43.8			43.8	43.8	43.8
N	A				39.3							39.3	39.3	39.3
H	A							45.1				45.1	45.1	45.1
V	A				33.0							33.0	33.0	33.0
CC	A					60.0						60.0	60.0	60.0
Y	A					30.2						30.2	30.2	30.2
G	A						67.7	54.3	32.0	60.0	65.2	55.8	67.7	32.0
O	B						51.3					51.3	51.3	51.3
Z	A				86.0							86.0	86.0	86.0
AA	A						70.0					70.0	70.0	70.0
AVERAGE					47.5	22.0	63.0	49.7	37.9	60.0	65.2	47.0	50.5	42.6
MAXIMUM					86.0	60.0	70.0	54.3	43.8	60.0	65.2	86.0	86.0	86.0
MINIMUM					33.0	(24.4)	51.3	45.1	32.0	60.0	65.2	5.2	30.2	(24.4)

Annex 6. Write-Offs as Percentage of Total Accounts Receivable.

COUNTRY	UTILITY	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	AVG	MAX	MIN
R	A								18.1	1.6		9.8	18.1	1.6
J	A						19.4	22.2	14.5			18.7	22.2	14.5
H	A							9.7	9.3			9.5	9.7	9.3
AVERAGE							19.4	15.9	14.0	1.6		12.7	16.7	8.5
MAXIMUM							19.4	22.2	18.1	1.6		18.7	22.2	14.5
MINIMUM							19.4	9.7	9.3	1.6		9.5	9.7	1.6

Annex 7. Procurement Complexity and Inefficiency.

1. The complexity of the procurement process, including both utility and government procedures, correlates closely with the utility's access to foreign exchange. In Table 1, the last two columns show this correlation qualitatively. The estimate of foreign exchange availability (Avail) is based on EPUES missions and World Bank staff appraisal reports. High availability means the utility can apply for a letter of credit and expect quick approval. Medium availability means letters of credit are sometimes held up for several months due to lack of foreign exchange. Low availability means that letter of credit requests are often not granted. With respect to complexity (Complex), high, medium, and low ratings reflect the mission's judgment of the utility's procurement system.

Table 1. Spare Parts Procurement By 15 Utilities in the EPUES Study.

Country	Utility	Status	Complex	Avail
GG	B	Priv.	Low	High
E	A	SOE	High	Low
A	A	SOE	Med	Med
LL	B	SOE	Med	Med
LL	A	Priv.	Med	Med
J	A	SOE	High	Low
F	A	SOE	High	Low
DD	A	SOE	Low	Med
H	A	SOE	Med	High
L	A	SOE	Low	Med
CC	A	SOE	Med	Low
Q	A	SOE	Med	Med
M	A	SOE	High	Low
D	B	SOE	Hi/Low[1]	Low/Hi[1]
D	A	Mixed[2]	Med	Med

1 Availability of foreign exchange is low from the national bank, but high from a special fund for spare parts.
2 Half government, half private; controlled by the private owners.

2. The inverse correlation between availability and complexity is nearly perfect. In cases that do not conform, one finds that foreign exchange is available because a donor provides a utility with spare parts. For example, the complexity of the ordering and delivery system in Country H is low and availability high thanks to the donor, GTZ, but there are still significant delays in delivery because of the complexity of GTZ's own conditions.

3. The situation in Country D is particularly instructive, because the country has two distinct procurement systems, one administratively complex and the other simple. EPUES found that spare parts requests from diesel plant managers processed through the first system often took months to fulfill, and often were never fulfilled. Requests made through the second system were completed within weeks. The critical difference between the two systems was the greater availability of foreign exchange in the second. Country D illustrates the fact that utilities with low availability of foreign exchange tend to have complex procurement systems.

4. This observation is significant because many diesel plant managers complained that the inefficiency and uncertainty of the spare parts procurement system made it impossible to plan maintenance, causing operating problems to follow. One solution is to ensure that the foreign exchange allocation process for the utility is simple and transparent--not an easy task, since the allocation system may be beyond the purview of a power project, and is likely to be part of a broader structural adjustment program. But even if a transparent system is implemented, it will not guarantee a utility's access when foreign exchange is scarce. In that case, direct donor procurement of spares may be the only way to ensure spares availability. Donors should take care, however, that their own procurement regulations and procedures do not introduce new delays and complexities. Donors might establish spare parts accounts in supplier countries, as discussed in Annex 8.

Annex 8. Spare Parts Fund Example.

1. The assumption is that a financing institution creates a spare parts bank account in the country where the institution or spare parts manufacturer is located. The objective is to make the processing of spare part orders more efficient for all parties involved.

Conditions

2. The account is accessible only to the financing agencies, a subcontracted consultant, or a procurement agent designated jointly by the agency and the utility.

3. The utility can use this account to buy only a certain class of spare parts, including consumables and parts required for regular maintenance and top overhauls. The utility could have a preapproved list.

> This arrangement has been successfully used by the parastatal in Country D. The utility is 50 percent privately owned and is allowed to transfer a small fraction of its foreign exchange automatically into a UK hard currency account, which can be used for purchasing power plant spares. A procurement agent in the UK buys the spares on behalf of the utility on a competitive basis, manages the necessary letter of credit and other financial arrangements, and arranges delivery of the parts.

