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GUIDELINES FOR PRELIMINARY APPRAISALS OF CAPITAL PROJECTS

PART II - ELECTRIC POWER PROJECTS

Prepared for

AGENCY FOR INTERNATIONAL DEVELOPMENT
Under Contract AID/csd-2583

by

ROBERT R. NATHAN ASSOCIATES, INC.
Washington, D.C.

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FOREWORD

The project analyst using these guidelines should first read Part I, General Guidelines. The General Guidelines provide insights into key considerations for preliminary project appraisals (PPA's) in all sectors, with a detailed discussion of the methodology for valuation of inputs and outputs and for calculating the internal rates of return, cost-benefit ratios, and other relevant measures of the worth of a project.

These guidelines deal expressly with matters relevant to electric power. They tell the analyst how to approach a power project proposal; what to look for; and how to assure consideration of the factors essential to an appraisal of a project. They suggest possible institutional, cultural, political, and environmental constraints. They encourage concentration wherever possible on big issues in broad orders of magnitude, leaving details and matters of lesser importance to be explored in a detailed feasibility study. Finally, they lead the analyst through the input and output quantification and the computation of the estimated rate of return for the project, in terms of which the desirability of future action on the project can be determined.

I. INTRODUCTION

An electric power system encompasses the generation, transmission and distribution of electrical energy. Power systems are a basic part of a nation's economic infrastructure. Electric power is employed for the performance of essential electronic, thermal, and mechanical functions in industry, communications, and commerce, as well as for a variety of purposes in the home. Electricity has contributed to the phenomenal growth in human economic productivity and to enhanced creature comforts during the last century. The manifold benefits of electric service are recognized and sought in the LDC's; in fact, increased production of electric power is often regarded as an index of economic development and rising standards of living.

Scope of Guidelines

These guidelines are applicable to all elements of electric power systems, including investment in outside and inside physical plant, operations and maintenance, management and technical personnel, operating procedures, economic and financial analyses, and system planning.

Using the basic approach of the General Guidelines for PPA's, these guidelines will cover the following:

- The relation of the project to macroeconomic variables and national economic goals and strategies

- Contributions of sector studies to power project appraisals

- Political considerations and power projects

- The principal factors to be examined to disclose the strong or weak points of the project

- The fundamental mechanics of project preparation and appraisal

- A summarization of hard core data requirements.

Characteristics of Electric Power Systems

Electric power systems include relatively expensive components. They are the epitome of a high capital-intensive, low employment type of project. The range of choice in the investment decision-making process for altering the relative inputs of labor and capital is very limited. A listing of typical electric power system elements and alternatives is given in appendix A.

The physical function of power generation is the transformation of primary energy into electrical energy. Projects in this sector are very heavy users of fossil fuels (coal, oil, gas), water for hydroelectric production, and nuclear fuels.

The power sector possesses its own system of transportation in the form of transmission and distribution facilities. If fossil fuels are used, electric power utilities may also put heavy demands on the transport sector. In many countries, rail transport is, in turn, a heavy power consumer.

Another characteristic of electric power is the considerable hourly and seasonal fluctuation in consumer demand. This, combined with associated peaking problems and system load duration curves, requires that the attention of the analyst be directed to measures of capacity in the technical appraisal of projects in the power sector.

Electric power is frequently supplied or distributed through system networks or grids. It is often desirable for interconnections to be made between them, thereby improving the operations of both systems through the sharing of excess capacity. Such interfaces and the technical considerations associated with them are typical of the more important engineering design problems encountered in the power sector.

The quality of electric service has an important impact on the revenues and the rates of return earned by projects. If delivered voltage to the consumer is too low, his equipment may not only operate at lower levels of efficiency, it may also be impaired. Interruptions of electric power not only reduce revenue but also result in loss of customer confidence. If the supply is of poor quality or suffers frequent interruptions, increased use of electric power through additional electrical appliances and facilities

is discouraged. In the extreme, major consumers may decide to invest in their own electric supply system. In the latter event the national cost of electricity is increased, with the increase in cost representing an impediment to development.

The characteristics noted above have important implications for project analysis. First, the heavy capital investment in such projects requires a careful consideration of the availability and costs of funds for construction and installation. Second, in most LDC's, a very large part of the equipment -- and some of the skilled labor required in construction, installation and operation in the early years of the project -- must be imported. If domestic currency is overvalued or undervalued, the use of shadow or accounting prices is of critical importance because of the large import content of total investment; if fuel is imported, shadow pricing is equally important in the valuation of inputs for operations.

In computing the project rate of return to the national economy, shadow or accounting prices should be used in place of actual market prices in pricing inputs and outputs when market prices do not provide an accurate measure of costs or benefits. Shadow pricing is discussed in the General Guidelines (chapter II and appendix B).

The potential economies of scale available with large-scale installations and the rapid rates of growth in power demands -- experienced and expected -- lead to proposals involving the installation of considerable excess capacity in the early years of project operation. To prevent uneconomic commitments of capital, the analyst must evaluate the "cost" of different levels of excess capacity through the use of the discounting procedures explained in chapter III and appendix A of the General Guidelines.

As compared to relatively large and interconnected power systems occurring in the more developed countries, small, isolated power systems in LDC's may require relatively greater reserve capacities for unscheduled outages and maintenance purposes. This may be particularly true when a system has just installed new and more complicated units of much larger than customary size, because considerable time is required for the acquiring of operating experience.

The high fixed cost -- and comparatively small variable cost -- mix of power systems poses special problems and opportunities in pricing of output. These are discussed in a later section and in appendix B.

Power projects are often prestige undertakings. Therefore, decisions about the type, scale, location and rate structure may be influenced by social, regional and political -- as well as economic -- considerations. Economic rates of return along with such considerations will form the basis for final decisions. The PPA can point up the economic consequences of different alternatives in juxtaposition with these other considerations.

II. RELATIONSHIP OF PROJECTS TO MACROECONOMIC VARIABLES, NATIONAL ECONOMIC OBJECTIVES AND POLICIES

If a national economic plan exists, development goals will have been established and national resource allocations planned to achieve these goals. Power projects can be affected in a number of ways by such a plan:

1. The planned rate of overall economic growth is an important factor in projecting the rate of increase in the demand for electric power.

2. The pattern of change in industrial structure will influence the future location of power projects and the magnitude of increases in power requirements. For example, a heavy commitment to industrial development will imply faster growth in power requirements than a similar emphasis on agriculture.

3. Policy guidelines for investment decisions may impose certain restraints on power projects. For example, national policy may place heavy emphasis on labor-intensive projects, on projects requiring small foreign exchange inputs, on projects that can be completed quickly, and on projects yielding a high rate of return. Some or all of these may have a constraining effect on power projects.

4. If the national plan also provides for regional development, this will clearly affect the spatial pattern of future power requirements and the location of projects. As an essential component of infrastructure for industrial development, power projects may be used to accelerate development in specified regions, but the economic possibilities of such efforts will depend in part on the location of primary energy resources.

5. Policy measures to limit imports and conserve foreign exchange may influence the choice between thermal and hydro installations, and between the use of domestic and imported fuels.

6. Projected government revenues and current expenditures will set the planned flow of government funds available for direct investments and/or loans for power projects.

7. Policy measures to restrain domestic production of nonessential consumers' goods (e.g., electric washers, driers, refrigerators and air conditioners) and high import duties on appliances will restrain the rate of increase in residential and commercial power requirements.

