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FRAMEWORK FOR THE ANALYSIS OF RURAL ELECTRIFICATION PROJECTS

A REPORT TO THE AGENCY FOR INTERNATIONAL DEVELOPMENT

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EXECUTIVE SUMMARY

The purpose of this monograph was the systematization of a framework for the analysis of rural electrification projects, which was capable of overcoming the apparently contradictory approaches currently in use. A framework has been suggested based on the general UNIDO methodology for project appraisal. This has the advantage of approaching the projects by stages that can provide an economic analysis from the country's perspective, and inter- and intra-temporal analysis based upon the social and political interests of the decision makers. The approach suggested permits the government clearly to assess the cost to the economy of any decision based on non-efficiency considerations. It is also fairly easy to alter the appraisal to take into account changing priorities and the concerns of the decisionmakers. In this respect the apparent contradiction between social benefit analysis and economic benefit analysis can be elucidated by increasing levels of social adjustments to the pure economic approach.

Costa Rica was chosen as a case study because it is a country which has recently vigorously pursued the implementation of rural electrification. With over 70% of the rural population now covered by electricity the Costa Rican government is still promoting rural electrification.

Applying the methodology to two Costa Rican case studies we found that in both cases, the financial returns could not justify the projects. Using economic prices, and willingness to pay measures of benefits, we found that one of the projects was a very attractive investment, the other project was still not an attractive choice. Applying the social adjustments to the costs and benefits make both of the projects highly desirable choices. These results contradict the usual gloomy predictions about the economic advisability of investments in rural electrification.

We carried out some surveys in three rural towns on the west coast of Costa Rica and found that one of the basic assumptions made in the literature on rural electrification -- namely that the benefits are much higher for commerce and industry than for households -- does not hold. This is a surprise and may have something to do with the relatively middle-income status of Costa Rica.

Finally, our studies contradict some of the standard views on the level of reliability of rural electrification systems. Generally it is assumed that there is an overinvestment in system reliability in rural areas of developing countries. Our studies on the optimum level of reliability indicate that the currently provided level of reliability (which is high) is close to the optimum. The implication

of this is that there are no easy ways of reducing the cost of transmission and distribution of electricity in rural areas.

Chapter I

CENTRAL ISSUES IN RURAL ELECTRIFICATION

1. Introduction

With the introduction of central station electricity generating plants at the end of last century a movement was set in motion that will probably see its culmination at the end of this century: universal electricity grid connection. The advantages of electricity over other fuels for lighting and for stationary shaft power are so compelling that there is little prospect for any major technological change of the order of the shift to grid electricity of the last century. This does not mean, however, that there will not be cases, or circumstances, where local generation or substitution of electricity by other fuels will not be the best solution. But, by and large, we will see that either for economic reasons or for political and social reasons the bulk of the world's population--i.e. those who live in rural areas will be served by central station electricity by the end of this century or early next century.

The trend in the developing world follows that of what happened in the developed world. First, urban areas were electrified followed by the rural areas; beginning with the city peripheries. Given this trend, and the history of investment in rural electrification on a worldwide basis, and given the current financial constraints faced by the developing countries of the world, we believe that this is an opportune moment to devise a methodology that would put some rationality into the choice of rural electrification projects. In an era when resources were more readily available there was less pressure to be able to justify investments in programs such as rural

electrification which always had large amounts of political support. This is no longer true under the resource picture of the late 1980's.

The objective of this book is to provide a coherent methodology for analyzing investment possibilities in rural electrification. The methodology is meant to be of general application for use in different countries under different economic circumstances. We have attempted to be as objective as possible in our analysis of Costa Rica as a case study. No researcher is unbiased, however, and we wish to warn the reader that we were from the outset believers in the proposition that rural electrification is a good investment in Costa Rica, and that the dismal evaluations of it were a fault of the methodology of assessment rather than anything inherent in rural electrification itself. One other bias--and one that is widely held by others in the literature on rural electrification--was that the bulk of the benefits accruing to rural electrification are production benefits stemming from the industrial and commercial sectors. As an example of our objectivity we can report at this time that only one of the biases was borne out by the detailed study we carried out in Costa Rica.

This book is not meant to be a text on the economics of project evaluation. As we will see that literature is well served by many excellent texts. This book is aimed at planners who are faced with recommending investment options to planning commissions, or ministries, in developing countries. The planner has to be able to integrate both the technical and economic aspects of developments into a political decision making arena. In the book we make use of some economic concepts and explain them when they are first introduced. In a similar manner this is not a book on the technology of electric systems. There are excellent references already

available in that area. This is a book about planning aimed at planners.

For the planner it is important to be able to distinguish between those parameters of the system over which little choice exists outside of the narrow engineering definitions and those parameters over which there is a lot of discretion and which, at the same time, may make large differences in the social or economic ranking of a project. In other words, the planner needs to parameterize a project in terms of those parameters that will make the largest difference to the outcome.

Figure 1 sketches an electricity supply system from the generator to the final user giving typical equipment and voltages used. In Figure 2 we show some important components of the economics of electric supply at different levels of voltage. From this sketch we see one of the most important "facts of life" of rural electrification--the high level of cost per kwh delivered. Another related fact is that, almost universally, the tariff charge is only a fraction of the actual marginal cost.

Figure 3 shows a schematic of an electric system and indicates where the key technical, economic and planning assumptions lie. Our case study of Costa Rica concentrates on the distribution end of the system. What becomes readily apparent from this figure is that the key planning assumptions are issues of the reliability of the system, the coverage of the supply (demand), the materials used (again referring to reliability), the choice of type of generation (relating to energy self sufficiency) and the tariff structure.

The body of literature on Rural Electrification (RE) covers a wide range of substantive issues (Rogers, et al, 1984). The various approaches

taken toward the basic RE issues can be classified under the headings of the global perspectives and the methodological approaches taken.

2. Global Setting

There appears to be two major dichotomies involved in the global setting for Rural Electrification.

i) Rural Electrification vs. Rural Development.

Should Rural Electrification and Rural Development be treated as competing or as complementary investments? If the former is true, then RE can be considered through a "commodity view" of development which stresses that RE can generate income in the same way as any other development program can. If the latter holds, then RE can be taken as a complementary investment, and it will be approached through an "infrastructure view", i.e., that complementary inputs are needed and that higher income is a precondition for, or concomitant event with, the full materialization of load demand.

ii) Rural Electrification vs. Decentralized Energy Options.

This addresses the question of the policy's aim. Is it RE per se, or is it the provision of electricity at a village or regional level, taking into account other options aside from central grid electricity? Or, going one step further, is it the use of other local energy resources not necessarily electricity (Smith, 1980)?

3) Methodological Setting

From a methodological perspective there are also generally two dicho-

tomous approaches to studying Rural Electrification.

i) Ex-ante vs. Ex-post Approach.

An electricity utility normally uses the ex-ante approach for its feasibility studies. It usually stresses the engineering and commercial appraisal of regional or village level projects and sometimes includes an economic appraisal (ICE, 1979; NCRER, 1977). The ex-post approach covers a wide range of studies: 1) Impact Studies targeted to measure the impact of RE on growth and equity (Saunders, 1978; Cecelski, 1979; Strout, 1978). 2) Assessment of benefits obtaining a certain number of years after electrification has occurred. This type of study will usually include direct and indirect economic and social benefits (Broadman, 1982; USAID-CR, 1981; USAID-Philippines, 1980).

ii) Social Benefit Analysis vs. Economic Benefits Analysis.

Social benefits analysis stresses the social realm of RE and views RE as an infrastructure investment similar to those of schools, health facilities, etc. Therefore such analysis places more weight on social issues and needs. The need for and role of subsidies will, indeed, be a likely component of the analysis. The Economic Benefit analysis, on the other hand, assumes that the productive uses are the central factor RE projects. Therefore, the analysis will stress the economic benefits especially increased productivity and expansion of new production.

4. Contradictions or complements?

The different pairs of apparently conflicting views and methodological

approaches presented above need not necessarily be contradictory and exclusive elements. Rural Electrification still lacks an integrated framework in which each of the issues can be set in the correct perspective. This confusion about Rural Electrification stems from the following:

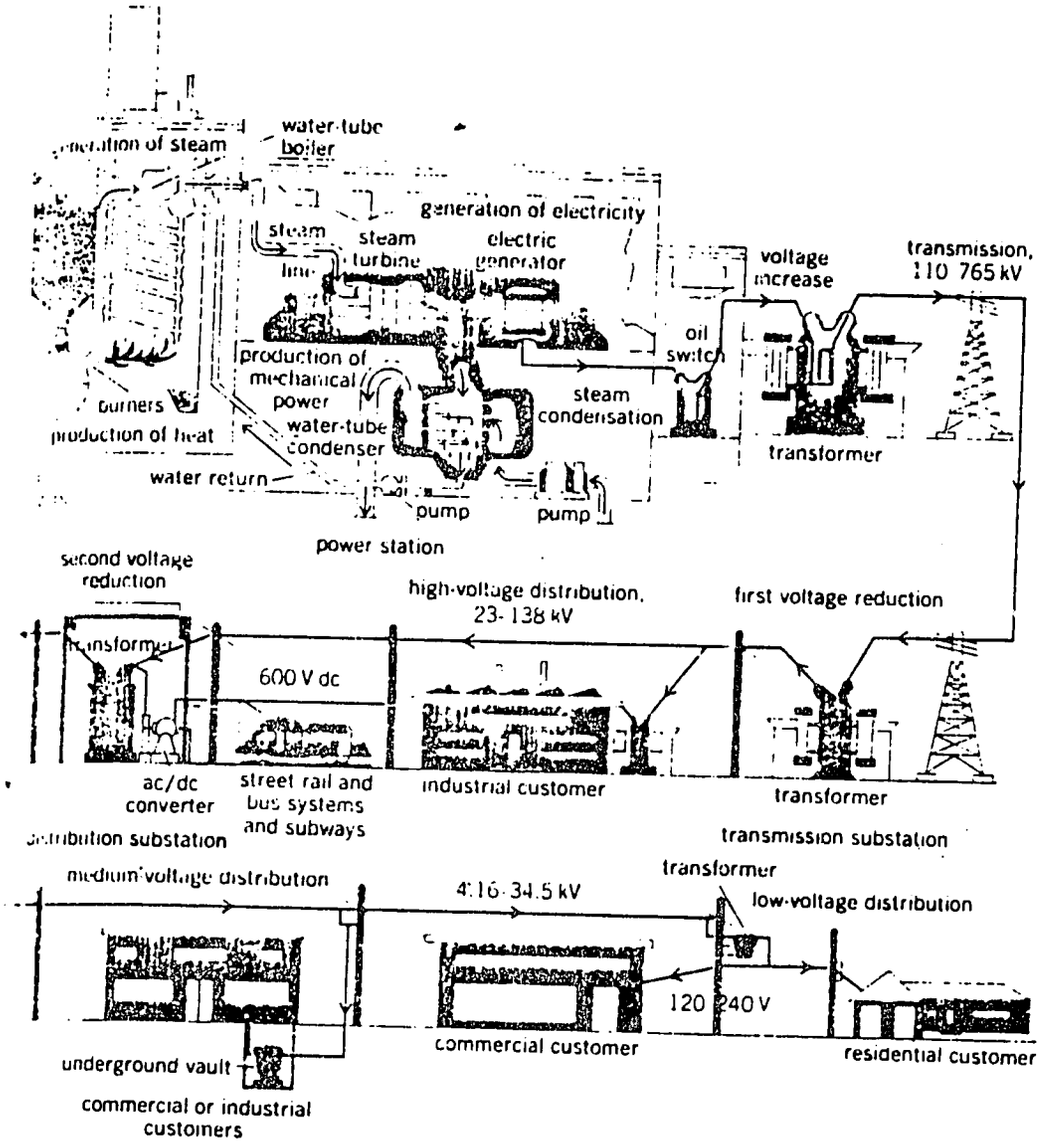
i. There cannot be a general recipe applicable to every country and to every region of each country. The income of the rural population, energy uses, the level of infrastructure, the degree of governmental support, etc., have an overwhelming influence on any conclusion about the convenience of RE. This also implies that there are particular characteristics of every country which should be incorporated into a general framework that serves as a reference for RE. These characteristics include financial constraints, political priorities and equity considerations. A major aim of this monograph is to understand this feature and to incorporate its implications in a framework for RE studies.

ii) RE studies reflect the gap between the "two cultures" - ex-ante analyses have normally been the responsibility of engineers, utility related economists or international funding agencies' technical personnel, ex-post analysis, including impact studies and economic and social benefits, has been the usual area of concern for social scientists - particularly sociologists, social workers and economists who are unrelated to the utilities. Typically there is not an extensive feedback between these types of studies. There is the need to bridge this gap and to develop a methodology where ex-post studies serve as the primary input for the design of new projects.

This monograph begins with an assessment of RE in Costa Rica. The Costa Rican case study illustrates some of the limitations of the

approaches used. Based on this review, a general framework for RE studies which starts from a Cost/Benefit Analysis approach is suggested. This points out the feedback necessary from previous RE projects. Thus a framework for a RE ex-post assessment which includes a description of the necessary information is suggested.

FIGURE 1

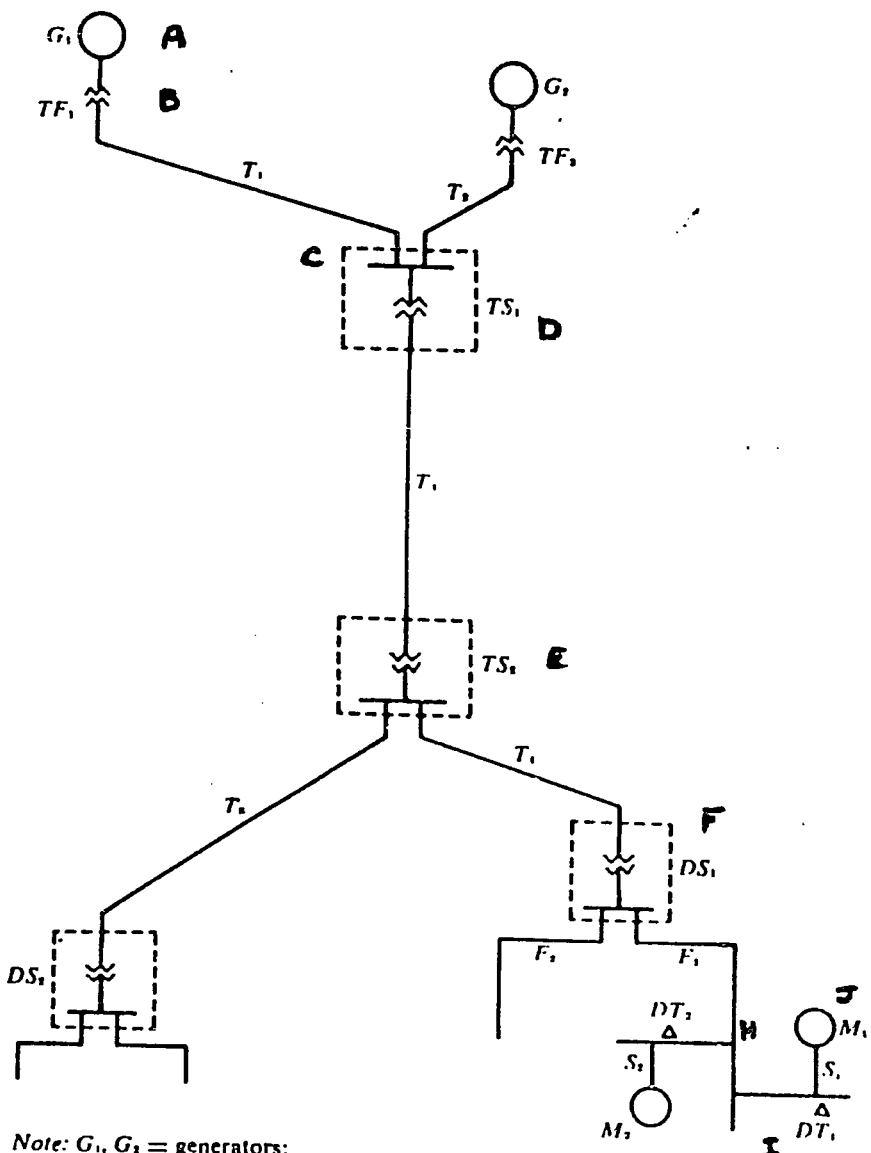


Major steps in the generation, transmission, and distribution of electricity.

FIGURE 2
TYPICAL COSTS AND TARIFFS IN AN ELECTRICAL SYSTEM

	GENERATION	TRANSMISSION 110-765KV	TRANSMISSION 23-138KV	DISTRIBUTION 4.1-34.5KV URBAN	DISTRIBUTION 120-240V RURAL
ENERGY LOSSES		1.52%	1.52%	4.93%	10.2%
POWER LOSSES			2.29%	7.15%	15.0%
ANNUAL POWER COSTS $/KW	5567.0		1380.0	508.0	4513.0
ENERGY COSTS $/KWH	1.483		3.313	3.65	6.18
TARIFF $/KWH			3.63	1.55	1.61

Schematic of a Simple Electric Power System



Note: G_1, G_2 = generators;
TF_1, TF_2 = voltage transformers;
T_1, T_2, T_3, T_4 = HV transmission lines;
TS_1, TS_2 = transmission substations;
T_5 = EHV transmission;
DS_1, DS_2 = distribution substations;
F_1, F_2 = primary feeders (or circuits);
DT_1, DT_2 = distribution transformers;
S_1, S_2 = secondary lines;
M_1, M_2 = customer service inlets and meters;

FIGURE 3
KEY TECHNICAL, ECONOMIC, AND POLICY ASSUMPTIONS FOR ELECTRICAL SYSTEM PLANNING

LOCATION ON SKETCH	TECHNICAL ASSUMPTIONS	ECONOMIC ASSUMPTIONS	POLICY ASSUMPTIONS
A	types of boilers gensets, turbines, etc	system capacity, fuel cycle	energy self sufficiency. manufacturing capability
B	types of transformers	capacity	reliability
B - C	voltage, size of line and supports	capacity, voltage. materials	material suppliers, reliability
D	technology of substations	capacity, materials	source of supply, reliability
D - E	voltage, technology of transmission	capacity	materials suppliers
E - F	switchgear, voltage breakers or fuses, types of busbars	capacity	reliability, materials
F - H	wire gauge, poles, phase of supply, transformers	capacity	reliability, materials
H - I - J	secondary lines, house wiring, meters	type of prices	tariff setting

Chapter II

RURAL ELECTRIFICATION IN COSTA RICA

1. Costa Rica: Background

As is the case with many other Latin American countries, Costa Rica has been recently faced with severe economic problems: external debt, devaluation and underemployment, for example. And while the country adheres to a democratic political system and is very stable internally, it has encountered increasing problems with neighboring Nicaragua. This brief sketch of Costa Rica is based upon Nelson (1983).

Social Characteristics

The population of Costa Rica is approximately 2.4 million, with an annual growth rate of 2.5% (1983 estimate). This population growth rate is lower than most other Latin American countries. In general, the levels of health and education indicators are significantly higher than in most developing nations. Indeed, many of these rates are comparable to industrialized nations. This is due to the availability of uncontaminated water and the high degree of investment put into preventive medicine and health care in general. School attendance is compulsory up to the ninth grade. The literacy rate is estimated at 90%. The population is very homogenous, both ethnically (mainly of Spanish and European descent) and linguistically.

Economic Characteristics

The Costa Rican economy is an agricultural one; the chief exports are bananas and coffee. Costa Rica's economy is very dependent upon agricul-

tural goods; price decreases have severe impacts. It was the combination of this factor (low international prices for the country's main commodity exports), the high external debt, and domestic structural problems which brought about the economic crisis in the early 1980s.

The agricultural sector is the largest employer (about 30% of the total in 1982). The main export crops of 1983 were coffee, bananas, sugarcane, and cacao. Manufacturing employs just 15% of the labor force. However, much of the production is dependent upon imported goods; there is not a great degree of production using domestic raw materials.

Due to the economic problems mentioned earlier, the IMF granted the country emergency aid in 1980. In conjunction to this, the Costa Rican government agreed to an austerity program which sought to reduce the public sector deficit and to limit the growth of domestic credit. These were not achieved by 1981, and a new package was approved. Still, the government had to suspend all interest and principal loan payments to commercial banks in late 1981. 1982 saw a new government and IMF negotiations: these resulted in new aid, the resumption of token interest payments. In 1983, the rescheduling of the commercial bank loans was accomplished.

Energy

The chief domestic energy sources are wood, hydroelectric power, and vegetable waste. In 1981, wood and vegetable waste comprised 39% of total energy use, while hydroelectric accounted for 13%. Petroleum (imported) accounts for 47% of energy consumption. There is still a greater potential for hydroelectric power.

Transportation

Roads are the key element in the system, some 30,000 km of roads exist, including the Inter-American Highway which extends from Nicaragua, through the capital of San Jose, to Panama. Forty percent of the road network is "all-weather," the rest dirt and gravel, making them relatively useless for major transportation uses during the rainy season.

The government owns two major rail lines connecting the Central Valley of the eastern port of Limon and western port of Puntarenas. Costa Rica has an international airport, and 33 airports with paved runways. There are a total of 175 airfields.

Political Characteristics

Costa Rica operates under a democratic form of government, power is shared by the executive, legislative and judicial branches. At present, there are two major political parties, the National Liberation Party and the Social Christian Unity Party. Costa Rica has no army as such since 1949; there is a Civil Guard and a Rural Guard; these are public security forces (they perform primarily as police). In 1980, spending on security forces was less than 3% of the total government budget. This amount is about 10% of the expenditure for education.

With a heavy political emphasis on social welfare programs Costa Rica is among the most electrified of the developing countries. Currently 85% of the total households in Costa Rica have access to electricity and use it at least for lighting. There is also a political committment to expand the grid system to the entire population. This makes Costa Rica a particularly interesting country to study from the point of view of rural electrification.

2. The RE Program in Costa Rica.

The fifteen years period starting with 1948 saw a sustained effort by the Costa Rican Institute of Electricity (ICE) to expand the supply of electricity; it succeeded in constructing two major hydroelectric plants (La Garita and Cachi) and extending service to the increasingly urbanized population and to some rural communities. In the 1950s and early 1960s, rural electrification was left to regional public utilities. By the mid 1960s, a healthy cooperative movement widened its affiliation by promoting the strengthening of Rural Electrification Cooperatives. This opened the possibility of a more systematic RE program.

Initial Stages of RE in Costa Rica.

In 1963, ICE in a Joint Program with the National Bank (a state owned commercial bank) and USAID began the development of a RE project consisting of 836 kilometers of distribution lines, 11,000 KVA of voltage reducing substations and 17,460 KVA of distribution transformers, all serving a total of 9,896 consumers. This program was implemented in 1965. The first and early stage of RE consisted of a USAID project backed by a $3.3 million loan to the Banco Nacional de Costa Rica for the purpose of electrifying three regions of the country through member-owned cooperatives. This loan was executed between 1965 and 1969 and included the regions of San Carlos, Guanacaste and San Marcos. USAID performed a general ex-ante justification of the loan (USAID, 1965) and several ex-post evaluations of its outcome (USAID, 1969; USAID, 1971; and finally USAID, 1981). As another source of RE evaluation, the National Rural Electric Cooperative Association of the U.S. (NRECA) performed two studies in the late 1970s, which dealt mainly with the performance of three cooperatives (NRECA, 1978a and b, and a

recent one of 1984). Parallel with this institutional effort three other studies were conducted which assessed the results of Rural Electrification in Costa Rica. They correspond to the work of a group of researchers linked with the University of Florida and deal mainly with the impact of RE on the standard of living for the rural population and with the perceived benefits of RE as expressed by the users (Moses, 1969; Ross, 1972; Saunders, 1978).

Following this project, the Inter American Development Bank (IDB) provided ICE with $3.8 million in funding for RE, mainly to strengthen the Rural Electrification Cooperative of Guanacaste in the Northwestern region of the country. This project, which started in 1970, permitted the incorporation of this province into the national electric grid. The program was also extended to the Province of Limon in the Caribbean, and the overall package consisted of 128 kilometers of transmission lines, 275 kilometers of distribution lines and 1,5 MW of thermal generation; all serving 6,500 new customers.

The First Stage of Rural Electrification.

In 1975, ICE undertook a comprehensive RE program called Stage I RE. The purpose of this national RE program was to cover 18,658 new customers, construct 1,662 kilometers of distribution lines in a large number of areas of the country within five years. The total cost was around $20 million. The target of this stage was to reach all central towns which were county seats, as well as to build along all national roads, thus bringing electricity to a large area of the country.

The Second Stage of Rural Electrification.

The Second Stage plans to bring electricity to all central towns at the district level. This implies an in-depth penetration dispersed over an extensive geographic area. The purpose is to cover 20,066 new customers, corresponding to a population of 100,000 (7% of the rural population of the country). With this program now in its final stages, the percentage of electrification in the rural areas is 71% and 85% nationally (homes using electricity for lighting). The second stage consisted of the construction of 2,669 kilometers of primary and secondary lines and 30Km of transmission lines. Nine distribution companies participated, including Rural Electrification Cooperatives.

The Second Stage was backed by an extensive feasibility study which mainly dealt with traditional engineering and accounting criteria for ex-ante appraisal of projects, and a concise economic appraisal using shadow prices (ICE, 1979). Nonetheless, an ex-post appraisal of either of the two stages of RE has not been done. Therefore, the present review of the literature dealing with RE in Costa Rica will further concentrate on two different types of studies. The first one was a benefit evaluation of RE after a short period following electrification. The second one, carried out eleven years after the project's completion, addressed the project impact evaluation and followed the guidelines of USAID evaluation reports.

3. <u>The University of Florida Study (UFS)</u>.

A preview of our work was the study performed by one of the researchers of the UFS (Moses, 1969); however, his treatment did not sufficiently account for the benefits of centrally distributed RE. Trying to overcome some of the limitations of that work, the University of Florida Study (U. of Florida, 1973; Saunders, et al, 1978) was viewed by its authors as "...

the only one known to the authors which attempts systematically to assess the social and economic consequences of rural electrification projects after energization." (Saunders, 1978; pp.4).

This later study (UFS 1973) consisted of 500 interviews with domestic (household) users and non-users of electricity in a district of the San Carlos Region served by a rural electrification cooperative. The field work was complemented by case studies based on interviews of about a dozen productive businesses. The field work was carried out in mid-1972.

The main focus of the study was to assess the benefits perceived by the household at least a year and a half after energization. The core of their methodology is based on the development of a "level of living scale" which is linked to the performance of household functions rather than to the possession of material goods. This scheme was used to measure satisfaction-with-life-situation; this measurement was then correlated with perceived benefits from RE. A rather extensive compilation of information on the consumer included demographic characteristics (age, sex, education, occupation, migration, etc.), social and economic factors (level of living, satisfaction with life situation, exposure to mass media, social participation, size and type of land holding owned, etc.), power consumption and alternative energy sources. Through the household interviews and the case studies, the employment and income effects of RE were analyzed.

The interpretation of their findings can be summarized at the <u>household level</u> as follows:

1. The level of living is the variable most consistently positively associated with electricity use. Those persons who enjoy the higher lev-

els of living in an area are the most likely to adopt electricity.

2. Mass media exposure is also positively associated with both the level of living and electricity use. The explanation given is that mass media exposure may raise aspirations which lead to improvements of the sort that increase the respondent's score on the level of living scale. The use of electricity in turn facilitates the achievement of high scores for those items on the level of living scale that require electricity (such as radio and TV) which then raise mass media exposure.

3. Once the decision to connect with a central station distributor has been made, the level of average monthly electricity consumption is closely related to the economic means for purchasing electrical appliances. In other words, those using more than 48 KwH per month were younger, better educated, and in higher occupational categories.

4. The issue of who benefits from the availability of electricity and how they benefit naturally follows from the use of electricity which is demonstrated by consumption levels. The conclusion that the study reached was that the household benefits of electricity, for the majority of respondents, stem from its use for lighting and ironing. The ownership of stoves, refrigerators, and television sets is concentrated among those in the higher socio-economic occupations; the potential benefits here are not even perceived by most consumers, despite the fact that electricity has been available for some time.

5. The rate charged for electricity service also determined the direction and the amount of benefits. It was found that relatively high rates

resulted in low-consuming electricity users paying more (on a direct cost basis) for electric lighting than for candles. However, as demonstrated by the willingness to continue service, any additional expenditures are apparently offset by the convenience and dependability of electricity especially for lighting and ironing purposes. Nonetheless, as the ownership of major appliances increases, central station electricity becomes a cheaper energy source in relation to such alternatives as kerosene and gas.

Although they do not possess the reliability of more comprehensive surveys, the case studies of businesses pointed out the following results:

1. The primary advantages of electricity for productive uses in Costa Rica, from a technical standpoint, derives from its use as a stationary source of energy for permanent equipment installation. The major economic benefit of RE was its lower cost compared to that of obtaining energy from private diesel or hydro plants. In addition, economic benefits resulted from the provision of central station electricity for productive functions that cannot be served by any alternative energy.

2. The primary benefits for other commercial and dairy farm enterprises also lies in the cost of electricity. Still, secondary benefits resulted from greater efficiency, increased productivity, and enterprise expansion potential.

Finally, the study points out some important relations between electricity use and infrastructure developments:

1. The question of infrastructure and RE is project specific. The construction of a RE project is affected by, and has an impact upon, other infrastructure development. The study suggests that the problem is to initiate RE projects when other infrastructure projects can most contribute to electricity utilization; infrastructure in turn then receives the maximum development boost from the availability of electric energy.

2. The study recommends that at least minimal levels of infrastructure development are in place prior to RE.

3. The study concludes while RE has suggested spinoff effects, such as that of prompting communities to undertake other self-help projects to develop infrastructure (based on the cooperative experience) this has not been demonstrated in the area surveyed within Costa Rica.

One of the UFS study's strengths is the careful analysis of how the consumers perceive their present levels of living, and the clear relation they make of RE as one important element which contributes to an elevation of the standard of living. The study was carried out in the 1970s, prior to the oil shock and of particular importance, prior to the pressures the economic recession and severe increases in RE rates. What must be stressed is that most RE studies are "clinically clean" from the real macroeconomic context of the country. A necessary question is in what ways the benefits from electricity are perceived differently when other indicators of the standard of living show decreasing trends, and when the rates for RE are sharply increasing.

The UFS study has a bias toward stressing the benefits for household consumers, particularly due to electricity use for lighting and ironing. The productive uses from RE are less studied, and the dynamics of productive uses are not fully developed. Are RE projects a source of investment from which economic benefits can accrue, and thus be conceived of mainly as a productive investment? Or, on the contrary, is the purpose to provide a service which rural inhabitants are entitled to, hence making RE a social good?

Although this question is posed in most RE studies, it is usually a final comment after the study has been designed and carried out (as is the case with UFS). On the contrary, this should be the initial question; i.e., whether RE is considered under a social benefits approach or under an economic benefits approach, or serving both purposes if this is in any way viable.

Finally, in the UFS study, as in most RE studies, it is difficult to reach a final conclusion. There is a need for a summary table that can, as clearly as possible, assess cost and benefits, compare stated initial objectives of the project with real outcomes, and provide useful patterns to be considered in other forthcoming RE projects.

4. The USAID Project Impact Evaluation (AIDPIE).

The project feasibility studies of the early 1960s were based primarily on the potential of the three regions studied for food production both for export and for domestic use. It was predicted that RE would stimulate this primary goal and, additionally, the project planners predicted the following would result (USAID, 1981): 1) Diversification of

agriculture; 2) Expansion of the existing food processing and other agro-industries; 3)Introduction of new agro-industrial and commercial enterprises; 4) Higher incomes for the area's inhabitants; 5) A deterrent to out-migration from these areas and a magnet for immigration; and 6) Development of successful cooperative models to be replicated by other communities.

It is obvious that the stated goals overestimate the strength of RE to be a catalyst for a whole range of development processes in rural areas. More difficult to understand, therefore, is the methodology employed by the AIDPIE study in assessing the impact of the area's electrification through Rural Electrification Cooperatives. The survey had a universe of 17 different communities, within eight cantons (counties), in four provinces, but with a total sample of 96 households. The survey instrument contained 61 questions, all closed-ended except for the last one, which addressed the perceived values and the utility of electrification. Moreover, commercial and industrial activities were surveyed as part of the household interview, and considered only those which were part of, or attached to, the respondents' dwellings. Apart from the sample, a few interviews were conducted with the Cooperatives' leaders and with different types and sizes of commercial and industrial users of rural electrification.

The problem of this type of methodology is that only a few (from five to ten) interviews were done in each region of the country. The results portray some common general impacts, but lack a more in-depth analysis of the dynamics of RE in a community. It also lacks a very important element; that is, the comprehensive survey of the impact of RE's on productive uses. This is even more relevant for the project because a great deal of emphasis

is given to the expected increase in productivity, and expanded production. However, although based on limited information, the study reaches interesting and useful conclusions.

In regard to use at the household level, the following are the relevant conclusions:

1. The cooperative siting and rate policies which were designed to show sensitivity to local needs were slightly directing the benefits of electricity service to the poor. Based on the accepted categories used in the country to measure "Poverty" and "Extreme Poverty", the study found that 54% of the households in the sample with electricity and 50% of the households without it are below the Poverty Line, and that 39% of the households with electricity and 36% of the households without electricity are below the Extreme Poverty Line. The AIDPIE concludes that in Costa Rica electrification is reaching the poor. This is indeed an interesting finding compared to other studies which usually assert the contrary (Smith, 1980).

2. The households surveyed seemed to value electricity very highly. The study points out how clearly, for example, the male respondents seemed to understand the relationship between electrification and the advantages for women.

3. Households from a region considered a "growth zone" were those which most often cited the direct economic benefits from electrification; those with a less promising economic situation in another region were more likely to cite the advantages of electric lighting for studying, a more indirect economic motivation.

In regard to the impact of RE on the economic growth of the regions studied, AIDPIE concluded that:

1. The best determinants of successful utilization of electricity were the type of agricultural activity engaged in (whether growing sugar, rice, coffee, etc.) and the point along the production/processing continuum where electricity was applied.

2. For most agricultural activities, the availability of a cheap and reliable source of electricity had a greater impact during the processing stages and less on production at the farm. The exceptions were dairy, pig and poultry farming where it was used in the production stages. On-farm use of electricity in coffee, rice and sugar production was minimal.

3. However, RE was beneficial to the rice, coffee and sugar farmers in the proliferation of machinery and equipment repair shops.

In regard to the general findings of the study, the following are the most relevant:

1. The probability of electricity having a significant impact on economic growth depends considerably on the setting of the project area, the production potential, and the coordination and timing of other interventions, especially roads. The impact is maximized in settings where expansion and improvements of infrastructure and social services are planned or underway, and where agricultural potential is greatest.

2. As income goes up, the ability to utilize RE productively goes up. This in turn further raises income.

3. The impact of electrification on agriculture and agro-industry can be partially predicted according to the types of production activities taking place in the area. The three general findings are important recommendations that can make valuable contributions for future RE projects. This is precisely one of the merits of the study.