4. The fund is set up as part of a loan or grant arrangement. It consists of two parts: (a) a sum made available by donor agencies to supply spare parts for the first two or three years of operation; and (b) a revolving fund to be replenished by the utility as it orders spare parts. For countries in which foreign exchange is especially difficult to acquire, the revolving fund may be replenished periodically by the donor agency.

Procedures

5. If parts are needed, the utility manager approves the order as usual, then sends it to the procurement agent.

6. The procurement agent checks the account for sufficient funds, procures the parts quickly, and sends them to the utility, along with a parts list, a statement of the new account balance, and an invoice. The donor also receives copies of these documents.

7. The utility follows the usual procedures to obtain foreign exchange, and transfers it as soon as possible to the hard currency account.

Advantages

8. A spare parts fund would eliminate the most time-consuming aspect of spare parts purchasing, aside from the acquisition of foreign exchange: the delay in sending out the order with the letter of credit. EPUES missions found this takes three months to a year, during which time the lack of parts causes machines to be further damaged or not available at all, with a consequent loss, for the utility, of income and reputation for reliability.

9. A spare parts fund would help the objective of regional development, since, as all missions reported, the reliability of electric supply is important both for industrial development (Country DD) and for rural consumers who use electricity for irrigation pumps (i.e. Country K).

10. The fund could be linked with better monitoring of plant performance, enabling the manufacturer to identify critical machine problems earlier and initiate counteraction to prevent a costly total breakdown.

Problems

11. The donor agency must determine the extent and duration of spare parts funding at the time of project design. If the objective of the project is to supply sustainable and reliable power, the donor must incorporate a revolving fund concept. If the objective is to develop a region, and reliable power supply, as one of the required inputs, is to be financed by the donor on a long-term basis, the fund must be designed to also take care of recurring expenses. These two different approaches are exemplified by the KfW-financed power plants in APA, and DANIDA's support of rural development in Africa.

12. With respect to the revolving fund, it may not be possible for the utility to replenish the fund for the same reasons it could not get foreign exchange in the first place. A donor agency setting up a revolving fund should help ensure government support, perhaps by making its own funding conditional on the government not letting the spare parts revolving fund fall below a certain level.

13. The administration of the fund may impose a burden on an understaffed donor agency. This could be solved by subcontracting supervision of the fund to a consulting company.

14. The disbursement procedures for loans and grants may not permit the creation of a spare parts account. Bureaucratic rules may require that a loan be closed after a certain period. The regulations governing the donor agency may not allow the creation of a revolving or continuing fund which it must supervise and replenish over a long period of time (e.g. 10 years).

15. The fund may make accounting more difficult for the utility, since it has to pay for parts which were already supplied without payment. A pilot project in a country with a poor payment record could provide useful insights.

Chapter 5. Manpower.

Annex 1. Detailed Profile of Manpower.

This table provides a detailed profile of manpower issues and problems for individual utilities in the EPUES study.

Staffing Numbers	Power Utility	Country	Reported Skills Mix Problems	Hiring & Firing (P)	Hiring & Firing (A)	Training (P)	Training (A)	Incentives (P)	Incentives (A)	Staff Morale (P)	Staff Morale (A)	Manpower Planning. & Dev't. (P)	Manpower Planning. & Dev't. (A)
Shortage	B	Z & BB	Yes	-	R	-	R	-	-	-	-	-	R
	A	T	Yes	Yes	P,R	Yes	R,B	-	-	-	-	Yes	R
	A	A	Yes	Yes	B	Yes	O	-	R	-	-	Yes	B
	A	W	Yes	-	-	-	B	-	P	-	-	-	-
Appropriate	A	F	No	-	-	-	R	-	-	-	-	-	-
	B*	R	No	No	-	No	-	No	-	No	-	-	-
	A	Q	Yes	No	R	-	R,B	No	-	No	-	No	-
	A	V	Yes	-	P,R	-	P,R	-	-	-	-	-	-
	A	M	Yes	Yes	B	Yes	B	-	O	Yes	-	-	-
	A	AA	Yes	-	-	Yes	B	Yes	B	Yes	-	-	-
Overstaffed	A	BB	Yes	-	-	Yes	B	-	-	-	-	Yes	R
	A	B	Yes	Yes	O	-	-	-	-	Yes	-	Yes	O
	A	R	Yes	Yes	O,P,R	-	-	Yes	P	Yes	-	-	O
	A	J	Yes	Yes	R,B	-	-	Yes	R	Yes	-	-	R
	A	F	Yes	Yes	-	-	O	-	-	-	-	-	-
	A	N	Yes	-	R	-	-	-	-	-	-	-	R
	A	H	Yes	No	-	Yes	-	-	O	-	-	-	O
	A	X	Yes	Yes	B	-	B	-	R	Yes	-	Yes	B
	A	Y	Yes	Yes	O,R	-	O,R	-	-	Yes	-	-	B
	A	G	Yes	Yes	R,B	-	-	Yes	-	Yes	-	Yes	-
	A	K	Yes	-	O	-	O	-	-	Yes	R	-	B
	B	D	Yes	Yes	-	-	-	Yes	B	-	-	-	-
	A	Z	Yes	-	O	Yes	O,R,B	-	-	-	-	Yes	B

* Parastatal

Legend: (P) problems.