If a national economic plan exists the analyst should examine the implications for power projects. If there is no formal plan, objectives, policies and strategies will have to be inferred from such sources as budgetary documents, the statements of government officials, "white papers" and the actual pattern of economic decisions during the recent past. Whatever the source of his information, the analyst should seek a perspective from which the project can be viewed in the context of the general economic situation.

III. SECTORAL STUDIES AND THE PRELIMINARY PROJECT APPRAISAL

Project appraisals are preferably made in the context of a sectoral plan or comprehensive study of the sector. If such a plan or study is available, the analyst should examine its contents in terms of the following considerations:

1. Does the power sector plan or study at the national, regional, and local level include the following features:

- Projections of power demand
- Optimum methods of meeting demand based on engineering and economic criteria
- Appraisal of indigenous sources of primary energy
- Integration of local and regional power supplies into a national grid
- Standardization of engineering and power supply characteristics
- Optimum phasing of additions to generating capacity and extensions of transmission and distribution systems.

2. Was the power sector plan prepared by professionally competent engineers and economists, with proper balance between the two, and with sufficient objectivity to eliminate possible bias in terms of recommended alternatives for the supply of electric power? Was it sponsored by or were its findings accepted by international financing institutions such as the IBRD?

3. Was the power sector plan developed in concert with a national economic development plan to insure mutual consistency and coordination of all essential elements, including projected growth in demand, phasing of additions to capacity, regional and national priorities, the supply of fuel or other primary energy from indigenous sources or imports, etc.?

4. Assuming the existence of a power sector plan meeting the above requirements, is the proposed project in conformity with that plan? If it is not, what rationale or justification is presented for deviating from the plan? Has this been examined and approved by the authorities at the national level having responsibility for national planning, economic policy, and administration of the development of the power sector?

5. Have alternative methods of meeting the prospective demand for power been examined which might permit postponement of the proposed project through improved use of present facilities? Among these, the following should be considered:

- Improved management and operation of existing plant to reduce or eliminate interruptions in service

- Flattening out the daily and seasonal load curve by shifting peak requirements to periods of low capacity utilization through incentive pricing and administrative changes

- Load sharing through interconnection with other plants or systems if required capacity is available.

6. Has selection of the proposed investment been based on equal consideration of all possible alternatives, including all the economic variables? Among these alternatives are the choice of fuel, the source of fuel, the type of generator, the size of generator, and the choice of increased generating capacity versus interconnection.

7. Were the cost-estimating techniques and methodology employed for such widely divergent alternatives as hydroelectric, nuclear, or fossil fuel, and interconnection versus increased generating capacity, on a comparable basis? Are underlying assumptions on future costs of fossil and nuclear fuels equally reliable?

8. Is the proposed technology adaptable to the technical capabilities and requirements of the country? What would be the effect of a different technology on investment and operating costs?

9. Is the project fully integrated with all related elements, and are these taken into account in estimates of investment and operating cost? Are all elements of generation, transmission, and distribution taken into account? Have possible additional investments in fuel production and transportation facilities been taken into account?

10. Has attention been given to manpower training programs required to improve efficiency of existing operations and to assure efficiency in the operation of new plants at all management, technical, and clerical levels? Have the costs of such programs been taken into account?

11. If a new plant is proposed, has adequate provision been made in both land and building structures for future capacity expansion? The same consideration applies to the planning of investment in transmission and distribution facilities.

12. Have the economies of scale applicable to the production of electrical generating equipment been fully taken into account in the selection of generator size? Have the economies of scale been fully evaluated against the diseconomies of investment in excess capacity?

A power sector study may incorporate what is essentially a preliminary review of a project. If this is so, the analyst merely needs to check the work that had been done previously, perhaps bringing the project study up to date or providing whatever the previous study lacked to upgrade it to a PPA.

If a power sector study or plan has not been made, the project analyst should identify the minimum informational requirements for a preliminary appraisal as a guide in assembling data. Much of the required data can be developed from operating statistics from existing power systems in the country and from population and industrial censuses.

If the essential data are not available within the country, useful information can be obtained for other countries at comparable stages of economic development and with similar industrial structures and degrees of urbanization.

IV. STEPS IN THE PRELIMINARY APPRAISAL

Project preparation and appraisal consist of the following steps:

1. Identification of need for project and category of project
2. Formulation of promising physical resource flow plans
3. Pricing the project
4. Selection of the most promising alternatives
5. Computation of rates of return
6. Sensitivity analysis of rates of return
7. Evaluation summary

While the above steps can be discussed as discrete steps that will occur in the stated order, it should be recognized that in the course of carrying out these steps there will be considerable interaction. For example, in carrying out step 4, the analyst may find that other alternatives suggest themselves, and he may find it necessary to return to step 2.

Identification of Need for Project and Category of Project

Evaluation of Existing Demand-Supply Situation

The first step in the appraisal is to review the existing demand-supply situation. This includes the demand for power (average weekly and peak) for recent years compared with the available capacity. Special attention should be given to instances where the available capacity was insufficient to meet demands. Based on scheduled additions to present capacity (less scrapping), the scheduled capacity (without further additions) can then be determined.

Of particular importance are indications of unsatisfactory quality and dependability of electric service, such as power rationing, "brown-outs," and the number of industrial plants and institutions with their own generating equipment (usually a high-cost source of power). These indications

and information on unavailability of installed capacity due to breakdowns may indicate the need for improved maintenance, training and other corrective measures involving supplementary investments. Correction of diagnosed deficiencies or improvements in management can yield very high returns with little investment and therefore deserves very high priority.

Where there are sharp but short peaks in demand, it may be useful to explore ways to reduce peaks by rescheduling industrial demand. Suitably designed rate adjustments can be helpful in achieving such reduction.

The existing demand-supply situation should be related to previous forecasts, including assumptions.

Demand forecasts available from a previous sector study should be reviewed for completeness and timeliness in the light of current conditions. Certain underlying economic factors may have changed since the original demand estimates were made. The analyst should check the original data sources and update or modify the estimates as necessary. For example, a recent census may show population growing at a slower rate than was previously projected, or it may be found that a planned industrial complex is materializing on a scale different from that originally anticipated. The PPA should reflect the latest developments or plans in the proposed service area.

As part of the review one should attempt to note slippages in scheduled installation of capacity and the current status of such installation, including uncertainties in the completion dates.

Demand Projection

For the purpose of a PPA, it is very important that future demand for electric power is projected as accurately as existing data permit. Demand projections should be disaggregated by class of consumer: domestic, commercial, small industrial, large industrial, institutional, and governmental. Each of these classes will usually have a different peak loading period for which electric system capacity must be provided. If the intended service area is large, estimates should be made for subregions within the overall proposed geographic service area.

Power projects that are original installations or plant additions must be reviewed for engineering and performance characteristics in the light of the demand for

power for at least the next 20 years. This time frame is required as a minimum because of the long lead time required for construction of facilities and the long economic life of the equipment. The estimates for the early years will be most critical.

In many LDC's the principal growth in demand is associated with requirements arising in the industrial sector. A project analyst, therefore, should be familiar with those aspects of the national economic plan which deal with industrial (including mining) development and with an industrial sector study (if existent). Of particular importance is the type -- and timing -- of proposed industrial schemes.

In other countries rapid urbanization makes domestic use an important part of growth of demand. In projecting demand for electricity, it is necessary to analyze trends in both the number of house connections and the usage per connection.

Demand projections for power might be developed in several ways, each with its own logic and limitations.