Nonetheless, this study is also "macroeconomically sterilized", advancing conclusions and casual relations that do not help to strictly assess RE projects. The study points out as major RE impacts those found in the processing stages, such as "... In San Marcos (one of the regions studied), electrification contributed to the quadrupling of coffee production." (USAID, 1981, p. ii). The problem with this type of conclusion is that it does not take into account major national events such as: strong governmental support to coffee production in various parts of the country, including San Marcos; the coffee price boom of 1976 and 1977 which was a major incentive to coffee production, etc.

5. The Context of Rural Electrification in Costa Rica.

With financial assistance from the United Nations and USAID, and with the technical support of the leading Costa Rican agencies in the energy sector, a national study was carried out regarding residential energy consumption. This study, done in 1983-84 (DSE, 1985) provides excellent background information on the use of energy in urban and rural households. For the purpose of the present study on rural electrification, the most relevant information will be summarized.

A major finding is the widespread use of electricity for lighting:

85.6% of the households are electricity users. Even in the rural areas this level is very high: 71.7%. 47.5% of the households use electricity for the purpose of cooking in comparison to 34% who use firewood stoves. However, most people considered electricity as the most convenient method for cooking, as shown in Figure 1. The modernization appeal that electricity has is more clearly stated once a detailed analysis of appliance use by the households is made.

For 1983, electrical appliances and equipment most frequently used in the households are shown in Figure 2. However, there are differences between urban and rural dwellers. Table 1 summarizes the differences and also gives an indication of the percentage of those appliances that use electricity.

In Figure 3, the different types of lighting sources used by the households is depicted. The most common source is electricity, constituting 71.7% in the case of rural households, followed by candles, kerosene lamps, and others.

In Figure 4, the appliances used for cooking are shown for all households. For cooking, 47.5% of the households use electricity; 67.6% in urban areas and 23.2% in rural areas. Of total households, 34% cook with firewood; 61.5% in rural areas and 11.2% in urban areas. Of total households, 14.5% use LPG for cooking; 17.1% in urban areas and 11.3% in rural areas. Finally, kerosene is used by only 1.3% of total households.

There are other important activities performed at the household level that are worthwhile mentioning. 86.9% of the households do ironing. Electricity is the major source for ironing as can be shown in Table 1. For

other household activities, such as refrigeration and laundry, electricity is the major source of energy. Another piece of relevant information related to energy sources is the way in which the customers perceive the availability of such sources. Electricity is acknowledged as the easiest source to obtain, as indicated by 70.9% of those interviewed, 93.3% for the urban areas and 63.5% for the rural areas. For kerosene, 58.3% thought it easy to obtain; 69.5% in the urban areas and 44.8% in the rural areas. In the case of charcoal, 47% thought it very difficult to obtain; 59% in the rural areas and 37.1% in the urban areas. For diesel, 59.9% considered it easy to obtain; however in the rural areas 41.4% considered it very difficult to obtain.

For LPG, 62% consider it easy to obtain; 78.5% in the urban areas and 42% in the rural areas. However, in the rural areas a majority, 50.1%, considered it difficult to obtain. In the case of gasoline, 33.2% considered it difficult to obtain; 17.2% in the urban areas and 52.5% in the rural areas. Nonetheless, in general, 59.7% considered that it was rather easy to obtain. Finally, in the case of firewood, 42% consider it difficult to obtain and 45% consider it easy to obtain. For the rural areas, 63.6% consider it easy to obtain, in the urban areas 53.3% consider it difficult to obtain.

Figure 5 summarizes the previous comments on availability of the different energy sources. In Figure 6, a classification by energy source in relation to opinions about their respective prices is shown. In general there are no significant differences between urban and rural users.

Given the widespread use of electricity in Costa Rica, it is useful to determine the per household consumption of electricity by level of income

and by urban-rural categorization. Table 3 summarizes this informtion.

Clearly the rural user consumes less than the urban, and the average consumption for the rural areas is around 180 KWh/month. On a per capita basis, the consumption of electricity nationwide is 1.2 KWh/per capita-day, for the urban areas this is 1.8 and for the rural areas it is much lower: 0.6.

Another study more targeted towards rural electrification was done by the Costa Rican Institute of Electricity (ICE, 1983) in order to comply with the IDB-ICE contract Number 598-CR which required an assessment of the socio-economic impact of rural electrification. For the purpose of the present study, the most important aspects studied were the sources and uses of energy without a rural electrification project.

For cooking, 85.1% of the households used firewood, 11.8% LPG, and 3% kerosene, coal or diesel. For lighting, 56% use candles, 7.7% diesel power plants, and 2.5% gasoline plants, or batteries. In relation to the appliances used, 61% have irons. Of those with irons, 90.8% use firewood to heat it, 3.7% use LPG, 3.4% use a diesel and 2.1% kerosene, coal or another source.

68.1% of households own radios, and 98.1% of those use batteries. 28.8% own televisions; 69.7% use batteries, 21.1% their own power plant and 9.2% electricity given by neighbors who own power plants. A sewing machine is rather popular, 24.5% of the households own one, although most of them--except for 3.1% that use electricity--are operated manually. In the case of other appliances and equipment such as stereos, refrigerators, blenders, washing machines, and electric cleaners, the percentage of ownership is

1.1%, 6.1%, 2.1%, 2.3% and 0.8% respectively. It seems that those who own this equipment are hoping to have rural electrification in the near future.

In relation to the amount of income devoted to electricity, 55.8% of the households (non-electrified) have a monthly energy expense of less than 300 ($7.5 at 40/$ in 1983). The average is 438.27 (($10.96). Table 4 and Figure 7 illustrate the findings.

With regard to the willingness to pay for rural electrification, 63.2% of the households interviewed said they would pay less than 400 ($10). The average of the amount which they are willing to pay is 452.88 ($11.32). At the time of the ICE survey they were making energy payments which averaged 438.27 per month ($10.96). Table 6 and Figure 8 summarize these findings.

Table 6 shows the results for consumption and average monthly expense for electricity by households in urban and rural areas from the national survey made in the same year as the ICE study (1983-84).

Consumers who do not have electricity have a higher willingness-to-pay for this service than do those consumers who already have electricity in the rural areas, as reflected by the national average. The rural households with electricity were paying an average of 257.45 per month, compared to the average willingness-to-pay ($452.88) for the households without electricity. This probably reflects the fact that the non-electrified households are already paying an average of 438.27 per month--which is much higher than the amount paid by electrified consumers.

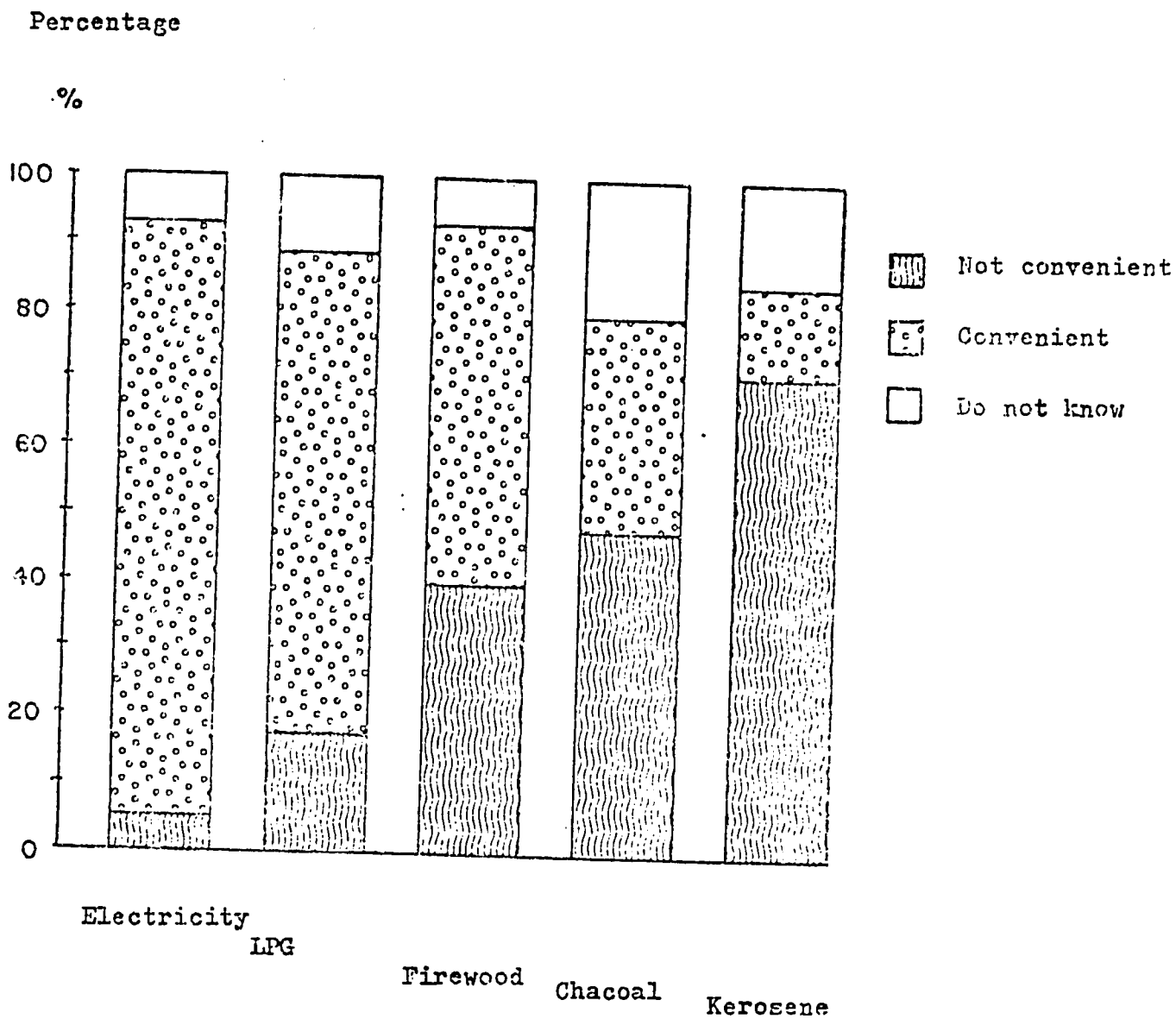
The present study will address the assessment of benefits and costs of rural electrification, not from an evaluation of general characteristics of

the impact of electrification as some of the studies reviewed in this chapter do, nor from a national characterization of energy and electricity uses, but the study concentrates on the application of a rigorous methodology in order to perform ex-ante analysis of rural electrification projects. A survey of two electrified towns and one non-electrified town are reported. This information is used to present a benefit-cost analysis of the electrification of town in the caribbean coast of Costa Rica. Our methodological approach is also complemented with a marginal cost and pricing analysis and with a cost-reliability optimization analysis, all of them applied to the Costa Rica setting.

FIGURE 1

Opinion about the most convenient method for cooking

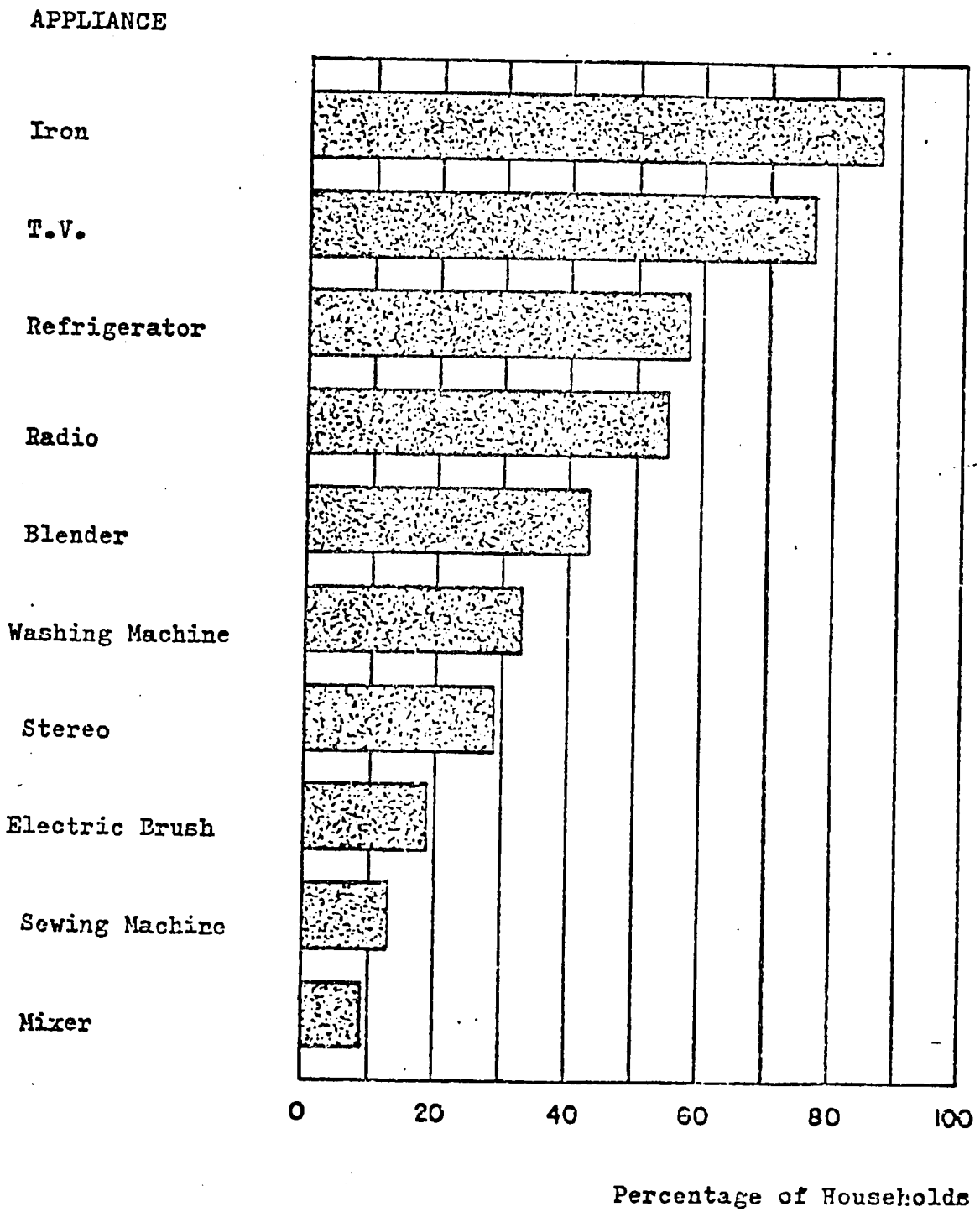
(1983)



Source: DSE, 1985.

FIGURE 2

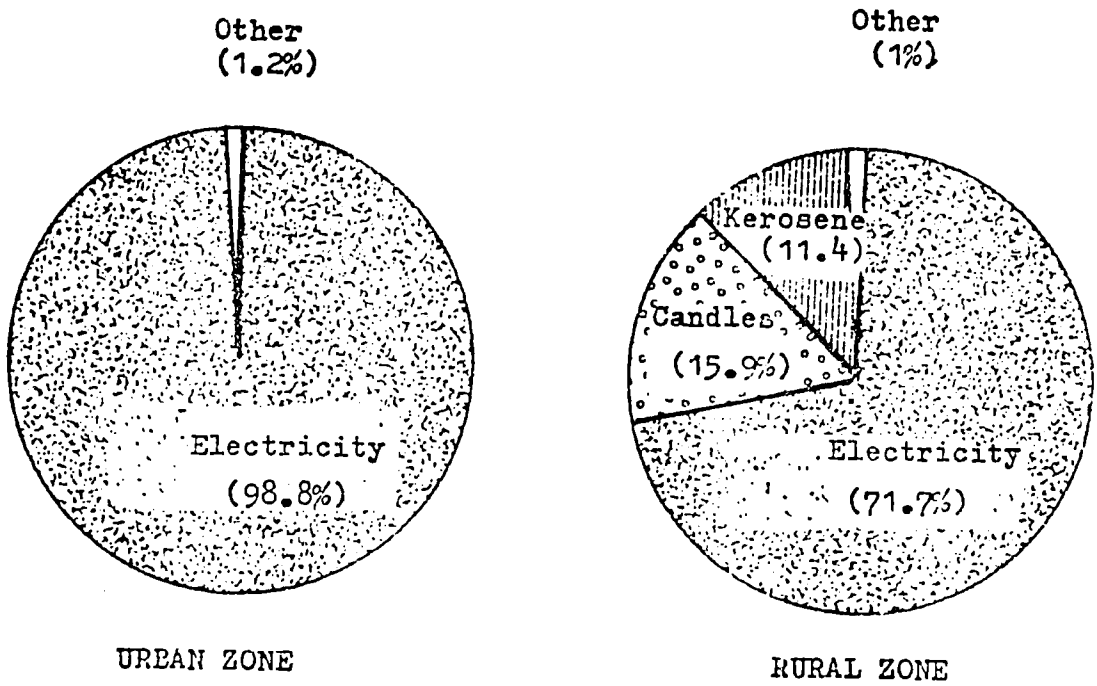
Electrical Appliances most commonly used by households
(1983)



Source: DSE, 1985

FIGURE 3

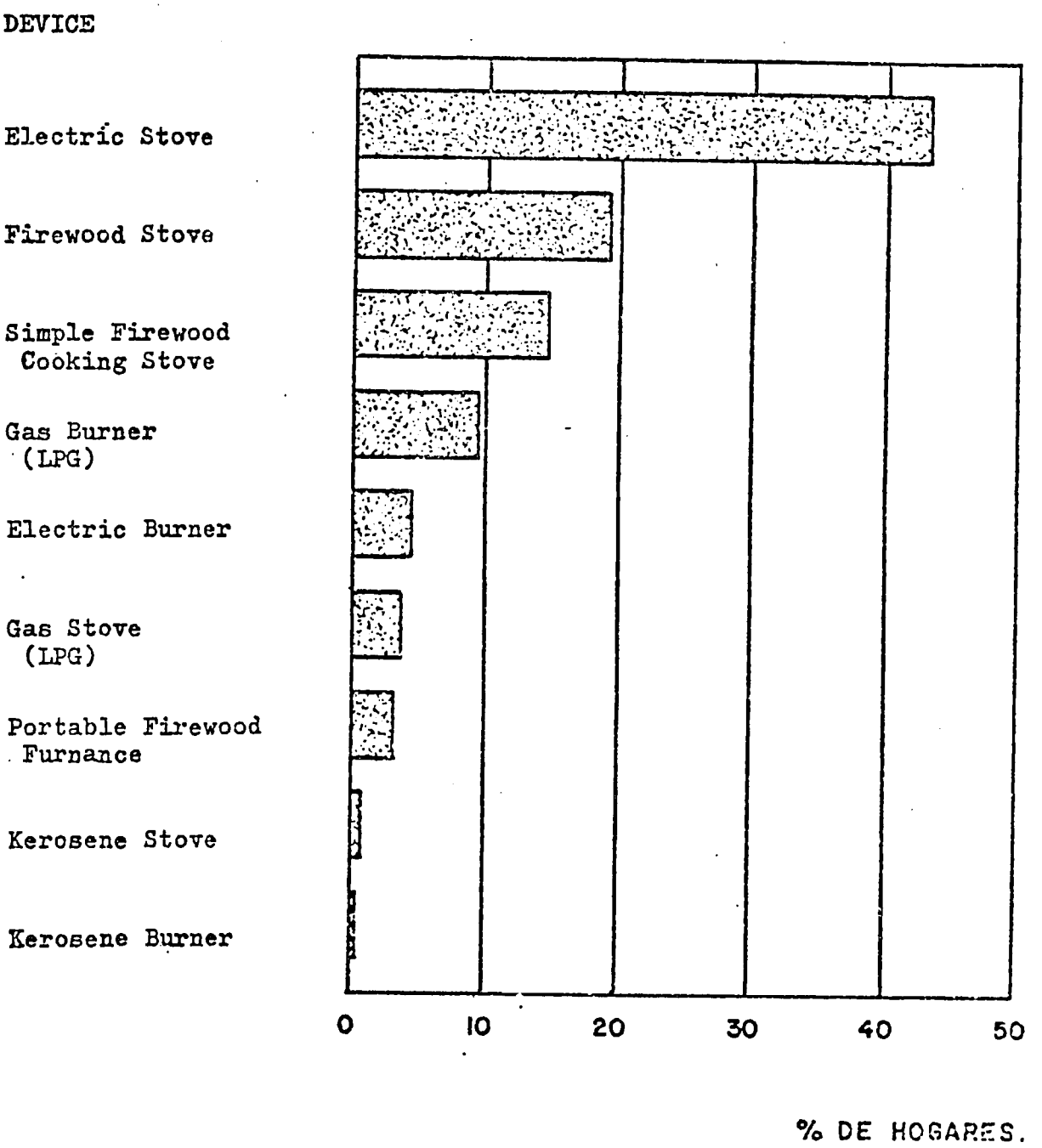
Different Types of Lighting Sources - 1983



Source: DSE, 1985

FIGURE 4

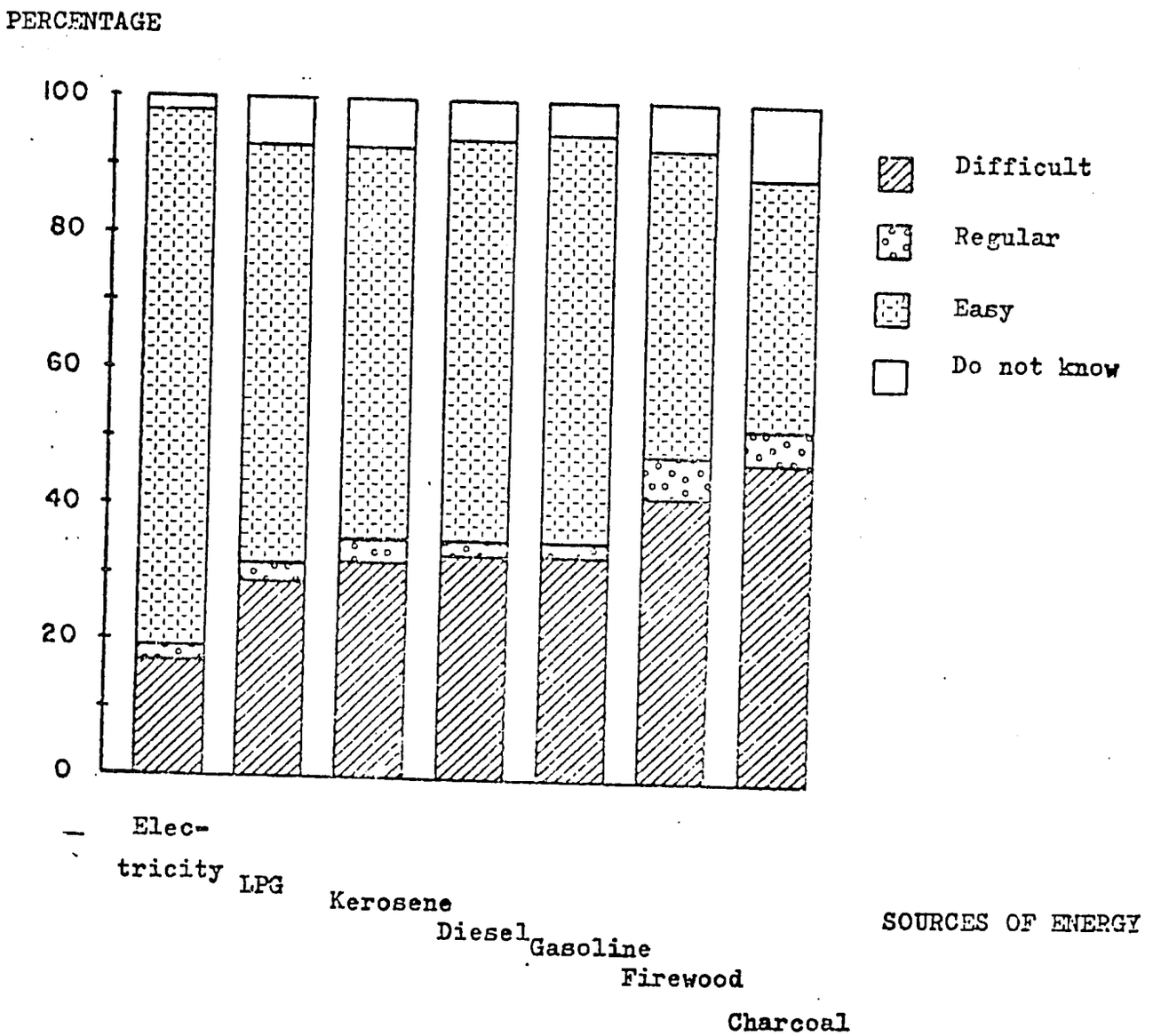
Devices use for cooking (1983)



Source: DSE, 1985

FIGURE 5

Opinion about the availability of energy sources at households level - 1983

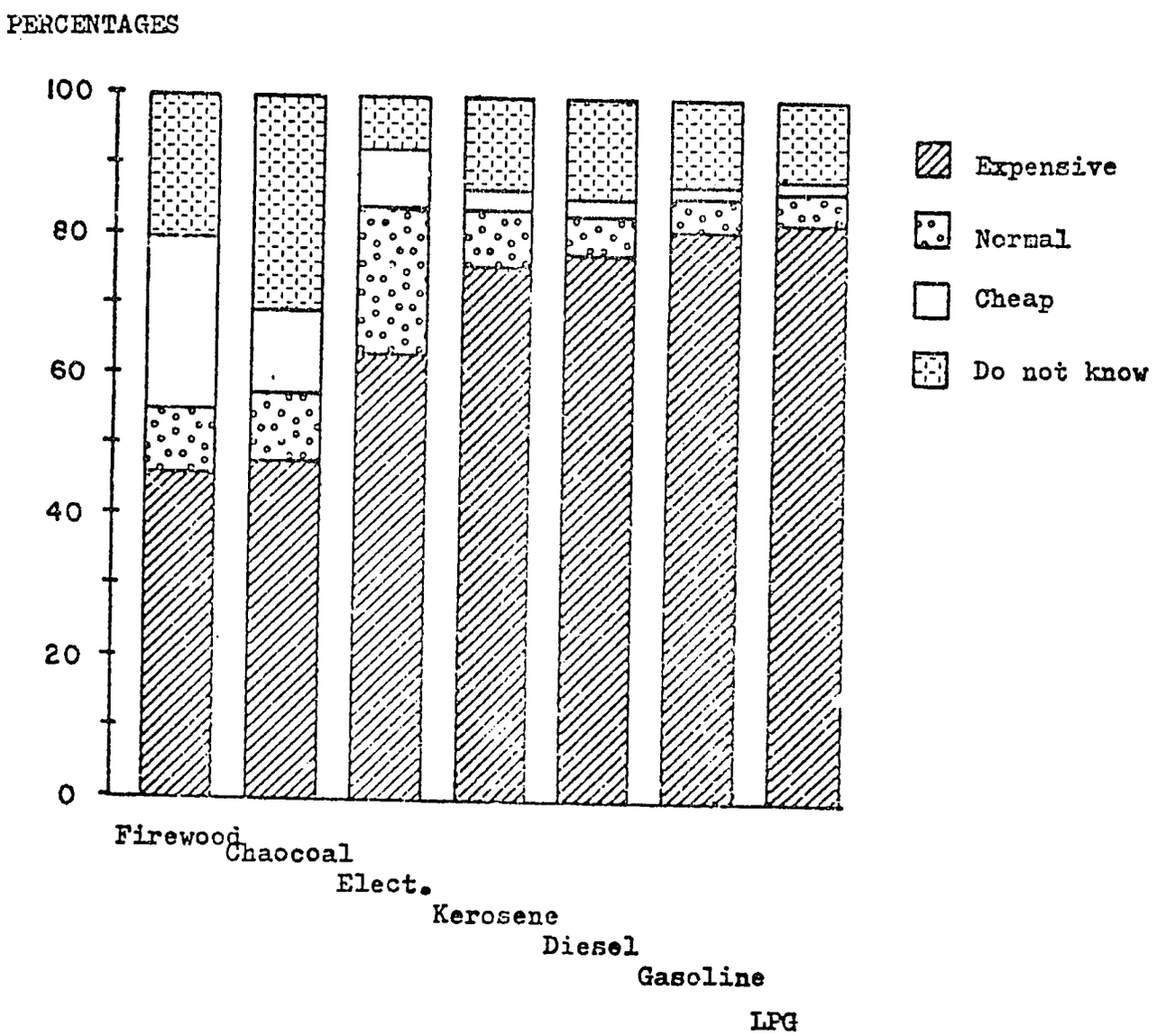


Source: DSE, 1985

FIGURE 6

Opinion about the cost of energy sources: household level

1983

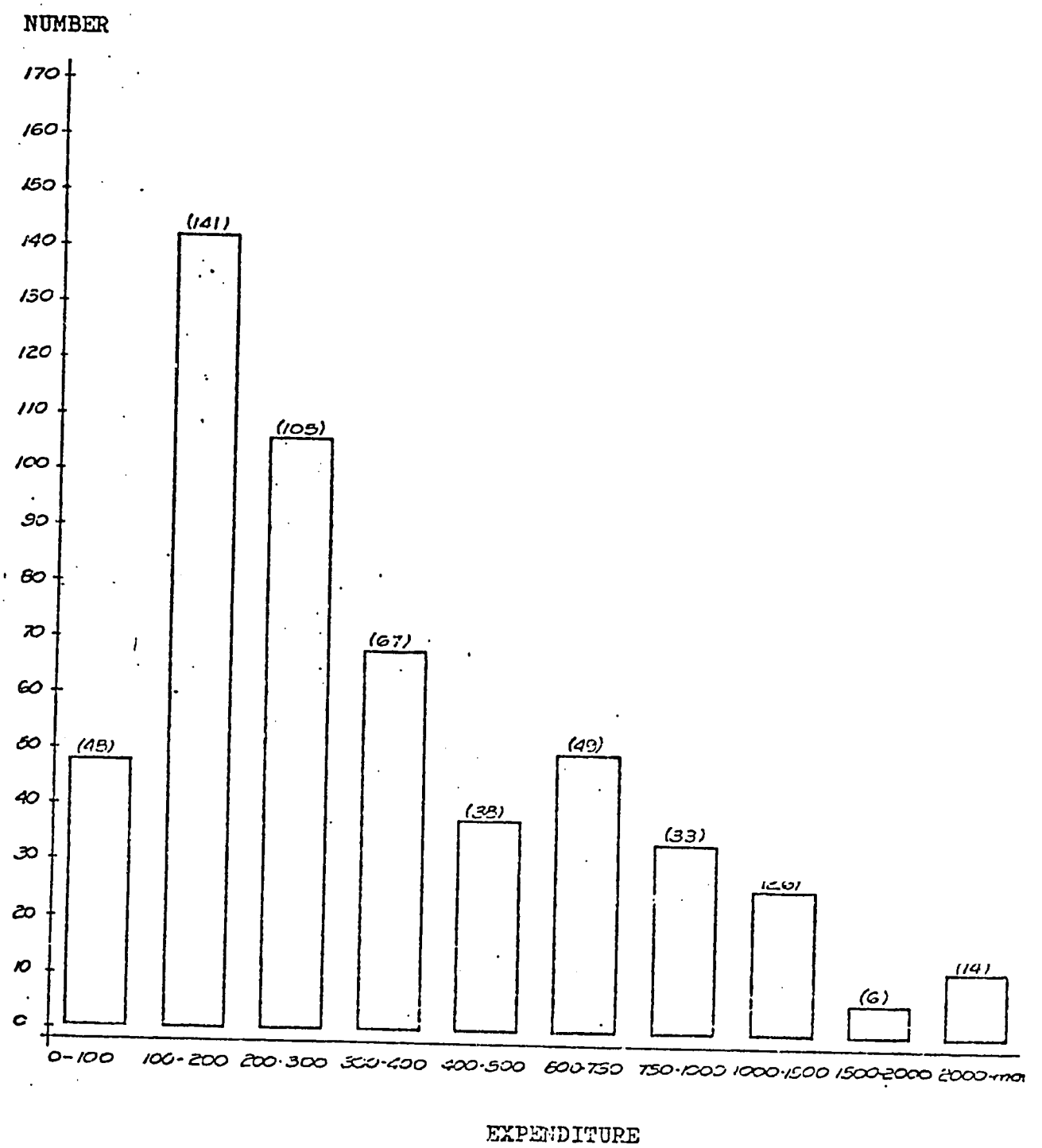


Source: DSE , 1985

FIGURE 7

FREQUENCY DISTRIBUTION of EXPENDITURE ON ENERGY SOURCES

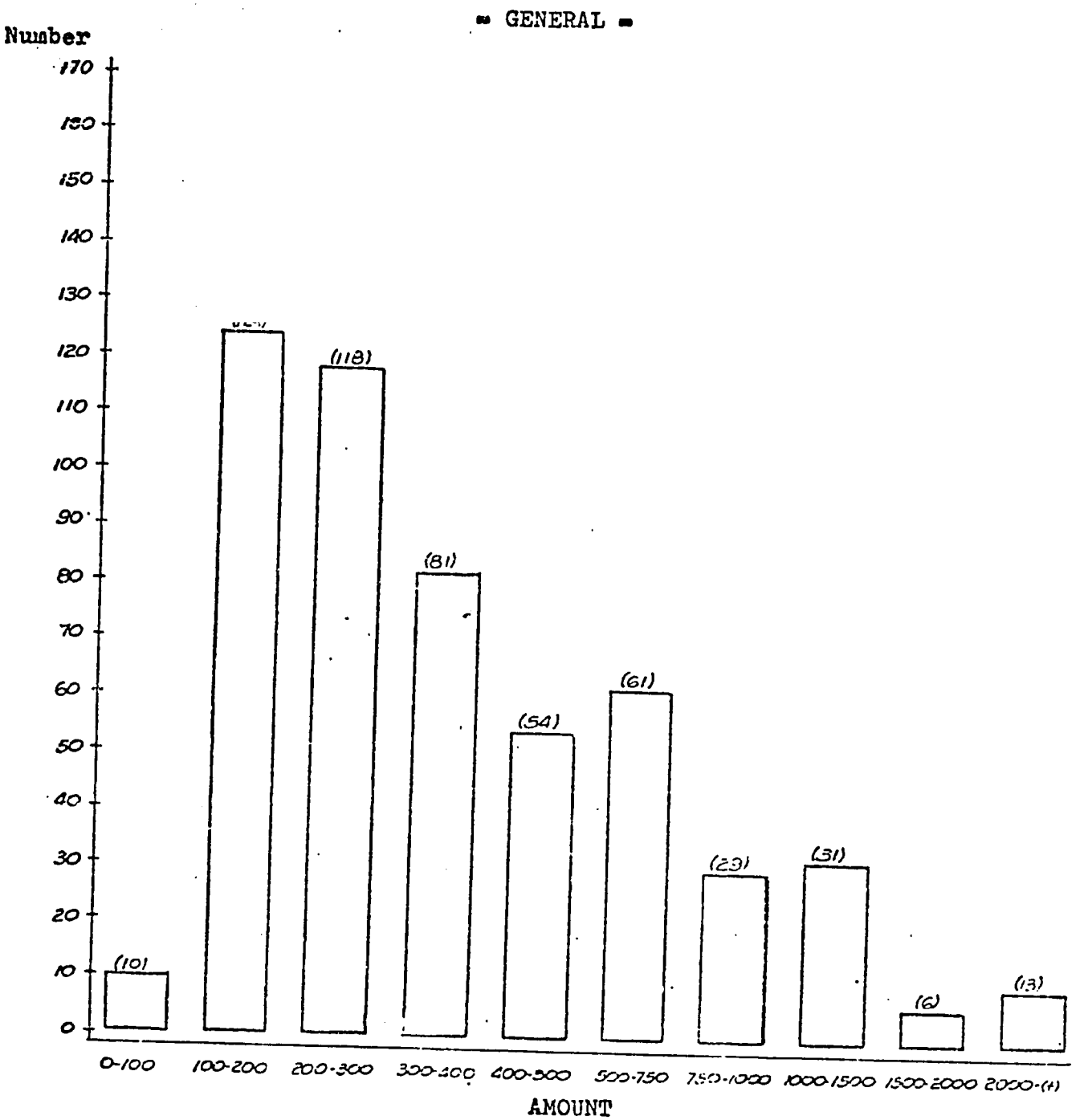
- GENERAL -



Source: ICE, 1983

FIGURE 8

FREQUENCY DISTRIBUTION OF THE AMOUNT OF WILLINGNESS TO PAY



Source: ICE, 1983

TABLE 1

Electrical Appliances by Urban and Rural Household
(for the three most common)

Type	Percentage of Families		Percentage that use Electricity as main source.
	Urban	Rural	
Iron	57.6	42.4	87.1
TV	63.2	36.8	86.4
Refrigerator	68.6	31.4	98.8

Source: DSE, 1985. pp. 27-29.