(A) Remedial courses of action:
- O Presently ongoing.
- P Planned for future implementation.
- R Existing recommendations.
- B Initiated by the World Bank.

Annex 2. The Parastatal in Country D.

1. During the EPUES mission to Country D in September 1989, an investigation of the parastatal was undertaken. It is in a closed community which includes a farm, dairy, schools, recreational facilities, and other facilities which enable the community to be a self-standing operation.

2. The power plant was constructed in the 1950s and has been expanded several times since. Currently, the installed capacity is 14.5 MW. Of the 8 diesel engines in the power plant, 6 were operable at the time of the mission. One of the engines, a 900 kW, 375 rpm, Ruston 8VLBX, was retired after 109,476 operating hours; another identical engine was still operational after 110,648 hours. Both were installed in 1956. Five Mirrlees-Blackstone engines were operational. The oldest, installed in 1962, had 149,307 operating hours.

3. The power plant control room was immaculate and the engine room was well-designed and clean. At one end of the engine room a large space was used for engine repair. Staff interviewed at the plant were clearly very proud of the plant and their role in keeping it fully operational.

4. During the 33 years this diesel plant has been in operation, it has never shut down because of technical failure. The plant was forced to shed load occasionally due to lack of fuel. This remarkable operating record far exceeded the performance of the other African diesel plants investigated by EPUES missions.

5. EPUES compared this parastatal with others in Country D to determine the factors critical to its high performance, and concluded that the parastatal had no technical advantages.

6. With respect to the availability of fuel, lube oil, and spare parts, the parastatal also had little advantage over Country D's other diesel plants. Some years ago, it bought spare parts through a procurement agent in London who had access to a hard currency account maintained by the private owners. As the private owners began to suffer financially from other business operations, the procurement of spares for the diesel plant was reduced to essential items. Nevertheless, the mission was impressed with the inventory, control, and maintenance of spare parts. A computer system was used to keep a daily account of the parts. The mission concluded that timely access to spare parts contributed to the parastatal's high performance.

7. Maintenance at the parastatal was exceptional. Every Thursday the entire mine operation was shut down to perform regular maintenance. The shutdown decreased electrical demand sufficiently to allow engine maintenance at the plant to be kept on schedule. The results of this regular maintenance were reflected in each machine's long lifetime and high availability.

8. EPUES had learned from other missions that the availability of spare parts and regular maintenance are not sufficient to guarantee high performance. The power plant management and staff must have appropriate training and they must be motivated. In both areas, the parastatal was exceptionally strong. High quality technical training was available at or near the plant, and all personnel started their employment with an apprenticeship program. Apprentices were trained on the job and at the technical school. The program was well-structured.

9. Motivation was high, EPUES concluded, because the parastatal provided very strong incentives. All personnel received free housing, electricity, water, and medical care. Free

education was provided up to college level courses. These benefits made up for the extremely low State-controlled salaries. The salaries of the power plant personnel were actually lower than the salaries of staff in comparable positions at the national utility. Managers suggested that the low turnover in skilled personnel was due primarily to the benefits provided by the private corporation.

10. With the exception of controls on salaries, the Government did not interfere with the parastatal's operation. The managers of the power plant had very clear objectives and were held accountable for good performance. The quality of the managers interviewed by the mission was very high. The accounting and other financial control systems were excellent. Thus, all of the explanatory variables identified by EPUES as key to explaining good performance were positive: a high level of autonomy, clear objectives, good management, well-trained personnel, transparent accounting systems, access to foreign exchange, and no problems resulting from donor policies.

Annex 3. General Plant Operation Manual.

1. For all types of power plants, the operations and maintenance consultant, owner, design consultant, and plant manufacturer should form a working group to produce a *Generation Plant Operation Manual* to cover the following aspects: a) routine operational and daily/weekly minor maintenance procedures; b) operators' daily duties and checklists; c) operators' weekly duties and checklists; d) detailed description and procedure for operators' routine tasks; e) generation and auxiliaries plant log format; f) methodology for analyzing plant logs and analysis report format; g) station instrumentation, alarm and control schedule identifying the physical location of each instrument, alarm sensor and control loop; acceptable reading range, "cause for concern" and "urgent action required" reading ranges; calibration requirements; h) water treatment procedures, checklists and fault investigation flow chart; water treatment chemical handling and storage instructions; i) schedules of recommended lubricants, lubrication points, and frequencies; j) emergency procedures (e.g., black start of plant, fire, personnel accident, response to critical alarms, etc.); k) abnormal procedures (e.g., dealing with oil spillages, chemical handling accidents); l) plant isolation schedules for use in conjunction with safety rules when isolating plant items for maintenance work; m) systems diagrams indicating unique plant item, valve, and switch identifications to facilitate positive identification of points of isolation for safety documents.

2. From the *Generation Plant Operation Manual*, an assessment can be made of the time necessary to undertake the duties for each job. From the individual jobs, a reporting and responsibility structure can be drawn up, taking account of local customs and practices. The staff structure and job descriptions should be treated flexibly to suit local circumstances and the aptitudes of the staff.