For additions to existing plants, a basic approach in projection of demand is the extrapolation of a historical trend. This involves fitting a curve to past data either graphically or by the method of least squares. The most common form is a semilogarithmic curve which, in effect determines an annual rate of increase over time.[1/] A trend is the result of long-term, slow-moving forces and therefore can be used where it is expected that such forces will continue into the future. Where there are categories of demand for which discontinuities in growth patterns can be anticipated, it is better to exclude such past usage from the base and extrapolated years and to project the excluded categories separately.

The so-called sector approach projects electricity demand either through the extrapolation of a trend for each sector or the calculation of demand from national or regional

1/ See Annex III, "Summary of Some Main Types of Statistical Projections Used in Energy Forecasting," in Methods and Principles for Projecting Future Energy Requirements (New York: United Nations, 1964), ST/ECE/Energy 2.

plans, using coefficients. Such coefficients preferably should be based on country experience, although they may have to be taken from the experience of similar countries.

In projecting historical trends one must be sensitive to changes in the future that will change both average and peak usage (e.g., introduction of air conditioners on a substantial scale).

It may be useful to project values based on past data and to make adjustments for expected changes based on information on plans.

Any segments of demand that are sensitive to deliberate policy should be estimated on the basis of specific assumptions about such policy so that estimates can be readily updated as changes in assumptions appear necessary.

Another approach to projecting demand is to do so using past correlation of usage with variables such as GNP; nonagricultural gross domestic product; value added by industry, mining and agriculture; national income, per capita income; population, etc. It may be useful to use one or more of these variables plus time as independent variables. The relationship of demand for electric power and specific independent variables can then be projected into the future using values for these variables given by the country's plans or based on what are considered reasonable expectations.

An important advantage of using mathematical projections is that one can also readily obtain bands of uncertainty based on the standard error of estimate of the projected demands.

Atypical industrial developments that are foreseen, e.g., an aluminum smelter, should be projected separately and then be added to the originally projected series.

Peak load requirements differ widely among the various classes of consumers, and it is necessary to analyze past records in the country to determine the magnitude and timing for the largest users in each of the classes. It is difficult to estimate possible peak demand from new industrial undertakings, but reasonably satisfactory estimates can be based on similar industries in the country or elsewhere. The project analyst should be alert to the potential for large blocks of power requirements; he should anticipate -- if possible -- the timing of these demands to assess the optimum timing of projects.

Chart 1 depicts the type of situation faced by a project planner. He has a projection based on an extrapolation from past data. If there is a large user of electricity scheduled for future operation, the projected demand might have a bulge. The step-like line is the installed capacity less allowance for repairs and maintenance, with the last step representing the scheduled installation of new capacity. The estimated upper and lower limits of the demand projection are based on a computed standard error of estimate of a mathematical projection or on informed judgments of the range of prospects.

A comprehensive review of 75 projections of the demand for electric power in various developing countries by the Sector and Project Studies Division of the IBRD[1/] indicates that one out of three forecasts of growth in demand diverge by more than one-third from the actual growth; that is, if the actual demand increase was 100, one out of three forecasts of the increase is either more than 133 or less than 67. There was no discernible tendency for the divergence to be over or under the actual increase in demand.

The study cited indicates the need to reckon with a substantial risk that demand estimates will be either too high or too low.

In the situation depicted in chart 1, additional capacity (beyond that to be provided by the expansion already scheduled) will be required by 1980 if the higher limit of the projected demand is realized, and by about 1985 if demand grows at a rate approximating the lower limit of the projection.

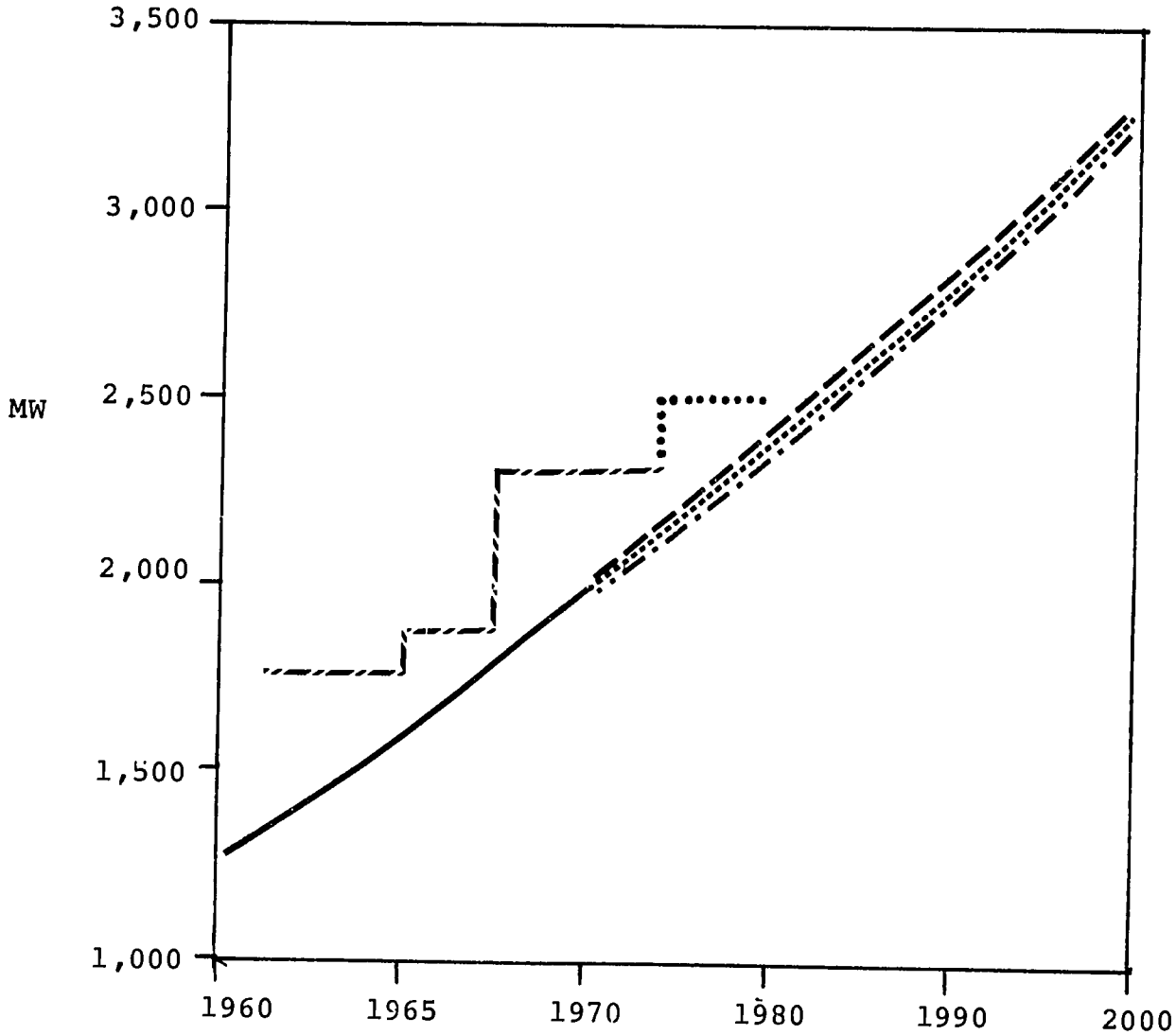
If a PPA for additional power were being undertaken in 1971, an important element of the appraisal would be the determination of the latest date at which a decision on the project must be reached if the projected requirement is to be met.

A first step is to consider (1) different ways to achieve the expansion and (2) the amount of time needed from the time that the decision to go ahead is reached until the time power is available from the planned project. It may be that certain alternatives (say hydro) would leave little time to spare in reaching a decision if 1980 requirements are to be met. Other

1/ IBRD, Ex-Post Evaluation of Electricity Demand Forecasts, No. 79, Washington, D.C., June 18, 1970.