TABLE 2

Energy Sources for Ironing in Urban and Rural Areas:

Source	Total from Survey	Urban	Rural
Number of Households	1,933	1,114	819
Percentage Totals	100	100	100
Electricity	87.1	97.9	72.5
Charcoal	2.5	0.5	5.3
Other	10.4	1.6	22.2

TABLE 3

Average Monthly Electricity Consumption per Household, (KWh), 1983

Level of Income	Total	Urban	Rural
Less than ₵ 6000	168.6	198.8	130.0
₵ 6000 to ₵ 11,999	241.9	269.3	191.6
₵ 12,000 and more	374.7	388.5	325.5
Total	245.7	280.0	181.3

TABLE 6

Consumption (KWh) and Average Monthly Expense (₵/Household-Month) in Electricity

	Households with Electricity			Total of Households Surveyed		
	Total	Urban	Rural	Total	Urban	Rural
Consumption	245.0	280.0	181.3	181.7	245.6	104.4
Expense ₵	347.90	397.60	257.45	258.01	348.75	148.25

TABLE 4

FREQUENCY DISTRIBUTION of EXPENDITURE IN ENERGY SOURCES

BY REGION AND BY TYPE OF RURAL CONSUMMER - 1983

EXPENL. (₡)	Coto Brus No.	Coto Brus %	Atlántico No.	Atlántico %	Interamericana No.	Interamericana %	S. R. D.* No.	S. R. D.* %	S. R. P.** No.	S. R. P.** %	General No.	General %
0 to less 100	13	9.3	6	5.6	12	10.7	31	8.6	17	10.2	48	9.1
100 " 200	32	22.9	19	17.6	25	22.3	76	21.1	65	38.9	141	26.8
200 " 300	39	27.9	9	8.3	15	13.4	63	17.5	42	25.1	105	19.9
300 " 400	18	12.9	11	10.2	17	15.2	46	12.8	21	12.6	67	12.7
400 " 500	11	7.9	12	11.1	6	5.4	29	8.1	9	5.4	38	7.2
500 " 750	9	6.4	19	17.6	16	14.3	44	12.2	5	3.0	49	9.3
750 " 1000	6	4.3	12	11.1	10	8.9	28	7.8	5	3.0	33	6.3
1000 " 1500	9	6.4	10	9.3	4	3.6	23	6.4	3	1.8	26	4.9
1500 " 2000	1	0.7	4	3.7	1	0.9	6	1.7	-	-	6	1.1
2000 and more	2	1.4	6	5.6	6	5.4	14	3.9	-	-	14	2.7
TOTAL	140	100	108	100	112	100	360	100	167	100	527	100

S.R.D. = Disperse Rural Sector ; S.R.P. = Peripheric Rural Sector

Source: ICE, 1983

TABLE 5

FREQUENCY DISTRIBUTION of the AMOUNT OF WILLINGNESS TO PAY BY REGION AND BY TYPE OF RURAL CONSUMMER - 1983

	Coto Brus		Atlántico		Interamericana		S. R. D.*		S. R. P.**		General	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
0 to less 100	3	2.1	1	0.9	2	1.8	6	1.7	4	2.4	10	1.9
100 a menos 200	26	18.6	15	13.9	20	17.9	61	16.9	63	37.7	124	23.5
200 a menos 300	46	32.9	16	14.8	24	21.4	86	23.9	32	19.2	118	22.4
300 a menos 400	15	10.7	15	13.9	16	14.3	46	12.8	35	21.0	81	15.4
400 a menos 500	17	12.1	11	10.2	9	8.0	37	10.3	17	10.2	54	10.2
500 a menos 750	15	10.7	20	18.5	19	17.0	54	15.0	7	4.2	61	11.6
750 a menos 1000	4	2.9	11	10.2	9	8.0	24	6.7	5	3.0	29	5.5
1000 a menos 1500	11	7.9	10	9.3	6	5.4	27	7.5	4	2.4	31	5.9
1500 a menos 2000	2	1.4	3	2.8	1	0.9	6	1.7	-	-	6	1.1
2000 y más	1	0.7	6	5.6	6	5.4	13	3.6	-	-	13	2.5
TOTAL	140	100	108	100	112	100	360	100	167	100	527	100

S.R.D.= Disperse Rural Sector ; S.R.P. = Peripheric Rural Sector

Source: ICE,1983

Chapter III

A FRAMEWORK FOR R.E. ANALYSIS: GLOBAL SETTING

1. Rural Electrification vs. Decentralized Energy Options.

The first decision that must be made is between: Rural Electrification or Decentralized Energy Options. Traditionally, both international funding agencies and national public utilities support the perspective that RE is more economically sound vis-a-vis alternative energy sources and that central-grid electricity is more economic than independent autogenerators. (USAID, August 1977; Development Alternatives, Inc., 1977; USAID, April 1979).

The World Bank (World Bank, 1975) suggests that there are four stages in rural electrification:

> PHASE ONE: Only a few isolated businesses install their own generators.
> PHASE TWO: A collective but still small demand for electricity may develop from businesses and households.
> PHASE THREE: Growth of demand and increased consumer attraction due to the original microgrid leads to the connection to the central grid.
> PHASE FOUR: Once the network is established, the centers of low demand are now close to the network and can be connected to the central grid at a very low marginal cost.

In dealing with the decision regarding RE vis-a-vis autogeneration the dynamics of these four phases should be taken into account, as well as the following elements:

1) At the macroeconomic level, a single investment at one point in time for expansion of the central-grid is considerably more costly than stretching out these same expenditures over time and spreading them over a series of local contributions as is the case with investment

for autogeneration. This is due to the scarcity of capital in LDC's, the usual budget deficits and the limits on additional foreign loans.

2) From the perspective of a more accurate matching of supply and demand, the development of electricity supply by means of autogeneration systems avoids the longer periods needed for larger plants' start-up operations and also the long periods of excess capacity that occur with the central-grid before demand has fully materialized. As a corollary, it is clear that the growth in demand is easier to calculate for each particular region or town and that further expansion of plants at a local level is easier to implement.

3) At a financial level, if the electricity is being generated locally it is easier to mobilize resources and local financial support to pay for the local power plant. This relaxes the financial pressure on the central utility.

4) The advantages of autogeneration over central-grid electricity depend on the level of utilization (load factors) the overall kw size of the system, reserve requirements, the distance to the central-grid, the concentration of users, the nature and growth of load and load development, the cost of generation, timing of rural load peak, of rural load peak, the conditions of the terrain, availability of human resources and the share of large loads vis-a-vis small dispersed loads. (See, for example: World Bank, 1975, "Rural Electrification").

5) A final point worth mentioning is the fact that autogeneration could minimize the uncertainties inherent in projecting rural loads. If this point is valued by the central-grid utility it very well could

help reduce that uncertainty.

These points should be considered in defining RE vis-a-vis decentralized energy options. However, there is not necessarily a contradiction between the two. As Tendler points out (USAID, 1979):

> It should be clear... that autogeneration and central-grid systems are not being discussed here as mutually exclusive alternatives. Each approach corresponds to a stage of electricity power development (Page 61).

Effectively, the four phases of rural electrification suggested by the World Bank have a dynamic which points out that, given certain parameters already mentioned, the autogeneration stage (Phase Two) should always be taken into account as a possible alternative. This can further evolve to a full connection with the central-grid.

The cost of generating electricity varies with the capital costs (which depend on the type of generator) and the recurrent costs (which depend mostly on the type of fuel used). Comparing the costs of alternatives is no easy task, given that these costs differ according to location, over time, with different demand levels, and with the degree of equipment utilization. But with few exceptions, the capital costs of the grid exceed those of autogeneration, and the recurrent costs of autogeneration exceed those of the central grid system. Finally, transmission and distribution costs must be considered. Distribution costs depend on the system of charging customers. Power costs per kWh are especially sensitive to the load factor (utilization rate). This is low in rural areas, as both consumer density and per capita demand are low. Yet investors assume that utilization will rise over time and thus increase their returns, with only fuel expenditures rising.

The comparison between autogeneration and supply from the grid depends on a variety of parameters (World Bank, 1975). There is a direct relation between the size of the project (load being served) and the costs of autogeneration and supply from the grid. In the example summarized in Table 1, for all cases the average length of the subtransmission line for each village is four kilometers. From the table it is clear that there are economies of scale in capital costs. In a comparison between autogeneration and supply from grid, although the capital costs of supply from the grid are sometimes higher, however the operating and maintenance costs are, indeed, much less. When the project is expected to have high load factors, this favors a project more capital intensive and less fuel intensive, thus favoring a supply from the grid alternative. This is shown in a stylized example in Table 2.

Another parameter that influences the decision between an autogeneration alternative and the supply from the grid is the distance from the village or town to the electricity grid. Holding constant the size of the load to be served, there are two components that have to be considered in order to determine between the extension of the line or the autogeneration solution, those are: a) the load factor and b) the distance between the electricity grid and the village or town to be served. Table 3 shows an example of the comparison between the costs of the three different alternatives. For the ease of a low level of load factor it is not advisable to extend the network to supply that type of load and thus, the autogeneration alternative is the most likely alternative. Nonetheless, if the load factor is higher, the same network extension proposal can become an adequate solution. This points to the fact that as the load factor increase, indicating the development of stable productive and consumption activities,

average costs decline and the extension of the grid becomes more advisable.

For each town within a region, it is advisable to make an annual cost comparison taking into account:

1) Network capacity that incorporates the load density as well

2) Load factor

3) Terrain characteristics incorporated in capital investment costs

4) Distance from central grid that is also incorporated in the costs (capital investment)

In each case a comparison should be made between:

* Central grid interconnection;

* Central grid interconnection but with lower standards;

* Autogeneration by hydro, oil-based, or biomass;

* Village energization not necessarily using electricity.

Once the RE project is decided upon, it is a complicated matter to convert the costs into tariffs. The determination of tariffs is a key question, given that price determines the level of demand (as opposed to costs). The "traditional" method has been to base the tariffs on recovering sunk costs. A newer approach is to set prices according to the Long Run Marginal Cost (LRMC) of grid extension. This is discussed later; LRMC is a measure of the extra resources needed to meet a permanent increase in demand.

Once prices are set, though, consumers may not be willing or able to pay them. This means that subsidization of electrification and its supply is a common situation in RE project implementation. These subsidies are often justified by pointing out anticipated socio-economic benefits. Subsidized electricity prices are usually seen by government officials as

means of income redistribution.

i) Example: The Case of a Small Town in Costa Rica

Based on the Second Stage of the National Plan on Rural Electrification of Costa Rica (ICE, 1979) an example dealing with the choice between autogeneration and grid electrification was drawn up. The data are drawn from the town of Boca del Parismina on the Atlantic Coast of the country with a population of around 300 inhabitants based upon market demand forecasting based on past experiences of similar towns.

The information in Tables 4, 5 and 6 give, in a very simplified manner all the information that is needed for analysing the choice between central grid or autogeneration. The costs used in the three tables can be financial costs or economic costs based on shadow prices considerations. Details of which to choose are discussed later in this monograph.

In this example the Net Present Value of the Costs of Autogeneration is slightly smaller than the central grid alternative and therefore it may be advisable to propose an autogeneration solution.

However, because the present values of both alternatives are almost identical the decision should take into acount other factors. In the examples shown previously in this chapter taken from the 1975 study of the World Bank, there were a series of parameters that were suggested as being important to take into account when the decision is being made between autogeneration and extension of the network. In the present example all of those parameter are fixed and the decision must be made based on other types of factors, such as the expected trend in fuel prices, the price of

foreign exchange at the time of actually doing the capital investment and of the priorities of the government in relation to import substitution and so on.

Thus, this example complements the types of parameters that must be taken into account when a project analysis suggests the decision between autogeneration and extension of the grid. Certainly in a much more detailed case there can be other factors that become important and the aspects refered to in this chapter serve only as a general guideline that do not substitute the richness and complexity of a specific project.

2) Rural Electrification vs. Rural Development.

A second choice that shou'd be made is related to the following alternatives: RE as an infrastructure investment or RE as a complementary investment. Both of these need to be considered as either a self-contained project or as part of a rural development package of projects.

In analysing the RE project as a self-contained project the analysis will be limited to the direct and indirect benefits and costs it accrues, but without explicit 'internalization' of complementary inputs or other forward or backward oriented projects. This has been the traditional approach to RE however, accurate cost-benefit analyses are not often performed, project decisions are often made without such input. It has been found that there is the tendency to overestimate the benefits (including the social benefits) and to underestimate the costs in RE project appraisals (Fluitman, 1983, p. 53).

The major problem with cost-benefit analysis is accurately to include and evaluate the benefits of the project. As explained later, the total

economic value of a project's output is equal to what the consumer is willing-to-pay. But how can this amount be measured for a household? Generally, then the determination of this amount is often guesswork or it is totally ignored. Yet, benefit-cost analysis is not in vogue for RE projects. Their implementation is often attributable directly to political factors alone.

In the second case, as part of a rural development package, stress is put on the "internalization" of a set of complementary inputs and/or projects in order to enhance the materialization of the load demand and in order to increase the overall benefits from the electrification scheme. More and better impact studies can help to identify these complementary inputs and/or conditions. Close attention should then be paid to these factors in order to realize greater benefits from RE.

For RE considered as a complementary input as a self contained project, empirical evidence exists (Brodman, 1982) to suggest that the potential benefits obtained are limited by not taking into account what has been called the necessary complementary inputs. This is particularly clear for electricity use in productive activities. For example, the evidence points out that wider use of electricity among businesses is limited by three factors:

1) Capital: Access to credit.

2) Marketing: Access to markets.

3) Information: Access to equipment information, rates structure information, comparative costs information, etc.

In the case of Indonesia, Brodman concludes that:

> Thus, lack of responsiveness and absence of complementary inputs severely limits the development of a significant portion of readily realizable productive uses: use by business owners who are using or plan to use diesel engines for shaft power, and use by business owners who feel that electrical equipment would improve their businesses, but are prevented from buying the equipment due to lack of capital. Perhaps most importantly, it indicates how lack of responsiveness can actually build obstacles to achievement of project goals into the program design. It makes clear the need for a coordinated RE program addressing the related needs of potential productive users. (Brodman, 1982; page 53).

Similar considerations can be found in other studies (USAID, Oct. 1981; USAID, Dec. 1980b). In the case of the Philippines, for example, the evidence supports the following conclusion:

> The introduction of electricity into an area does not automatically produce significant economic diversification and growth. The contribution of electricity to the development process depends on the level of development of the area. the availability of capital and other financial and human resources well as the implementation of programs which stimulate the use of power. Of the complementary inputs required to stimulate power-based industrial investment, the availability of start-up capital is critical. (USAID, Dec. 1980b, Page 13).

Therefore it is argued that the RE project should include the complementary inputs necessary to reduce the gap between potential benefits and actual benefits.

For RE considered as a complementary input or part of a rural development package of projects it is important to analyze what Tendler (following Hirschmann's scheme) called the forward and backward linkages of RE (USAID, 1979). Both backward and forward linkages refer mainly to productive activities. In the first case, to the inputs of the RE project; in the second case to the uses of the output of a RE project (electricity).

Backward linkages imply that the RE, taken as a package, should try to maximize the linkages between electrification and local suppliers. The effects of backward linkages are functions of the amount of investment, its

domestic content, and the country's ability to produce the needed goods--poles, insulators, transformers, conductors, etc., at competitive prices. The achievement of backward linkages should include the maximization of local procurement.

Project design plays a key role here: standard designs and specifications can be modified in order to encourage local suppliers, and thus the development impact can be increased.

While few developing countries are able to manufacture the necessary equipment, the production of lighter inputs (poles, wires) is a much more likely possibility. These backward linkages should not be ignored, as they often are in RE plans.

However, the availability of electricity is most likely to create a demand for complementary goods rather than for inputs--goods such as small motors, lights, irons, televisions, etc. Of course there are benefits such as employment production to be gained here, too.

Forward linkages look at the uses of the electricity produced by the project. The benefits of forward linkages are generally assumed to be quite substantial, and include various developmental goals and the promotion of economic growth. But economic growth is not an automatic result of RE. The previously cited USAID comment regarding the need for complementary inputs/conditions explains much of this. Also, the W[illegible] (El Salvador, 1975) adds that for an RE project's successful contribution to development, 3 conditions should be present: (1) high load density; (2) good potential demand from households and commerce; and (3) good potential demand from farms and agro-industries. That is, without a good demand

base, there will be no substantial use of the electricity, and thus no substantial benefits. The RE project should be linked with development programs aimed at increasing rural output and productivity in order for these conditions to be met.

Regarding rural industry, Sigurdson (1979, p. 59) points out that aside from the necessary political commitment, the primary requirements for rural industrialization are (1) access to electricity for productive purposes and (2) the development of the capacity to design and manufacture simple producer goods locally. These conditions are both necessary; it is not sufficient to provide electricity and then expect rural industry to expand.

In addition, it is important to note that not all industries have the same ability and need to utilize electricity. A World Bank study (El Salvador, 1975) found that there are generally several energy alternatives to electricity for use in rural production processes. These complementary conditions--industrial capacity for electricity use and access to alternative energy sources--must be examined before the decision on RE for a particular area, along with the consideration of the extent of the above-mentioned complementary inputs.

With respect to the impact of RE on agricultural production, an IDB study (Latin America, 1979) found no significant evidence that RE caused any output or productivity gains. Perhaps greater benefits could be achieved if certain complementary inputs and conditions were more prevalent; i.e., RE alone will not produce production increases unless there is a need for it and a capacity to use it.

USAID (Costa Rica, 1981, p. 6) noted that, in general, electrification had a greater effect in the processing stages than in farm production. This emphasizes that the capacity to utilize electricity must be examined when a project is being decided upon. Still, rice, coffee, and sugar farmers cited productivity gains, which were attributed to the increase in repair and maintenance facilities made possible by electricity generation.

Tendler suggests that possible ways of exploring the potential uses of electricity is to determine realistic cases where electric power facilities led to a positive employment increase; to discover the ways in which various policy decision about rates, layout of facilities, selection of communities, etc. have influenced the location of rural industries. Finally, to try to forge the link between electrification and employment-creating uses for the RE project, the project plan should include credit and technical assistance for the location of different types and sizes of industries.

What exactly are the benefits to be gained through forward and backward linkages? One of the most often assumed is that of employment generation. Yet the results in this area are ambivalent. While employment would rise due to an output increase, it would fall in response to a productivity gain. The overall effect, then, would depend on which of these two effects was dominant. While there is not much empirical evidence in this area, it would seem that any employment creation may be significant with respect to backward linkages and with respect to the actual extension of RE supply, especially in laying lines. Further employment may result from the increased production of complementary goods.

Other assumed benefits are: increases in agricultural productivity, promotion of rural industry, improvements in health, education, training,

and the standard of living in general, reduced rural-to-urban migration (due to increased employment) and more equitable income distribution.

These benefits are difficult to measure, and no strong evidence exists that such results are indeed attributable to RE. On the contrary, Fluitman (Fluitman, 1983), p. 47) concludes that RE accentuates income disparities, and that there is no demonstrable impact on migration.

The benefits (social and economic) of electricity consumption depend on the use to which it is put and the amount used for each purpose. In rural households, electricity is used almost exclusively for the purpose of lighting.

TABLE 1 TYPICAL COSTS OF AUTOGENERATION AND PUBLIC SUPPLIES, 1972

Item	Autogeneration[a]		Supplies from grid[b]	
	50-kilowatt project	25-kilowatt project	50-kilowatt project	25-kilowatt project
Consumers served	140	70	140	70
Capital costs (thousands of U.S. dollars)	34	25	56	38
Fuel, operation, and maintenance (cents per kilowatt-hour)	6	6	0.5	0.5
Billing and administration (thousands of U.S. dollars per year)	2	1	2	1

a. Includes one standby motor generator.

b. Average length of subtransmission line for each village is assumed to be 4 kilometers. Note the economies of scale in capital costs. The 50-kilowatt and 25-kilowatt projects could serve fully developed loads in villages of about 2,000 and 1,000 persons, respectively. Demands from farms and agro-industries outside the village may add anything from 20 to 100 kilowatts or more to total capacity demands. Capital costs, it can be seen, range from $400 to $550 per customer in the above case of supplies from the grid (or $40 to $55 per capita in the village served). However, for large villages of 5,000–10,000 population, these costs may drop to $200 per consumer ($20 per capita) or less.

SOURCE: World Bank, *Rural Electrification: A World Bank Paper* (Washington, D.C., October 1975), p. 19.

TABLE 2 RELATIVE ANNUAL COSTS OF 50-KILOWATT PROJECTS

Cost components	Autogeneration (thousands of U.S. dollars)			Supplies from grid (thousands of U.S. dollars)		
	10 percent load factor	25 percent load factor	50 percent load factor	10 percent load factor	25 percent load factor	50 percent load factor
Annual capital costs[a]	4.5	4.5	4.5	5.6	5.6	5.6
Fuel, operation, and maintenance	2.6	6.6	13.2	0.2	0.5	1.0
Billing and administration	2.0	2.0	2.0	2.0	2.0	2.0
Total	9.1	13.1	19.7	7.8	8.1	8.6
		(cents per kilowatt-hour)			(cents per kilowatt-hour)	
Average	21	12	9	18	7	4

a. Annuity of 10 percent used on electrical components, 15 percent on mechanical components of autogenerators (taking their shorter lifespan into account).

SOURCE: World Bank, *Rural Electrification: A World Bank Paper* (Washington, D.C., October 1975), p. 20.

TABLE 3 AVERAGE COSTS OF AUTOGENERATION AND PUBLIC SUPPLIES BY LOAD FACTOR (cents per kilowatt-hour)

Load factor	Autogeneration	Public supplies	
		4 kilometers from grid	29 kilometers from grid
10 percent	21	18	40
25 percent	12	7	17
50 percent	9	4	8

Note: Since average costs in urban areas are about 3 cents a kilowatt-hour, it is extravagant to extend networks to meet small demands in areas remote from the grid. However, the same subtransmission networks can be used to meet much larger demands. If adequate demand develops from farms, agro-industries, and several villages, average costs decline very quickly to about 4–8 cents a kilowatt-hour.

Table 4

Town of Boca del Parismina
Consumers, Energy and Power Needs

	1978	1983	1984	1985	1986	1987	1988	1989	1990	1990	1992
1. Potential Consumers (No.)	68	82	85	88	92	95	99	102	106	110	115
2. % to be served	80	80	82	84	86	88	90	90	90	90	90
3. Consumers	54	66	70	74	79	84	89	92	95	99	104
*Residential	47	57	61	64	69	73	77	80	83	86	91
*General	7	9	9	10	10	11	12	12	12	13	13
4. Consumption (MWH)											
*Residential		54	67	80	97	114	132	143	154	166	183
*General		24	25	30	31	36	42	43	43	43	43
*Public Lighting		16	16	16	16	16	16	16	16	16	16
**TOTAL		94	108	126	144	166	190	202	213	225	242
5. MWH at Substation		105	121	141	161	185	212	226	238	251	270
6. Maximum Demand (KW)		22	25	29	33	38	44	47	49	52	56

Source: ICE, 1979.

Table 5
Central Grid Supply Costs
(Thousands of Colones)
Present Value

	Network capacity(Kilowatts) 75 Kw
Consumers served(number)	115
Capital Costs($)	
Transmission	
*Imports	1276
*Local	867
**Subtotal	2143
Distribution	
*Imports	139
*Local	85
**Subtotal	224
***Total Capital Costs	2367
Operation and Maintenance	
*Imports	00
*Local	100
TOTAL	
*Imports	1415
*Local	1052
**Total	2467

Table 6
Autogeneration Costs in Thousands of Colones
Present Values

	Network capacity(Kilowatts) 75 KW
Consumers served(number)	115
Capital costs	
Generators	
*Imports	55.6
*Local	79.4
**Subtotal	135
Local Distribution	
*Imports(Fx)	139
*Local	85
**Subtotal	224
Total Capital Costs	359
Running costs:	
Fuel(diesel)	
*Imports	1790
Local	00
Operation and Maintenance	
*Imports	00
*Local	300
TOTAL	
*Imports	1984.6
*Local	464.4
**Total	2449

Chapter IV

EX-ANTE APPRAISAL: IDENTIFYING RELEVANT COSTS AND BENEFITS

1. Introduction

The implementation of any project will always reduce the supply of goods used as inputs consumed by the project and increase the supply of outputs produced by the project. This means that without the project the supply of these inputs and outputs to the rest of the economy would have been different. A correct appraisal of the project must identify the benefits and cost derived from this difference.

In regard to the method of cost-benefit analysis on which the ex-ante appraisal is based, E. Cecelski has pointed out that:

> Clearly, benefit-cost analysis is the most appropriate framework of the four described above (meeting targets or forecasts, financial viability, impact analysis and benefit-cost analysis) to use for getting at the role of rural electrification in development. It is perhaps surprising, then, that this approach has been so rarely used in the evaluation of rural electrification programs. (Cecelski, July 1979, page 10.)

The backbone of the cost-benefit analysis is formed by three basic streams (World Bank, 1975):

BENEFIT STREAMS:
1 - Direct benefits to households.
2 - Direct benefits to businesses.
3 - Direct benefits to the village or region as a whole.
4 - Surplus benefits to households, businesses and to the village or region as a whole.

COST STREAMS:
1 - Generation capital costs.
2 - Transmission capital costs.
3 - Distribution capital costs.
4 - Generation energy costs.
5 - Operation, administration and maintenance costs.

Finally, as will be addressed in Chapter V:

SHADOW PRICE ADJUSTMENT STREAMS:

1 - Wages.
2 - Capital.
3 - Foreign Exchange.
4 - Other, e.g., net tax revenues.

2) Benefits

Most studies conclude that there exists a close relationship between the level of use and the level of benefits derived from RE (World Bank, 1975; Cecelski, 1979; Brodman, 1982). RE may cost less than alternatives providing the same energy service, may allow the performance of entirely new tasks, or may perform the same tasks so much more efficiently than the other energy sources that they actually provide a qualitatively new task. The availability of RE and its ability to perform essentially new tasks can result in more energy being used and in new production being undertaken. All this sums up to increase the standard of living in the community and could help to stem migration from rural areas to cities.

The National Rural Electric Cooperative Association (NRECA) gave a rather extensive list of 50 different potential benefits. For the purpose of this paper a more concise approach will be developed. Quantitatively we are interested first of all in the monetary benefits and their calculation; second in the qualitative elements that can be stated as complementary considerations.

The monetary benefits are the amount of their income that the families, businesses and local governments are prepared to allocate to the service. As the World Bank suggests (World Bank, 1975), this consists of actual revenues and surplus revenues:

i) Actual Revenues, the direct consumer benefits indicated by the actual amount consumers pay for electricity. To measure the actual revenues the most reliable way is to obtain evidence from other projects in regions and villages with similar characteristics. This implies the following four steps:

First gather information about the economic and social characteristics of the region or village:

Non-domestic:

a) Type and growth of local agriculture;

b) Development of local agro-industries;

c) Extent of local commerce;

d) Quality of local infrastructure: roads, schools, water, health, etc.;

e) Plans on other projects in the region or village;

f) Accessibility of complementary inputs such as credit, markets and information.

Domestic:

a) Family income data;

b) Quality of housing;

c) History of the area;

d) Dynamics of migration out of or towards the region.

This information is useful for the determination of similar regions or villages that can serve as references for the demand forecast of the new RE project. Once this comparison is performed, the relevant information from the control region or village can be used for the new RE project.

Second, the evidence obtained from the similar region or village

should provide the following information:

a) The growth in the number of consumers;

b) The growth in consumption per consumer;

c) Types of consumers: large/small, agriculture production, process/agro-industry, commercial and public uses, various categories of household, etc.;

d) Changes in load factor over time;

e) Kinds of uses to which electricity is put.

The information obtained from the similar region should be expanded and modified through a field study in the region to be electrified. This will be even more relevant when the surplus monetary benefits are calculated in point number two, as explained below.

Third, it is necessary to obtain some evidence of the energy used before electrification in the region or village. The following points are relevant:

a) Types of various energy sources;

b) Cost of each energy source;

c) Extent of motive power;

d) Sources and cost of refrigeration, lighting in business and homes, heating and other energy uses.

Fourth, in order to produce a reliable forecast it is necessary to assess the effect of country-level macroeconomic changes or regional level socio-economic changes from the time the historical data for the similar region (or village) was obtained. This means that the effect of the following elements must be weighted:

a) Any increase or decrease in the purchasing power of the consumer;

b) Medium and long term trends in wages, electricity rates, food prices and inflation in general;

c) Changes in consumption due to variations in the region's central crop prices in the national or international market;

d) Changing perceptions about the role of electricity and the importance people assign to it as macroeconomic variables intervene.

The four points discussed in the previous paragraphs are the central elements useful in designing a survey to obtain the information necessary for a RE project appraisal.

ii) Surplus Monetary Benefits, given by the amount that consumers are willing to pay for the service. In other words, consumers generally do value the service by more than the amount they may be asked to pay for it.

Figure 1, shows a demand curve which represents the maximum amount which the consumer would be willing-to-pay for a given quantity of a good or service. For example, at a price of 2 colones kwh., the consumer would demand 10 kwh. However, there is more to the analysis; the concept of consumer surplus. Consumer surplus is the difference between the amount which the consumer actually pays and the maximum amount which he is willing to pay. In the above example, the consumer would be willing to pay 2.5 colones each for the first two kwh, 2.4 colones each for the next 2, etc. But he or she need only pay 2 colones each for the entire ten kwh. Thus his or her consumer surplus is equal to the shaded area, ABC. And the total economic benefit to this cnsumer is equal to the consumer surplus, area ABC, plus the amount actually paid, area OABD, totalling to area OCBD.

It is clear that the consumer's excess benefits not captured by the price-quantity traditional relation do not constitute a revenue for the

utility. However, they indeed form an integral part of the social benefits. In the feasibility study for the Second Stage of Rural Electrification of Costa Rica (ICE 1979) a survey was carried out in three towns in order to infer some information about the magnitude of the consumer surplus. The results showed the average magnitude of the total willingness-to-pay measured was 1.7 times the amount measured by the electricity tariff. In each of the study regions it was:

1.53 in the Atlantic Region
1.80 in the Chorotega Region
1.70 in the North Region.

The study concludes that the operational implication is that the revenues obtained in the traditional way should be multiplied by 2.7* in order to obtain the real social benefits. The study reached the following conclusions:

1. The consumer surplus obtained by the rural consumer is great, both for the center of the town as for the scattered consumers of the rural areas;

2. The amounts of the social benefits that rural electrification generates are considerably superior to those accrued by using only the revenues obtained by the tariff method;

3. Given the fact that the consumer protects him or herself against any raise in tariffs, the information obtained can still be biased in showing lower potential benefits;

4. The consumer surplus concept is a central element of any cost/benefit analysis intended to measure the feasibility of a rural electrification project.

The following steps can provide the necessary information for assessing this second element of monetary benefits:

First, it has been observed in RE studies (e.g., Brodman, 1982) that the households that adopted electricity were willing to commit an increas-

*This appears to be a mistake. The figure should be 1.7.

ing proportion of their expenditures to electricity and to electrical appliances, thus indicating the substantial benefits obtained from RE. The extra benefits are weighted by the consumer, and his willingness to pay for electricity is directly related to those benefits. Although the surplus for the household is difficult to appraise, the following elements can help to assess the consumers surplus benefits at the <u>household level</u>:

a) Increased income due to an increase in working hours;

b) Increased income due to increases in production in their home industries;

c) Value of electrical appliances, i.e., the monetary benefits would be the amount of income the households are prepared to allocate to such goods;

d) Other benefits that, if quantifiable, could be incorporated at this stage in the analysis, for example: home security, increase in children's study time, improvements in clinic treatment, etc.

<u>Second</u>, the surplus benefits for productive uses are even more important than at the household level. This is so not only because they are less difficult to measure than in the household case, but also because of the larger potential benefits involved. The following are the relevant surplus benefits at the <u>farm, agro-industries and commerce level</u>:

a) The surplus benefits are the net advantages of electricity (RE) over the alternative energy sources such as autogenerators, animal traction, etc.;

b) The surplus benefits are also obtained from the net increase in the profits of the activity that the business is engaged with. The alternative for activities like refrigeration, including associated capital and maintenance, are often too expensive or unreliable, and the business cannot make a profit without them. So business activities can and do spring up if costs are cut sufficiently for them to become profitable. Refrigeration in shops and corn grinding are common examples in Central America.

c)The extent to which electricity was used in general to increase production, sales, income or employment. Brodman suggests three elements that contributed to this purpose: (1) Use of electric lighting to extend work hours or to work more productively at night; (2) Use of

electrical equipment; (3) Increased sales due to the indirect effect of 'community changes'; for example greater nighttime activity in the area.

The Anderson and Turvey study suggests that in order to quantify this surplus the following procedure is advisable:

> By taking a representative sample of such activities, covering different types and size, it is possible to estimate a typical ratio of surplus benefits to actual amounts paid for electricity. From these ratios, and knowing the number of different types and sizes of business consumers, it is possible to calculate total surplus benefits directly. The level of these benefits rises commensurately with the number and total demand of these consumers. (Turvey and Anderson, 1981, page 165)

Third, in regard to the surplus benefits for the village as a whole, the relevant aspect is the willingnes of the local government to pay more for the lighting of the town or for other uses which the community uses due to RE. If not captured by the previous two points, the following could be some of these benefits:

a) Increased income of all paid businesses in the village due to electrification;

b) Establishment of new businesses;

c) Increase in village security and nighttime security, including more participation in local government activities.

iii) Externalities and Linkages

The following factors seem to appear to be important in determining whether or not businesses develop due to electricity (if benefits actually occur) (Brodman, 1982): (1) Size of business reflected in their income per year seems to have a strong relation with use of electricity and to reflect positively on the willingness-to-pay of the consumer; (2) Access to formal capital sources that contribute to the effective purchase of electrical

equipment and/or to the effective installation of the electric service; (3) For manufacturers and agricultural/food businesses, the kind of market outlets available to them is another important factor.