3. The following principles should be observed in defining the station staff structure: a) keep the management chain of command as short as possible and avoid one-over-one situations and duplicate responsibilities; b) emphasize personal accountability with clear job descriptions; c) appoint staff with conditions which give the management the right to deploy staff flexibly; d) once established, do not change the management structure; e) match staff levels to workload, training requirements, and efficiency; f) identify functional links with the utility service departments and headquarters personnel accountable for provision of those services; g) hire only employees with appropriate skills and experience and with potential for career progression; h) the station manager agrees to and certifies appointments, staff transfers onto and off site, and extended leaves; i) make staff appointments, transfers, and promotions subject to a probationary period with authority for the station manager to reject personnel who (or reverse promotions that) prove unsuitable within the probationary period; and j) link staff reward and renumeration, at least in part, to performance.

4. The *Generation Plant Operation Manual* should form the basis of operator training to ensure that all personnel fully understand the theory underlying the tasks they are carrying out, the procedure for correctly executing each task, the relevance of the task, and the possible consequences of failure.

5. Where craftsman skill levels require enhancement, appropriate training should be provided. Fitters should be tested and certified as competent to carry out specific routines. Records of certifications should be maintained. Only certified craftsmen and trainees should be permitted to undertake maintenance tasks.

6. The plant manager's job description should define responsibility for plants within "system boundary" (e.g., all plants within the input terminals to the distribution substation), and

provide authority to: a) define operating limits for plant, b) employ permanent staff, c) employ temporary staff to meet workload peaks, d) replenish consumables and authorize purchase of spare parts and miscellaneous materials, e) define plant outages necessary for maintenance and defect rectification requirements and time frames when plant is released from service, f) approve working practices and procedures, g) take disciplinary action against staff within a defined framework, h) define management policy for the plant, i) define staff development and training policy, j) define nondiscriminatory criteria for staff selection and promotion based on merit, k) define a budget for headquarters approval, and l) establish free flows of information necessary to enable the whole power station complex to work as a cohesive team with a common objective.

7. Specification for new projects should require the contractor to provide technical reference books in a language which is readily understood by the operations staff, together with shelving. These books should also enable station craft and operations staff to enhance their technical understanding by self learning.

8. Consideration should also be given to funding a means of access to any expert technical advice and assistance the plant manager requires during the early operational life of the plant, and particularly during the first major engine overhauls. Any contacts with equivalent personnel operating similar plants in other utilities should be fostered, as should the confidential exchange and comparison of performance data.

Chapter 6. Training.

Annex 1. Possible EPUES Training Activities.

1. Clarify training needs and identify possible components of intensified training efforts for all types of plants.

2. Identify institutions that could participate in regional training efforts, especially in Africa. Analyze alternative institutional structures and possible obstacles.

3. Review training programs in developed and middle-income countries to determine which resources, curricula, and training methods have been effective, and what methods these countries use to certify skill levels.

4. Develop a system that interrelates the certification requirements of different industrialized countries. This would faci!itate the development of regional programs. It would also encourage long-distance or self-paced study and make the task of manpower needs assessments less complicated.

5. Investigate innovative education tools, including interactive videodisc and computer instruction, to facilitate long-distance or independent study where there are resource constraints. The team can study the possibility of soliciting manufacturer buy-ins in exchange for teaching trainees how to use their equipment for diesel plants. Such programs could combine generic diesel training material with manufacturer-specific models. See the discussion of training technologies in Annex 3.

6. Investigate expert systems that would facilitate fault diagnosis and other communications, enabling managers to supervise employees and monitor equipment from long distances. These systems would facilitate better supervision of scattered power plants by transmitting routine equipment readings, guiding staff during fault finding and repairs, and tracking spare parts needs. See Annex 3.

7. Investigate (a) possible specialized curricula for operators with low levels of education; and (b) expert and communications systems that could support and manage poorly-educated trainees, especially in countries where the scarcity of high school and technical school graduates forces utilities to rely on undereducated personnel.

8. For diesel plants, increase the availability of diesel training materials and manuals, both generic and manufacturer specific, in local plants.

9. Investigate using service contracts with manufacturers, local affiliates, or contractors, financed at the time of purchase through the loan or grant. Such contracts could facilitate recruitment and retention of trained maintenance personnel by removing them from civil service and parastatal salary limitations.

10. Since the power sector includes not j utilities, but also such private generation facilities as industrial plants and mines in off-grid area., investigate the possibility of private sector participation in training. This could help reduce competition for skilled employees, especially where private generation is meeting demand that utilities are unable to meet. Donors may want to consider providing training to equipment technicians and operators as a way of contributing to development, whether or not the trainees stay with the utility.

Annex 2. Recommendations For Financing and Technical Assistance Agencies.

1. All parties should devote greater attention and resources to training during project/loan analysis, implementation, and day to day operations.

2. A comprehensive training needs analysis should be an integral part of any power sector project. Assessing human resources will help identify proposed plants that cannot be supported by current utility staff, are clearly unsustainable, or are sustainable only with expatriate managers and consultants or significant training intervention. Identifying in advance the need for expatriate assistance or training intervention will result in a more realistic assessment of total project costs. Assessing training needs can be the first step towards developing a comprehensive training plan.

3. Training programs should be as lengthy as those in industrial countries, and similar in the way theoretical knowledge and practical experience are combined. Donors should take near-term steps to provide training courses of longer duration.