Chart 1. Forecast of Annual Demand (MW) in Relation to Capacity

(Illustrative figures)



Key:

- Past usage
- Installed capacity
- Scheduled to be installed
- Projected demand (best estimate)
- Maximum estimated demand
- Minimum estimated demand

alternatives may permit more time for a decision to be reached and construction to begin. The preliminary appraisal can determine the most promising form of expansion and its required lead time. This provides a provisional schedule for plant expansion which is adjusted on the basis of actual growth in demand in subsequent years. For example, the preliminary appraisal may indicate that if actual demand develops as projected in the best estimate, the detailed engineering study should begin in 1974. The actual date of such a study would be adjusted at a later time depending on the growth of demand actually experienced.

Identification of Types of Projects

When best estimates -- or a range of estimates -- of existing and projected requirements have been prepared, attention should be directed to the determination of the general type of project most appropriate in the circumstances.

An established need for, say, increased suburban service does not necessarily determine the specific form of project best suited to meet this need. Projects fall into one of the following categories:

- Original installations
- Additions to and/or modernization of existing plant
- Emergency measures
- Improved operation of existing facilities, e.g., by better management, training, preparation and use of operation and maintenance manuals.

Original Installation

Proposals for original installations are commonly put forward as a part of an infrastructure program for regional development. The analyst will generally have a somewhat broader range of choice in consideration of alternatives for projects of this type than for projects involving additions to existing systems. The possibility of serving the area by the extension of transmission lines from existing (or expanded) installations should not be ignored. Moreover, the possible integration of the original installation in future system networks should be borne in mind.

Plant Additions

Because of the rapid growth of power demands in many countries, additions to existing municipal or regional systems are the most common type of project proposals. Additions impose technical interface problems for a project appraisal. Existing equipment and its configuration must be well understood. When an addition to a system requires new generating capacity, the project analyst must evaluate not only capacity requirements but also the possible kinds of generation (thermal, hydro, etc.) and alternative fuels.

Formulation of Alternative Physical Resource Flow Plans

Physical flow plans should relate physical requirements of resources to needs. Appendix B outlines some of the special technical considerations that will influence alternatives to be considered in electric supply projects. While the technical aspects impose important constraints on the selection of alternatives, the choice is for the most part economic, based on the least-cost procedures described in the General Guidelines.

Scale of Project

One of the most important tasks facing the analyst is that of subjecting the proposed scale of the project to evaluation in terms of economic and financial criteria. Although economies of scale, rapid growth in demand, and the desire to avoid short time intervals between additions have merit, the undeniable advantages of early, large-scale installations must be weighed against the cost to the national economy of committing large amounts of capital (and foreign exchange) to the creation of capacity that will not be utilized for several years.

Alternative Operational Features

In the comparison of the operational features of alternatives it is important that recognition of the potentialities and limitations of existing operations be considered. The PPA should include a discussion of how a possible alternative will affect system operation.

Peaking Versus Base Loading

If the new capacity is to be used for peaking purposes, the primary objective would be reduced unit cost of the capacity and simplified operation, even at the expense of economy of operation. On the other hand, if the added capacity is to be used as a base-load unit, then economy of operation is of paramount importance, and system operating practice would call for the new unit to be operated at full load for as long a period as possible.

Spinning Reserve, Firm Capacity

A new generating unit will have an appreciable impact on system operating practices. In general, electric power systems are operated on the basis of maintaining so-called firm capacity, whereby the system maintains sufficient spinning reserve[1/] to carry the system load in the event that the largest element of the system suffers a nonscheduled outage.

Diversity of Loads

Interconnections between separate power systems and between separate elements of the same power system will often pay a dividend by taking advantage of the diversity of peak loads of the two systems. This is especially true if the interconnected elements are located in different time zones or have complementary system load characteristics. In comparing an interconnection with additional generating capacity, the analyst should be alert to such features of load diversity and should account for the relative advantages and disadvantages.

Generator Unit Priority Scheduling

For peaking purposes, it is possible to utilize (1) older, less efficient units, (2) hydro units where there is a minimum availability of water, and (3) specially installed peaking units, such as gas-turbine-driven generators. The analyst should not develop detailed priority schedules for system operation of generator units, but an evaluation of the benefits and costs of operation and scheduling of the various alternatives in relation to existing units should be included in the appraisal.

1/ Spinning reserve is generating capacity that is kept running but is not connected, and is therefore available for the immediate supply of electricity.

Maintenance Requirements

The analyst should compare the maintenance requirements for the various alternatives under consideration to highlight their relative advantages and disadvantages.

Pricing the Project

Although it may be possible for the analyst to choose among some alternatives on physical grounds alone, there will be choice situations that will require pricing of alternatives before decisions can be made; i.e., the choice will involve economic as well as technical considerations.

Conversion to Value Flows

Use of Cost Modules

In preparing cost estimates, the project analyst should avail himself of macro-unit prices, or cost modules, to the maximum extent possible. These should be reasonably representative figures obtained within the country. Such cost modules may be based on similarly sized plants and features, with the existing plant costs extrapolated to present-day prices by the use of, for example, a construction cost index.

Typical quantities for macro-unit prices are:

- Cost per kilowatt of gross generating capacity for thermal plants
- Cost per mile of transmission line for the voltage being considered
- Cost per kilovolt-ampere of transformer capacity
- Cost per position for a switch yard
- Cost per feeder circuit in a distribution substation
- Cost per mile of primary distribution circuit
- Cost per kilovolt-ampere for secondary distribution circuits.

The estimates developed by the above unit prices will require some additions to recognize cost elements necessary to round out the order-of-magnitude capital cost estimates.

The cost of a dam will have to be approximated by estimating the unit cost of the dam volume for a gravity-type dam, or by approximating a cost based on span and height for an arch-type dam. For a hydroelectric station, the distinctive large cost item is the cost of the dam, an item that is not present in the thermal alternative.[1/] Either the unit price can be made broad enough to accommodate the cost of penstocks, gates, forebays, tailraces, and powerhouse structure, or these items can be estimated separately if so desired. Of necessity, the analyst will need to include approximate costs for compensation in removing residents and their habitations and in establishing alternate routes for railroads, power lines, communication facilities, etc.

Other Cost Elements

Other elements for which costs should be approximated include the following:

- Cost of site, including site preparation
- Cost of cooling water intake structure and intake and outfall circulating water lines for steam electric stations
- Cost of cooling towers where required
- Cost of transmission line rights-of-way
- Cost of special relay equipment, supervisory control equipment, and communications equipment.

The capital cost estimates should represent the total installed cost, that is, should include all costs associated with design, engineering, construction and startup. Additionally, for imported equipment, a separate item should be shown for import duties, taxes, and other charges applicable to such items.

All allowances for contingencies should be tailored to the local conditions. The contingency should depend on the degree of reliability of the cost estimates and should reflect the analyst's evaluation of the unknown factors. These unknowns should be identified in the analyst's report and the contingency should be identified as such. Factors which might influence the contingency include reliability of data, population growth, future market

1/ This item, peculiar to hydroelectric projects, is on the average about 59 percent of the total cost of U.S. projects. This figure varies considerably, both in the United States and in other countries, according to the location and size of the dam.

demand and others. Where the effects of these factors might be large, the recommendation should be made that they be investigated in a later and more detailed study. In hydroelectric projects, the two major uncertainties are likely to be dam construction costs and water flows.