The responsiveness of business to what has been previously mentioned as 'complementary inputs' is a first order element to be assessed in any RE project. The findings in many of the studies already mentioned for Costa Rica, the Philippines, Indonesia, etc., all point out that a substantial part of the potential productive uses of electricity remain unfulfilled due to the absence of complementary inputs.

These complementary inputs and other factors suggested at an earlier point in this paper are what is usually called externalities. Following the approach suggested by Squire and van der Tak, (1981) these effects should be included in the economic analysis if they affect the achievement of the country's objectives, even though they are externalities.

In this same direction the 'forward' and the 'backward linkages' are also elements to be taken into account, because the project may result in lower demand and prices for competing products or services or higher demand and prices for complementary ones. Forward linkage effects may occur in industries that use the electricity, and backward linkages in industries that supply its inputs to the public utility (transformer, cable or pole industries). In both cases, such industries are encouraged or stimulated by increased demand and higher output or lower prices for their inputs. If these effects, due to externalities, are difficult to quantify then it could be helpful to internalize them by considering a package of closely related activities as one project.

A package for RE where the externalities are internalized could include credit, marketing and information components which account for the complementary inputs. It could also include the deals with local suppliers of construction materials for the RE project and the key farming, commercial and agro-industries that will be installed in order to take advantage of the electricity. In this case the RE project would be the central component of a wider rural development program.

iv) Other Benefits

Other effects that are important to the role of RE for economic development, if not already incorporated before, are the following (CECELSKI, 1979):

1) Social and Public Uses: Uses in vocational teaching schools, refrigeration for, or vaccine applications in, health clinics, pumping water, and others. This will point to further benefits for the poor and should thus be accounted for.

2) Employment: Employment benefits from productive uses of electricity in the rural area could be significant and are related to the expansion in output and the existence of a market for the output.

3) Foreign exchange savings due to the substitution of kerosene and diesel oil for lighting or autogeneration, if the central grid is not based on oil imports as well.

4) Demographic Effects: The effects of RE on levels of living, employment and income could help to reduce the impact of rural migration to cities.

5) Political Stability: Insofar as RE contributes to a perception of advancement. This is very much linked with the last point, i.e.:

6) Innovation and Modernity: This follows from the fact that electricity can be perceived as an instrument of modernity, innovation, and as a sign that things 'are moving' for the rural area.

3) Costs

In Chapter III, when we discussed the alternative between Rural Elect-

rification and Decentralized Energy options a first approximation to cost analysis was performed. The following paragraphs build on that previous section. The necessary steps to perform a cost analysis are the following (World Bank, 1975):

1) Determine the least cost means of meeting demand, including the decentralized energy option. The main alternatives are:(a) Public supply from a central grid (RE): (b) Public supply from a central grid but with different network layouts, equipment capacities and expansion plans; (c) Local autogeneration serving local microgrids.

2) Determine the possibility of a further reduction in costs by lowering design standards and accepting an increase in supply interruptions.

Both sets of costs are affected by: (a) changes in demand, (b), characteristics of the load factor, and (c) cost structure over time. Therefore in estimating the stream of costs the following items should be included:

1) Running Costs related to kilowatt-hour sales (fuel, variable maintenance and administration costs);

2) Capacity costs related to kilowatt peak demand referred at the generation, transmission and distribution levels;

3) Fixed overhead, including administrative costs.

The time component is relevant in RE because conditions will change over time due to the following trends: there is a large initial fixed cost, and equipment cost per unit capacity declines with size; costs decline as consumer density increases; the fixed administrative, billing and maintenance costs decline in relation to demand; and as the demand per consumer increases, load factors improve, therefore the investment in increased capacity (due to peak demand) does not rise as quickly as does energy demand. The latter characteristics are well documented for various countries (Turvey and Anderson, 2nd Ed. 1981).

All relevant costs should be 'shadow priced' in order to account for economic efficiency considerations. The costs can be further studied by dividing them into construction costs (investment), and operating and maintenance costs (annual costs).

i) Construction Costs.

The construction costs can be disaggregated into the following items:

a) Cost of Generation Stations

* Civil Works

* Electromechanical Installation.

b) Substations

* Line-section including all the protection, control and measurement equipment needed for transmission and distribution lines.

* Transformer-section including all equipment for protection, control and measurement.

* Base-section that includes the necessary equipment for the construction of the substation.

* Transformers

c) Transmission Lines

d) Distribution Lines

e) Consumer Connection

* Reduction transformers

* Measurement equipment

f) Public Lighting

All of the above costs should be disaggregated as follows:

* Imported Materials and Equipment
** Domestic Materials and Equipment
*** Labor Costs:
  - Skilled
  - Unskilled
  - Imported Labor.

ii) Operation, Maintenance and Management Costs.

In this section the disaggregation of each item should be carried out with respect to imported and domestic components and to labor.

a) Generation:

* Operation
* Maintenance
* Management

b) Transmission:

* Operation
* Maintenance
* Management

c) Distribution:

* Operation
* Maintenance
* Management.

Sections i) and ii) constitute the relevant information for evaluating the largest portion of the costs. However, as with the benefits it is important to explore other indirect costs that can be present.

iii) Other costs.

These costs can include the following which deal mainly with costs for the economy as a whole (economic costs):

a) Loss of production for right of way in transmission lines paths;

b) Loss in taxes or other collections from the sale of equipment powered by other alternative sources;

c) Unemployment caused by the use of equipment using electricity.

4) Consumer's Surplus and Demand Curves

This section expands and explains the concept of consumer's surplus (Boadway, 1979) which was introduced earlier. Consumer's surplus (CS) is calculated in order to estimate the change in benefits to an individual or household which results due to change in prices and/or income. Figure 2 shows a consumer's utility curve and budget line before and after a price decrease in good x. After the fall in P_x, the budget line rotates out and the consumer can reach the higher utility curve U_2. The objective is to calculate the utility change gained--this is the concept of CS. The CS measures the change in income needed to go from U_1 to U_2.

To do this, the change in quantity (from x_1 to x_2) is separated into an income effect and a substitution effect. The latter is represented by the shift along U_1 from x_1 to x_2. The income effect is reflected by the move from x_2 on U_1 to x_3 on U_2. The amount of income involved in this income effect is called the compensating variation and is equal to the amount $M^*\bar{M}$.

The same relationship can be shown with an individual's demand curves. To do this, we first need to explain 'ordinary' versus 'compensated' demand curves (see bottom Figure 2). The ordinary demand curve, D_o, is estimated by plotting all the points of price and quantity along the price-consumption line associated with a given income level. The compensated demand, D_c, curve is estimated by listing the quantities of good x demanded at various prices while compensating the consumer through income changes in order for him to remain at U_1. It is the same as the quantity and the slope at each point along U_1. Thus D_c differs from D_o by the amount of the income effect.

The compensating variation, $M^*\bar{M}$, is the area p_1abp_2, and is called the CS. Before the change in price, the amount of income spent on x_1 was p_1ax_10. With the reduced price of P_2, the amount spent would be p_2bx_20 if the consumer's income is compensated such that he remains on U_1. He saves p_1adp_2 on the amount x_1 due to the fall in price. He would have been willing to pay x_1abx_2 for the amount x_2-x_1, but he pays only x_1dbx_2; thus receiving a surplus of abd. Thus, his total benefits, net of expenditures, (i.e., net benefits) is p_1abp_2: this is the compensating variation which must be taken from him in order for him to stay on curve U_1. And area x_1abx_2, the total benefit, is the maximum amount which the consumer is willing to pay for the increase from x_1 to x_2.

Most applications calculate CS as amount p_1acp_2, using the ordinary demand curve; although this is an approximation of CS it generally yields only a small amount of error. The approximate total benefits are x_1acx_3, using the ordinary demand curve.

For the purpose of cost-benefit analysis, estimation of total benefits is more relevant and useful than the sole calculation of CS. These concepts have basically the same use. For example, if a consumer is choosing between two goods (x and y), and P_x falls, he will increase his consumption of x and reduce his consumption of y. It can be shown that the change in CS is equal to (the change in total benefits from consumption of x) minus (the change in the amount of y). The same principle works when there are more than one y-type good (i.e., goods which are substitutes for x).

The above describes what occurs when the price of one good changes, all else constant. Other types of changes are as follows.

i) When income changes (all else constant), the consumer's demand curve shifts out (or in as the case may be) parallel to the original curve. The change in welfare is equal to the increase in spending on consumption.

ii) Now assume that both income and price of one good (P_x say) change. The welfare change is calculated by separating the effects, estimating them as before, and then summing them up. This sequential approach is also utilized when calculating the welfare change due to a simultaneous change in the prices of two goods.

5. Benefit-Cost Analysis (CBA): It is important to state that usually in rural electrification the objective is to supply electricity to new users. This is a completely different situation in comparison to the expansion of the service to areas already served such as the increase in demand in an urban setting. Figures 3 and 4 depict this difference. As Figure 3 indicates a rural electrification project appraisal, is performed with the objective of determining whether the benefits of the capacity increment outweigh the necessary costs. The most difficult problem here is to accurately assess the benefits, given that the costs of electricity vary by time of day and by season, it is used for different purposes, and is supplied to varied markets. Gutierrez-Santos and Westley (1979) outlined four possible methods for benefit estimation, as follows.

(1) Financial Benefit Approach: This approach assumes that market prices are accurate measures of the actual economic costs, and thus simply estimate revenues and costs, and then compares the rate of return with the average. A tarrif level is set in order to determine financial viability. Yet such a beginning assumption is generally quite unrealistic.

(2) Consumer Surplus-Average Demand: Here the analyst estimates economic benefits by first making the assumption that electricity is a homogenous good serving only one market. After an aggregate demand curve is estimated, the area under the curve gives the total economic benefits; i.e., society's willingness-to-pay.

One problem with this approach is the difficulty involved in estimating the shape of the demand curve at one point in time. The usual solution is to estimate the price elasticity of demand and to assume a linear demand function. Furthermore, the analyst must estimate demand each year over the project's life. This is quite complicated given

that new projects coming into stream must be taken into account. The major problem, however, is that in practice utilities recognize the existence of different markets; aggregate demand is not estimated. And the aggregation of the demand curve here produces additional inaccuracies due to the demand variations over time (peak vs. off-peak). In addition, because most tariffs in developing countries fall below the LRMC, the loss to producers must be subtracted from the net benefits. Another key consideration is that in order to accurately measure benefits, the estimation would be the consumer's WTP (willingness-to-pay) for each additional unit, rather than an average market price. Finally, the analyst using this appraoch must take care not to attribute to the project the causality of certain benefits which were generated by other projects.

(3) Input-Output: This approach attempts to determine the amount of loss to the economy which would occur without the project; this amount is an estimate of the project benefits. This loss is estimated by calculating the costs of power interruptions: the costs of energy alternatives plus the loss in production. The production loss is estimated with the help of an input-output function. However, this approach probably yields results similar to those of the second methodology, and is fairly time consuming.

(4) Benefit Estimation by User Classes--Recommended Approach: This approach attempts to estimate consumer benefits according to tariff breakdown. The 'typical' breakdown lists five separate classes: (1) residential; (2) commercial; (3) industrial: (a) agro-industrial and (b) other industrial; (4) public lighting and other public uses; and (5) foreign (exports). For classes 1, 2, and 4, benefit estimation is reflected by consumer WTP. Class 3 benefit estimation is based on cost elimination, and exports of electricity are valued as the value of foreign exchange earned as their result.

The following sections describe the methodology in more detail.

I. Residential and Commercial Users.

The procedure is to first estimate a demand equation and to derive a demand curve for each year of project life, and then calculate the WTP as the area beneath the demand curve. This method is more appropriate than the cost savings (elimination) method, because it accounts for quality difference and is more appropriate given that electricity has more specific uses in this category (i.e., fewer substitutes).

The dependent variable in the demand equation is the average

electricity consumption. Other variables (may) include the following:

1. Real price of electricity; the marginal price.

2. Price variable which measures the income effect; this equals the extra amount paid on the blocks preceding the final marginal block rate paid.

3. System type.

4. Time since connection to the system (proxy for appliance stock).

5. Degree days or average temperature.

6. Amount of time reflecting service malfunction.

7. Service time per year.

8. Stock and price of complementary electric capital goods (e.g., lightbulbs, radios).

9. Costs of substitute energy sources and their fuels.

10. Indicators of the degree of urbanization

11. Socio-economic-demographic variables

In deriving the demand equation, care must be taken to use real prices and income. Then, the demand curve is obtained through use of the resultant demand equation. Now the consumer's WTP for electricity supply increases can be estimated for both new and existing users (see Figures 3 and 4).

To measure benefits over time, the analyst must judge the degree to which the demand curve shifts (and the direction). This is done with the help of the demand equation and judgmental factors. Then WTP is calculated as usual.

Finally, in estimating the demand equation and the WTP, it is important to make some judgment about the likelihood and extent of power losses. Reliability of service is a key factor in the quality of electricity. If

many blackouts occur after the original demand equation was estimated, then the WTP will fall, and vice versa.

II. Industrial Users.

i) Approach 1: Industrial Demand.

This follows the same basic procedure as that for residental and commercial users. However, the demand equation proves to be more difficult to estimate for industrial users, due to the more varying and diverse uses in industrial demand. Because these uses may be as many as there are products and technological processes, if output composition changes, the previously estimated aggregate demand equation would be completely inaccurate. It seems that the end result is generally a short-run industrial demand curve which is steep and inelastic and a long-run demand curve which is discontinuous.

ii. Approach 2: Cost Elimination Approach

This approach is easier than the above and presumably at least as accurate. The method proceeds as follows.

Analyze only those industries which consume a great deal of electricity; this narrows the field. Then judge whether electricity is a viable substitute now or in the near future, in existing production processes; or whether the industry is unable/unwilling to switch over soon. Lastly, the amount of cost elimination is estimated. These would include fuel costs, differences in capital costs, input costs, and revenues, and any scrap or conversion costs required for the switchover.

To estimate the cost elimination benefits for producers currently

without electricity, the cost savings are based on the existing fuel and technology being used. For future electricity users, the savings are based on the next cheapest production method, where the limit on production costs is always set at the c.i.f. import price of the good being produced.

III. Public Lighting and Other Public Uses

Given that this class demand is very small as compared to the residential class, the analyst need not estimate a separate demand equation and curve. Instead, he or she calculates the ratio of kWh consumed for public services to kWh of residential demand. The the WTP for public sevices is estimated as the above ratio times for residential electricity service.

This means that public uses are seen as a certain percent shift (the ratio amount) of the residential demand curve, and WTP is estimated at the residential marginal block price. The assumption here is that benefits from electricty for public sevice are equivalent to the benefits generated by the supply of residential electricity.

IV. Export Benefits.

The benefits of electricity exports are equal to the value of foreign exchange earned.

6) Criteria for Project Acceptability

The compact result of the cost-benefit analysis is to obtain an internal economic rate of return (IERR) equal to or higher than the opportunity cost of capital and to obtain a positive net present value (NPV). These are basic criteria for project acceptability. However, if some of the benefits are not completely accrued (e.g., surplus benefits of households

and others), the IERR can be lower than the opportunity cost of capital. How low can it go and still leave the project acceptable? Following the World Bank's 1975 study suggestions, the following arguments should be taken into account in assessing the appropriate lowest level for the IERR:

i) RE is usually placed within a productive context in the rural areas. On a good project with strong demand from consumers, the IERR should easily exceed the opportunity cost of capital. Nonetheless, if the IERR is low, it could be a sign that demands for productive uses may be low, and that the contribution of RE to raising production is rather limited.

ii) A low IERR may signal that insufficient attention has been paid to the complementary inputs such as credit and access to markets (roads, bridges, commercialization, etc.). 'Electricity is only one of many factor inputs needed for development. If the complementary inputs are neglected, the contribution of electricity to development is diminished.' (World Bank, 1975, pp. 43)

iii) Low economic returns can indicate that benefits are not that extended or that the costs of actually materializing the demand is high. This can easily lead to disillusionment among investors and consumers.

iv) When there is a strong demand from households and businesses, a low IERR probably indicates that tariff rates are wrongly structured or too low.

v) A basic reason for a low IERR is a low-level of use for the RE project that usually has a high initial cost. In such cases, it is possible that a least-cost solution has not been found.

vi) A low IERR could also signal that the investment is inefficient, that it is not a priority for the community and the resources could be put to work in a higher priority project.

The six points above should help in determining the acceptability of a project. They are also the key elements that can explain the origin of low IERR.

7) Deadweight Losses in Benefit Extimation

There are some problems, however, in the straightforward application of the willingness to pay method in many actual situations. In the basic

theory of benefit-cost analysis when an 'economic' analysis is performed it is assumed that each of the prices used is an economic price. In order to do this many adjustments usually have to be made. Once these adjustments are made to both the benefits and the costs the analysis can be carried out. In the usual situation the actual prices charged for project outputs are not considered explicitly except in their impact on project benefits. In the situation where we are evaluating the benefits in terms of consumer surplus, however, the price charged is an important determinant of the level of the consumer surplus. In this case, we either have to evaluate the benefits as though marginal cost pricing would be used or we have to deduct the 'deadweight' losses from the actual (non-efficient) price charged.

This situation is a fairly common situation in the provision of electricity in the rural areas of many developing (and developed) countries. For political and social reasons many governments are committed to the provision of electricity in the rural areas well below marginal costs. The discrepancies can be very large - for instance in Costa Rica the marginal cost for rural electricity is 6.18 colones per Kwh and the tariff is 1.61 colones per Kwh. Similar fivefold discrepancies are found in many other countries. In this case the consumer surplus of the user is larger than it would otherwise be - by the area BDEC in Figure 5 - than under marginal cost pricing - area ABC in the figure. Associated with this transfer of benefits from the producer to the consumer is a corresponding 'deadweight' loss - area CEF in the figure.

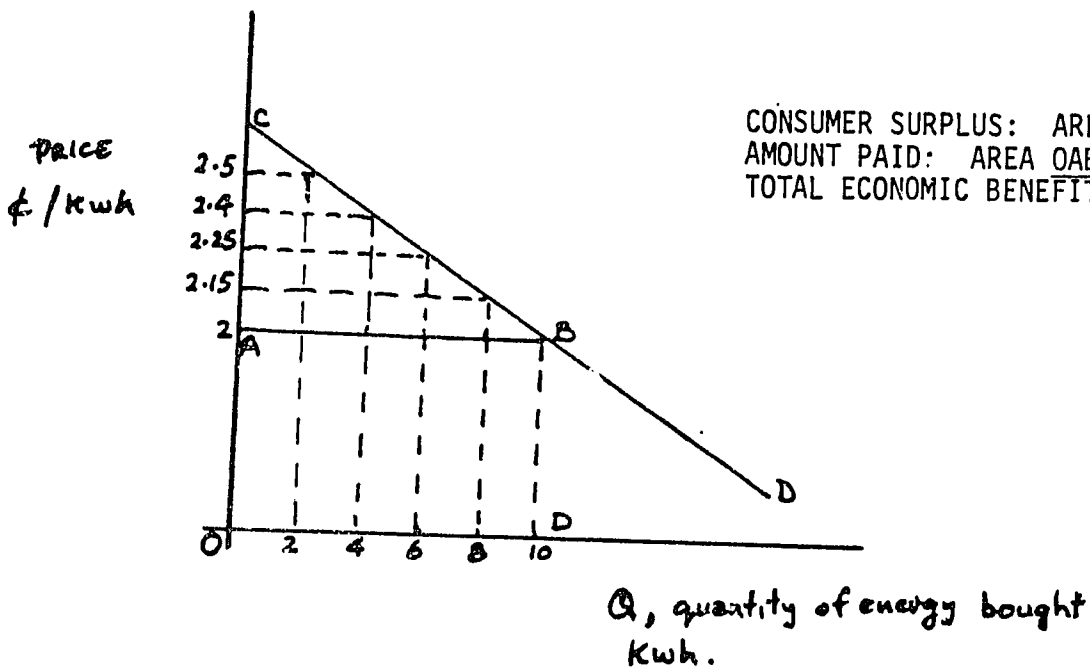
The correct estimate of total benefits to use in this case is, therefore, the consumer's willingness to pay, area AGHE, minus the deadweight

losses, area CEF. In a forthcoming paper Rogers, Doryan and Umana (1986) estimated the relative magnitudes of the deadweight loss as a fraction of the total willingness to pay as a function of the assumed elasticity and the shape of the demand surves. For elasticities of -0.3 to -0.7 with a linear demand curve the deadweight losses ranged from 0.14 to 0.44 of the total willingness to pay benefits. For constant elasticity demand curves the range was from 0.27 to 0.50 of total willingness to pay.

With large differences between the marginal cost and the tariff substantial amounts of the total benefits are lost to society as deadweight losses. If these are considered the economic attractiveness of the project may suffer considerably.

FIGURE 1

ECONOMIC BENEFIT OF AN OUTPUT



CONSUMER SURPLUS: AREA ABC
AMOUNT PAID: AREA OABD
TOTAL ECONOMIC BENEFIT: AREA OCBD

FIGURE 2

CONSUMER'S SURPLUS AND DEMAND CURVES

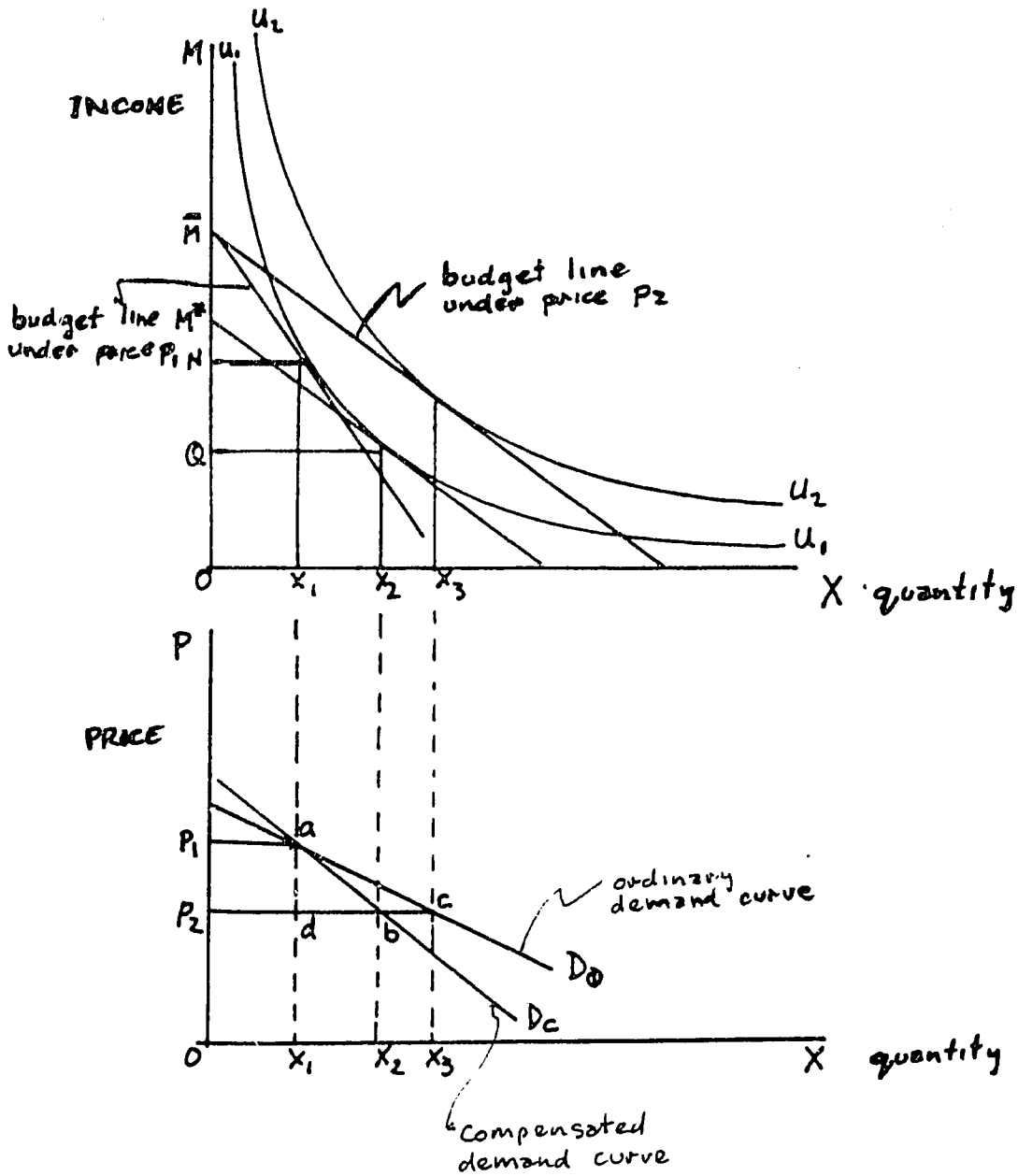


Figure 3
Electricity Benefits for New Users

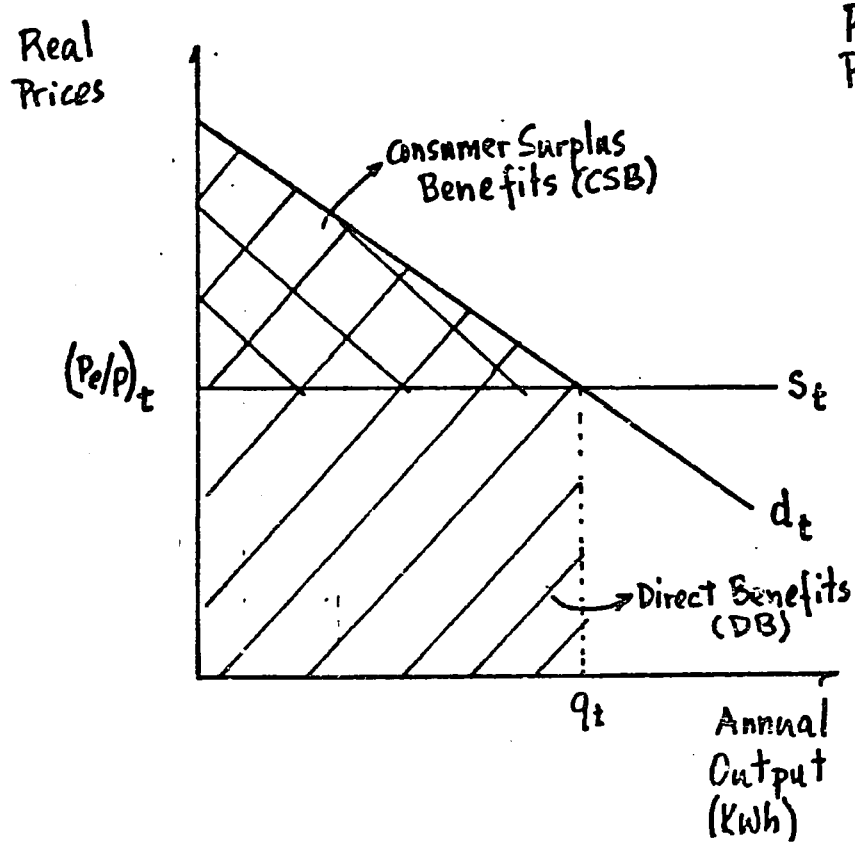


Figure 4
Electricity Benefits for Existing Users

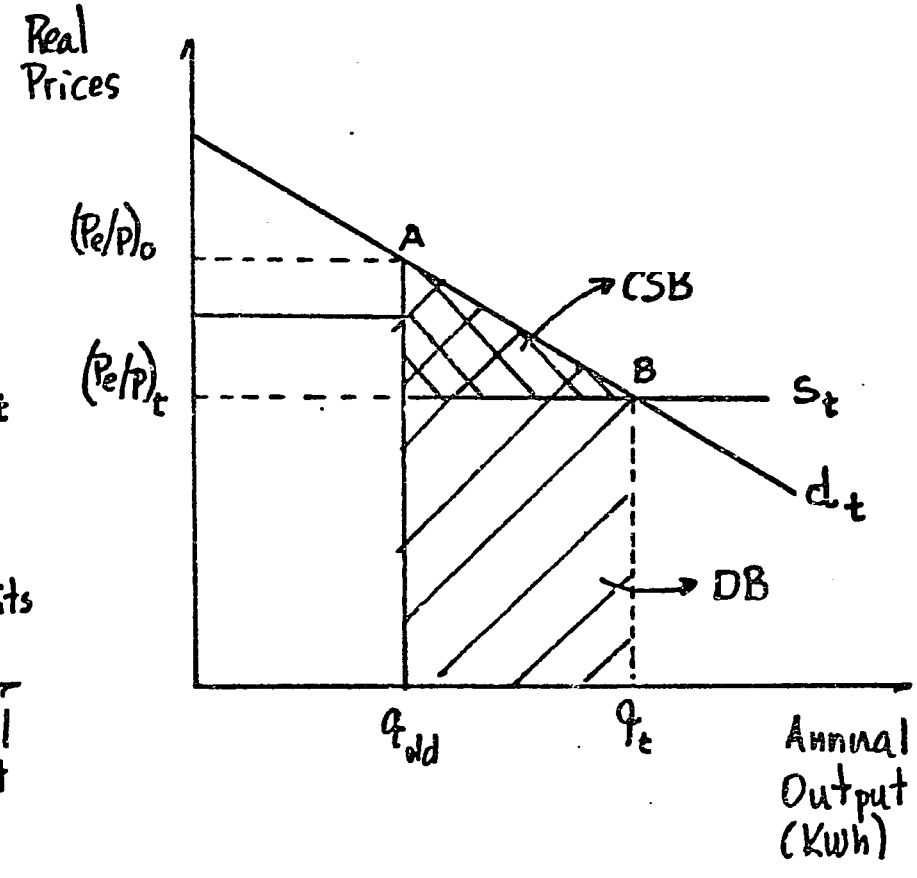
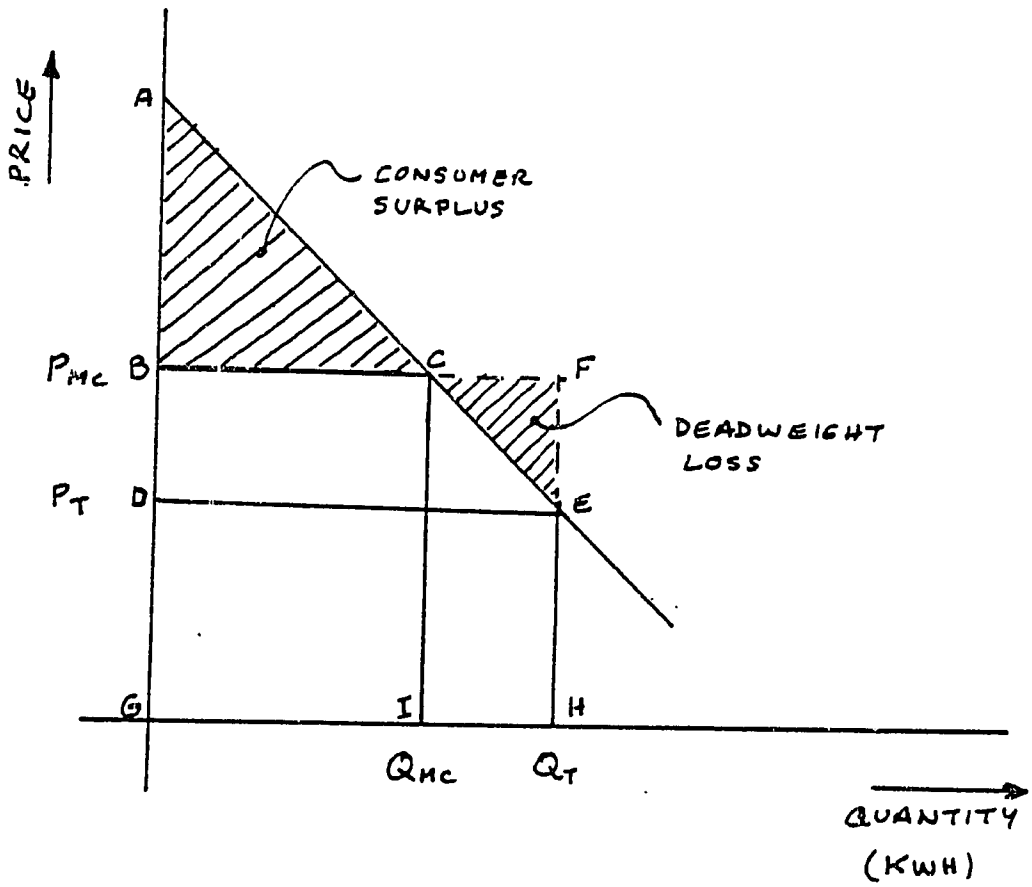


FIGURE 5
BENEFITS AND LOSSES FROM CONSUMPTION
OF ELECTRICITY BY RURAL HOUSEHOLDS



Chapter V

A FRAMEWORK FOR RE ANALYSIS: METHODOLOGICAL SETTING

1. A Method for Ex-Ante Analysis of RE

The basic justification for Rural Electrification Projects range from their social importance (insofar as there is the need to raise the standard of living in the rural areas and to provide a counterweight to urbanization) to other arguments such as that of seeking to increase the production of small industrial activities for rural areas. So RE has always lain between two objectives: social vs. productive. The evaluation of a RE project should determine the project's contribution toward reaching the objectives articulated by the government, utility or cooperative.

Government objectives are usually not completely explicit, or at least they are not necessarily systematized. Therefore, the RE analyst must use a method that incorporates by stages the different objectives of the government concerning the financial, economic, social or political aims pursued within the project. This stage-by-stage method also has the advantage that the desirability of a project can be measured against different objectives. Data limitation can be overcome by limiting the scope of each stage or by evaluating the project just for some, but not all, of the objectives.

The projects should be selected within the context of a wide variety and number of projects. Actually, the basic economic problem is that of allocating resources to a variety of uses, and the precise purpose of project appraisal is to evaluate each alternative in a comprehensive way; assessing the benefits and costs and reducing them to a common yardstick

capable of being used to determine if benefits outweigh costs. The <u>real-politik</u> of project appraisal in RE must deal with two problems:

i) Although in some LDCs there are methods of defining the implementation of projects which are based on a large array of proposals, the most common project definition considers a project by itself, or at the most in comparison with a few alternatives which deal with the same basic goal (RE, for example). Therefore the method used must be flexible enough to give relevant information even if used to assess one single project.

ii) Usually governments will not have clear and stable objectives. A set of elements converge in the decision process; these decisions can change and policy objectives will have to be redefined (Killick, 1976). Planning offices throughout the world are full of proposals that were abandoned because they were not in accordance with new policies. Therefore, the method used must be able to state the policy objectives at various levels and must also be easily re-tuned to match the changing moods of the government policy decision makers.

Before a more direct reference is made to the method for RE project appraisal it is useful to define the scope of benefit/cost analysis. As pointed out by Annandarup Ray (1984), this methodology can be defined only by the effect of the project on some fundamental objectives of the economy, that then constitute the common yardstick to assess the various effects of a project. Hence by measuring both costs and benefits with the same yardstick, one can assess the net impact of the project on the chosen objective.