4. Donors should coordinate training among themselves and with recipient countries. The process could include information sharing, exchange-study programs between recipient countries, and the development of regional training programs and facilities.

5. Donors should consider organizing a working group of representatives from donors, lenders, manufacturers, training institutions, and EPUES staff. The group would coordinate training activities, conduct workshops, and develop and refine proposals for regional cooperation. EPUES could play a coordinating role.

6. For diesel plants, donors could design and offer a comprehensive one- to three-year training course for future diesel trainers that incorporates course work, study at manufacturers' facilities, observation of different training or apprenticeship programs, and work experience (perhaps with an elite mobile repair/overhaul team).

7. Middle management diesel training programs should also be upgraded, to help plant managers meet their technical, organizational, and human responsibilities.

8. Donors may wish to include private sector trainees in diesel training programs, including the technical staff of major autogenerators and of other entities competing for scarce skilled labor. This is a possible area for EPUES to investigate.

Annex 3. Interactive Videodisc and Computer Training Systems, and Expert Systems.

1. A variety of innovative tools can facilitate long-distance training, self study, maintenance, and oversight for all types of plants. These tools, which all rely on computers or interactive videodisc (IVD) technology, are increasingly being used in the United States and Europe to improve training and lower associated costs.

2. IVD presents material on a video screen in still, text, or video formats. This technology has two major advantages over videotape instruction programs: (a) material can be accessed at random (a videotape being only sequential), as the trainee requests or as the computer program determines; and (b) the IVD system monitors the trainee's comprehension and progress and presents material progressively as the trainee demonstrates comprehension in short question and answer sections. When a trainee does not understand material, the system can review it, present background information, or offer remedial material. This method enables trainers or supervisors to monitor a trainee's progress at long distance. Each IVD videodisc has six to eight separate soundtracks, allowing for narration in six to eight different languages.

3. The U.S. military has been a major investor in education and training technologies. Over the past three decades, the military has provided three fourths of all funding in the United States for educational technology research and development. This is due to the military's immense need to train poorly-educated recruits. Simulators are one major training application which have gone through several generations.

> The Navy's Taskteach Tutorial simulated equipment for maintenance training, and led to development of a General Maintenance Trainer/Simulator and the Sophisticated Instructional Environment (SOPHIE). SOPHIE received Tri-Service support and is considered the "mother" of several other intelligent tutoring systems developed by the services for training personnel in troubleshooting tasks and equipment operation and maintenance. (*Power On!: New Tools for Teaching and Learning*, US Congress Office of Technology Assessment, pp. 151, 155-158.)

4. The U.S. military and many industrial and service firms rely heavily on IVD to teach relatively uneducated personnel to operate and maintain highly complex equipment. IVD increases trainees' attentiveness through constant interaction and decreases their reliance on instructors, which saves travel costs.

5. Expert systems also rely on IVD technology to facilitate equipment operation and maintenance. General Electric (GE), one of the largest manufacturers of diesel-electric train locomotives, developed its Diesel Electric Locomotive Troubleshooting Guide (DELTA) to replace one employee who was the core of its entire service system. DELTA, an expert system to aid mechanics in fault diagnosis and repair, is now servicing more than 20,000 diesel-electric locomotives in the United States alone. Because diesel engines in power plants use similar technology, it would be useful for donors to learn more about DELTA and its impact.

Annex 4. Common Types of Training Programs.

1. EPUES subject countries use a wide variety of training programs and methods. The following list is not exhaustive, but is intended to facilitate the discussion of training options. Table I indicates the types of programs used by each utility.

2. *In-house training programs.* Local dedicated programs run by and for a utility, dealing specifically with skills and technology relevant to that utility. Country D has technical training programs at both the national utility and the parastatal.

3. *Local technical/vocational school, or engineering college/university.* Usually part of the public education system. For example, Country D has several technical colleges, and an engineering faculty at a university in the capital.

4. *Diesel manufacturer training programs.* There are two types: (a) factory-based training programs offered by Mirlees-Blackstone, MAN, FINCANTIERI, Wartsila, and others manufacturers. Courses last from a few weeks to more than a year, and cover a range of subjects. And (b) in-country training offered by most diesel manufacturers, or by their distributors, usually during plant installation or commissioning.

5. *Ad hoc expatriate-instructor training.* In some cases, expatriate managers and engineers perform unstructured on-the-job training in addition to their principal responsibilities. Ad hoc training is also sometimes offered by manufacturers' personnel or by donor-funded consultants.

6. *Free-standing training institutions (also called informal training programs).* These are nondegree institutions, often outside the government education system, that provide training in economically useful skills.

7. Donor countries also offer training programs for utility personnel, ranging from long-term university study to specialized short-term seminars.

8. *Long-term higher education overseas, in either degree or specialized certificate programs.* USAID, for example, offers university training through Energy Training Program (ETP), as well as through generic education support programs. Several donors support extensive training at diesel manufacturers' facilities.

9. *Short-term specialized training courses.* Donors support trainee attendance at short-term manufacturers' courses in Europe. One is a two-month course for diesel operators and mechanics offered jointly by USAID ETP and EGSA; another is the NRECA/CARICO Diesel Course.[1] There are similar courses in a variety of utility-related technical and management subjects, such as the one given by the Ireland Electricity Supply Board (ESB).