Operating and maintenance costs which run over the life of the project can also be approximated by the project analyst on the basis of such knowledge as local labor costs, capability and availability. In developing the cost of operation the following categories may be used:

- Operating labor, skilled and unskilled
- Maintenance labor, skilled and unskilled
- General and administrative costs
- Maintenance materials and supplies
- Fuel costs.

The operating and maintenance labor should include the cost of supervision as well as payroll extras to account for vacation, sick leave, and other benefits.

General and administrative expenses can be estimated as a percentage of operating and maintenance labor; in lieu of available specific cost estimates a figure of 25 percent of the operating and maintenance labor costs may be taken.

Maintenance materials and supplies are intended to cover spare parts and other items of equipment (excluding interim replacements), as well as the lubricants, chemicals, paint, etc., necessary to keep the plant in good operating condition. In lieu of available data, an overall average figure of 0.8 percent of plant investment may be utilized. For thermal power stations, a figure of 1 percent should be used; for all other facilities, such as transmission and distribution lines, 0.5 percent of the capital cost should be used.

Fuel costs should be estimated on the basis of actual delivered costs at the site and should be calculated by estimating the heat rate for the type of unit under consideration. The source of fuel and possible alternative supplies should be identified. If all or some of the fuel must be imported, then the analyst should highlight this situation.

The following costs should be entered in operating statements but, in accordance with the procedures established in the General Guidelines, should not be treated as costs either from

the point of view of the business enterprise or the net national rate of return:

- Interest on borrowed investment capital
- Depreciation on plant and equipment.

Taxes on real property, if paid, should be treated as a cost from the point of view of the business enterprise but not the net national rate of return unless the tax is, in effect, identified with the cost of a governmentally provided service which, if not provided by government, would necessitate an expenditure by the project.

Fire and casualty insurance should be treated as a real annual fixed cost for both the business and the national points of view, even though the policy of the company is to self-insure its property. Insurance values are normally based on assessed values as determined by local and regional demands and economies. Therefore, a fixed value should be determined at the time of construction through the aid of a local economic and real property study.

Economic Lifetimes

The economic lifetimes of equipment or facilities selected for economic analysis have an impact on the rate of return. Assuming that equipment will be well maintained and repaired with proper spare parts when necessary, the following economic lifetimes are generally used:

. Thermal electric stations	35 years
. Hydroelectric stations	50 years
. Dams	50 years
. Transmission lines, wood poles	35 years
. Transmission lines, steel tower	50 years
. Substations	35 years
. Distribution lines	25 years
. Underground installations	35 years

If, because of local conditions, the experienced service life of equipment in the above categories is found to be significantly less than shown, it is recommended that the shorter lives be used, with the cost of replacement (including labor) treated as an investment in the expected year of occurrence.

Accounting or Shadow Pricing of Inputs

As has been noted, calculation of the net national rate of return will probably require shadow pricing of several inputs for a power project. The rationale for so doing is explained in chapter II and appendix B of the General Guidelines, and the methodology is illustrated in chapter VII.

In countries where the domestic currency is overvalued, shadow price adjustments should be made to the cost of imported original and replacement equipment and to those wages, fringe benefits, and travel costs of foreign technical advisers not paid for in local currency.

In the case of a high national unemployment rate, a shadow price is required for unskilled labor. Here the pricing adjustment reflects the lower (than market wage rates) real cost of such laborers. On the other hand, if administrative and technical personnel necessary to the project are in short supply and institutional or other forces impose a ceiling on the money wages of such workers, a shadow price higher than the money wage may need to be applied to obtain a better measure of the real costs of using these workers.

Valuation of Outputs of Power Projects

The outputs of a power project consist of:

- New or additional revenues from the sale of electricity
- Benefits external to the project itself.

Revenues from Sales of Electricity

Original facilities and additions to existing plant will generally produce growing revenues over time as a result of steadily increasing loads on the system. Such revenues are a measure of the value of output.

Improvement of existing service, such as raising the formerly substandard voltage levels in consumers' premises to standard levels, can increase the revenue quite directly. Revenue projections should reflect such changes.

Benefits External to Project

If the generation of distribution of electric power might result in the utilization of previously dormant national resources or make possible a higher value added by industrial consumers, such benefits or linkages are appropriate for inclusion in the value-of-output stream of the project. However, this is true only if no change would occur in the status quo in the absence of the project. One example is the utilization of an existing but untapped source of fossil fuel suitable for a thermal plant. If this fuel source is to be developed for the purposes of a steel mill or for export, a linkage effect should not accrue to the power project. (For a more detailed discussion of the treatment of linkages and multiplier effects of capital projects, see General Guidelines, chapter III.)

A hydroelectric facility may give rise to such benefits as increases in fishing or recreational opportunities or possible irrigation for improved agricultural production. The nation or region may gain more than the electric power itself. Such economic gains should not be included in the PPA unless the enhanced benefits are included as definite elements in the total scheme (and, of course, costed out on the project's input side as well). The value of economic gains that are unequivocal and do not require additional investment or expense can be added to the benefits of the project.

In connection with rural electrification programs, the question may arise as to whether or not external economic benefits might be included in a PPA. Here the answer is again a qualified no. Because of relatively inexpensive alternatives (such as battery-powered radios and kerosene lamps) to central station power that are available to the local population with a given capacity-to-pay, the likelihood of the costs of these items exceeding the cost of public power is very small.

Selection of the Most Promising Alternatives

In considering the various possible physical arrangements, the analyst will have formulated alternatives that appear promising. In this process attention is narrowed to relatively few promising projects. By applying the techniques of comparing alternatives and choosing the least-cost alternative as described in the General Guidelines (chapter IV), the analyst will select one or possibly two alternatives which are most promising. Where the margin of difference between alternatives is considered sensitive to cost estimates, it may be desirable to consider a

particular choice as open, to be resolved at a later time by means of more detailed engineering studies.

The concept of finding the least-cost alternative is a very powerful one and applicable to alternatives on equipment, technology, scale, timing, location and other variables.

The least-cost alternative concept is extremely useful even where, as a matter of national or regional policy, electric power projects are operated with price schedules that yield a preset low rate of return, say 6 percent. The decision on how the required amounts of power are to be generated and distributed must be based on the opportunity cost of capital rather than on the low rate for power projects as a whole or the rate at which capital is borrowed. For example, suppose that national policy prescribes a 6 percent return for power projects and the question arises as to whether a large generator or a smaller generator should be installed. If the opportunity cost of capital is estimated to be 12 percent in the country, then one would test the difference flow to see if it yields at least 12 percent. If the present value at 12 percent is negative, this indicates that the earlier investment required by the larger generator will not yield the opportunity cost of capital. Thus, even if a decision is made to distribute electric power on a concessionary basis, a decision on the design of the facility should be based on getting a return at least equal to the opportunity cost of capital on the investment which is optional under existing policy.

Revenues: Charges for Electric Power

Revenues should be estimated at the schedule likely to prevail and at the schedule the analyst has estimated to be appropriate for the service. The dual revenue flows are necessary in this sector because actual power rates (prices), being administratively determined, may or may not reflect the real value of output. Revenue, along with costs, can be projected in worksheets such as those shown in the General Guidelines (chapter VII). In the calculation of the net national rate of return, the problem arises of how to value the services to be provided by the project.

If rates likely to prevail yield revenues that are higher than costs, including the opportunity cost of capital, the value of services can be taken to be at least equal to the revenue because those using the service would not pay for it otherwise.

In this case, the calculation of the net national rate of return presents no problem.