Traditionally, benefit/cost analysis postulated that, for example, the objective of the country is to maximize the present value of the stream of consumption changes that the use of its resources in a particular project will lead to. The measurement of consumption changes at any point in time is made by summing all consumption changes, regardless of the characteristic of the groups to which they accrue, that is, to aggregate equally weighted consumption. The comparison between present and future changes is made in two ways:

a) If the private capital market is a perfect one (no taxes, subsidies) the market interest rate would be an appropriate rate of discount. In this scheme, for the economy to be on an optimal path, the maximization of national income, that is, aggregate consumption (C) and investment (I) is the rule. At the margin under this assumption both the investment and consumption are equally valuable.

b) However, when there are market distortions, investment and consumption are not equally valuable at the margin and a specific weight must be introduced. Instead of maximizing the change in C and the change in I, now there is the need to maximize $\Delta c + a \Delta I$, where a is an appropriate weight on investments.

This traditional approach evades discussion of the key problem of development economics, i.e., the trade-off between equity and efficiency. As stated by Ray:

> a two percent rate of growth with an even distribution of benefits is hardly the same as a two percent rate of growth with a highly uneven distribution. Tradeoffs between growth and distribution pose important policy choices that cannot be dismissed by putting forward 'trickle down' or similar theories of the development process. (Ray, 1984; p. 10)

Chenery in his well-known work, Redistribution with Growth (1974) reminds us that the most 'efficient' development strategy often leaves the present inequities of income distribution unchanged and may even make them worse. In the methodology that we suggest for evaluating investments in rural electrification this problem must be dealt with explicitly.

We will not analyze in a systematic way all the different techniques available for benefit/cost analysis, only a short introduction is presented. For a useful study guide the interested reader can consult the following references: Ray, 1984; Boadway, 1979; Jenkins, 1985; Marglin, 1962. Weiss, 1976; makes a comparison between the various methods.

It is the opinion of the authors that the concerns expressed in the previous paragraphs are broadly taken into account best in the methodology developed by UNIDO (UNIDO, 1978). The method has the following practical utility when applied to RE:

a) The method is useful where market prices have been distorted by heavy reliance on protection, subsidies, etc.

b) When market price distortions cannot be removed by direct policies, one way of improving economic efficiency and social equity is to make investment decisions based on the shadow prices that reflect the true value to the country of its resources. For example, LDC's problems with the scarcity of foreign currency given the debt crisis is one element that must accurately be incorporated in the concept of the shadow price of foreign exchange.

c) The method is not only concerned with the efficiency of the use of resources, but with the inequities of income distribution. This

aspect is relevant for RE projects because they are usually intended to contribute to the well-being of the rural population and are assumed to have a trickle-down effect.

d) The method must deal with the assignment of values to future consumption and present investment in terms of present consumption. In other words, it asks whether or not today's consumption should be sacrificed for investment that will yield even more consumption in the future. This is relevant for projects that generate benefits to groups who save very little out of additional income, especially in countries short of capital because of a gap between actual and needed savings. This is the case with RE projects.

e) The method recognizes that trade barriers are going to prevail and that benefits must be maximized within this non-optimal environment. Therefore it is necessary to look for what the consumers are willing to pay for goods in the domestic market. This implies that the domestic rather than the foreign currency is chosen as the unit of account or numeraire. For RE, where most likely electricity is a non-tradable good, this method proves to be a very straightforward one.

f) The method has been extensively applied for other types of investments and it has been used in India for assessing RE, with promising results (Venkatesan, 1982).

2) Introduction To Benefit/Cost Analysis

Benefit/cost analysis is a widely-used method for determining the advisability of undertaking a project, to choose among projects, and to

determine the size of projects. Simply put, it consists of deriving a project's net benefits, and then accounting for time through the use of a discount rate. In addition to the financial appraisal, an economic analysis will take into account the 'true' economic values of the various costs and benefits. Finally, a social analysis can incorporate a distributional weighting system; this analysis evaluates the project from the viewpoints of various societal groups.

The basic rationale behind benefit/cost analysis is that the project which makes the best use of available scarce resources is the one which should be implemented. Under certain conditions (for certain project types and restrictions), benefit/cost analysis can reduce project information into several common measures (such as present value, or the rate of return). Then, various projects or project sizes can be directly compared.

Present Value

The most useful criterion of benefit/cost analysis is the present value, or rather the net present value, (NPV), of benefits over costs. While other criteria such as the internal rate of return, payback time, and the benefit-cost ratio are often used in project evaluations, they are generally less straightforward and less reliable than the NPV criterion.

The method is as follows: the analyst will arrive at the net benefits of the project by subtracting total costs from total benefits <u>for each period</u>. Next, the opportunity cost of funds to be used in the project is accounted for through the application of a discount rate to the stream of net benefits. This opportunity cost is the rate of return which the funds would have received in their best alternative use. Thus, the discount rate

incorporates the time value of money and the value which would have been earned in the best alternative use. For a project such as rural electrification, the discount rate will be opportunity cost of public funds.

Once the discount rate is chosen, it is a simple matter to obtain the net present value. The concept is based on the fact that 'a dollar today is worth more than a dollar tomorrow.' For instance, if the annual interest rate is 10% and you deposit $100 today, next year you will receive ($100) x (1.1) = $110. By the same token, what is $110 in year 1 worth now? It is $110/1.1 = $100. The general formula, in terms of benefits and costs, is

$$NPV_r^{o} = \sum_{t=o}^{n} \left[\frac{B_t - C_t}{(1 + r)^t} \right]$$

where NPV_r^0 = NPV in year 0 at rate of discount

n = number of years of project life span

B_t = Benefits in year t

c_t = Costs in year t

r = discount rate

The choice of discount rate is of key importance; a slight change in this rate can make the difference between the acceptance or the rejection of a project. The higher the discount rate, the lower the NPV of a given project (and vice versa). And when a project's benefits are more heavily distributed toward the end of the project's time-span, the lower the NPV will be (and vice versa). (See Figures 1 and 2) Thus it is critical to choose an accurate discount rate--one which reflects the opportunity cost of public funds.

Finally, the NPV rule states that the NPV of a project must be greater than or equal to zero in order for the project to be acceptable. Secondly, when choosing among alternative projects, that project with the highest NPV is the one to be undertaken. In sum, the objective is to maximize the NPV, whether it is one project or several that are under consideration.

Social Discount Rate (SDR)

The social discount rate (SDR) reflects the opportunity cost of public funds. This rate may be arrived at through several methods. Essentially, the various approaches differ according to the consideration given to foreign private investment. The UNIDO methodology uses the consumption rate of interest. This looks at the marginal consumption returns from public sector projects only, thus there is no intent optimally to allocate resources between projects in the private and public sectors. The consumption rate of interest allocates funds to the best public sector projects.

Harberger (1973) has put forth a method for calculating the SDR whereby this discount rate is composed of a weighted average of the private sector's marginal productivity of capital and the rate of time preference for consumption. (Jenkins, 1985 p. 6-2). Under Harberger's method, the consumption and investment foregone in the private sector are accounted for, along with the extra cost of external borrowing needed due to the growth in the public sector. (In addition, it must be kept in mind that the social discount rate used for a project should be specific to that project; the rate will vary according to the type of project. The economic opportunity cost of public funds is not the same in all cases. As an example, if the public sector is undertaking a private sector-type activity, such as a petroleum processing plant, then the rate of return should be the

same as that received in the private sector.)

The social discount rate under Harberger's method is based on the economic opportunity cost of government borrowing, as this is generally where the government finds its incremental funds, rather than through further taxes, grants, etc.

In sum, then, Harberger's social discount rate in contrast to the UNIDO method, will be calculated as a weighted average of the private sector's marginal productivity of capital and the rate of time preference for consumption.

Shadow Prices and Economic Analysis

The determination of shadow prices is key to an accurate economic analysis. Shadow prices are used in the adjustment of the financial analysis to form the economic analysis. They are used when the financial, or market, prices do not reflect the true economic value of a cost or benefit.

Shadow prices measure the economic prices of a project's inputs and outputs. Rather than just taking the financial evaluation of benefits, the shadow price of a benefit will reflect the consumer's willingness-to-pay as measured by the demand curve. And the costs of inputs will be derived from the cost to the rest of the economy of its foregone consumption due to the project's existence. The calculation of shadow prices will remove the distortion of taxes, subsidies, and market imperfections from the financial prices.

What are the distortions which may be present in the financial, or

market, prices of inputs and outputs? Many of these distortions can be classified as either taxes or subsidies. In the markets of developing countries, these distortions between financial (market) prices and economic prices are often present. For example, the government may subsidize the importation of machinery in order to promote a domestic industry. In this case, the economic cost would exceed the financial cost. And taxes on goods cause the economic benefits of outputs to exceed the financial benefits.

To estimate the true economic prices of inputs and outputs in distorted markets, the analyst proceeds using the concepts of producer and consumer surplus as indicated earlier. These surplus values are derived from the supply and demand curves; i.e., the economic price is not what is actually paid (the financial price), but the price at which the consumer values the good (his willingness-to-pay) or, in turn, the price which reflects the true cost of an input. In order to expand the analysis to include distributional aspects, though, it is necessary to calculate the amount of distortions (taxes, subsidies, etc.) and to record 'who gets what?' and 'who gives what?'

Further distortions arise due to imperfect markets such as the existence of monopolies, oligopolies, etc. Or the government may be fixing prices. In these cases, the analysis becomes more complicated, but the same principles hold--the true economic price is sought, often through the discovery of the black market price. Again, the analyst must then measure producer (and/or consumer) surplus.

In developing countries, especially, labor markets are often characterized by non-competitive situations such as surplus labor and segmented

labor markets. These conditions must be assessed in order to derive the economic wage rate. For instance, if there is surplus labor in a region, then the actual wage paid will be greater than the economic price of labor. On the other hand, if there is a labor shortage, such as may exist for a certain type of skilled labor, then the economic wage rate will exceed the financial wage rate.

How can we measure the economic wage rate; i.e., the economic opportunity cost of labor? One approach is to use the private wage rate as a measure--this will account for the foregone production in another project/business, plus any margin due to incentives (such as location, job type, income taxes, etc.).

Another critical measurement is that of the economic price of foreign exchange. It is often the case that the official exchange rate does not reflect the true economic value of a country's currency--the home currency may be either overvalued or undervalued. The correct economic exchange rate must be used in the economic appraisal when both non-traded and traded goods are involved; this economic exchange rate will be used to convert the traded goods international price levels so that they are in the same terms as the non-traded goods price levels. In addition, taxes and subsidies on foreign exchange may complicate the determination of the economic exchange rate, as these distortions do for any input or output.

Framework for Benefit-Cost Analysis

First the financial prices must be found and the financial appraisal made. Then the economic, or shadow, prices must be determined for all inputs and outputs. 'Conversion factors' (CF) must be calculated; the CF =

(economic price)/(financial price). The CFs are used for the ease of performing the analysis. The economic values are then derived:

$$\text{economic value}_i = (\text{financial value}_i \times CF_i).$$

In addition, adjustments will be made for the values of tradeable goods, where

$$\text{economic value}_i = (\text{financial value}_i \times CF_i \times (E_e/E_m).)$$

Here, E_e is the economic exchange rate and E_m is the market, or financial, price of foreign exchange. Once all of the economic values are listed, the costs are subtracted from the benefits, <u>for each period</u>, in order to derive the net benefits. Finally, the NPV is calculated, using the social discount rate, since the project under consideration is in the public sector.

<u>Distributional Analysis</u>

Once the economic and financial analyses are complete, a distributional analysis may be performed. This simply breaks up the analysis into the relevant segments--for example, one for the labor market(s), one for the government, one for the economy as a whole, etc. These segments are fairly arbitrary, but for a specific case they are chosen with the social goals of the government in mind. The distributional analyses first adjusts for the distortions between the financial values and the economic values. For instance, if a rural household receives $100 in economic value and $60 in financial value from a rural electrification project, then $40 will go in the benefits section of the rural household analysis. This same procedure will be followed for all sectors and all benefits and costs. The

analyst may then determine weights for the various sectors, according to the government's, or society's, preferences. For example, the poor would receive more weight than the government agency responsible for the project.

Finally, it should be kept in mind that benefit-cost analysis is accurate and useful only within the context of an overall project appraisal--that is, an appraisal which begins with project definition and design, and which includes feasibility studies and evaluation.

3) The Five Stages of Ex-Ante Analysis

An ex-ante benefit-cost analysis can be disaggregated into the five following stages (UNIDO 1978 p. 3).

1) Calculation of financial profitability at market prices. This stage must have a good technical analysis as a precondition. (Financial Analysis)

2) Shadow pricing of resources to obtain the net benefits at economic prices. (Economic Analysis).

3) Adjustment for the project's impact on savings and investment. (Inter-Temporal Analysis)

4) Adjustment for the project's impact on income distribution. (Intra-Temporal Analysis)

5) Adjustment for the project's production or use of goods whose social or policy value are less or greater than their economic values. (Social and Policy Preference Analysis)

This five-stage analysis is a realistic one, because it allows a variety of insights into the merits of a project and allows presenting them in a clear way that helps decision makers to assess the project and its various impacts. Each of those steps are discussed in more detail below.

Stage One:

The financial profitability produces an estimate of the project's financial profit; i.e. the net present value of the projects when all inputs and outputs are measured at market prices. Three basic tables are the basis for the entire financial analysis (UNIDO, 1978, pp. 81-83): the financial income statement, the cash flow statement and the balance sheet.

The financial income statement is used to record the inputs and outputs of the project, all measured at market prices. The net cash flow is derived from the previous table by standard accounting procedures; i.e. it is equal to the gross cash flow (operating profit before interest and taxes plus allowance for depreciation) minus capital investment. Finally the financial balance sheet breaks capital costs down into various categories that can be helpful for further shadow pricing of capital investment in the later stages.

Stage Two:

This stage produces an estimate of the net present value of the project measured at efficiency shadow prices instead of market prices.

> Shadow prices are determined by the interaction of the fundamental policy objectives and the basic resource availability. If a particular resource is very scarce (that is, many alternative uses are competing for the resources), then its shadow price, or opportunity cost (the foregone benefit is the best available alternative that must be sacrificed), will tend to be high. If the supply of this resource were greater, however, the demand arising from the next best uses could be satisfied in decreasing order of importance, and its opportunity cost (or shadow price) would fall. Market prices will often reflect this scarcity correctly, but there is good reason to believe that in less developed countries imperfect markets may cause a divergence between market and shadow prices. Such divergences are thought to be

> particularly severe in the markets for three important resources: labor, capital and foreign exchange. (L. Squire and H. van der Tak, 1981, p. 16)

The derivation of shadow prices for labor, capital and foreign exchange will not be dealt with extensively in this monograph because there is an extensive bibliography on them (UNIDO, 1978; Squire and van der Tak, 1981; Little and Mirlees, 1974), nonetheless, a short comment is in order.

For labor, the analyst must consider the impact of the project on the rest of the economy when it hires labor:

1) the project may take labor away from other users;

2) it may stimulate the participation or 'production' of new workers, and

3) it may cause the importation of workers from other countries.

In the first case it is reasonable to assume that they are being paid a competitive wage in both the previous job and in the project; therefore their wage reflects fairly well their marginal product and hence their economic value. Thus there is no difference between shadow and market wages. In the second case if the workers were previously unemployed it would be reasonable to assume that the production that would be given up is virtually zero; hence their shadow wages will be also zero. However, as the UNIDO Guide recommends, since the workers will be unwilling to supply their labor for less than some minimum wage, a positive shadow wage is appropriate; this would be the minimum wage in urban areas or in rural areas, whichever is applicable. In the third case, the workers hired from abroad generally have an economic cost which should be determined accordingly.

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The analyst must consider two occurrences with respect to capital. First, when an investment of $x is made, the $x is converted into real physical assets that are incorporated in the real financial cash flow as investment. Pricing of the asset component is exactly the same as for any other resource, for each case (labor, tradeables, non-tradeables, etc.), the adjustment factor is calculated, and an appropriate economic adjustment is added to or subtracted from the net present values of the capital investments at market prices. Second, in making the investment, the investor removes the $x from the national pool of savings that eventually could have been used in alternative projects. There is the need to measure the opportunity cost of capital, the benefits foregone by having invested in the project being appraised and not an alternative one. The UNIDO Guide suggests that 'To the extent that capital for the project is generated from additional savings, its economic cost is the price, or rent, savers must pay to forgo an additional unit of present consumption, the consumption rate of interest (CRI)' (UNIDO, 1978, page 41).

A theoretical formula for deriving the CRI is as follows:

$$CRI = ng + p$$

where n = elasticity of marginal utility of consumption with respect to changes in per capita income;

g = annual growth of average per capita income;

p = pure time preference

In practice, instead of attempting to estimate these somewhat esoteric parameters, the analyst 'at the bottom' can prepare the project appraisal indicating that the internal rate of return is Y% and present it to the

planners 'at the top'. If accepted, CRI is around Y%.

The adjustments for capital and labor constitute what has been called the Preliminary Economic Adjustments. This is labelled preliminary because the effect of foreign exchange has not yet been taken into account.

For foreign exchange, the adjustment needs to be applied only to those goods that were valued at border prices, since input and output shadow prices with reference to domestic consumer willingness to pay or cost of production already implicitly include a premium on foreign exchange. The UNIDO Guide describes the foreign exchange shadow prices in the following way:

> Since the UNIDO method uses domestic currency as the numeraire, the project's foreign exchange impact must be identified so that the project's net present economic value may be adjusted by an appropriate premium, assuming, of course, that foreign exchange is more valuable than indicated by the exchange rate. This process increases those economic-efficiency values that were measured in border rupees (border prices in dollars multiplied by the market exchange rate) by the percentage premium on foreign exchange, a factor that roughly indicates the level of protection in the economy, i.e. the difference between average market and average border prices. This adjustment makes the prices established with reference to border prices compatible with prices based on domestic consumer willingness to pay in the protected market. If the foreign exchange impact is positive, the net present value before adjustment will be increased by the adjustment; conversely, if it is negative, the net present value will be reduced. (UNIDO, 1978, p. 46)

A simple formula for calculating an average shadow exchange rate (SER), based on a given year's data is as follows:

$$SER = OER\ [(M+Ti)+(X+Sx)]/(M+X)$$

where OER = official exchange rate;

M = c.i.f. value of imports;

X = f.o.b. value of exports;

Ti = import tax revenues;

Sx = export subsidies.

Once the shadow price for foreign exchange has been determined, the adjustment factor for foreign exchange (AFf) can be calculated. It is the premium of foreign exchange over the market rate and it is equal to the shadow exchange rate (SER) divided by the market exchange rate minus one. The adjustment for the value of foreign exchange determines the shadow price fully on the basis of the domestic local currency. With the inclusion of the adjustment for foreign exchange, the economic adjusted values are obtained.

The values of shadow prices for labor, capital and foreign exchange needed for RE analysis can also be obtained directly from estimations performed by the Ministry of Planning in most countries.

Stage Three:

This stage is designed to determine the amount of income gained or lost by different income groups due to the project, to evaluate the net impact of these gains and losses on savings given the marginal propensity to save for each of these groups, and finally, to place a premium on the additional savings the project will induce by its impact on income distribution. To accomplish this stage an adjustment factor for savings (AFs) is calculated in order to measure the percentage by which the social value of the local currency (rupee, pesos, etc.) invested exceeds that of one consumed. The UNIDO Guide suggests the following formulae:

$$AFs = [(1-s)q/(i-sq)] - 1$$

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$$AFs = [MPC(MPcap)/CRI-MPcap(MPS)] - 1$$

where: MPC = 1-s = marginal propensity to consume

MPS = s = marginal propensity to save

MPcap = q = marginal productivity of capital

CRI = i = consumption rate of interest.

In practice planners, rather than working with the previous formula, set the premium on savings more on the basis of a subjective valuation of the difficulties the country has in raising the capital required for its investment program. An adjustment of 0 to 20% is recommended by the UNIDO Guide.

Stage Four:

This stage provides the analyst with a means of placing a value on the effects of a project on income distribution among income groups and among regions. Once the impact has been valued by the adjustment factor suggested by the UNIDO Guide, they are added (+ or -) to the net present value found at the end of stage three in order to produce the <u>social net present value</u> of the project.

Stage Five:

This stage takes into account what can be called the socio-political merit or demerit of a project. The procedure is similar to the ones in the previous stages. First its socio-political value is estimated so as to reflect the concerns and weights assigned by the government to the project or to aspects of it. Next the adjustment factor (premium for merit goods,

penalty for demerit goods) is calculated. Its efficiency price is then multiplied by the adjustment factor to obtain the adjustment. This adjustment is added algebraically to the net present value of stage four, and the result is recorded in the project summary matrix. The advantage of this method is that it incorporates the real concerns and aims of the government, thereby generating a series of estimates of the project's desirability. This makes it possible to see the exact cost in terms of net present value or rate of return foregone by pursuing objectives other than that of pure economic efficiency. As the UNIDO Guide concludes: 'Once this information is available, the decision maker can weight the costs against the anticipated social benefits and make his choice.' (UNIDO, 1978, p.77)

4) Case-Study: The Second Stage of Rural Electrification in Costa Rica

In order to illustrate the application of the methodology suggested in the present chapter a numerical example is developed in the following pages. This example is based on data from the Second Stage of the National Plan on Rural Electrification of Costa Rica (ICE, 1979).

Stage 1: Financial Analysis.

In Table 1 the Financial Cash Flow for the Investment is presented. Each item is separated into local resources and imports. The investment covers the period 1979 to 1983.

In Table 2 the financial cash flow for Maintenance and Operation is presented. The life-span of the project is 30 years. The values from 1993 to 2013 are considered a perpetuity that is lumped in the year 1993 and discounted to the present.

In Table 3 the financial cash flow of revenues is presented. The revenues are calculated from demand forecasting studies made by the Costa Rican Institute of Electricity at the time of the project appraisal.

Finally, the summary of the financial cash flow is presented in Tables 4 and 5. The data for revenue and net cash flow are shown in Tables 6 and 7. The calculations of Net Present Values and the Internal Rate of Return (IRR) are shown in Table 8. The IRR is 3.0% which is considerably lower than the values found for other alternative market opportunities. From the perspective of a private sector investor, the project is not an attractive investment.

In a similar manner in Tables 9, 10, 11, 12 and 13 the Economic Analysis is summarized. To build these tables, the data of Table 4 and 5 were used. The shadow prices used are those stated by the Ministry of Planning and are as follows:

*Shadow price of foreign exchange = 1.1628 (Official Exchange Rate)

*Shadow price of labor = 1.0 (Market price for skilled labor)

= 0.6 (Market price for unskilled labor)

Based on a survey carried out in 1978-79, the Costa Rican Institute of Electricity uses a consumer surplus benefit adjustment factor of 1.70, indicating that the willingness of the consumer to value the real economic benefits from a rural electrification project is much larger than the traditional values assigned as benefits. This issue was discussed in Chapter IV.

Further assumptions are that eighty percent of the labor force working

in the construction stage is skilled labor and twenty percent is unskilled. After construction is completed, all labor is skilled labor. Again, all domestic resources are assumed to be labor.

Stage 2: Economic Analysis

Table 20 lists the shadow prices and economic values for the entire project. The adjustment factors show the distortion between the financial and economic prices. For example, the adjustment factor (AF) of 1.1628 for foreign exchange means that one unit of foreign exchange is worth 16.28% more than the market price i.e., the premium is: $(P_e/P_m) - 1 = 16.28\%$. These AFs are then applied to the financial values, as shown in the bottom half of the table, in order to arrive at the economic values.

Table 13 lists the economic net present values of the project at discount rates of 0%, 3%, 6%, 9%, and 12%, 15%, 18% and 21%, and Table 8, gives the respective financial net present values (NPVs). Given the social discount rate of capital of 13%, the project is unacceptable. The internal rate of return at this stage is 9.0%.

Stage 3: Inter-Temporal Analysis

In order to determine the values for this stage, the analyst must construct an income-flow analysis. As stated in the preceding section, the inter-temporal analysis takes into account the RE project's impact on savings and thus the impact on the distribution of consumption over time. In order to determine the impact on savings, the analyst must first construct an income flow analysis, as shown in Table 14.

The method proceeds as follows: (1) calculate the amount of income

accruing to or taken away from each class of savers; (2) using the MPS (marginal propensity to save), calculate the net impact of the above on savings, and (3) calculate the premium on the additional savings generated by the project's impact on income distribution.

The income flow analysis (Table 14) takes care of step (1): it shows where the amount of the distortion is going to or coming from. The final values are then incorporated into Table 15; which shows the distribution of benefits and losses to each group due to the project at different discount rates.

Using the hypothetical value of 5% for an adjustment factor for savings (The AF of 5% means that the net impact of the savings are valued at 1.05 times more than their actual value.), we arrive at the bottom row of Table 15. The results reported here are just an example; all of the distribution values are realistic but hypothetical in Costa Rica. Furthermore, with an actual project the analyst would do a sensitivity analysis for factors such as the MPS for each class. Due to shortage of accurate information regarding such factors that the analyst generally bases the inter-temporal AF on his determination of the country's ability to raise capital.

Table 16 shows the net present values of different discount rates. The internal rate of return is slightly less than 10%.

Stage Four: Intra-Temporal Analysis

This stage takes into account the project's impact on income distribution; this stage incorporates the government's goals regarding income distribution. As opposed to most other stages in project analysis, the

weights given to the various groups are not determined empirically. They are based on government objectives. For instance, the lower income groups would receive more weight than those at the top.

Table 17 shows the intra-temporal analysis, which proceeds much as that in stage 3. The rows again show the distribution of benefits and losses accruing to each group; the values are taken from the income-flow analysis of Table 14. The hypothetical AFs are given in Table 20; these adjust the income impacts by a premium or a penalty according to society's preferences. The application of these adjustment factors to Table 17 yields the adjustment values for each group. In our example, for the numbers assumed, this stage has resulted in added project value; with an IRR of more than 15%.

Stage Five: Social and Policy Preference Analysis

This stage is shown in the final summary table, Table 19. In this case, there are only merit goods, which receive premiums. For example, the premium placed on the project-caused reduction in rural-to-urban migration is 1% the ratio of its socio-political value to its economic value. (See Table 3.20)

As before, these adjustment factors are applied to the <u>economic</u> prices, in order to obtain the values in Table 3.19. Under the assumed weighting factors the project is always good regardless of the discount rate chosen. Figure 3 gives a graphical summary of the five stages. If we wish to include deadweight losses described in Chapter IV then the consumer surplus benefits need to be reduced. Figure 4 shows that the economic rate of return drops to 5% but the 'social' stages still have high

rates of return of more than 15%. This is an interesting result since it clearly demonstrates the possible conflict between the economic stages and the social stages which re-distribute the subsidies and include them as benefits to different groups.

FIGURE 1

NPV UNDER DIFFERENT DISCOUNT RATES

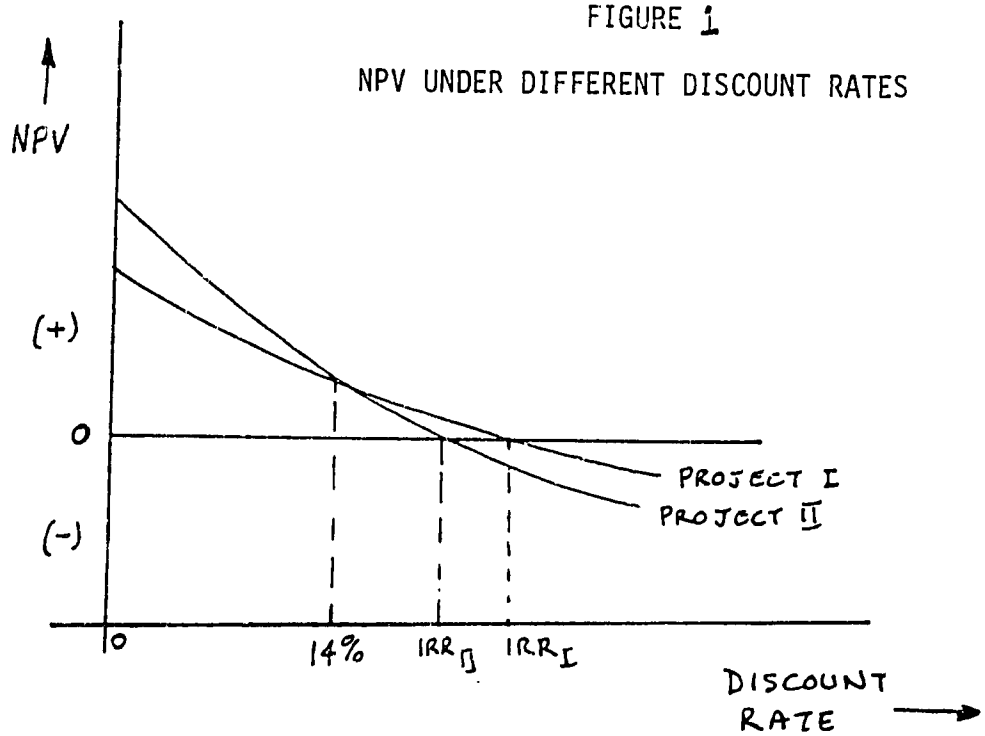

FIGURE 2

BENEFIT STREAMS

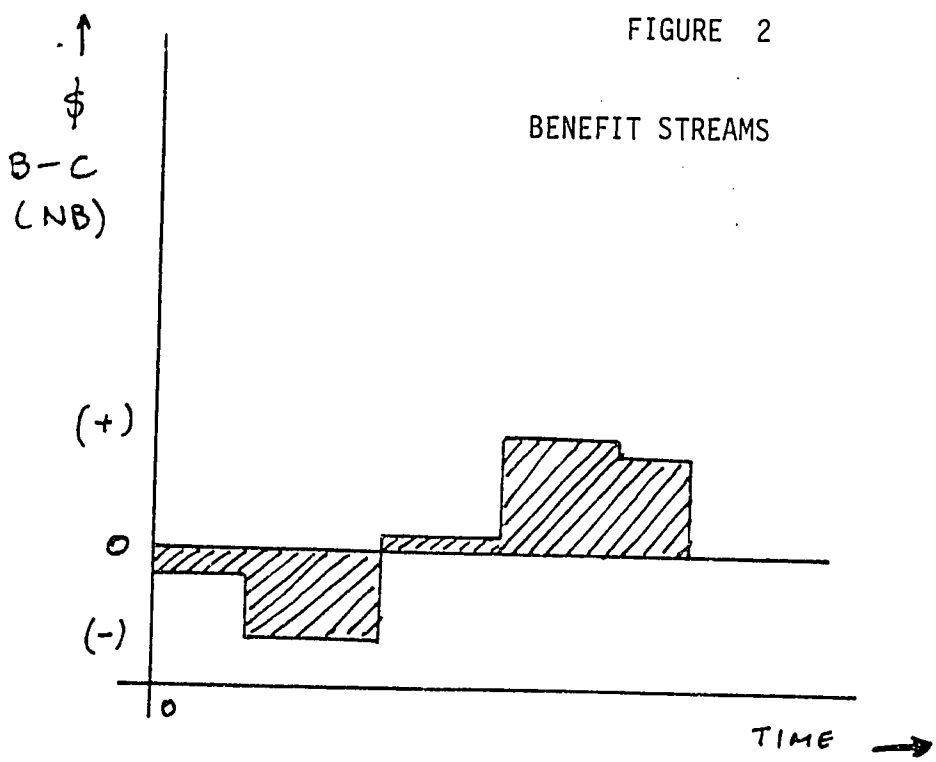

FIGURE 3 INTERNAL RATE OF RETURN

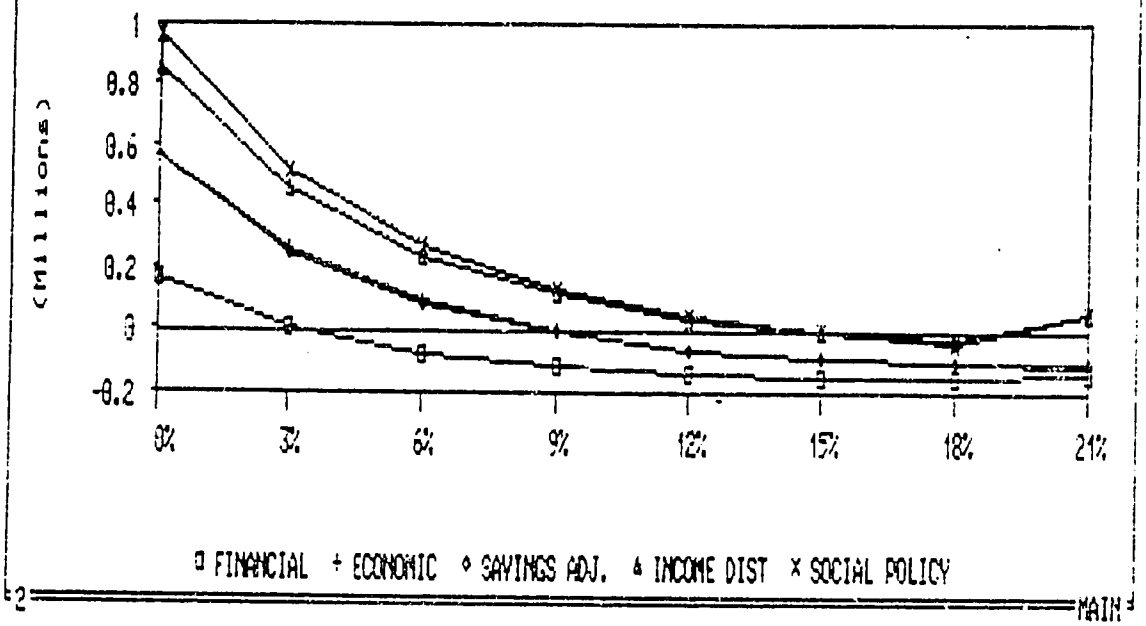

FIGURE 4 INTERNAL RATE OF RETURN

0.4 DEADWEIGHT LOSSES

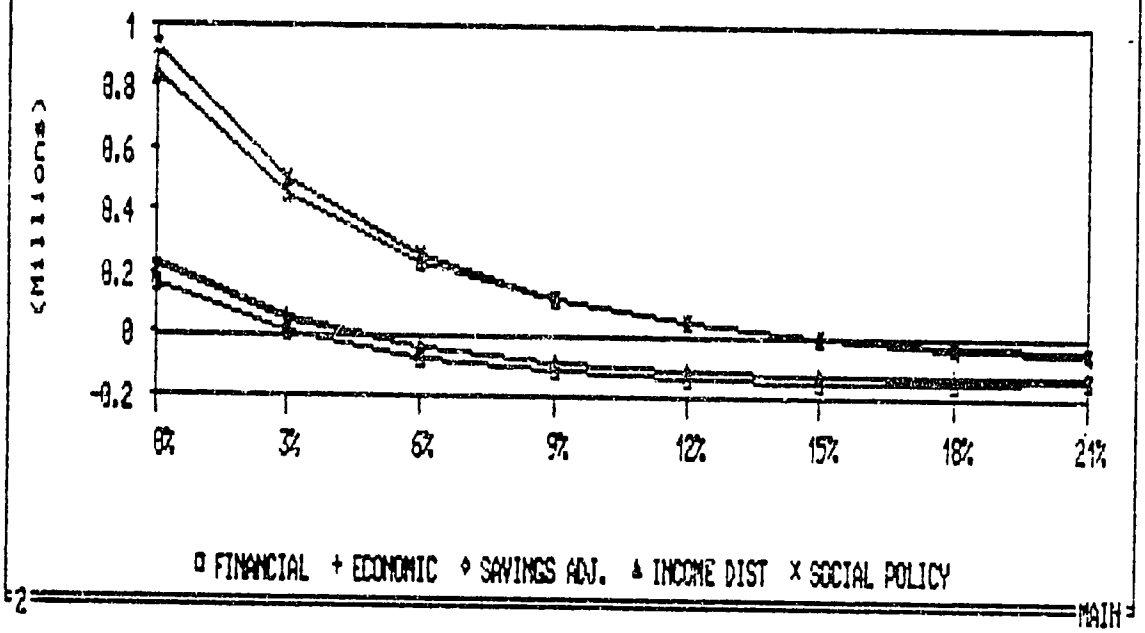

TABLE 1
BASIC DATA FOR INVESTMENT COSTS
(local cost in 1000 colones at market prices and foreign costs 1000 dollars cif)