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[1] EGSA is the Electrical Generating Systems Association, a U.S.-based association of manufacturers of combustion turbine and other engine-driven generating systems. NRECA is the National Rural Electric Cooperative Association (U.S.), which has an international division active in power programs in developing countries.

Table 1. Training Programs.

Country	In-House	Expat/Man	Free-Stand	Overseas	Engineer Univ/College	Tech/Vocational School
Alaska	Y					
Equat Guinea		Y		Y		Y
Gambia		Y	Y			Y
Guatemala	Y	Y		Y	Y	Y
Guatemala2		Y				
Guinea	Y	Y		Y		
Guinea-Bis		Y	Y	Y		Y
Indonesia	Y	Y				
Mali	Y	Y				
Mauritius	Y					
Mozambique	Y	Y				
Sierra Leone		Y*				
Somalia		Y	Y			Y
Tanzania	Y	Y		Y		Y
Tanzania2	Y			Y	Y	Y

* Recently closed.
<u>In-House</u> refers to in-house utility training programs.
<u>Expat/Man</u> refers to in-country training by manufacturer or expatriate personnel.
<u>Free-Stand</u> refers to free-standing or informal training programs, as opposed to formal voc/tec schools.
<u>Overseas</u> refers to overseas training at manufacturers donor programs, etc.
<u>Engineer Univ/Col.</u> refers to in-country universities with electrical and mechanical engineering curricula.
<u>Tec/Voc School</u> refers to technical and vocational schools with electrical and mechanical curricula.

Alaska: Informal on-the-job training. While not structured, significant time and effort go into training. Occasional two week outside courses on electrical subjects.

Guatemala: No formal in-house training, except for very short (<1 week) in-house courses.

Indonesia: In-house training program is of fairly high quality, but due to the limited number of openings, most operator and maintenance staff instead receive only manufacturer training at the time of plant commissioning.

Mali: There is a utility training center in Bamako, supported by EDF, which has generally focused on administration and finance. It has recently started diesel training program.

Somalia: Only unstructured on-the-job training by the Finnish technical advisor.

10. *In-service training or internships.* Utilities in developed countries have in-service training and internships. Management staff from some African countries, for example, serve internships with Electricite de France (EDF).

11. By examining training programs in Europe, Japan, and the United States, donors can determine what training the utilities need to develop specific employee skills and capabilities. There are different ways of reaching the same training goal and several possible models.

12. *Vocational/technical school approach.* In the United States, students study mechanics in specialized technical/vocational schools, then go on to full-time employment. The employer then determines how much on-the-job training is needed to fully prepare the individual for his or her duties.

13. *Combination of technical/vocational school and on-the-job training or apprenticeship.* This is common in the European countries, including Germany. Participants attend school part-time and work part-time as an apprentice.

14. *Intensive on-the-job or in-service training of personnel lacking prior technical education.* This is common in Japanese industry and the U.S. military. In both cases, the initial part of the training is often a year or more of full-time classroom instruction.

15. *Self-paced or independent study.* This is often an alternative to classroom programs. It can take advantage of new pedagogic technologies, but requires an organized and reliable examination system with a high degree of integrity. In the U.S. Navy, for example, operators and mechanics for all types of engines can progress through the grades by independent study and examinations, or by combining continued classroom training and experience. The Navy's Personnel Qualifications Standard (PQS) formally recognizes both avenues to advancement.

16. *Short-term in-service training.* Often used to upgrade or refresh employee skills, or to introduce new components with different maintenance requirements. Such training is often provided by diesel manufacturers.

Annex 5. Broad Reviews of Training Experience.

1. There have been a number of reviews of World Bank and contractor experience with project, sector, vocational/technical, and management related training.[1] These reviews are not focused solely on the power sector, but they are valuable summaries of training experience with possible relevance to the EPUES training review.

2. The reviews found that in loan or project analyses for all types of power stations, the coverage of manpower and training factors was insufficient. Manpower and occupational assessments were rarely attempted, and the effects of these issues on the sector were rarely addressed. Specific findings include the following: (a) manpower and training issues had low priority, and analysis of these issues was underbudgeted, (b) the capability of operations staff to do training/manpower analysis was relatively weak compared to their technical and financial skills; and (c) insufficient efforts were made to develop an institutional memory to facilitate learning from prior experience.

3. The findings of these reviews correspond with EPUES findings that donor-financed diesel projects usually had insufficient training components and lacked consideration of whether trained/trainable staff were available to operate and maintain plants.

4. The following findings were common to a number of the broad training reviews for all types of plants:

5. Expatriate managers and consultants often could not train counterparts because of their need to focus on their primary responsibilities.

6. Trainers were often of low quality or poorly motivated; the trainer was accorded little respect.

7. Donor-supported training programs were often not supported in the recipient country, and ended when donor funding ended.

8. Trainees often did not have enough education or experience to enable them to benefit from training, particularly in Sub-Saharan Africa.