A more typical and difficult situation occurs when rates are set at levels that do not yield sufficient revenues to cover all costs, including the opportunity cost of capital. In this case, we can be sure that the outputs have a value, for the marginal user, that is at least as large as the rate charged. The problem is to determine if the real value of the electric power is higher for some or all classes of users than the actual rates in effect. If there is a waiting list for connection, or if power service to connected customers is rationed by some non-price technique over long periods of time, these factors may indicate that electric power rates understate the real value of the service to users and would-be users. In these circumstances a shadow or accounting set of (higher) rates is indicated.

By estimating the costs of the alternative source of supply, upper limits on the value of electric power might be estimated for certain classes of consumers (e.g., commercial, institutional, and industrial) who are able to self-supply their requirements with their own diesel generators.

As noted above, "prices" for electric power are administratively determined, i.e., they are established by formulas reflecting one pricing theory or another that has been developed for public utilities. As an integral part of the PPA, therefore, the analyst should examine the existing rate structure in the light of the following criteria:

- Does the level of rates yield sufficient revenues to cover total costs of the services to be provided by the project, including a return to capital equal to at least the marginal opportunity cost of capital?

- If the project is to rely on private sources for (nonconcessional) capital, are rates sufficiently high to attract necessary funds?

- Does the level of rates restrict demand for the service to quantities (and service levels) that the system can supply? Does the level of rates curtail demand to the point that excess capacity exists?

- Is the structure of rates such that it reflects the government's priorities with respect to the essentiality of different categories of users (e.g., residential versus industrial consumers)?

There is a tendency in LDC's for government to establish rate levels and structures that do not meet the criteria noted above. In particular, there is a tendency to set rates below total costs (as defined above). Rates that are, in general, too low have two undesirable effects: (1) the demand for the service(s) is stimulated; and (2) the revenues generated are inadequate to permit replacement of equipment, much less expansion of capacity to meet the rapid growth in demand stimulated by the low level of rates. The results are accumulated backlogs of unfilled demands, deterioration of service, and continuous drains on the general revenues of government to supplement the revenues of the facility.

The review of rate levels and structures recommended above may indicate modifications in the valuation of outputs for power projects. If so, these should be presented as alternative formulations of the project. (Rate structures are discussed in some detail in appendix B of these guidelines.)

If the project is to be subsidized in any way (perhaps for social or political reasons), the analyst must still assure himself that operational funding requirements will be available from national or local treasuries when needed to make up for annual revenue deficits. Lack of any type of current financing can lead to an inefficient, a deteriorating, or even an abandoned project.

Sensitivity Analysis of Rates of Return

The basic technique and rationale underlying sensitivity analysis are discussed in chapter VI of the General Guidelines. In the power sector, the larger, more technically difficult, and more costly the project, the greater is the need for sensitivity analysis.

The project analyst should bear in mind, however, that the purpose of such an analysis is to isolate only those major input or output elements which can very importantly influence rate of return calculations if realized values turn out to be substantially different from the best estimates used in the computations of rates of return. The end objective of a

sensitivity analysis at the PPA level is to indicate for the feasibility study those project elements critical to design and final evaluation. It may be worthwhile to spend more time and money at a later date to try to narrow or eliminate the uncertainty concerning those critical elements if the PPA is favorable. For noncritical elements, rough estimates will suffice for the PPA, and may even suffice for a final feasibility analysis.

Examples of possible critical elements should be viewed with caution, because one cannot know a priori with certainty exactly what elements are critical to any given power project. The following examples are put forward, nevertheless, because a good deal of uncertainty is usually associated with them:

- Fuel costs, especially when imported

- Heat rate, as related to fuel costs

- Transmission losses; depending on the distance from the generator to the point of supply in the system, there could be a significant difference in the kilowatt capacity and kilowatt-hour energy losses

- Site conditions, depending on the accuracy of geological data

- For hydroelectric projects, the height, foundation, and spillway of a dam due to uncertain hydrologic records and geological and subsurface conditions

- Spinning reserve requirements

- Anticipated revenues, related to both the growth in demand and possible future rate structures.

The project analyst should recognize that there may well be uncertainties that cannot be diminished by further intensive study. In such cases, a proper sensitivity analysis in the PPA consists of the presentation of values for those elements or variables which span the likely range of uncertainty. This requires the attachment of the estimated probability values as illustrated in the General Guidelines, chapter VI.

Evaluation Summary

In accordance with the General Guidelines (chapter VII) an evaluation summary should be prepared in which the major findings are presented for consideration.

APPENDIX A. TYPICAL ELEMENTS IN ELECTRIC POWER SYSTEMS

To provide a uniform approach to the analysis of proposals for electric power system additions, this appendix includes a listing of typical electric power system elements and alternatives. The analyst may use this checklist to assure that the elements in the proposed project comprise a complete system or a relevant portion of a system.

Obviously, in a PPA, time will not permit the gathering of all of the following information. The list is included as a guideline. Those items of major importance which should be evaluated are followed by an asterisk.

I. Generating Plants

A. Steam boiler and turbine-driven generators*

1. Fuel type*
   a. Coal
   b. Oil
   c. Gas
   d. Nuclear
2. Fossil fuel storage (quantity)
3. Nuclear fuel care
4. Condenser cooling water source (and temperature)*
   a. Sea water; _____ °F to _____ °F
   b. Fresh water; _____ °F to _____ °F
   c. Cooling towers; dry bulb, _____ °F to _____ °F
      wet bulb, _____ °F to _____ °F
5. Number of generating units and size of each unit*

B. Hydroturbine-driven generator*

1. Dam type and height*
   a. Gravity; _____ feet
   b. Arch; _____ feet
2. Stream flow*
   a. Maximum _____ cfs
   b. Minimum _____ cfs
3. Impoundment _____ acre feet
4. Number of generating units and size of each unit*

C. Internal-combustion-engine-driven generator*

1. Fuel*
   a. Oil; _____ gallons storage
   b. Gasoline; _____ gallons storage
2. Engine type*
   a. Hp.
   b. R.p.m.
3. Number of generating units and size of each unit

D. Gas-turbine-driven generator*

1. Number and size of generating units*

E. Atomic energy generator*

II. Substation

A. Type of service*

1. Transmission step-up*
2. Transmission step-down*
3. Transmission switching*
4. Distribution

B. Equipment and facilities*

1. Transformer*
   a. Type*
   b. Number installed*
   c. Size
   d. Voltage rating
   e. Tap changing under load
   f. Cooling provisions
2. Switchgear*
   a. Voltage rating*
   b. Current rating*
   c. Breaker interrupting capacity
   d. Number of breakers installed
   e. Number of air break switches installed
3. Structure, protection, etc.
   a. Prefabricated
   b. Custom designed
   c. Metal-enclosed unit type

III. Transmission Lines*

A. Application data*

1. Voltage and frequency*
2. Delivered power and power factor
3. Length*
4. Conductor size and material
5. Number of conductors per phase

B. Physical data*

1. Structures*
   a. Single circuit
   b. Double circuit
   c. Metal*
   d. Wood*
   e. Concrete*
2. Overhead ground wire*
   a. None
   b. One
   c. Two
3. Right-of-way
   a. Character of terrain

IV. Distribution Lines*

A. Principal characteristics*

1. Is new substation or transformer capacity needed?*
2. Line voltage*
3. Length to most distant proposed load*
4. Total immediate load*
5. Type of area served*
   a. Residential-urban
   b. Commercial
   c. Light industrial
   d. Suburban
   e. Rural
6. Load distribution
   a. Uniform
   b. Lumpy
   c. Sparse
   d. Few large loads
   e. Large industrial load
7. Potential for load growth*