TEM	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
1. Engineering and Management																					
Foreign(labor)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Local(labor)	6424.2	7877.6	8204.4	10173.8	7826.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2. Direct Costs of Construction																					
a)Generation																					
Import(labor)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	33	134	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Local(labor)	0	0	1823.4	10320	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
b)Transmission																					
Import(labor)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	0	334	780	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Local(labor)	0	0	570.8	4007.6	2003.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
c)Distribution																					
Import(labor)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	4884	6217	1569	169	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Local(labor)	0	3551.8	15738	23194.2	22566.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
d)General Facilities																					
Import(labor)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	323	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Local(labor)	0	0	53	159	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3. Costs without Specific Assignment																					
Import(labor)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	985	1889	915	84	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Local(labor)	0	2081.2	7378.8	15763.8	27883.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL INVESTMENT																					
Import(labor)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	6225	8574	3284	253	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Local(labor)	6424.2	13510.6	33068.4	63618.4	59480.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 2
BASIC DATA FOR OPERATION AND MAINTENANCE EXPENDITURES
(local cost in 1000 colones at market prices and foreign cost in 1000 US$ cif)

ITEM	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
1. Operation																					
a) Generation																					
Foreign (labor)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Local (labor)	0	0	0	0	412.8	412.8	412.8	412.8	412.8	412.8	412.8	412.8	412.8	412.8	412.8	412.8	412.8	412.8	412.8	412.8	4128
(materials)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
b) Transmission																					
Foreign (labor)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Local (labor)	0	0	0	0	172	172	172	172	172	172	172	172	172	172	172	172	172	172	172	172	172
(materials)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
c) Distribution																					
Foreign (labor)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Local (labor)	0	0	0	0	971.8	1032	1083.6	1143.8	1212.6	1281.4	1324.4	1358.8	1401.8	1444.8	1444.8	1444.8	1444.8	1444.8	1444.8	1444.8	14448
(materials)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2. Maintenance																					
a) Generation																					
Foreign (labor)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Local (labor)	0	0	0	0	103.2	232.2	335.4	438.6	567.6	567.6	567.6	567.6	567.6	567.6	567.6	567.6	567.6	567.6	567.6	567.6	5676
(materials)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
b) Transmission																					
Foreign (labor)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Local (labor)	0	0	0	0	34.4	68.8	94.6	129	163.4	163.4	163.4	163.4	163.4	163.4	163.4	163.4	163.4	163.4	163.4	163.4	1634
(materials)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
c) Distribution																					
Foreign (labor)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Local (labor)	0	0	0	0	309.6	645	1023.4	1436.2	1892	2083.8	2064	2150	2210.2	2279	2279	2279	2279	2279	2279	2279	22790
(materials)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3. Insurance																					
Foreign	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Local	0	0	0	0	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	172
3. Fuel																					
Foreign	0	0	0	0	41	48	55	63	72	82	87	94	100	107	107	107	107	107	107	107	107
Local	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL																					
Foreign (labor)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	0	0	0	41	48	55	63	72	82	87	94	100	107	107	107	107	107	107	107	107
Local (labor)	0	0	0	0	2021	2580	3139	3749.6	4437.6	4618.2	4721.4	4841.8	4945	5056.8	5056.8	5056.8	5056.8	5056.8	5056.8	5056.8	50568
(materials)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 3
BASIC DATA FOR LOAD FORECAST

TEM	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
ales of Energy(GWH)	0	0	0	0	29.4	32.8	36.5	40.6	45.1	50	53.2	55.7	58.8	62.1	62.1	62.1	62.1	62.1	62.1	62.1	62.1
verage Price (UScent/KWH)	5.12	5.12	5.12	5.12	5.12	5.09	5.08	5.05	5.03	5.03	5.01	5.01	5.01	5.01	5.01	5.01	5.01	5.01	5.01	5.01	5.01
otal Revenue					1505.28	1669.52	1854.2	2030.3	2268.53	2515	2665.32	2790.57	2945.88	3111.21	3111.21						

PHASE ONE: FINANCIAL ANALYSIS
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TABLE 4
BASIC DATA FOR INVESTMENT COSTS
(All costs in 1000 colones at market prices)

ITEM	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
1. Engineering and Management	6424.2	7877.6	8204.4	10173.8	7826.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Foreign(labor)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Local(labor)	6424.2	7877.6	8204.4	10173.8	7826.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2. Direct Costs of Construction	0	48615.8	74976.2	58054.2	26823.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
a)Generation	0	283.8	2175.8	10320	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Import(labor)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	283.8	1152.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Local(labor)	0	0	1023.4	10320	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
b)Transmission	0	0	3543.2	10715.6	2003.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Import(labor)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	0	2872.4	6708	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Local(labor)	0	0	670.8	4007.6	2003.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
c)Distribution	0	45554.2	69204.2	36859.6	24019.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Import(labor)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	42002.4	53466.2	13665.4	1453.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Local(labor)	0	3551.8	15738	23194.2	22566.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
d)General Facilities	0	2777.8	53	159	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Import(labor)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	2777.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Local(labor)	0	0	53	159	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3. Costs without Specific Assignment	0	10552.2	23624.2	23632.8	28526.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Import(labor)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	8471	16245.4	7869	722.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Local(labor)	0	2081.2	7378.8	15763.8	27803.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL INVESTMENT	6424.2	67045.6	106804.8	91860.8	61576	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Import(labor)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	53535	73736.4	28242.4	2175.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Local(labor)	6424.2	13510.6	33068.4	63618.4	59400.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 5
BASIC DATA FOR OPERATION AND MAINTENANCE EXPENDITURES
(all costs in 1000 colones at market prices)

ITEM	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
1. Operation	0	0	0	0	1556.6	1616.8	1668.4	1728.6	1797.4	1866.2	1909.2	1943.6	1986.6	2029.6	2029.6	2029.6	2029.6	2029.6	2029.6	2029.6	20296
a) Generation	0	0	0	0	412.8	412.8	412.8	412.8	412.8	412.8	412.8	412.8	412.8	412.8	412.8	412.8	412.8	412.8	412.8	412.8	4128
Foreign (labor)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Local (labor)	0	0	0	0	412.8	412.8	412.8	412.8	412.8	412.8	412.8	412.8	412.8	412.8	412.8	412.8	412.8	412.8	412.8	412.8	4128
(materials)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
b) Transmission	0	0	0	0	172	172	172	172	172	172	172	172	172	172	172	172	172	172	172	172	1720
Foreign (labor)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Local (labor)	0	0	0	0	172	172	172	172	172	172	172	172	172	172	172	172	172	172	172	172	1720
(materials)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
c) Distribution	0	0	0	0	971.8	1032	1083.6	1143.8	1212.6	1281.4	1324.4	1358.8	1401.8	1444.8	1444.8	1444.8	1444.8	1444.8	1444.8	1444.8	14448
Foreign (labor)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Local (labor)	0	0	0	0	971.8	1032	1083.6	1143.8	1212.6	1281.4	1324.4	1358.8	1401.8	1444.8	1444.8	1444.8	1444.8	1444.8	1444.8	1444.8	14448
(materials)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2. Maintenance	0	0	0	0	447.2	946	1453.4	2003.8	2623	2734.8	2795	2861	2941.2	3010	3010	3010	3010	3010	3010	3010	30100
a) Generation	0	0	0	0	103.2	232.2	335.4	438.6	567.6	567.6	567.6	567.6	567.6	567.6	567.6	567.6	567.6	567.6	567.6	567.6	5676
Foreign (labor)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Local (labor)	0	0	0	0	103.2	232.2	335.4	438.6	567.6	567.6	567.6	567.6	567.6	567.6	567.6	567.6	567.6	567.6	567.6	567.6	5676
(materials)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
b) Transmission	0	0	0	0	34.4	68.8	94.6	129	163.4	163.4	163.4	163.4	163.4	163.4	163.4	163.4	163.4	163.4	163.4	163.4	1634
Foreign (labor)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Local (labor)	0	0	0	0	34.4	68.8	94.6	129	163.4	163.4	163.4	163.4	163.4	163.4	163.4	163.4	163.4	163.4	163.4	163.4	1634
(materials)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
c) Distribution	0	0	0	0	309.6	645	1023.4	1436.2	1892	2003.8	2064	2150	2210.2	2279	2279	2279	2279	2279	2279	2279	22790
Foreign (labor)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Local (labor)	0	0	0	0	309.6	645	1023.4	1436.2	1892	2003.8	2064	2150	2210.2	2279	2279	2279	2279	2279	2279	2279	22790
(materials)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3. Insurance	0	0	0	0	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	172
Foreign	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Local	0	0	0	0	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	172
3. Fuel	0	0	0	0	352.6	412.8	473	541.8	619.2	705.2	748.2	808.4	868	920.2	920.2	920.2	920.2	920.2	920.2	920.2	920.2
Foreign	0	0	0	0	352.6	412.8	473	541.8	619.2	705.2	748.2	808.4	868	920.2	920.2	920.2	920.2	920.2	920.2	920.2	920.2
Local	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	0	0	0	0	2373.6	2992.8	3612	4291.4	5056.8	5323.4	5469.6	5652.2	5805	5977	5977	5977	5977	5977	5977	5977	51488.2
Foreign (labor)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	0	0	0	352.6	412.8	473	541.8	619.2	705.2	748.2	808.4	868	920.2	920.2	920.2	920.2	920.2	920.2	920.2	920.2
Local (labor)	0	0	0	0	2021	2580	3139	3749.6	4437.6	4518.2	4721.4	4841.8	4945	5056.8	5056.8	5056.8	5056.8	5056.8	5056.8	5056.8	50568
(materials)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 6
BASIC DATA FOR LOAD FORECAST
FINANCIAL ANALYSIS

ITEM	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Sales of Energy(GWH)	0	0	0	0	29.4	32.3	36.5	40.6	45.1	50	53.2	55.7	58.8	62.1	62.1	62.1	62.1	62.1	62.1	62.1	621
Average Price (Colones/KWH)	0.4403	0.4403	0.4403	0.4403	0.4403	0.4377	0.4369	0.4343	0.4326	0.4326	0.4308	0.4308	0.4308	0.4308	0.4308	0.4308	0.4308	0.4308	0.4308	0.4308	0.4308
Total Revenue(1000 Colones)	0	0	0	0	12944.82	14356.56	15946.85	17632.58	19510.26	21630	22918.56	23995.56	25331.04	26752.68	26752.68	26752.68	26752.68	26752.68	26752.68	26752.68	267526.8

TABLE 7
FINANCIAL ANALYSIS
NET CASH FLOWS
(Thousand Colones)

ITEM	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Net Cash Flow	-6424.2	-67045.6	-106884.	-91860.8	-51004.7	11363.76	12334.85	13341.18	14453.46	16306.6	17448.96	18345.36	19526.04	20775.68	20775.68	20775.68	20775.68	20775.68	20775.68	20775.68	216838.6

TABLE 8

NET PRESENT VALUE AT DIFFERENT DISCOUNT RATES (1000Colones)

	0%	3%	6%	9%	12%	15%	18%	21%	IRR
Net Present Value	161448.3	3548.648	-78649.7	-120137.	-139413.	-146458.	-146764.	-143406.	0.030956

TABLE 9
INVESTMENT COST IN ECONOMIC TERMS
(All costs in 1000 Colones at border prices)

ITEM	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
1. Engineering and Management	6424.2	7677.6	8204.4	10173.8	7826.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Foreign(labor)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Local(labor)	6424.2	7877.6	8204.4	10173.8	7826.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2. Direct Costs of Construction	0	54531.49	77751.01	50426.66	16432.13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
a)Generation	0	330.0026	2363.410	10320	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Import(labor)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	330.0026	1340.010	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Local(labor)	0	0	1023.4	10320	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
b)Transmission	0	0	3742.506	10204.62	1202.28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Import(labor)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	0	3340.026	7800.062	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Local(labor)	0	0	402.48	2404.56	1202.28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
c)Distribution	0	50971.47	71613.29	29806.64	15229.85	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Import(labor)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	48840.39	62170.49	15890.12	1690.013	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Local(labor)	0	2131.08	9442.8	13916.52	13539.84	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
d)General Facilities	0	3230.025	31.8	95.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Import(labor)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	3230.025	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Local(labor)	0	0	31.8	95.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3. Costs without Specific Assignment	0	11098.79	23317.43	18608.35	17522.28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Import(labor)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	9850.078	18890.15	9150.073	848.0067	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Local(labor)	0	1248.72	4427.28	9458.28	16682.28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL INVESTMENT	6424.2	73307.89	109272.8	79208.82	40980.62	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Import(labor)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	62250.49	85740.68	32840.26	2530.020	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Local(labor)	6424.2	11257.4	23532.16	46368.56	38450.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 10
BASIC DATA FOR OPERATION AND MAINTENANCE EXPENDITURES
(All costs in 1000 Colones at border prices)

ITEM	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
1. Operation	0	0	0	0	1099.08	1135.2	1166.16	1202.28	1243.56	1284.84	1310.64	1331.28	1357.08	1382.88	1382.88	1382.88	1382.88	1382.88	1382.88	1382.88	13826.8
a) Generation	0	0	0	0	412.8	412.8	412.8	412.8	412.8	412.8	412.8	412.8	412.8	412.8	412.8	412.8	412.8	412.8	412.8	412.8	4128
Foreign (labor)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Local (labor)	0	0	0	0	412.8	412.8	412.8	412.8	412.8	412.8	412.8	412.8	412.8	412.8	412.8	412.8	412.8	412.8	412.8	412.8	4128
(materials)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
b) Transmission	0	0	0	0	103.2	103.2	103.2	103.2	103.2	103.2	103.2	103.2	103.2	103.2	103.2	103.2	103.2	103.2	103.2	103.2	1032
Foreign (labor)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Local (labor)	0	0	0	0	103.2	103.2	103.2	103.2	103.2	103.2	103.2	103.2	103.2	103.2	103.2	103.2	103.2	103.2	103.2	103.2	1032
(materials)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
c) Distribution	0	0	0	0	583.08	619.2	650.16	686.28	727.56	768.84	794.64	815.28	841.08	866.88	866.88	866.88	866.88	866.88	866.88	866.88	8668.8
Foreign (labor)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Local (labor)	0	0	0	0	583.08	619.2	650.16	686.28	727.56	768.84	794.64	815.28	841.08	866.88	866.88	866.88	866.88	866.88	866.88	866.88	8668.8
(materials)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2. Maintenance	0	0	0	0	292.72	636.4	966.64	1331.28	1737.2	1804.28	1840.4	1892	1928.12	1969.4	1969.4	1969.4	1969.4	1969.4	1969.4	1969.4	19694
a) Generation	0	0	0	0	61.92	139.32	201.24	263.16	340.56	340.56	340.56	340.56	340.56	340.56	340.56	340.56	340.56	340.56	340.56	340.56	3405.6
Foreign (labor)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Local (labor)	0	0	0	0	61.92	139.32	201.24	263.16	340.56	340.56	340.56	340.56	340.56	340.56	340.56	340.56	340.56	340.56	340.56	340.56	3405.6
(materials)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
b) Transmission	0	0	0	0	55.04	110.08	151.36	206.4	261.44	261.44	261.44	261.44	261.44	261.44	261.44	261.44	261.44	261.44	261.44	261.44	2614.4
Foreign (labor)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Local (labor)	0	0	0	0	20.64	41.28	56.76	77.4	98.04	98.04	98.04	98.04	98.04	98.04	98.04	98.04	98.04	98.04	98.04	98.04	980.4
(materials)	0	0	0	0	34.4	68.8	94.6	129	163.4	163.4	163.4	163.4	163.4	163.4	163.4	163.4	163.4	163.4	163.4	163.4	1634
c) Distribution	0	0	0	0	185.76	387	614.04	861.72	1135.2	1202.28	1238.4	1290	1326.12	1367.4	1367.4	1367.4	1367.4	1367.4	1367.4	1367.4	13674
Foreign (labor)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Local (labor)	0	0	0	0	185.76	387	614.04	861.72	1135.2	1202.28	1238.4	1290	1326.12	1367.4	1367.4	1367.4	1367.4	1367.4	1367.4	1367.4	13674
(materials)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3. Insurance	0	0	0	0	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	172
Foreign	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Local	0	0	0	0	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	172
3. Fuel	0	0	0	0	410.0032	480.0038	550.0044	630.0050	720.0057	820.0065	870.0069	940.0075	1000.008	1070.008	1070.008	1070.008	1070.008	1070.008	1070.008	1070.008	1070.008
Foreign	0	0	0	0	410.0032	480.0038	550.0044	630.0050	720.0057	820.0065	870.0069	940.0075	1000.008	1070.008	1070.008	1070.008	1070.008	1070.008	1070.008	1070.008	1070.008
Local	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	0	0	0	0	1829.003	2268.803	2700.004	3180.765	3717.965	3926.326	4038.246	4180.487	4302.408	4439.488	4439.488	4439.488	4439.488	4439.488	4439.488	4439.488	34764.60
Foreign (labor)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	0	0	0	410.0032	480.0038	550.0044	630.0050	720.0057	820.0065	870.0069	940.0075	1000.008	1070.008	1070.008	1070.008	1070.008	1070.008	1070.008	1272.008	1070.009
Local (labor)	0	0	0	0	1384.6	1720	2055.4	2421.76	2834.56	2942.92	3004.84	3077.08	3139	3206.08	3206.08	3206.08	3206.08	3206.08	3206.08	3206.08	32062.8
(materials)	0	0	0	0	34.4	68.8	94.6	129	163.4	163.4	163.4	163.4	163.4	163.4	163.4	163.4	163.4	163.4	163.4	163.4	1634

TABLE 11
TOTAL CONSUMER SURPLUS
(Thousand Colones based on estimated consumer surplus)

ITEM	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Sales of Energy(GWH)	0	0	0	0	29.4	32.8	36.5	40.6	45.1	50	53.2	55.7	58.8	62.1	62.1	62.1	62.1	62.1	62.1	62.1	62:
Average Price (Colones/KWH)	0.4403	0.4403	0.4403	0.4403	0.4403	0.4377	0.4369	0.4343	0.4326	0.4326	0.4308	0.4308	0.4308	0.4308	0.4308	0.4308	0.4308	0.4308	0.4308	0.4308	0.4308
Total Surplus(1000 Colones)	0	0	0	0	22006.19	24486.15	27109.64	29975.38	33167.44	36771	38961.55	40792.45	43062.76	45479.55	45479.55	45479.55	45479.55	45479.55	45479.55	45479.55	454795.5

TABLE 12
ECONOMIC ANALYSIS
NET BENEFIT FLOWS
(Thousand Colones)

ITEM	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
et Cash Flow	-6424.2	-73507.8	-109272.	-79208.8	-20803.4	22137.34	24409.64	26794.62	29449.47	32844.67	34923.30	36611.96	38760.35	41040.06	41040.06	41040.06	41040.06	41040.06	41040.06	41040.06	420030.7

TABLE 13
ECONOMIC ANALYSIS
NET PRESENT VALUE AT DIFFERENT DISCOUNT RATES (1000Colones)

	0%	3%	6%	9%	12%	15%	18%	21%	IRR
Net Present Value	664025.4	319904.9	128636.6	20981.26	-39861.9	-73935.5	-92414.3	-101669.	0.098537

TABLE 14
INCOME FLOW ANALYSIS
(all values are in border Colones)

ITEM	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
PROJECT																					
Costs.																					
Imports	0	8715.498	12004.28	4597.862	411.6235	67.20384	77.0044	88.20504	100.8057	114.8065	121.8069	131.6075	140.008	149.8085	149.8085	145.8085	149.8085	149.8085	149.8085	149.8085	1070.008
Labor(skilled)																					
Labor(unskilled)	0	-2253.2	-9536.24	-17249.8	-21586	-860	-1083.6	-1327.84	-1603.04	-1675.28	-1716.56	-1764.72	-1806	-1850.72	-1850.72	-1850.72	-1850.72	-1850.72	-1850.72	-1850.72	-18507.2
Benefits.																					
Revenue	0	0	0	0	-9861.37	-10849.5	-11162.7	-12342.8	-13657.1	-15141	-16042.9	-16796.8	-17731.7	-18726.8	-18726.8	-18726.8	-18726.8	-18726.8	-18726.8	-18726.8	-187268.
PRIVATE SECTOR																					
Costs.																					
Imports																					
Labor(skilled)																					
Labor(unskilled)																					
Benefits.																					
Revenue	0	0	0	0	1359.206	1507.438	1674.419	1851.420	2048.577	2271.15	2406.448	2519.523	2659.759	2809.031	2809.031	2809.031	2809.031	2809.031	2809.031	2809.031	28290.31
GOVERNMENT																					
Costs.																					
Imports	0	-8715.49	-12004.2	-4597.86	-411.623	-67.2038	-77.0044	-88.2050	-100.805	-114.806	-121.806	-131.607	-140.008	-149.808	-149.808	-149.808	-149.808	-149.808	-149.808	-149.808	-1070.00
Labor(skilled)																					
Labor(unskilled)																					
Benefits.																					
Deadweight loss	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LABOR																					
Costs.																					
Imports																					
Labor(skilled)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Labor(unskilled)	0	2253.2	9536.24	17249.84	21586	860	1083.6	1327.84	1603.04	1675.28	1716.56	1764.72	1806	1850.72	1850.72	1850.72	1850.72	1850.72	1850.72	1850.72	18507.2
Benefits.																					
Revenue																					
CONSUMERS																					
Costs.																					
Imports																					
Labor(skilled)																					
Labor(unskilled)																					
Benefits.																					
Revenue	0	0	0	0	7702.167	8542.153	9488.375	10491.38	11608.60	12869.85	13636.54	14277.35	15071.96	15917.84	15917.84	15917.84	15917.84	15917.84	15917.84	15917.84	159176.4
Total Net Flow	0	0	0	0	-4.5E-13	-4.5E-13	-9.1E-13	9.1E-13	4.5E-13	4.5E-13	0	-4.5E-13	4.5E-13	4.5E-13	4.5E-13	4.5E-13	4.5E-13	4.5E-13	4.5E-13	4.5E-13	

TABLE 15
ECONOMIC VALUE OF SAVINGS
(Based on Income Impact and MPS)

ITEM	0%		3%		6%		9%		12%		15%		18%		21%	
	PV Income Derived	Savings Impact	PV Income Derived	Savings Impact	PV Income Derived	Savings Impact	PV Income Derived	Savings Impact	PV Income Derived	Savings Impact	PV Income Derived	Savings Impact	PV Income Derived	Savings Impact	PV Income Derived	Savings Impact
Project	-505578.	-252789.	-318297.	-159148.	-208573.	-104286.	-142002.	-71001.1	-100175.	-50087.6	-72974.6	-36487.4	-54685.5	-27342.7	-41992.8	-20996.4
Other Private Sector	66051.48	33025.74	40852.00	20426.00	26215.93	13107.96	17435.60	8717.803	11996.15	5998.079	8512.244	4259.122	6225.279	3112.639	4568.569	2334.084
Government	-28689.3	-17213.6	-25478.6	-15287.1	-22965.0	-13779.0	-20912.0	-12547.2	-19182.3	-11509.4	-17692.2	-10615.3	-16387.7	-9832.63	-15232.3	-9139.39
Workers	93924.56	9392.456	71429.93	7142.993	56766.05	5676.625	46677.06	4667.706	39533.63	3938.363	33878.76	3367.876	29571.44	2957.144	26101.37	2610.137
Consumers	374291.7	112287.5	231494.6	69448.40	148556.9	44567.09	98801.77	29640.53	67978.23	20393.47	48270.04	14481.01	35276.58	10582.97	374291.7	112287.5
Net Impact		-115297.		-77418.7		-54714.3		-40522.3		-31267.3		-24974.7		-20522.6		87096.13
Total Economic Impact		-5764.85		-3870.93		-2735.71		-2026.11		-1563.36		-1248.73		-1026.13		4354.806
Adjusted NPV		658260.5		316033.9		125900.9		18955.14		-41425.3		-75184.3		-93440.4		-97314.5

TABLE 16
INTER-TEMPORAL ADJUSTMENT FOR SAVINGS
NET PRESENT VALUE AT DIFFERENT DISCOUNT RATES (1000Colones)

	0%	3%	6%	9%	12%	15%	18%	21%
Net Present Value	658260.5	316033.9	125900.9	18955.14	-41425.3	-75184.3	-93440.4	-97314.5

TABLE 17
INCOME DISTRIBUTION IMPACT VALUES
(Based on Income Impact and Preference Value for Type of Income)

ITEM	0%		3%		6%		9%		12%		15%		18%		21%	
	PV Income Derived	Income Impact	PV Income Derived	Income Impact	PV Income Derived	Income Impact	PV Income Derived	Income Impact	PV Income Derived	Income Impact	PV Income Derived	Income Impact	PV Income Derived	Income Impact	PV Income Derived	Income Impact
Project	-505578.	0	-318297.	0	-288573.	0	-142082.	0	-100175.	0	-72974.8	0	-54685.5	0	-41992.6	0
Other Private Sector	66051.48	-13210.2	40852.09	-8170.40	26215.93	-5243.16	17435.62	-3487.12	11996.15	-2399.23	8518.244	-1703.64	6225.279	-1245.05	4668.569	-933.713
Government	-28689.3	0	-25476.6	0	-22965.0	0	-20912.0	0	-19182.3	0	-17692.2	0	-16387.7	0	-15232.3	0
Workers	93924.56	187849.1	71429.93	142859.8	56766.05	113532.1	46677.06	93354.13	39383.63	78767.26	33878.76	67757.53	29571.44	59142.89	26101.37	52202.75
Consumers	374291.7	112287.5	231494.6	69448.40	148556.9	44567.09	98801.77	29640.53	67978.23	20353.47	48278.04	14481.01	35276.58	10582.97	374291.7	112287.5
Net Impact		286926.3		204137.8		152856.0		119507.5		96761.50		80534.90		68480.81		163556.5
Adjustment to NPV		286926.3		204137.8		152856.0		119507.5		96761.50		80534.90		68480.81		163556.5

TABLE 18
ADJUSTMENT FOR INTRA-TEMPORAL INCOME DISTRIBUTION EFFECTS
NET PRESENT VALUE AT DIFFERENT DISCOUNT RATES (1000Colones)

	0%	3%	6%	9%	12%	15%	18%	21%
Net Present Value	950951.7	524042.8	281432.6	140486.8	55899.53	6599.305	-23933.4	61687.16

TABLE 19
SOCIAL POLICIES

ADJUSTMENT	0%	3%	6%	9%	12%	15%	18%	21%
Rural-Urban Migration	9509.517	5240.428	2814.926	1404.868	568.9953	65.99305	-239.334	618.8716
Production Increase	19019.03	10480.85	5629.853	2809.776	1137.990	131.9861	-478.669	1237.743
Employment Generation	20311.64	16063.18	13215.88	11198.63	9697.432	8533.143	7599.497	6830.859
Wood Fuel Use	106940.5	66141.33	42444.85	28229.07	19422.35	13791.44	10079.02	7558.635
Self-sufficiency	-29751.2	-26767.2	-24314.2	-22243.2	-20460.2	-18902.6	-17526.9	-16301.5
Total Adj. NPV	1076981.	595201.3	321283.9	161887.8	67266.03	10219.22	-24499.8	61831.72

TABLE 20

COST BENEFIT ANALYSIS FOR RURAL ELECTRIFICATION IN COSTA RICA
A SOCIAL BENEFIT APPROACH

PLANNING PARAMETERS		
Non-residential % (PCT)	0.15	
Market Discount Rate(MDR)	0.15	
Social Discount Rate(SDR)	0.1	
Opportun. Cost Capital(OCC)	0.13	
Official Exchange Rate(OER)	8.6	
Shadow Exchange Rate(SER)	1.1628	(premium)
Market Wage Rate(MWR)	1	
Shadow Wage Rate(SWR1)	0.6	(unskilled)
Shadow Wage Rate(SWR2)	1	(skilled)
Adjust. Factor Savings(AFS)	1.05	
Adjust. Factor Invest.(AFI)	1	
Adjust. Factor Consump(AFC)	1	
Colones/US$ in 1979 (EX)	8.6	
Elec. Consumer Surplus(CS)	1.7	

STAGE III

ADJUSTMENTS FOR INTER-TEMPORAL EFFECTS

ADDITIONAL REQUIRED DATA

Marginal Propensity to Save	
By Project(MPS1)	0.5
By Private Sector(MPS2)	0.5
By Government(MPS3)	0.6
By Workers(MPS4)	0.1
By Consumers(MPS5)	0.3

STAGE IV

INTRA-TEMPORAL EFFECTS

ADJUSTMENT FOR INCOME DISRTRIBUTION

ADDITIONAL DATA REQUIREMENTS

Relative Weight given	
To Project Income(IW1)	0
To Pvt. Sector Income(IW2)	-0.2
To Government Income(IW3)	0
To Workers Income(IW4)	2
To Consumers Income(IW5)	0.3

STAGE V

SOCIAL AND POLICY PREFERENCE

ADDITIONAL REQUIRED DATA

Merit Wants Weighting Factors:		
Reduction of Rural-Urban Migration	0.01	% of Total NPV
Production Increase in Rural Areas	0.22	% of Total NPV
Generation of Employment	0.1	% of Total Wage Bill
Reducing Use of Wood Fuels	0.1	% of Total Energy Value
National Self-sufficency	-0.15	% of Total Imports

Chapter VI

MARGINAL COST AND PRICING OF RURAL ELECTRIFICATION SCHEMES

1. Marginal Costs and Pricing of Rural Electrification Schemes

The marginal cost of power supply (Albouy, 1984) is defined as the change in total cost of service arising from a small change in demand. In other words, it is the cost to the economy of supplying each extra unit of electricity to the consumer who demands it. By performing a marginal cost analysis as a complement to the benefit-cost analysis, the planner will have a clear measure of the actual cost of rural electrification. Which can provide the planner with a tool that can determine the difference between the tariff structure (what consumers actually pay) and the marginal costs (what consumers' increased demand actually costs the economy). This methodology is a strong complement to the economic, social and political merit components of the UNIDO method of analysis discussed in Chapter V. It allows the planner to present the decision-makers with the real costs and the real benefits of providing a crucial good, such as electricity, to the rural consumer.

The conflict between the increasing marginal costs and the decreasing tariffs associated with rural electrification constitute the core of the arguments against rural electrification. The problem can be summarized taking as an example the costs and tariff structure of Costa Rica in Figure 1 which depicts the increases in marginal costs for energy, from the generation stage to secondary distribution in the rural areas. The cost of supplying electricity to the consumer sharply increases as voltage level and distance increase, and as type of consumer converges to the rural consumer. In Figure 2, a similar situation is presented, this time in relation

to the power component. The cost of supplying an additional unit of power per month to the rural consumer also increases sharply from transmission, to primary distribution, and to secondary distribution.

As a corollary to the cost structure as voltage level decreases, there is a wide gap between the marginal costs and the tariff structure at the level of rural consumer. Traditionally, rural electrification is subsidized and the actual prices that consumers pay are much lower than the cost of supplying that extra unit of energy to the rural consumer. Table 1 shows the average marginal costs for each type of consumer and the marginal cost of supplying the increase in demand. For rural electrification, the residential, industrial secondary and general secondary are the relevant cases corresponding to residential, industrial and commercial consumers.

The gap between the marginal costs and the tariffs is an important element which illustrates the dilemma facing the planner. The planner must interpret the priorities of society and the government, and define the role that rural electrification will fulfill within this context. If, as is the case in Costa Rica, rural electrification is considered almost as highly valuable and as necessary as health and education investments, then that gap between tariffs and marginal costs must be clearly interpreted as the willingness of the authorities to supply subsidized electricity to the rural inhabitants. Furthermore, the UNIDO method stresses the need to explicitly state the social and political merits that the decision maker assigns to a project. In this case the decision maker must assess the gap between costs and prices in rural electrification and define (usually implicitly) the weight that the authorities actually assign to the project.

In the following sections a more detailed explanation of marginal cost

theory is presented, followed by a step-by-step calculation of the marginal costs for the Costa Rican case.

An essential element of project appraisal, and one that serves as a complement to the benefit-cost analysis, is the determination of the real economic cost of any additional unit of energy demanded by the rural consumers due to the implementation of a RE project.

In micro-economic theory (Hirschleifer, 1984; pp. 173-199), the concept of marginal cost is of great importance. In the case of competitive firm, for example, the marginal cost (MC) is derived from the total cost function. To maximize profit, MC must equal MR (marginal revenues, and at this point the sum of producers' and consumers' surpluses will also be maximized.* Figure 3 depicts this in the economist's traditional way.

Another concept that is worthwhile to recall is that of short and long run costs. In the short run some costs are fixed; in the long run they all become variable. In Figure 4 the key elements of short and long run cost functions are depicted as a reminder of the theoretical microeconomic origin of the concept.

However, in the case of public utilities the marginal cost pricing problem should be stated in the context of a monopolistic situation--not a perfectly competitive case--and, as is often the case in this type of utility is considered a natural monopoly. Following Boadway's (1979) analysis, consider a public utility monopolizing the output of electricity as depicted in Figure 4c. If the utility were to operate as profit-maximizing

*In this case the consumer surplus is zero since the firm is a price-taker.

natural monopolist, it would set MR=MC and produce at an output of Q_m and price P_m. There are equity as well as efficiency considerations that put some caveats on this pricing scheme and thus reflects the problems that appear in the definition of an adequate tariff structure scheme. For an efficient outcome--Pareto optimality--the intersection of the demand curve and the marginal cost curve (Q_o quantity and P_o price) will maximize the sum of producers and consumers surpluses. The disadvantage is that at this point the utility would operate at a loss because it will be operating below the average cost curve.

Thus, when the monopolistic price P_m and quantity Q_m are enforced the approximate loss to society can be obtained from the diagram. The loss in total benefits to consumers from consuming Q_m instead of Q_o is approximately the area beneath the demand curve, i.e.: $Q_m acQ_o$. The saving in resources costs from the reduction in output from Q_o to Q_m is the area beneath the MC curve, i.e.: $Q_m b\ c\ Q_o$. The net cost to society is the difference between these two areas, i.e.: abc.

Another pricing scheme is to set price equal to average costs. A regulated utility can be instructed to set price in such a way as to earn just the normal rate of return on capital and thus produce a quantity Q_a priced at P_a. Using a similar reasoning as above, the net loss to society from the average cost pricing would be the triangular area dec.