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1 Reports include the following: *General Operational Review: Manpower and Training Issues in Sector Work* (PHREE Background Paper Series); *Vocational Education and Training: A Review of World Bank Investment* (World Bank Discussion Paper); *Improving Training Quality in Developing Countries: Toward Greater Instructional Efficiency* (PHREE Background Paper Series); *Review of World Bank Investments in Vocational Education and Training for Commerce* (PHREE Background Paper Series); *Training for Public Administration and Management in Developing Countries: A Review* (World Bank Staff Working Paper); and *The Reform of State-Owned Enterprises: Lessons from World Bank Lending*, Mary Shirley, Policy and Research Series, World Bank.

9. There were few incentives for employees to participate in training programs, due to salary ceilings and lack of subsequent career advancement. Employees who completed training courses often left for better paying jobs.

10. Training resources were often concentrated on elites, while training for mid- and lower-level employees was neglected.

11. Most state-owned enterprises or agencies in developing countries did not have an official training policy. This led to ad hoc decisionmaking and the insufficient allocation of resources.

12. Training efforts in Sub-Saharan Africa have been less successful than in other regions. Special approaches may have to be designed to respond to local needs and capabilities.

13. Middle-income countries have had success with training programs which use informal training centers and post-secondary technical schools as components of national training systems that are responsive to changing needs.

14. Informal training programs are often more effective than formal technical schools. These programs usually are not under a ministry of education, which frees them from bureaucratic obstacles and resource constraints.

15. Regional training and management development institutions may be more cost effective than a number of single country programs.

16. These findings are consistent with the EPUES observations, particularly concerning the use of expatriate trainers, the low status of trainers, the lack of recipient country support for training programs, the insufficient education of trainees, and the poorer results experienced in Sub-Saharan Africa. EPUES also agrees with the idea of regional training centers, particularly in Africa.

Chapter 7. Technical Issues.

Annex 1. Spinning Reserve.

1. Sufficient redundancy and excess capacity throughout the system to meet unexpected contingencies are the major safeguards against shortages. At the generation level, excess capacity is expressed in the form of reserves. Spinning reserves are intended to be maintained by power systems to follow minute-by-minute load variations and to meet sudden contingencies, such as the forced outage or unexpected failure of any kind of generating unit. These reserves consist of generators that are already connected to the busbars and are ready to take the load immediately, because, for example, they are operating at less than full output.

2. If reliable public electricity supplies are justified on economic grounds, which most reports indicate they are, then supply reliability is a criterion which should be considered as an element of system planning. The operation of "spinning reserve" is a significant element in the achievement of reliable electricity supplies to economically important consumers if the electricity distribution system is not arranged to automatically shed non-essential loads.

3. In many instances, spinning reserve is not the policy, because it increases operating costs. If spinning reserve unduly increases operating costs, however, the implication is that the system has not been correctly designed to facilitate generation plant despatch with spinning reserve coverage, most commonly because the selected unit sizes of generator were too large.

4. In Country DD, a comparison was carried out on a system to assess the effect of despatching a diesel plant with 100% spinning reserve coverage of the largest set in operation in comparison to how the plant had actually been despatched. The actual despatch had provided spinning reserve coverage for 23% of the period. Correct despatch would have provided 100% spinning reserve, reduced the total fuel consumed by 1.9% and reduced the number of engine cylinder hours by 15% thus reducing operating costs.

Annex 2. Equipment Required for Accommodation of Personnel in Diesel Power Plants.

1. A typical base load diesel power plant manned 24 hours a day, 365 days a year should have:

(a) A conference/training room large enough to hold one complete shift of staff plus supervisors and managers. The room should be equipped with tables, and chairs, blackout window blinds, a flip chart, slide and overhead projectors, whiteboard and appropriate training aids, and shelves for technical literature.

(b) Washing and toilet facilities, showers, personal lockers, and changing area.

(c) A mess room large enough to accommodate one full shift. It should be equipped with tables, chairs, cooking facilities, and refrigerator and other items according to the customs of the country.

(d) A maintenance engineer's office equipped with desk, table, chairs, filing cabinet, shelves for operations manuals and technical reference books, drawing cabinet, and planning board.

(e) An operations engineer's office equipped with desk, table, chairs, filing cabinet, shelves for operations manuals and technical reference books, and planning board.

(f) An administration officer's office equipped with desk, table, chairs, filing cabinets, and planning board.

(g) A maintenance supervisor's (foreman's) office equipped with desk, chairs, filing cabinet, shelves for plant manuals and technical reference books, small drawing cabinet, and planning board.

(h) A control room with fittings, desks, chairs, shelves plant operation manuals, drawing racks to hold system drawings, and safe working systems equipment (key safes).

(i) A station manager's office to hold meetings between senior station staff and equipped with desk, table, chairs, filing cabinet, shelves for technical reference books, and planning board.

Annex 3. Requirements for Workshops Areas.

1. Typical requirements for a base load diesel plant are:

(a) A workshop area with space to stand an engine set of overhaul components.[1] This area should have an overhead crane for handling heavy components and road vehicle access for off-loading large items. If air tools are used, an air system should be installed.

(b) A clean room with vapor extraction for fuel pump and injector overhaul and testing.

(c) An instrumentation workshop with benches and for calibration equipment.

(d) Storage for lockable tools and lifting equipment.

(e) A machine shop equipped, at a minimum, with pin drill, center lathe, cutter grinder, and machine hacksaw.

(f) A screened welding area with welding equipment.

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1 e.g. pistons and connecting rods, cylinder heads.