V. System Management and Operation*

A. Plant improvement

1. Generating plants
2. Transmission lines
3. Transmission substations
4. Distribution substations
5. Distribution lines

B. Protective facilities

1. Equipment
2. Coordination

C. Operation

1. Manual of procedures
2. Supervision
3. Training and classes
4. Load dispatching
5. Communications

D. Maintenance

1. Manual of procedures
2. Spare parts
3. Schedules
4. Supervision
5. Training and classes

E. Planning

1. Long-range
2. Near-term

F. Management

1. Staff
   a. Legal
   b. Planning
   c. Public relations
   d. Rates
2. Administration
   a. Accounting
   b. Finance
   c. Billing/collection

d. Customer service
e. Purchasing
f. Personnel

3. Engineering
   a. Studies and procedures
   b. Design
   c. Construction
4. Operations
   a. Generation
   b. Transmission
   c. Substations
   d. Distribution
   e. New connections
   f. Emergency service

APPENDIX B. SPECIAL TECHNICAL CONSIDERATIONS FOR POWER PROJECTS

Physical Plant and Equipment

The character of the existing system will in many instances dictate the nature and features of a proposed power system addition. The age, condition, size and efficiency of presently operating generating units on the system have an important bearing on the features of any proposed additional generating capacity. Frequently, the proposed additional generating capacity is intended to operate as a base-load unit because of its greater efficiency. This permits older, less efficient units to be operated fewer hours and as supplements to the base-load unit. Some of the older units may be operated simply as peaking units that can be operated on peak for a limited period of time and then shut down until the next peak. A thorough understanding of the efficiency and operating conditions of existing units is mandatory for the effective analysis of proposed new generating capacity. This information should be included in the supporting data for the PPA. Similarly, the existing transmission, subtransmission, and distribution voltages represent a vital constraint on the range of technically feasible alternatives in any extension of or additions to these facilities.

For the purposes of a PPA, the present system can be thought of as comprising two basic categories:

- The supply system, including generating plants, transmission and subtransmission lines, and transmission substations

- The distribution system, comprised of the distribution substations and distribution lines.

For ease in understanding proposed additions to a power system, it is recommended that a system diagram of the related category be included with the PPA for the respective electric power system addition. The supply system diagram should include sufficient information for an understanding of the technological and operating features, including estimates of normal power and reactive kilovolt-ampere flow on transmission lines which have redundant paths.

The distribution system diagram generally includes equipment information on the distribution substation and data on all outgoing distribution circuits to show circuit length, conductor size, and sectionalizing and protection facilities. Almost every project will have some impact, and the analyst should carefully analyze the entire spectrum of operations to find and bring to light such impacts. The following list shows some of the things to be looked for:

- More efficient generation resulting in rescheduling of generating units
- Fewer generating units due to an interconnection or to a new unit of larger size
- Light load problems on a large new base-load generating unit
- Greater flexibility in operation
- Reduced hazards
- Simplified operation.

The above list is far from exhaustive; it is included to indicate the types of influences on system operation that might bring forth alternatives for comparison by the discounted surplus flow technique.

It is possible that the effect of an alternative project will be a deterioration of service rather than an improvement because of the nature of the installation. For example, a new substation may be installed on a subtransmission system for supply of power to a large industrial customer. On peak demand, this load may cause an additional voltage drop on the subtransmission line, which could lower the supply voltage to the customers on this circuit. If the resulting supply voltage is still within acceptable limits, then there is no problem. However, it is possible that coincident peak loads or a demand greater than estimated may create problems of low voltage. Alternatively, if available transformer taps are changed to increase supply voltage at certain installations, a shutdown of the new load may create an unacceptable high voltage condition.

The project analyst should be certain that alternatives are sound from an engineering point of view. Such technical consideration would include a knowledge of the interrupting capacities of existing breakers on the system and the effect, if any, of the proposed project on these capacities. A quick calculation should be sufficient to determine the extent of any added interrupting duty. If existing breakers have adequate capacity for any added interrupting duty, this should be stated. On the other hand, if existing breakers will be overstressed, then measures should be taken to reduce the duty by conventional engineering techniques, or provisions should be made for modernization or replacement of the overstressed breakers, and costs included for this purpose.

Another technical factor is the effect of a new transmission line which may create a loop with other lines. A cursory calculation should be made to arrive at a rough estimate of the real and reactive power flow,[1/] and the advantages of any improved voltages should be pointed out.

There may be situations in which the supply of reactive power is a problem. In general, it is desirable that transmission lines and generators carry only a small amount of inductive reactive power. If the lines or the generators carry an excess amount, consideration should be given to the installation of capacitors or synchronous condensers to relieve this situation. If a high voltage cable is being considered for installation, it may supply too much charging reactive power. If large loads which could seriously affect the amounts of reactive power on the line are anticipated, power factor correctors should be considered when arriving at the incremental cost of kilowatt demand.

It is recommended that the analyst should include in his cost estimate provisions for tap-changing-underload on the receiving transformers on all interconnecting transmission lines with neighboring power companies and on all receiving substations from new generating plants.

It is very important that suitable consideration be given to the need for special protective equipment (such as carrier or pilot wire relaying) so that necessary cost estimates for such equipment are included. Also, if supervisory control equipment,

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1/ Reactive power is the amount (kw) by which the current and voltage are out of phase and represents a loss in the system.

load control equipment, or communications equipment is necessary or desirable in the opinion of the analyst, then the associated cost estimates should be included and the reasons for the installation explained.

Long-Range Planning

It is extremely important that the preparation of the project be based on the long-range system development plan so that the facilities that are proposed in a specific alternative for preliminary appraisal will be compatible with existing and planned future facilities. In preparing the PPA, the analyst should point out the salient features of the proposal and the way in which the proposal fits in with long-range requirements and plans.

Alternatives in Scale and Timing of Projects

Two of the more difficult factors to deal with in the analysis of power projects are determining the optimum size or scale of physical plants and the timing of their construction. Power system planners are usually faced with ever-increasing demands and the frequent need to add to installed capacity. (Capacity here refers to output of generating units and to higher voltages on transmission lines, etc.) An important feature of generation installation is that larger units usually are more efficient and can be installed on a lower unit cost per kilowatt. Similarly, higher voltage transmission lines increase capacity by the square of the voltage ratio, whereas costs are usually a more direct function of voltage.

Improved Operations

Improvements in operating techniques leading to more efficient use of facilities and personnel merit high priority because benefits can sometimes be large and immediate. The need for operational improvements can be the basis for proposals to study and make recommendations through technical assistance channels. It is not uncommon, for example, for some developing countries to have new or almost new electric power installations that are operated inefficiently or below intended capacity levels.

Consideration of Alternatives

A preliminary appraisal of a specified power project should point out alternative solutions without detailed technical investigations, but with sufficient technical rationale

to reflect the judgment of the analyst regarding the probable technical and economic feasibility of the alternatives.

Equipment

The following sections identify some of the technical features of equipment that should be considered and, when applicable, subjected to the discounting method to determine differences in surplus flows resulting from alternative equipment. The relevant techniques for computations of difference flows are discussed in chapter IV of the General Guidelines.

Alternative solutions to a power production installation will be influenced by the terrain and the type and cost of fuel that is most readily available. However, the analyst should consider the following questions:

- Can the plant operate on natural gas rather than diesel fuel?

- Is steam more cheaply obtained from gas or coal boilers?

- Is a gas turbine more practical and/or cheaper than a steam turbine?