With the price set equal to MC, in the case of a utility behaving as a natural monopoly, the operating losses must be made up somewhere. Price discrimination by type of consumer, hour of day consumption, geographic area, and so on could be used as a pricing scheme. This could approximate a perfect price discrimination situation and thus

the utility would collect an amount of revenues equal to the total benefits of consumers.

However, there is not one unique problem involved in the pricing of a service such as electricity. Not only how to raise the revenues of the utility is a problem, but also equity and income distribution issues are relevant. Furthermore, the overall role that the government and the consumers place on the extension of electricity services as a symbol of modernization, social mobility and political leverage is involved. As with benefit-cost analysis, marginal cost pricing brings back, once again, the complex interrelations between equity and efficiency, politics and economics.

As the previous paragraphs point out, marginal cost is theoretically defined as the derivative of the total cost function with respect to output. This definition, however, obscures both the conceptual and pragmatic problems that can be experienced in estimating the marginal cost in electricity services (Saunders, et al., 1977). If the electricity utility is operating below capacity, marginal cost involves the incremental (operating) cost of producing output units within the present system capacity. In contrast, if an increment to capacity is required, the marginal cost involves this new capacity increment.

In other words, it is necessary to work out an estimate of the costs at each level of voltage, by regions, by time of day, and by season if necessary, in order to indicate the real cost of supplying one additional unit of electricity to the consumer. This will permit the determination of a structure of prices that accurately reflects the real costs of the energy.

Following the line of argument given by Saunders, et al., if the electricity system capacity is less than fully utilized, the only costs immediately attributable to additional electricity usage are certain operating costs. These costs are referred to as short run marginal costs (SRMC). Long run marginal cost (LRMC), in contrast, refers to the sum of SRMC and marginal capacity cost (MCC) - the cost of extending capacity to accommodate additional usage. The two definitions of marginal cost - SRMC and LRMC - must be reconciled since a pricing policy which is associated with the efficient use of existing capacity will frequently result in non-optimal investment decisions. In sum, theoretically, prices should be increased with increasing demand in the period before a capacity increment is necessary; then when the capacity increment becomes available and excess capacity exists, prices should be decreased. However, in order to deal with both short- and long- run considerations, operating and investment costs and even consumption changes in different time periods, it is necessary to expand alternative definitions of marginal cost.

2) Definitions of Marginal Cost

Four definitions are presented following Saunders, et al. (1977) and then a two-step procedure is suggested for dealing with the operational calculations of marginal costs in electric utilities. The definitions vary in the extent to which they focus on short run versus long run allocative efficiency, and the extent to which they attempt to minimize price fluctuations in the presence of lumpy investments.

1) Textbook marginal cost (TMC). The TMC definition of MC reflects microeconomic pricing theory, with the modification that each increment is taken to be the change in output that occurs during one year.

As a result, TMC makes use of two concepts: SRMC, which reflects increments in operating and maintenance costs brought about by increases in output, and marginal capacity cost MCC, which reflects increments in capital expenditures (for capacity) that are necessary in order to increase output. Because they are considered only one year at a time, the TMC definition reflects a relatively short term horizon and is defined as follows:

$$TMC = SRMC + MCC$$

$$= [(R_{t+1} - R_t)/(Q_{t+1}) - Q_t] + [rI_t/(Q_{t+1} - Q_t)]$$

where: t = year for which TMC is being calculated

R = operation and maintenance expenditures in year t

Q = electricity produced in year t

I = capital expenditure in year t

r = the capital recovery factor, or the annual payment that will repay a $1 loan over the useful life of the investment with compound interest (equal to the opportunity cost of capital) on the unpaid balance.

With a lumpy investment stream, TMC for the years in which capacity expenditures take place reflects both SRMC and MCC; during years in which no capital expenditures take place TMC equals SRMC only. Hence, the problem with the application of this definition is the rather large fluctuations in price.

ii. <u>Textbook Long Run Incremental Cost (TLRIC)</u>.

This definition emphasizes the need to give investment signals to present and potential electricity users at the expense of some loss in short run allocative efficiency. It is defined as follows:

$$TLRIC = [(R_{t+1} - R_t)\ (Q_{t+1} - Q_t)] + [rI_k/(Q_{k+1} - Q_k)]$$

where k = the year in which the very next major investment expenditure is completed. As a result, during years t through k the term $rI_k/(Q_{k+1} - Q_k)$ remains constant, reflecting the annual equivalent of marginal capacity cost for the next lump-sum investment. In year k+1, after investment has taken place in year k, k is redesignated to be the next year in which a large investment is actually made, and again the same considerations apply as before. For years in which investment takes place, TLRIC will equal TMC.

iii. Present Worth of Incremental System Cost (PWISC).

This emphasizes the necessity of providing consumption and investment signals that reflect the magnitude of the forthcoming investment. It is defined as the present worth of the increment to consumption at the beginning of year t minus the present worth of the increment of system costs resulting from the same permanent increment in consumption starting at the beginning of year t+1. Algebraically:

$$PWISC = \frac{(R_{t+1} - R_t) + [I_k/(1+i)^{k-t} - I_k/(1+i)^{k+1-t}]}{(Q_{t+1} - Q_t)}$$

$$+ \frac{[I_{k+T-1}/(1+i)^{k+T-t} - I_{k+T}/(1+i)^{k+T-t}]}{(Q_{t+1} - Q_t)}$$

where k again denotes the year in which the very next large investment expenditure takes place; i.e., the year in which the system reaches capacity; i is the opportunity cost of capital and the useful life of investment is assumed to be T years. This is sometimes referred to as the Turvey Marginal Cost.

iv) Average Incremental Cost (AIC).

This definition represents an attempt to: (a) compromise between short run allocative efficiency goals and the need to signal the justification of investment in additional capacity; and (b) look beyond the traditional economic definition of the long run by including all future investment costs during a specific time period, usually ten to fifteen years, which would be the maximum period for which reliable data would be available.

AIC assumes that when investment is lumpy, marginal capacity cost (MCC) can be estimated as:

MCC = the present worth of the least-cost investment stream/ divided by the present worth of the stream of incremental output resulting from the investment.

Thus, if at any point in time consumers willingly pay a price equal to incremental operating costs plus MCC, as defined above, this indicates that the benefits of the investment program, which can include one or more projects and which would be measured in benefit-cost analysis as the present value of total revenue (PxQ), are at least equal to the costs, measured as the present value of the stream of costs to be incurred through time. The average incremental cost that we estimate is calculated by (1) discounting all incremental costs that will be incurred in the future to provide the estimated additional amounts of electricity that will be demanded over a specified period, and (2) dividing this amount by the discounted value of incremental output over the period. Algebraically:

$$AIC_t = \frac{\sum_{i=1}^{T} [(R_{t+i} - R_t) + I_{t+i-1}/(1+i)^{i-1}]}{\sum_{i=1}^{T} [(Q_{t+i} - Q_t)/(1+i)^{i-1}]}$$

where the notation is similar to that used before, except that T is the number of years for which electricity expenditures attributable to output are forecast and over which price is being smoothed. Theoretically, the discount rate i in the numerator of AIC should be set equal to the opportunity cost of capital, while that in the denominator should be equal to the time preference rate for consumption, reflecting the assumption that consumption today is more valuable than consumption in the future.

In practice, given the fact that marginal cost pricing is forward looking, that is, it considers only future costs and future output, there arise a series of problems when an attempt is made to implement it: the problem of attaining economic efficiency in the context of non-efficiency pricing objectives such as equity, the problem of price volatility given the lumpiness of capital investments and, finally, the problem of adequate revenue generation and financial viability. Actually there is a set of tradeoffs among price stability, financial viability, economic efficiency, equity, administrative-transaction costs, and political acceptability.

In order to overcome this complex set of tradeoffs, a two-step process seems to be the best alternative. The first is to estimate an economically efficient pricing structure which corresponds to the strict marginal (opportunity) cost of the various power plants and transmission investments used. The second step is to adjust that structure as required in order to achieve other financial, economic or social goals. In additiona the calculation of the long run marginal costs (LRMC) needs to be based on technical considerations regarding marginal costs by the time of the day (e.g., peak and off-peak period), by season (e.g., dry and wet), by voltage level

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(e.g., transmission level, distribution level, consumer level), by regions, etc.

The approach followed in this paper is based on the one suggested by Munasinghe and Warford:

> 'The modern approach to electric power pricing recognizes the existence of several objectives or criteria, not all of which are mutually consistent. First national economic resources must be allocated efficiently, not only among different sectors of the economy, but also within the electric power sector. This implies that prices that reflect cost must be used to indicate to the electricity consumers the true economic cost of supplying their specific needs so that supply and demand can be matched efficiently.
>
> 'Second, certain principles relating to fairness and equity must be satisfied, including: (a) allocating costs among consumers according to the burdens they impose on the system; (b) asserting a reasonable degree of price stability and avoiding large price fluctuations from year to year; and (c) providing a minimum level of service to persons who may not be able to afford the full cost.
>
> 'Third, the power prices should raise sufficient revenues to meet the financial requirements of the sector... Fourth, the structure of electric tariffs must be simple enough to facilitate the metering and billing to consumers. Fifth, and finally, other economic and political requirements must also be considered. These might include, for example, subsidized electricity supply to certain sectors to enhance growth or to certain geographic areas for regional development.' (Munasinghe and Warford, 1982, pp. 10-11)

3) <u>First Step</u>: <u>Strict Long run Marginal Cost</u> (<u>LRMC</u>).

The LRMC is estimated by first calculating the costs both from the utilities' perspective and from the country's perspective where shadow prices are utilized. Usually three categories of costs are identified for the LRMC calculation (Turvey and Anderson, 1981; Munasinghe and Warford, 1982); marginal capacity costs, marginal energy costs, and customer costs.

i) <u>Marginal capacity costs</u>: Costs of investment in generation, transmission and distribution facilities for the supply of additional

kilowatts. What we are interested in is the change in system capacity costs associated with a sustained increment in the long-run peak demand. This can be calculated at three levels: those of generation, transmission and distribution.

Generation: The required LRMC of generating capacity (LRMC-GC) may be approximated by the cost of advancing, or by the cost savings that result from delaying, one kilowatt of a thermal unit or a hydro unit that supplies the peak load. This is calculated by estimating the cost of a kilowatt installed, annuitized over the expected lifetime and adjusted for the reserve margin (RM) and appropriate percentage loss (LG):

$$\text{LRMC-GC} = (\text{annuitized cost per Kw})\ [(1+RM/100)/(1-LG/100)]$$

The annuitized value of a lump-sum investment as used here is defined as the fixed annual payment over the lifetime of the investment, whose present value at a given discount rate is exactly equal to the original expenditure and therefore is similar to advancing the capital outlay by one year.

Transmission and Distribution: All costs of investment in transmission and distribution are allocated to incremental capacity because their design is directly linked to the peak capacity needs. Capacity costs must then be identified at each voltage level. The approach normally used is the average incremental cost (AIC) method which estimates the LRMC of transmission and distribution:

$$AIC = \left[\sum_{T}^{i=0} I_i/(1+r)^i \right] / \left[\sum_{L+T}^{i=L} \Delta MW_i/(1+r)^i \right]$$

where: Δ MW = increase in demand served relative to the previous year

I_i = investment cost in year i

i = year of demand increase

r = discount rate (e.g. opportunity cost of capital)

T = planning horizon (e.g., 20 years)

L = average time delay between the investment and commissioning dates of new facilities.

The AIC for transmission and distribution is computed and annualized over the lifetime of the system to yield the marginal costs, ΔLRMCtrans, and the ΔLRMCdist. Then, the total LRMC of capacity during the peak period at the transmission level would be:

$$LRMCtrans = (LRMC-GC)/(1-Ltrans) + \Delta LRMCtrans$$

where Ltrans is the percentage of incoming peak power that is lost in the transmission.

Repeating the procedure for distribution:

$$LRMCdist = (LRMCtrans)/(1-Ldist) + \Delta LRMCdist$$

ii) Marginal energy costs: For a thermal plant, these are the costs of fuel and/or other operating costs needed to provide an additional kilowatt-hour; for a hydroelectric plant, these are part of the investment cost associated with storage.

The LRMC of energy should be calculated for the following two periods:

Peak Period: This will be the operating and maintenance of the machines to be used last in order of merit for meeting the incremental peak kilowatt-hours corresponding to the demand increment. These

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costs are adjusted by the appropriate peak loss factors at each voltage level in the same way as the marginal capacity costs were measured.

Off-peak Period: This will be the operating and maintenance costs of the least efficient base-load or cycling plant used during this period.

iii) Marginal customer costs: Incremental costs directly attributable to consumers such as metering, billing and hook-up. Added to the previous costs, this will give the low voltage (LV) marginal costs. In order to integrate the marginal costs (by level of voltage and by period of day, peak and off-peak) the capacity costs can be converted to equivalent kilowatt-hour costs, assuming different consumer coincidence and load factors.

4) Second Step: Adjusted LRMC.

After the LRMC costs have been calculated, the second step is to take into account several social and political objectives and constraints which lead to suggestions for setting the tariffs. The constraints that produce deviations in the final tariffs relative to the strict LRMC, are of two types:

i) Distortions that can be analyzed within an economic framework such as second-best considerations, subsidized tariffs for low income consumers, etc. Shadow pricing can take this component into account.

ii) Elements such as financial viability, socio-political constraints, metering and billing problems, etc.

The tariff structure suggested by the LRMC which gives the real economic costs at each level of voltage and at each period of day can be corrected to account for income distribution, financial or political considerations in relation to pricing. However, using this two-step approach for calculating marginal costs has the advantage of showing the policy maker the real cost to the economy of the extra demand due to the RE project and what, in a strict sense, each consumer should pay. Thereafter any different tariff structure can be established, but the departure from the actual costs can be easily seen. This provides the RE project appraiser with a new tool to assess the real social costs and benefits of the electrification scheme.

5. Case Study: Marginal Costs for a Rural Electrification Grid in Costa Rica

In this case study, the long-run marginal costs are calculated as the present value of the costs needed to expand the installed capacity of the national grid during T years, averaging over T, where T is the interval between investments. This Average Incremental Costs (AIC) method is intended to obtain an estimate of the structure of costs which allows for a coherent application of marginal costs to the tariff structures.

Although in a strict marginal cost calculation there is the need to correct for the distortions in the market by means of shadow prices, the present case study used the market prices. Only for the opportunity cost for capital was an appropriate correction for market distortions incorporated, by using a discount rate of 12%.

For the calculation of the marginal costs the following steps were

performed (ICE, 1984):

Step 1: Electricity Market Consumer Behavior

1. Calculation of generation needed.

2. Determination of sales forecasts by voltage level and type of consumer and calculation of the load curves by type of consumer;

3. Projection of energy and power by voltage level and type of consumer.

Step 2: Calculation of the Marginal Costs for Generation

1. Establish the investment plan needed to cover the increase in demand;

2. Calculate power costs distributed on a power and energy basis;

3. Calculate energy costs;

4. Calculate operation and maintenance costs.

Step 3: Calculation of Marginal Costs for Transmission

1. Calculation of marginal costs of investment in transmission;

2. Calculation of operation and maintenance costs.

Step 4: Calculation of Marginal Costs for Distribution

1. Calculation of the marginal costs related to power at the primary distribution level;

2. Calculation of marginal costs related to power at the secondary distribution level;

3. Calculation of consumer marginal cost.

Step 5: Establish Tariffs

1. Summary of the marginal costs at the generation, transmission and distribution levels;

2. Comparison between marginal costs, average costs and average tariffs for each level of voltage and type of consumer.

The present case study follows the guidelines suggested by the World Bank (Albouy, 1984). The empirical information and many of the calculations are based on the study performed by the Costa Rican Institute of

Electricity (ICE, 1984).

Step 1: Electricity Market and Consumer Behavior

1. Calculation of Generation Needed

The electricity market study was divided by type of consumer: residential, general, industrial and public lighting. Forecasting demand for each sector was done taking into account population increase, number of household inhabitants, degree of electrification and other parameters specific to the Costa Rican case. The total consumption was obtained by adding the four sectors in order to obtain an integrated energy demand. This provides an indication of the expected sales, and by assuming a factor of energy losses based on the historical data, the generation needed to meet demand is calculated.

For the projection of maximum power demand, a load factor is applied, and as shown in Table 2, the projection of total sales, generation, losses, maximum power and load factor can be calculated. Table 3 summarizes the forecasts of energy sales. Nonetheless, the information recorded in Table 3. does not provide the necessary data for marginal cost calculations. There needs to be a disaggregation of the sales by voltage level and type of consumer.

2. Calculation of Sales Forecasts by Voltage Level and Type of Consumer

The forecasting of the sales by sectors (residential, general, industrial and public lighting) was performed as previously explained, and the increments in sales per year are calculated. For ICE, the consumer types were divided into the following categories: residential, general primary,

general secondary, industrial primary, industrial secondary, industrial in transmission level, large distributing companies, public lighting, other minor distributing companies in primary, and other minor distributing companies in secondary. From measures of the load curves it is possible to integrate for each time of the day (every half hour) the load curves for a typical day by type of consumer, as is shown in Table 4.

The load factors were calculated from the load curves as:

$$\text{Load Factor} = \text{L.F.} = \frac{E}{Po \times NH}$$

where: E = total energy in KWH
Po = Power or maximum demand in KW
NH = Number of hours in hours.

This factor measures the relation between the energy actually produced (or consumed) and the maximum energy that can be produced (or consumed) with a specific power over a specific time period.

The Peak Contribution Factor (P.C.F.). The PCF measures the relation between the individual demand of the consumer type at the time of maximum system peak in relation to the maximum Non-Coincident demand. Before being added, the peak capacity for each consumer type must be adjusted to reflect the fact that the consumer's maximum capacity requirement may not coincide with the time of the system peak as expressed by the formulas already mentioned. The ratio of consumer demand at system peak to maximum KW consumer demand is referred to as the consumer's coincidence factor. The PCF is calculated based on the following formula:

$$\text{P.C.F.} = \frac{\text{Concident Demand (at the time of the system peak)}}{\text{Maximum Non-Coincident Demand}}$$

As can be seen in Table 5, there is a high degree of coincidence

between the peak calculated from the projected load curves by sector and the actual system peak for 1982, which was taken as the base year. A summary of the Power loss factor by voltage level and consumer type is presented in Table 6.

For the calculation of the energy losses, the Costa Rican Institute of Electricity uses historical measures of the losses at different voltage levels and by consumer type. This information is summarized in Table 7.

3. Projection of Energy and Power by Voltage Level and type of Consumer

Based on the sales forecasts by voltage level and consumer type (Table 3), with the definitive values for load factors and contribution to peak and power losses (Table 6) and energy losses (Table 7), it is possible to project the participation of each consumer type for energy and power in relation to the different levels of energy delivery.

The general procedure for this projection can be summarized as follows:

For each year of the study (1983-89) the raw data used were the projections for energy sales in MWH for each consumer type. For each consumer type, the respective load factor was applied and the maximum non-coincident demand was obtained. The formula used is as follows:

$$\text{Non - Coincident Peak} = \text{N.C.P.} = \frac{E}{\text{L.F.} \times \text{NH}}$$

where: E = energy in KWH
L.F. = Load Factor in percentage
NH = number of hours, in hours.

The respective contribution to the peak factor was applied to the non-coincident peak in order to obtain the maximum coincident demand with the maximum system load. The formula used is as follows:

$$\text{Coincident Peak} = \text{C.P.} = \text{N.C.P.} \times \text{P.C.F.}$$

where: C.P. = Coincident Peak in KW
N.C.P. = Non-Coincident Peak in Kw
P.C.F. = Peak Contribution Factor (percentage).

The respective energy and power losses were applied to the expected energy sales and to the Coincident and Non-Coincident Peaks. The losses were applied with regard to the respective levels of voltage that the consumers were being served with.

The equations for obtaining the energy and power quantity losses are as follows:

$$E_{IL} = E_{WL} \times \frac{1}{1 - EL/100}$$

where: E_{IL} = energy including losses
E_{WL} = energy without losses
EL = energy losses (percentage)

$$CP_{IL} = CP_{WL} \times \frac{1}{1 - PL/100}$$

where: CP_{IL} = coincident peak including losses
CP_{WL} = coincident peak without losses
PL = Power Losses

The power loss formula can also be used for the Non-Coincident Peak case. The summary for 1983 by consumer type and voltage level is shown in Table 8. This table provides the necessary basic information in order to calculate the marginal costs. The tables for the periods up to 1989—not shown—are similar to Table 8.

Step 2: Calculation of the Marginal Costs for Generation

The load curves show great regularity, where the peak period is from 6 a.m. to 11 p.m. (Figure 5). Included in this period are two clear extreme peaks at 11:30 a.m. and at 6:30 p.m. Aside from minor variations, the demand for electricity is rather constant all year round. On the supply side, the availability is reduced during the dry season and there is an increased supply during the wet season, particularly at night.

1. Establishing the Investment Plan Needed to Cover the Increase in Demand.

For the calculation of the marginal costs for generation, the only completely established investment for the period under study is the hydroelectric plant Ventanas-Garita. This project will have a daily regulation reservoir, a capacity of 90MW and a net energy of 270 GWH in critical low flow years and 433 GWH in average years. 25% of the energy will be produced in the dry (summer) period (January-May) and 75% in the rainy (winter) period (June-December). The plant factor will be 22% in the dry period and 81% in the rainy period. The characteristics of this plant are such that it is intended to produce base energy for the load curve of the system in the rainy period allowing the larger, and already operating, hydroelectric plant of Arenal which has an inter-annual regulatory reservoir to store energy. The energy stored in Arenal during the winter will be used in the dry period with a larger load factor for that plant than the system average as a whole. Thus Arenal will make up the supply for the energy shortage characteristic in the dry season.

Hence, under this operating scheme, the investments considered are the new investment of the Ventanas-Garita Project and the that part of the investment in the Arenal Project attributable to providing the additional capacity of the system. These investment costs must be distributed to a

charge for power (in KW) corresponding to the installed capacity and to a charge for energy (in KWH) corresponding to the energy provided by the project.

For the Ventanas-Garita project, all costs were initially allocated to a unique charge for power (KW) because it is essentially a run-of-the-river plant. This procedure will first be explained, and later on modified, because the charges of marginal costs that result would stimulate the installment of private plants for use during peak periods. The present value of the cost of the Ventanas-Garita project as of December 1983 and at a 12% discount rate is 2,756,000,000 colones. The present value of the demand is 494,995 MW.

The marginal cost of generation is defined as that value which must be assigned to the sales of power and energy produced by the new project during its useful life in order to recuperate the investment. In other words, the present value of the investment should be equal to the present value of the revenues:

$$\sum_{t=o}^{t=T} \frac{I_t}{(1+i)^t} = \sum_{t=o}^{t=n} \frac{C_m D_t}{(1+i)^t}$$

where: I_t = Investment completed at the end of year T

t = time

T = period of time for completion

i = discount rate

Cm = marginal costs

D_t = power or energy in year t

n = useful life of the investment

From the previous equation the marginal cost is as follows:

$$C_m = \frac{\sum_{t=o}^{t=T} \frac{I_t}{(1+i)^t}}{\sum_{t=o}^{t=n} \frac{D_t}{(1+i)^t}}$$

Applying the second formula to the actual data for the project gives a marginal annual cost for power equal to 5,567.73 colones/KW-year. Given that this cost is so large there are alternative ways of approaching the problem that would be more realistic. This is addressed in the next section.

2. Calculation of the power costs distributed by power and energy

In the case of Costa Rica the best alternative to hydro plants have usually being gas turbines. This is so because in this specific case the size of the alternative makes gas turbines: a) more rapid to get installed, b) relatively low capital costs, c) in the present system structure gas turbines are used for quick increases in energy supply. Thus, the unique charge for power discussed in the previous sections was distributed in a different way: first, a power charge equivalent to the cost per KW of a gas turbine installed as a substitute for the hydro plant, and secondly the difference between the cost per KW of the hydro project and the cost per KW of the gas turbine, is assigned to the energy charges in the peak hours. This is assigned to the peak hours because the power costs originally accrue during the peak hours. Once this new approach is worked out, the results are as follows:

$$\text{Marginal Cost per installed KW} = \frac{\text{Present Value of Investments in Power } (¢x10^6)}{\text{Present Value of Increase in Capacity (MW)}}$$

$$= ¢149.854/\text{kw-month}$$

Marginal Cost of Power Assigned to Peak Energy =

$$\frac{\text{MC Hydro Power - MC Thermal Power}}{\text{(Load Factor in Peak Period) x (Hour of Peak/yr)}}$$

$$= ¢\ 0.878/\text{KWH}$$

Applying a reserve margin of 10% gives final amounts for the two components of the marginal cost of power:

¢ 164.84 /KW-month
¢ 0.9658 /KWH

3. Calculation of the Energy Costs

As previously explained, the availability of energy exceeds its demand during the rainy season. This energy surplus will be stored in the Arenal reservoir. During this period, therefore, the Ventanas-Garita project has an energy marginal cost of zero. Once the dry season begins, Arenal's water starts to be used and the level of the reservoir falls. During the dry season the extra energy needed is satisfied thanks to the extra investment in storage capacity in Arenal. Thus, the marginal costs for energy during the dry season are related to the investment in the Arenal reservoir. Although the Arenal Project is already built and in operation, part of that investment was considered a complement to the Ventanas-Garita Project. For the marginal cost of energy during the dry period, the present value of the investment in the dam and reservoir of Arenal will be taken

into account. This calculation is equivalent to the ratio between the present value of those investments and the present value of the energy obtained and gives a value of 0.3723 colones/KWH.

The total charges for power and energy in generation investment is as follows:

	Rainy Period		Dry Period	
	Peak	Non-Peak	Peak	Non-Peak
Power: c/Kw-month	164.84	0	164.84	0
Energy: c/KWh	0.9658	0	1.3381	0.3723

To these marginal costs, the operation, maintenance and other minor expenses must be added to the energy charges. Table 9 summarizes the results obtained when those extra charges are calculated; this follows a procedure similar to the one already extensively explained. The important part of this Table is line 9 where the total marginal costs for energy at the generation level are presented:

	Rainy Period		Dry Period	
	Peak	Non-Peak	Peak	Non-Peak
Total Marginal Costs for Energy: c/KWh	1.0508	0.085	1.4231	0.4573

Step 3: Calculation of Marginal Costs for Transmission

i. Calculation of marginal costs of investment in transmission.

These costs are related only to power charges because the transmission lines are designed based on peak demand. The caculation was done as

follows: first, an average cost was obtained, equal to the sum of the additional investments for transmission for the period of 1982-1985 (c 1,089.8 millions). This was divided by the incremental peak demand for the same period (118,685 KW). Later on this was adjusted and annuitized using a 12% discount rate and a useful life of 30 years. The annuitized cost obtained was 1139.92c/Kw-year. With a 10% adjustment to take into account a safety margin, this gives 1253.91 c/KW-year.

ii. Calculation of operation and maintenence costs.

Table 10 shows how O and M costs are taken into account when assessing the total marginal costs for transmission are obtained (Table 10). The marginal cost of transmission works out at 115.03/KW-month.

Step 4: Calculation of Marginal Costs for Distribution.

The marginal costs for distribution must be divided into primary and secondary distribution investments in order to obtain a correct assignment of costs for the different consumer types. For this purpose 59% of total distribution investment was assigned to primary distribution and 41% to secondary distribution. The costs were then divided between those accruing to power and those accruing to consumers. For the latter, the minimum investment required to serve each consumer type was calculated and called consumer investment and total investment was assigned to power charges. In the distribution scheme there is no allowance for energy charges.

i. Calculation of the marginal costs related to power at primary distribution

The increase in investment for primary distribution required to supply

the increase in demand is divided by the increase in demand. The result is multiplied by a factor (uniform annual equivalent cost at a discount rate of 12% and a useful life of 30 years for the new investments. The same was done for the operation and maintenance costs. For the effective cash flow, this was assumed to be 1/8 of the expenses in operation and maintenance, and corresponding to a 45 day effective cash flow. The minor supplies are calculated as 1.406% of the investment in the 1983-86 period. A summary of the calculations is presented in Table 11. In Table 11 the sum of operation and maintenance costs, administrative, general, and institutional costs and revenues needed for effective cash flow are presented in line 10. This line, divided by the incremental peak demand shown in line 2, gives the annual incremental costs needed for the operation and administration of the primary distribution system.

As a final step, the annual costs for operation and administration expenses is added to the annuitized investment costs (lines 11 and 3), and the marginal total costs per year (line 12) and per month (line 13) are obtained.

To calculate the responsibility of the different consumer types for costs, the following formula was used:

$$A_i = CP_i \times NCP_i$$

where:

A_i = adjustment factor for the consumer type i

CP_i = coincident peak of consumer type i at the time of the distribution system's peak

NCP_i = maximum demand or non-coincident peak of the consumer type i.

The adjustment factor was based on Tables 7 to 13, and in Table 11 (lower part) the result of those adjustments is summarized by each consumer type.

ii. Calculation of the marginal costs of power related at the secondary distribution level.

Following the same procedures as were established for primary distributon, the secondary distribution marginal costs were calculatd and the results summarized in Table 12.

Step 5: Calculation of consumer marginal cost.

The marginal costs for the consumer include as a first component that part of the incremental investment in the distribution system destined to serve a nominal load. To calculate this, the minimum investment required to serve each consumer type was established, including the costs of services and measuring devices. Later on, the operation and maintenence costs, administrative, general, and institutional costs, and revenue required for the active cash flow were added.

The increase in the number of consumers for each type was estimated based on historical usage, to which a rate growth in energy consumption was applied given the forecasts of sales by voltage level and type of consumer that were calculated at the beginning of this case-study.

The results of the marginal costs are presented in Table 13. The total marginal costs per year related to the consumer by consumer type is as follows:

Residential:	c 3,097.12/consumer
General Primary:	c 5,440.35/consumer
General Secondary:	c 3,097.12/consumer
Industrial Second:	c 6,884.63/consumer
Industrial Primary:	c 18,602.27/consumer
Public Lighting:	c 2,832.88/consumer

Step 6: Establish Tariffs

i. Summary of Marginal Costs at Generation, Transmission and Distribution Levels

Once the marginal costs for each level of voltage has been calculated, they must be added for each consumer type, depending on the voltage level of the electric service provided. To perform this calculation the loss factors related to power and energy must be taken into account. Table 14 summarizes the loss factors applicable to each consumer type by voltage level. Once this correction for losses is applied to each marginal cost, a summary of marginal cost by period of the year (rainy or dry), by peak characteristics (peak or non-peak) and by class of consumer is obtained, as indicated in Table 15.

ii. Comparison between marginal costs, average costs and average tariffs.

In order to compare marginal costs by cosumer type with the actual tariffs, it is necessary to determine an 'average' marginal cost which is that price to be used when no distinction is made between peak and non-peak hours. In the tarriff structure, the charges for demand (c/KW) by time of day and by season of year are not taken into account for some of the consumers types. Hence, an averaging of those marginal costs for the purpose of comparison must be performed. This adjustment includes the following steps:

i) For the marginal costs for energy (colones/KWh) for peak and non-peak hours, an average marginal cost can be calculated based on the percentage of energy that each consumer type assigns to the peak and non-peak hours. These percentages are based on Table 4, which gives the forecasting for such loads related to each type of consumer. The formula used is as follows:

$$AMCE = PPH\ (MCE) + PNPH\ (MCENP)$$

where: AMCE = average marginal cost of energy (c/KWH)

PPH = percentage of energy for that type of consumer assigned in peak hours (%)

MCE = marginal cost of energy in peak hours (c/KWh)

PNPH = percentage of energy that type of consumer assigned in non-peak hours

MCENP = marginal cost of energy in non-peak hours

This equation must be applied for both the rainy period and the dry period. For example, the residential sector in the rainy period the calculations are as follows:

(1.2498 c/KWh) (0.8246) + (0.1011 c/KWh) (0.1754) = 1.0483 c/KWh

and for the dry period:

(1.6927 c/KWh) (0.8246) + (0.5439 c/KWh) (0.1754) = 1.4912 c/KWh

ii) As a second step, an annual marginal cost must be calculated, weighted for the average marginal costs of energy for each period (rainy and dry). The raiy period is seven months (June to December, inclusive). The dry period is five months (January to May). The formula for obtaining the average marginal cost of annual energy is as follows:

$$AMCEA = (7/12)\ AMCRP + (5/12)\ AMCDP$$

where:

AMCEA = average marginal cost of energy per annum
AMCRP = average marginal cost of energy in rainy period
AMCDP = average marginal cost of energy in dry period

For example for the residential sector, the average marginal costs for energy per annum based on the cost for each season (already obtained) are as follows: (1.0483 c/KWh) (7/12) + (1.4912 c/KWh) (5/12) = 1.2329 c/KWh. In Table 16 the information for each type of consumer is presented.

The marginal cost for demand (c/KW) assigned to peak hours for both seasons (rainy and dry) must be converted to average marginal cost for energy (c/KWh). To perform this transformation, the marginal cost for demand is divided by the hours of utilization. The latter is equal to the load factor for the type of consumer, multiplied by the number of hours in the month. The formula used is as follows.

$$MCDAE = \frac{MCD}{NHU}$$

where:

MCDAE = marginal cost for demand converted to an average marginal cost for energy (c/KWh).

MCD = marignal cost of demand (c/KW)

NHU = number of hours of utilization (hours).

For example, for the residential sector the marginal cost of demand is converted to an average marginal cost for energy as follows:

$$MCDAE = \frac{1141.66 \ c/KW}{344.6 \ Hours} = 3.3133 \quad c/KWh$$

The 344.6 hours come from multiplication of the load factor for the residential sector (47.2%) by the total number of available hours in a month (730). The annual marginal cost by consumer (c/consumer) must also be transformed to an average marginal cost of energy (c/KWh). To obtain that, the annual marginal cost per consumer for each consumer type must be divided by the aveage annual estimated consumption. The formula is as follows:

$$MCCAE = \frac{MCC}{AAC}$$

where:

MCCAE = marginal cost by consumer converted to an average energy cost (c/KWh)

MCC = marginal cost of the consumer (c/consumer)

AAC = average annual consumption (KWh/consumer)

Once the three components of the marginal cost has been calculated by type of consumer and summed in homogeneous units of average marginal costs of energy (c/KWh), this can then be compared to the tariff structure.

For example, for the residential sector the average marginal cost of energy is calculated as follows:

$$(1.2329 + 3.3133 + 1.6292) \text{ c/KWh} = 6.1754 \text{ c/KWh}$$

In Table 17 a summary is presented of the average marginal costs for each of its three components (energy, demand and consumer) as well as the average marginal cost for each type of consumer.

In Table 18 a comparison is made between the average marginal costs, the average costs and the average tariffs. For Rural Electrification the relevant tariff is type T-1 for rural residential consumers and T-3 Secondary Industrial for rural industrial consumers. In the former case the difference between the tariff and the marginal cost is 74% for the latter case 33%. In absolute terms, the averge marginal cost for the residential consumer in the rural areas is 6.18 c/KWh and the averaged tariff is 1.61 c/KWh. For the industrial consumer the average marginal cost is 5.30 c/KWh and the tariff is 3.56 c/KWh. These numbers focus directly on the problem of appraising a Rural Electrification project. Table 19 shows the costs for urban areas.