Annex 4. Requirements for an Effective Maintenance Management System.

1. An effective maintenance management system for a base load diesel power plant should include:

(a) a database containing details of every item in the power plant complex (including workshop machine tools, lifting equipment, access equipment, transport, etc.). The database should provide supplier name and address, item type and description, physical location, plant identification, performance data, and initial cost.

(b) data on all planned maintenance tasks, i.e. a description of the work; a procedure for doing the work; details of spare parts, tools, and manpower skills; estimated time to complete; plant isolation details and safety requirements; and periodicity.

(c) maintenance history records, with such details as when jobs were done by date and running hours; the condition of the plant prior to maintenance (including wear measurements, if appropriate); who performed the maintenance and how long it took, and results of any investigations of defects or breakdowns.

(d) long-term maintenance planning.

(e) plans for maximum plant availability (e.g. if a plant is taken out of service, the system will allow other maintenance work to be carried out simultaneously).

Annex 5. Inventory Control.

1. An effective inventory control and record system in a diesel plant should:

(a) provide the nonvariable data on each component, i.e. description, manufacturer, manufacturer's part number, unit of supply,[1] stores location, order quantity, and minimum stock level to stimulate reorder.

(b) monitor stock and supplier data, i.e. quantity in stock; dates and quantities of withdrawals from stock, supplier names and addresses; details of outstanding orders including anticipated delivery date, unit cost of last batch ordered, average cost of components in stock; any minimum order sum required by the supplier; and supplier quality record.

(c) audit stores periodically.

(d) ensure that goods received into store are the ones ordered, that they fit the purpose intended, and are adequately preserved and correctly labelled.

(e) provide for obsolete good or goods damaged in storage to be written off and scrapped.

(f) maintain records of components sent off site for refurbishment, and identify them when returned to storage.

2. Spares and miscellaneous consumables inventory should be developed in four categories:

(a) Miscellaneous consumables, including nuts, bolts, washers, lock wire, rags, thread lubricants, jointing materials, terminations, cable tags, wire, etc.

(b) Spares for planned maintenance and components necessary for routine maintenance work. Quantities will depend on lead times and experience with the operation of similar plants.

(c) Exchange subassemblies (e.g. complete cylinder heads, injectors assemblies, pistons and connecting rods, governor) which can be overhauled in the workshop while the generator is in service.

(d) Strategic spare parts to cover a breakdown (e.g. a cylinder line, complete electric motors, cams and follower assembles, alternator pedestal bearing).

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1 e.g. unit, litre, pair, box of 100, etc.

Chapter 8. Environmental Issues.

Annex 1. Environmental Pollution Observed by EPUES.

Country EE

1. Waste lube oil and oily wastes were dumped in the areas of the three diesel plants the mission visited in 1988. Oil was poured into holes dug by employees, and sludge and other wastes were irregularly dumped outside the powerhouse. Each plant was 1.5 MW and consisted of three machines of equal size; the pollution after two to three years of operation was significant. Transformer oils were also dumped in the repair shops, and incinerators on two of the sites were not used. The mission did not attempt an analysis of the long-term consequences or an estimate of the cost of cleaning up the site. The situation in other diesel plants is most likely similar; a nationwide analysis is required.

Country DD

2. The first mission to Indonesia in 1988 visited mostly remote locations with little industrial activity. All diesel sites had some pollution from waste lube oil. At one plant, waste lube oil and polluted water were discharged into the rainwater drainage system. At two others, oil was stored in drums outside the powerhouse. At another, the oil was burned in makeshift incinerators at low temperatures at a rate of a few liters per day. Oily wastes and transformer oil were usually dumped close to the powerhouse or repair facilities. The severe pollution at all older diesel plants gave an indication of how the situation will develop at plants installed in 1986 and 1987.

3. The second mission visited two other diesel power plants. One plant had several oil fields and refineries, and pollution caused by the plants appeared insignificant next to the environmental impacts of the oil industry. The plant managers reported that the waste lube oil is transported to the refineries or to steam power plants. There was no major pollution except for the oil filters and sludge dumped near the plant. The high temperature incinerators financed as part of the plants were not used.

4. The following passages are quotes from selected mission reports.

Country J

5. After oil changes, the waste lube oil (8.000 *l* per machine) is either sold to the personnel as used engine oil, or simply poured into the ground.

Country A

6. It is urgent that environmental aspects be evaluated during a future mission.

Country F

7. Waste lube oil is sold to the local population or, if not sold, pollutes the environment of the power plant. No measures are taken to reduce the pollution. Wide areas around the plant were polluted with oil.

8. All machine halls and ways should be cleaned from oil. Appropriate waste lube oil disposal should be introduced. The severe environmental pollution by waste lube oil should be reduced. Environmental protection practices are currently ignored.

Country G

9. The station area is in a disastrous condition. All buildings and installations are heavily spoiled. Oil leakages caused oiling up of surfaces and oil penetration into construction materials. Protective paintings and coatings are mostly damaged.

10. Pictures provided by another mission show severe pollution of the river close to the plant.

Country L

11. Waste lube oil is collected in the supplier's 210 *l* steel drums. The waste is sold on the local market at a price of Rs 450 per drum. The oil is mainly reused for truck and bus engine lubrication.

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