Size, Number, and Types of Generating Units

For a proposal recommending the installation of additional generating capacity, it is most important that the analyst give consideration to various sizes and types of generating units and their location and relationship to existing units in the system. First, consideration must be given to whether the additional generating capacity is to be installed as another unit in an existing generating station site, in a new station, or at a new site. The obvious advantages of installation at an existing site include reduced labor costs, possible improved utilization of transmission line capacity by fuller transmission line loading, possible reconductoring of existing transmission circuits, and improved reliability due to diversification if an additional transmission facility is installed.

If a new location is proposed, it is important that the new site and its availability be assured; it is also important that the point of connection to the existing electric power system be identified and provisions made for the required transmission and substation installations.

On systems where there are many small generating units and where load growth is rapid, it is possible that a significantly larger sized unit may be considered as the next unit on the system, thereby requiring a large amount of spinning reserve to derive the benefits of the larger unit's presumed lower unit cost and greater economy of operation. In such an instance, it is important that alternatives include consideration of an intermediate-sized unit for the next installation. In assessing this alternative, the opportunity cost of capital and the rate of increase in demand are critical factors.

If peak capacity is a problem (i.e., the source of the need), consideration may be given to peaking-type units, such as gas-turbine-driven generators, which can start up in a short period of time, operate at full load during the peak period, and then shut down until the next peak requirement. The choice should be arrived at through a comparison of the discounted stream of surpluses from installation of peaking-type and regular-type facilities. Restructuring of rates to shift peak demands to off-peak periods may also be considered.

When existing stream flow conditions appear to warrant the installation of hydro units, the analyst should include the probable longer time of construction; the possible longer transmission distance; the reliability of stream flow data, particularly with respect to maximum and minimum flow conditions; and the economic factors from savings in fuel and operating and maintenance costs, as well as from possible additional losses in transmission lines.

Cooling Water, Location

For a steam generating plant, it is important that an adequate supply of cooling water be available. This is a prime requirement in the selection of a site. The body of cooling water should have sufficient capacity to accept the thermal discharge without impairment of the ecology. In addition, the highest temperature of the available cooling water should be determined in order to take into account the possibility of larger condenser installation. When cooling towers must be installed, the wet bulb temperature should be determined. Economic damages which may result from the plant's effect on the local ecology should be included in the cost or input projections.

Fuels

The cost of fuel is an important consideration on the input side of a project. The dependability of supply should be carefully explored, and sufficient storage capacity should be provided for these fuels to afford some protection against interruptions in delivery. If gas is available, its interruptibility should be evaluated and a suitable standby supply of oil provided as backup.

Transmission Voltages

For proposals involving transmission lines, a review should be made of the AC-DC alternative and of the existing transmission voltages on the system to determine their adequacy in relation to the proposed new facility. As the distance which power may be transmitted will vary greatly, both AC and DC current should be considered. With new development in rectification and conversion to alternating current, direct current might well prove to be the most economical method for long-distance transmissions. If a long-range plan exists, it is probable that provision already has been made for one or more higher voltages. The analyst should be cognizant of such plans and should explore the reasons in the PPA for the selection of the voltage for the proposed facility in the context of its relationship to future system growth.

Providing the existing structures have the required additional strength, it is frequently possible to increase the capacity of a transmission line by utilizing bundled conductors. The additional capacity achieved in this manner is generally lower in cost than capacity achieved from higher voltage or additional line construction, but it does not provide the reliability that a separate line would provide. These factors should be explored in establishing alternatives for transmission line construction and should be discussed in the PPA.

Transmission Line Tower: Single/
Double Circuit, Steel/Wood/Concrete

The type of transmission line towers that are selected can result in significant cost differences. When planning for load growth indicates substantially higher future needs, it is generally possible to install double circuit towers with conductors for only one circuit, thereby providing the capability for a low-cost future increase in transmission line capacity. A double circuit tower does not provide the reliability of two

single circuit towers, but the large cost savings may justify a calculated risk. However, the decision must reflect the cost of capital sunk in unutilized capacity and the length of time before the excess capacity will be absorbed by growth in demand.

Generally, wood structures are less expensive than steel or concrete structures, particularly if wood is available locally and steel or concrete must be imported. The benefits and costs of the available materials should be explored and subjected to standard discounting techniques to ascertain the most economical of the alternatives.

Plant Retirements

If there is generating capacity, a substation, or a transmission facility that indicates the need for retirement, consideration should be given to any possible salvage of suitable equipment and materials for future use. In addition, the alternative should include a discussion of the effect of such a retirement on the system and the provisions, if any, for replacement.

Rate Structure

In estimating the rate basis for the revenue of an electric power system it is important to recognize that the salable quantity is composed of two parts:

- The amount of kilowatt capacity which must be available to supply the customer's kilowatt demand

- The amount of energy which the customer's equipment consumes in terms of kilowatt-hours.

Residental rate schedules are generally structured to meter only kilowatt-hours of consumption, with the cost of a kilowatt-hour being relatively high for the first few consumed kilowatt-hours and then decreasing in subsequent blocks of kilowatt-hours. The industrial user, on the other hand, generally is required to pay, in addition to kilowatt-hours of consumption, a kilowatt demand charge that is based upon his peak demand for a 15-minute period or, alternatively, a 1-hour period; this charge is then billed to the customer for an established period, usually 6 or 12 months, regardless of lower kilowatt demands during this period, or even no demand for the rest of the period. For this reason industrial customers have an incentive to keep their maximum demand at the lowest possible value.

To arrive at the figure to be used for the kilowatt demand charge in the rate, it is necessary for the system to have established accounting procedures to provide the basis for the kilowatt demand charge. For purposes of a PPA, the fixed investment portions of the proposed facility should be evaluated on an annual cost basis, and this figure should then be divided by the kilowatt capacity of the facility to arrive at a figure for the incremental cost of kilowatt demand.

The incremental figure obtained in this manner should be compared with the established kilowatt demand basis; if the incremental figure is lower, this should be used as an indication that the new facilities will have a tendency toward lower rates or increased profit margins or will provide a cushion for escalating costs. If the incremental cost per kilowatt demand is higher, this should be a danger signal that profit margins may be lowered and rates may have to be increased, depending upon the magnitude of the investment in relation to total system investment. In instances where a facility may be subjected to significantly varying loads over its lifetime, it is desirable to utilize present-worth discounting for annual kilowatt demand costs.

The variable charges generally include a portion of the annual operating and maintenance costs, exclusive of fuel costs. In the United States it has been determined that the variable portion of operating and maintenance costs exclusive of fuel for thermal power plants amounts to approximately 35 percent of the total. Local conditions can make a substantial difference in this percent. In the absence of definitive data on the power system being considered for expansion, this figure may be applied. For hydroelectric plants the variable costs are usually neglected.

The sum of the variable portion of the annual operating and maintenance costs exclusive of fuel (35 percent or the locally determined figure) plus the annual fuel cost represents the total annual variable costs. In determining the incremental cost per kilowatt-hour for the proposal being considered, the total annual variable costs are divided by the annual kilowatt-hours to be produced. These calculations preferably should be made on a present-worth basis because generating facilities are loaded quite heavily during the early portion of their lifetimes, and are then loaded to a lesser extent (possibly only for spinning reserve) during the latter portion of their lifetimes; other system facilities may be loaded in the reverse manner.

The kilowatt-hour incremental energy cost determined on the above basis should be compared with the basis for the energy charge per kilowatt-hour in existing industrial rates to establish whether the incremental cost is higher or lower than the existing cost basis.