Rural Electrification and electricity service, are considered to be a 'social good' comparable with health and education in Costa Rica. Hence, the tariffs reflect not the actual cost of supplying the good but the subsidized price that makes the good available to the large majority of Costa Ricans, including the rural consumers. Nonetheless, the fact that the marginal costs of supplying electricity to the rural consumer, are very high--the highest--makes a rural electrification project look less than promising from a financial point of view. Only when the economic, social and political merits are analysed as a whole can a more complete appraisal of a rural electrification project be stated. The marginal cost analysis allows the planner explicitly to address the social and political role that rural electrification schemes serve in each particular society and the weight that society and the state assign to such a project type. The application of the UNIDO methodology as explained elsewhere in this paper explicitly addresses this issue and allows the planner to put an appropriate weight on the social and political considerations regarding rural electrification. Marginal cost analysis clearly helps to establish a framework for analysis capable of showing the actual cost of new rural electrification schemes and the actual differences between costs and the amount paid. The decision makers can then support, reject or modify such a differentiated structure between costs and actual payments.

FIGURE 1

MARGINAL COSTS OF ENERGY FOR THE CASE OF COSTA RICA

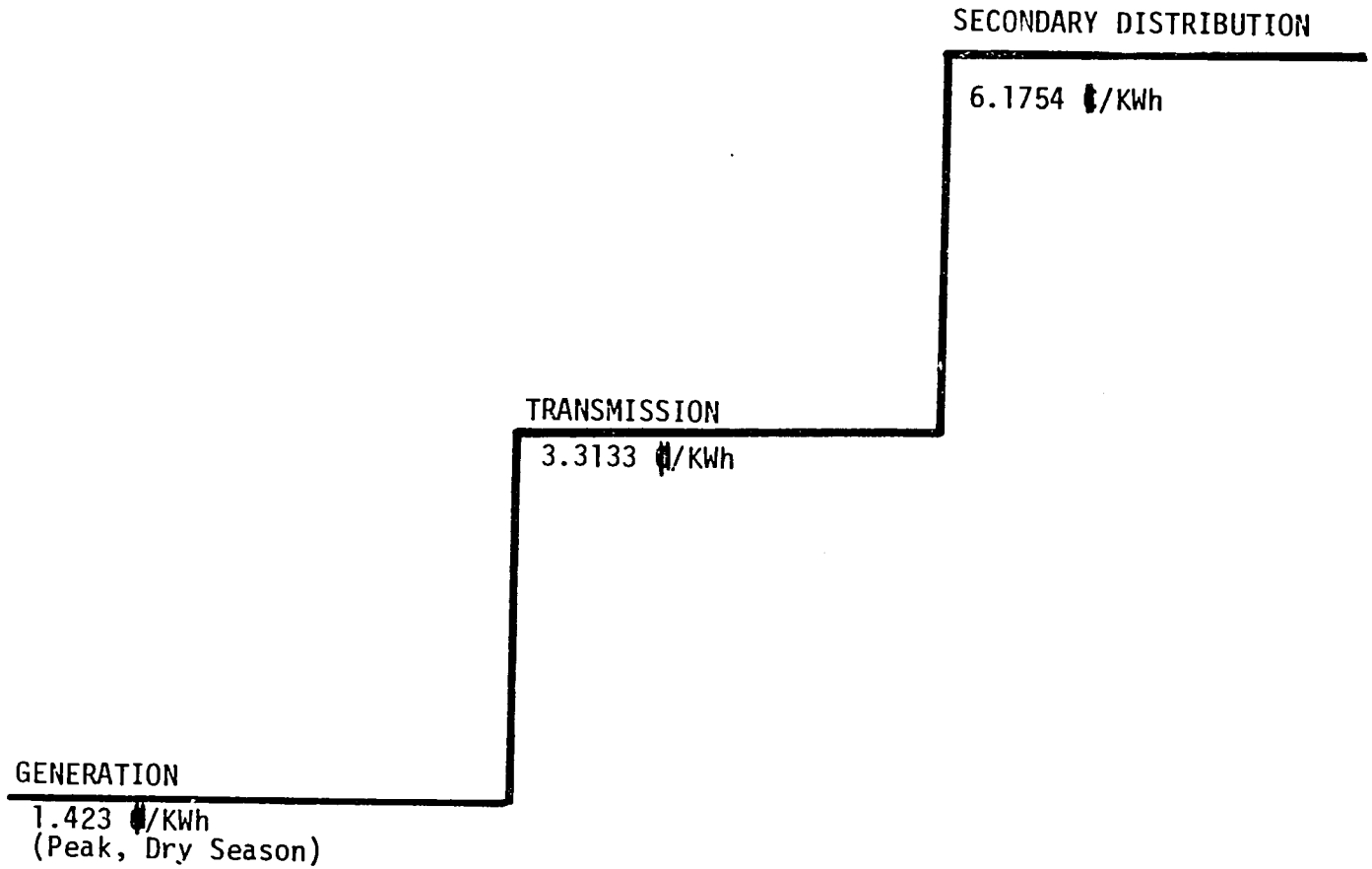


FIGURE 2

MARGINAL COSTS FOR POWER FOR THE CASE OF COSTA RICA

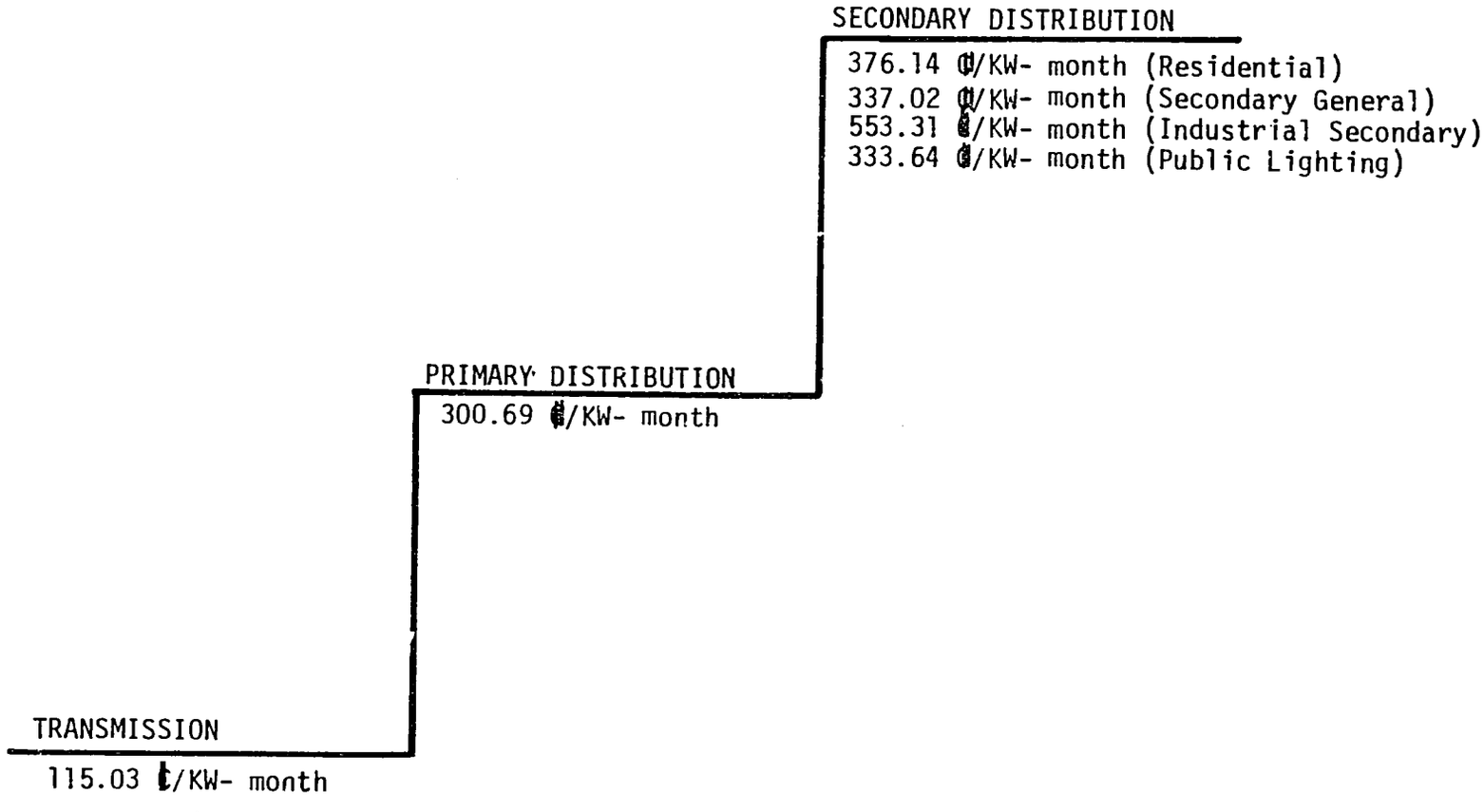
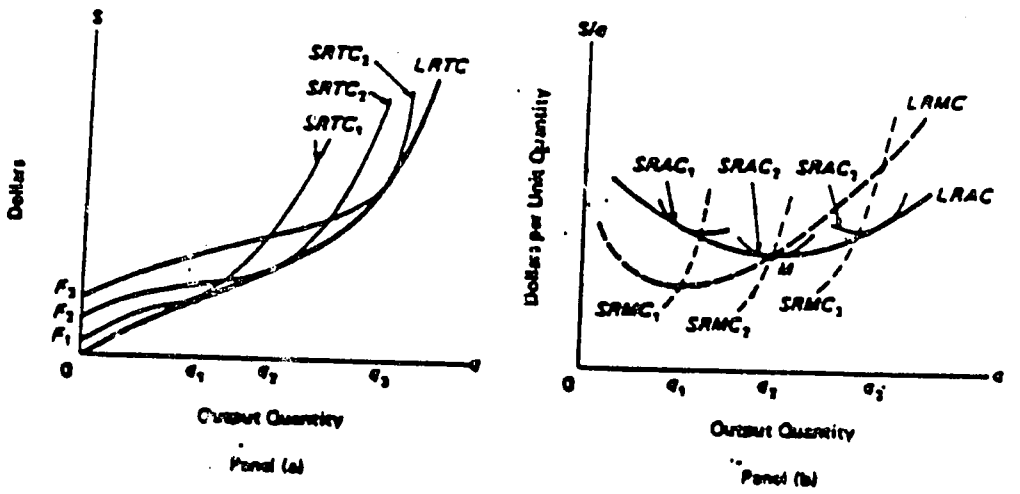


FIGURE 3

SHORT AND LONG RUN COSTS

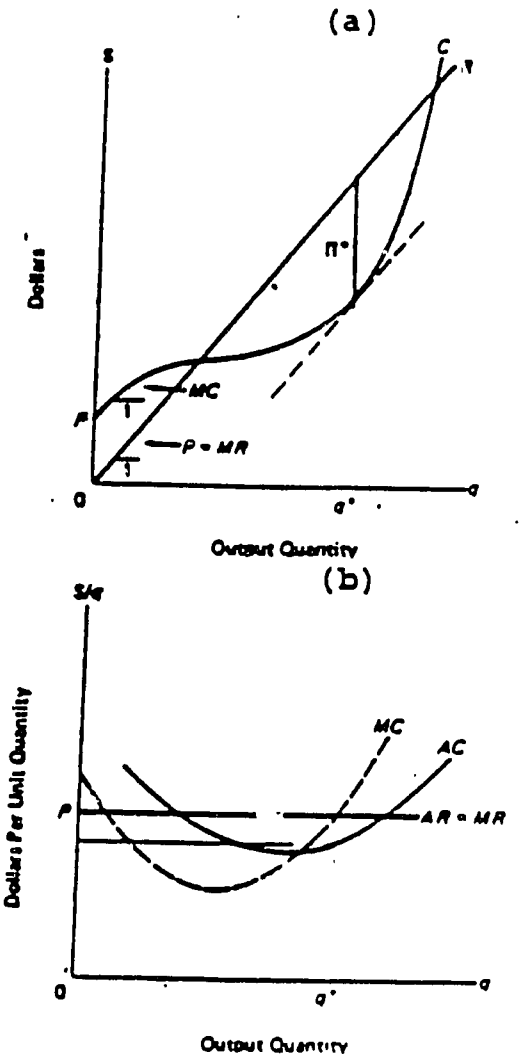


In Panel (a), *LRTC* is the Long-Run Total Cost function showing the cost of producing any output q when all factors are allowed to vary. The Short-Run Total Cost curve $SRTC_1$ applies when the fixed factor is held constant at a level appropriate for small-scale production (q_1); similarly, $SRTC_2$ and $SRTC_3$ are associated with the higher levels of fixed cost appropriate for medium-scale production (q_2) and for large-scale production (q_3). The corresponding average and marginal curves are shown in Panel (b). At output q_1, $SRAC_1 = LRAC$ (a tangency) and $SRMC_1 = LRMC$ (an intersection), and similarly for output levels q_2 and q_3. At any output, the Total Cost curves and the Average Cost curves are never higher in the long run than the short run. However, over certain ranges Short-Run Marginal Cost may lie below *LRMC*.

Source:Hirshleifer,1984.

FIGURE 4

MARGINAL COSTS



In Panel (a), at the optimal output q^* the vertical dollar difference between the Total Revenue curve R (a ray through the origin for a price-taking firm) and the Total Cost curve C is greatest. At output q^* the slopes along R and C are equal—implying that, in Panel (b), the horizontal Marginal Revenue curve MR must intersect the Marginal Cost curve MC at that output. The amount of the maximized profit, Π^*, is shown as the length of the vertical line-segment between the R and C curves in Panel (a), and as the shaded rectangle corresponding to the area $(AR - AC)q^*$ in Panel (b).

Source:Hirshleifer,1984.

FIGURE 4c

PRICING IN A NATURAL MONOPOLY

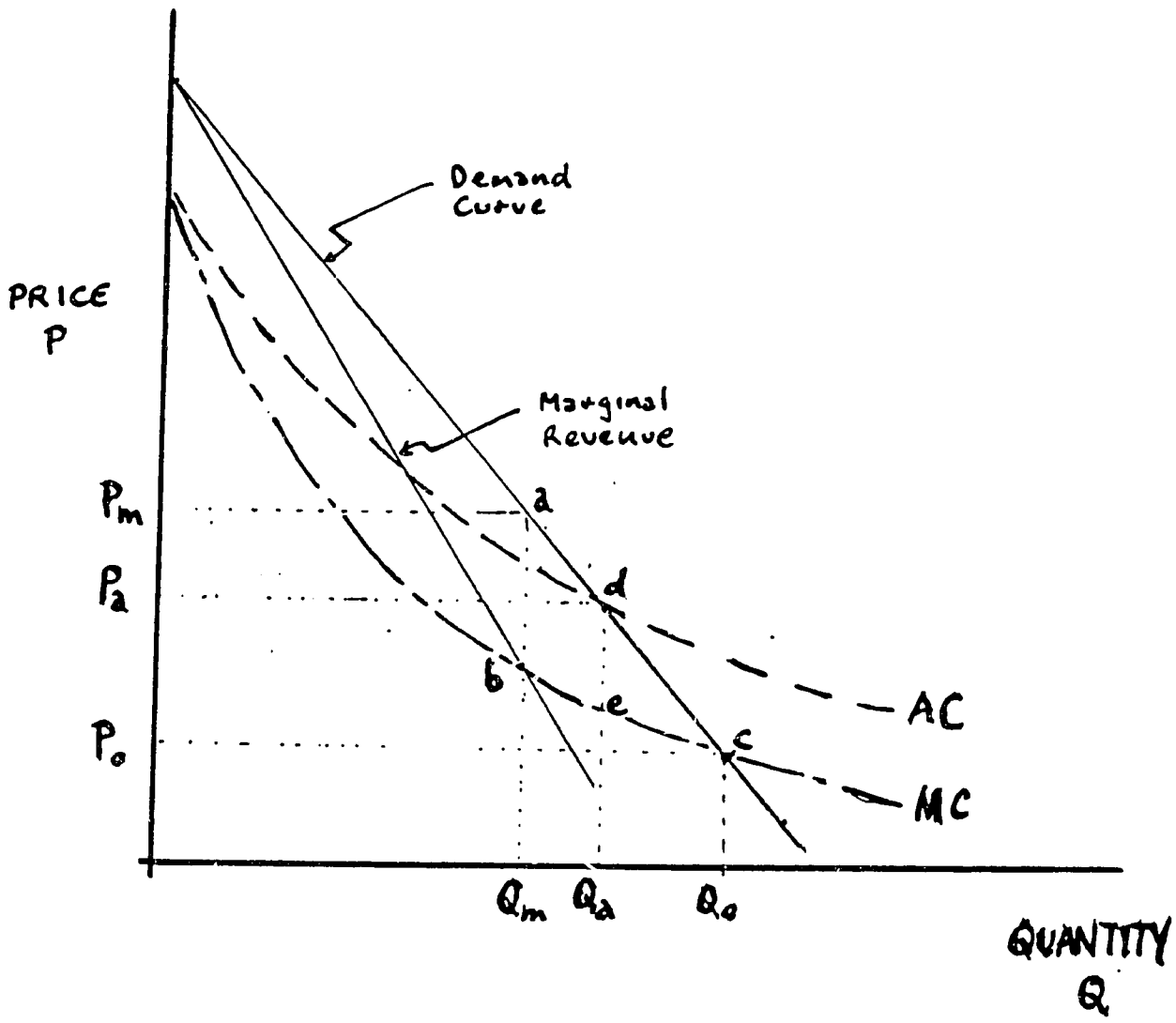
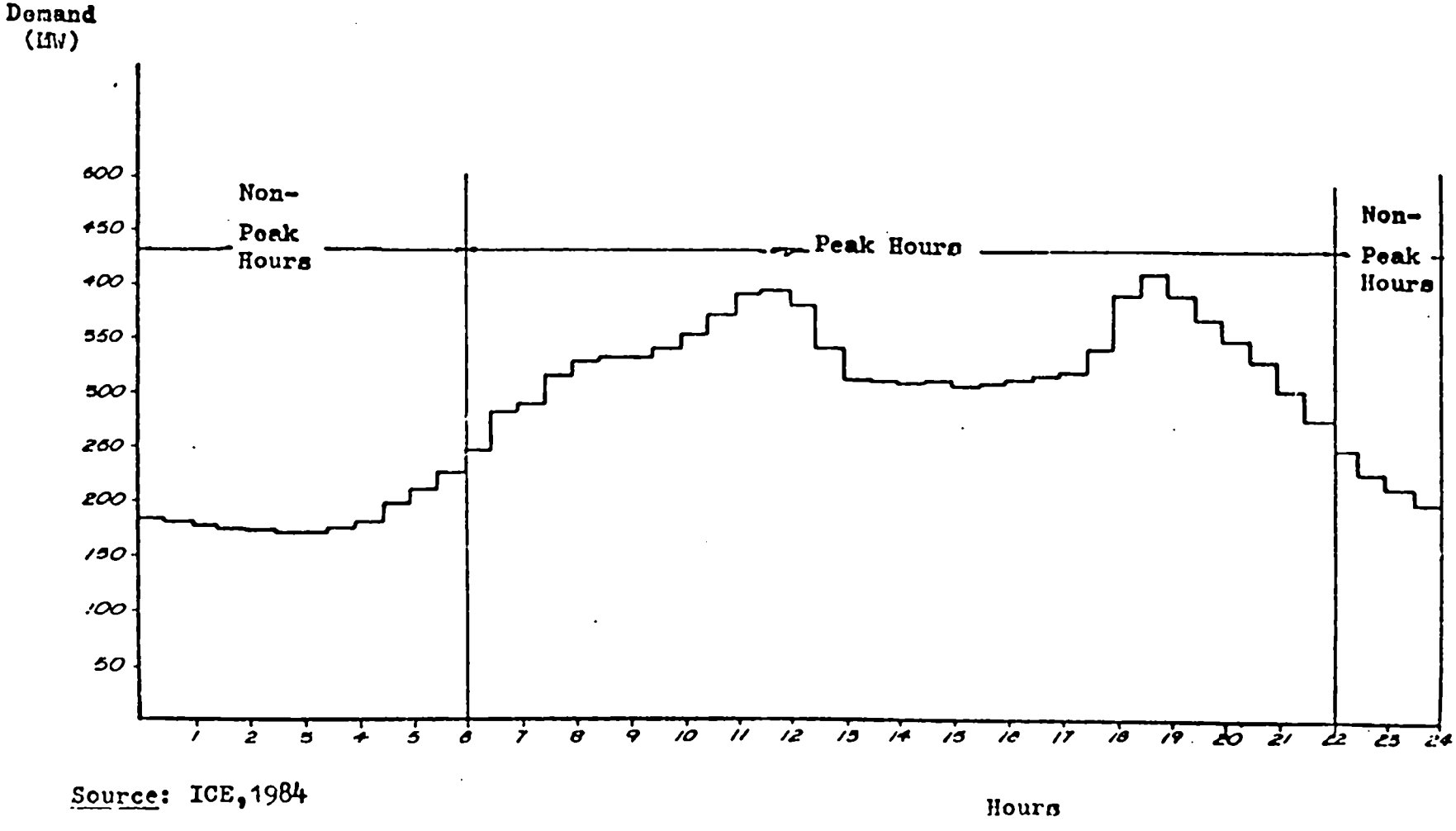


FIGURE 5

Typical Load Curve of the National Electricity Grid
(February 1, 1983)



Source: ICE, 1984

TABLE 1

PERCENTAGE CHANGES IN ELECTRICITY TARIFFS IN ORDER TO EQUATE AVERAGE AND MARGINAL COSTS

	Type of Tariff	Average Marginal Cost(¢/KWh)	Average Price: Tariff(¢/KWh)	Percentage of Change Needed
* Residential	T-1	6.18	1.61	+284
General Primary	T-2	2.68	2.46	+ 9
* General Secondary	T-2	5.12	3.63	+ 41
Industrial Primary	T-3	2.36	2.77	- 15
* Industrial Secondary	T-3	5.30	3.56	+ 49
Industrial Transmission	T-3	1.56	2.20	- 29
Large Indust.Distrib.	T-3	1.71	2.20	- 22
OED: Transmission	T-4	1.79	2.23	- 20
OED: Distribution	T-5	1.89	1.25	+ 51
Public Lighting	T-6	8.05	0.76	+959

OED: Other Electricity Distributors.

Source: ICE, 1984

$$\text{Percentage Change Needed} = \frac{\text{Average Marg. Cost} - \text{Average Price}}{\text{Average Price}}$$

* corresponds to rural energy supply

TABLE 2

Sale , Generation, Loses and Load Factor of the National Electricity Grid: 1982-1995

Year	Sales (GWh)	Generation (GWh)	Loses (%)	Maximum Power(MW)	Load Factor (%)
1982	2028.3	2273.7	10.8	420	61.8
1983	2084.2	2336.5	10.8	432	61.8
1984	2186.9	2451.7	10.8	454	61.6
1985	2320.0	2600.9	10.8	482	61.6
1986	2487.9	2789.1	10.8	517	61.6
1987	2679.7	3004.2	10.8	558	61.5
1988	2916.6	3269.7	10.8	603	61.9
1989	3185.1	3570.7	10.8	651	62.6
1990	3481.3	3902.8	10.8	705	63.2
1991	3808.4	4269.8	10.8	764	63.8
1992	4170.1	4675.0	10.8	830	64.3
1993	4572.9	5126.6	10.8	903	64.8
1994	5016.2	5623.5	10.8	981	65.4
1995	5510.2	6177.4	10.8	1070	65.9

Source: ICE, 1984

TABLE 3

Energy Sales Forecasts by Sector of Consumption in MWh

Year	Residential	General Primary	General Secondary	Indust. Primary	Indust. Secondary	Indust. Transm.	Large Indus. Distribut.	Public Lighting	OED:* Transm.	OED: Distr.	TOTAL
1983	250 840	88 130	33 730	94 940	14 770	52 300	120 580	22 020	1 421 480	125 620	2 224 410
1984	262 360	94 390	36 180	99 230	15 420	54 590	125 880	22 750	1 491 490	131 810	2 334 100
1985	274 450	102 070	39 080	106 000	16 520	58 320	134 500	23 460	1 582 170	139 830	2 476 400
1986	286 230	111 290	42 630	115 740	18 040	63 730	146 800	24 260	1 696 560	149 940	2 655 300
1987	299 330	123 090	47 120	126 560	19 680	69 690	160 640	25 090	1 827 310	161 490	2 860 000
1988	320 490	137 580	52 720	138 350	21 520	76 140	175 510	25 890	1 988 930	175 770	3 112 900
1989	343 620	155 610	59 630	151 150	23 500	83 130	191 740	26 810	2 177 460	192 440	3 405 090

* OED:Other Electricity Distributors.
Source: ICE,1984

TABLE 4

Load Curves Integration for a Typical Day (KW)

Hour	1	2	3	4	5	6	7	8	9	10
1	11 835	2 451	5 536	1 230	7 831	8 402	12 265	3 868	78 825	9 639
2	10 289	2 394	5 772	1 200	8 135	8 382	12 326	3 868	75 873	9 232
3	9 980	2 352	5 696	1 180	8 087	8 373	12 318	3 868	73 839	8 793
4	9 671	2 389	5 460	1 200	8 030	8 322	12 218	3 868	72 714	8 793
5	10 024	2 363	5 284	1 180	8 094	8 427	12 851	3 868	71 505	8 798
6	10 333	2 323	5 272	1 160	8 200	8 408	14 378	3 868	69 426	8 800
7	10 068	2 327	5 224	1 160	8 067	8 452	14 404	3 868	69 235	8 868
8	9 892	2 329	5 136	1 160	7 839	8 393	14 778	3 868	68 642	9 137
9	12 453	2 357	5 232	1 180	7 879	8 595	14 846	3 868	73 361	9 823
10	17 090	2 331	5 820	1 170	7 880	9 448	14 878	3 868	81 290	11 665
11	17 222	2 263	5 420	1 130	7 626	9 037	14 796	3 868	90 768	13 950
12	24 111	2 252	6 308	1 130	7 676	8 901	14 822	3 868	112 804	18 112
13	25 392	2 247	7 612	1 120	8 030	8 863	14 635	0	144 269	21 727
14	32 325	2 596	7 720	1 300	10 185	8 844	15 199	0	158 162	22 630
15	25 348	2 899	7 932	1 450	8 443	8 847	15 592	0	149 949	20 240
16	26 982	3 603	8 812	1 800	9 660	9 215	15 664	0	159 647	20 967
17	30 029	3 823	8 736	1 910	11 228	10 086	16 156	0	166 265	21 193
18	25 304	4 258	9 264	2 130	10 971	9 890	16 233	0	172 397	21 274
19	27 600	4 232	9 472	2 120	11 601	10 352	16 106	0	174 949	21 966
20	31 663	4 111	10 196	2 060	13 612	10 219	16 088	0	178 534	22 330
21	33 076	4 329	10 996	2 170	12 618	9 151	14 994	0	171 530	23 286
22	34 401	4 421	10 372	2 210	13 820	9 478	13 575	0	182 070	24 373
23	36 874	4 347	11 652	2 170	13 244	9 181	13 996	0	193 324	25 584
24	37 580	4 249	11 760	2 130	12 702	8 828	13 272	0	220 553	24 944
25	36 255	4 469	10 692	2 470	12 063	9 934	13 071	0	203 211	23 327
26	26 496	4 271	10 076	2 140	12 535	8 610	13 349	0	175 599	20 976
27	24 455	4 361	9 784	2 180	12 989	9 252	14 046	0	160 388	19 123
28	23 449	4 371	10 056	2 190	13 072	9 090	13 429	0	154 993	18 760
29	23 405	4 264	9 880	2 130	11 632	9 692	13 316	0	155 174	19 769
30	25 093	4 059	10 340	2 030	11 547	9 954	14 082	0	159 937	19 662
31	29 366	3 932	9 684	1 970	11 642	10 020	12 825	0	169 109	20 277
32	26 054	3 750	9 892	1 880	12 542	9 722	14 074	0	164 106	21 954
33	26 849	3 665	9 940	1 830	12 200	10 327	14 347	0	173 268	23 014
34	30 205	3 495	10 548	1 750	11 951	9 952	13 386	0	178 770	22 645
35	31 177	3 256	10 320	1 630	9 129	9 113	12 367	0	180 607	22 758
36	41 864	3 249	11 652	1 630	11 868	6 336	11 889	3 868	182 543	23 244
37	47 119	3 524	13 168	1 760	11 913	6 407	12 458	3 868	199 885	27 930
38	41 290	3 593	12 972	1 500	11 938	5 921	15 005	3 868	210 388	30 613
39	41 466	3 624	11 752	1 500	12 049	5 576	15 675	3 868	199 804	28 940
40	35 196	3 446	11 428	1 500	11 585	5 807	15 384	3 868	182 485	26 165
41	33 252	3 392	10 832	1 500	11 517	6 420	14 627	3 868	159 489	24 121
42	28 967	3 313	9 772	1 500	10 698	6 116	14 792	3 868	152 148	21 584
43	25 789	3 358	8 864	1 500	10 549	6 200	14 918	3 868	140 783	19 319
44	23 449	3 024	8 256	1 500	10 356	6 012	14 706	3 868	134 170	17 454
45	20 667	2 873	7 064	1 440	10 016	6 202	14 028	3 868	114 280	14 632
46	14 794	2 835	6 916	1 420	9 958	6 808	14 493	3 868	99 319	12 672
47	12 586	2 807	6 084	1 400	9 940	6 357	14 418	3 868	88 577	11 303
48	9 848	2 808	5 360	1 400	9 826	5 564	14 428	3 868	79 931	10 191
49	10 422	2 651	5 380	1 330	9 902	8 402	13 459	3 868	78 825	9 619

30 Minutes Range starting at 0:00

Note: 1=Residential;2=General Primary; 3=General Secondary; 4=Industrial Secondary;5=Industrial Primary;6= Indust. Transmission; 7=Large Industrial Distributor;8=Public Lighting;9=OED:Transmission; 10= OED:Distribution

Source: ICE,1984

TABLE 5
POWER AND ENERGY DISTRIBUTION BY CONSUMPTION SECTOR: 1982

	RESIDENTIAL	GENERAL 1	GENERAL 2	INDUSTRIAL SECONDARY	INDUSTRIAL PRIMARY	INDUSTRIAL TRANSMISSION	LARGE INDUST. DISTRIBUTION	OTHER ELECTRICITY DISTRIBUTORS TRANS.	UED DISTRIB.	PUBLIC LIGHTING	TOTAL
GENERATION											
Energy(MWh)	254829	80915	34522	17065	98634	51721	123212	1141330	162356	21601	2001402
Coincident Peak(MW)	62980	9577	7401	2873	14572	6095	20436	251148	30797	5994	306501
Non-coinc. Peak(MW)	71295	15178	7524	3956	17473	9490	24300	242294	33899	6024	432023
Energy Losses(%)	1.52	1.52	1.52	1.52	1.52	1.52	1.52	1.52	1.52	1.52	na
Power Losses(%)	2.29	2.29	2.29	2.29	2.29	2.29	2.29	2.29	2.29	2.29	na
TRANSMISSION											
Energy(MWh)	259178	79665	33997	16826	87133	50935	121339	1124049	159869	21352	1901115
Load Factor	na	na	na	na	na	0.627	na	0.542	na	na	na
Coincident Peak(MW)	61538	9358	7232	2519	14230	7910	19969	225855	33023	5000	307906
Peak Contrib. Factor	na	na	na	na	na	0.853	na	0.954	na	na	na
Non-coinc. Peak(MW)	70249	14831	7342	3965	17072	9273	23743	236745	33123	5096	402125
Energy Losses(%)	4.93	4.93	4.93	4.93	4.93	na	3.39	na	3.45	4.93	na
Power Losses(%)	7.15	7.15	7.15	7.15	7.15	na	7.15	na	7.15	7.15	na
PRIMARY DISTRIBUTION											
Energy(MWh)	243263	75757	32321	15996	92347	na	117226	na	154373	20299	761582
Load Factor	na	0.628	na	na	0.665	na	0.607	na	0.673	na	na
Coincident Peak(MW)	57139	8669	6715	2153	13220	na	18540	na	30662	5430	142555
Peak Contrib. Factor	na	0.631	na	na	0.834	na	0.841	na	0.997	na	na
Non-coinc. Peak(MW)	65226	13770	6817	3589	15832	na	22046	na	30754	5466	163420
Energy Losses(%)	10.2	na	10.2	10.2	na	na	na	na	na	10.2	na
Power Losses(%)	19	na	19	19	na	na	na	na	na	19	na
SECONDARY DISTRIBUTION											
Energy(MWh)	218451	na	29028	14365	na	na	na	na	na	18229	280070
Load Factor	0.472	na	0.6	0.564	na	na	na	na	na	0.47	na
Coincident Peak(MW)	46281	na	5439	1744	na	na	na	na	na	4405	57869
Peak Contrib. Factor	0.876	na	0.985	0.6	na	na	na	na	na	0.993	na
Non-coinc. Peak(MW)	52833	na	5522	2907	na	na	na	na	na	4427	65689

TABLE 6

POWER LOSES BY VOLTAGE LEVEL AND TYPE OF CONSUMER (%)

Type of Consumer	Voltage Levels		
	Transmission	Primary Distribution	Secondary Distribution
Residential	2.290	7.15	19.00
General 1	2.290	7.15	-
General 2	2.290	7.15	19.00
Ind.Primary-Second.	2.290	7.15	-
Industr. Secondary	2.290	7.15	-
Industrial Primary	2.290	7.15	-
Industrial Transm.	2.290	-	-
Large Indust.Distrib.	2.290	7.15	-
OED:Transmission	2.250	-	-
OED:Distribution	2.290	7.15	-
Public Lighting	2.290	7.15	19.00

Source: ICE,1984

TABLE 7

ENERGY LOSES BY VOLTAGE LEVEL

AND

TYPE OF CONSUMER

(IN PERCENT)

Type of Consumer	Transmission	Primary Distribution	Secondary Distribution
Residential	1.52	4.93	10.2
General 1	1.52	4.93	
General 2	1.52	4.93	10.2
Industrial Second.	1.52	4.93	10.2
Industrial Primary	1.52	4.93	-
Industrial Transm.	1.52	-	-
Large Indus.Distr.	1.52	3.39	-
OED:Transmission	1.52	-	-
OED:Distribution	1.52	3.45	-
Public Lighting	1.52	4.93	10.2

Source: ICE,1984

TABLE 8

POWER AND ENERGY DISTRIBUTION BY CONSUMPTION SECTOR 1993

	RESIDENTIAL	GENERAL 1	GENERAL 2	INDUSTRIAL SECONDARY	INDUSTRIAL PRIMARY	INDUSTRIAL TRANSMISSION	LARGE INDUST. DISTRIBUTION	OTHER ELECTRICITY DISTRIBUTORS TRANS.	DED DISTRIB.	PUBLIC LIGHTING	TOTAL
CONSUMPTION											
Energy(MWh)	298351	94130	40110	17567	101500	53107	126797	1443419	132116	26190	2333235
Coincident Peak(kW)	72310	11142	8601	2440	14995	8312	21021	292312	27502	7241	465684
Non-coinc. Peak(kW)	82555	17657	8732	4068	17900	9745	24995	306406	27585	7277	507000
Energy Losses(%)	1.52	1.52	1.52	1.52	1.52	1.52	1.52	1.52	1.52	1.52	na
Power Losses(%)	2.29	2.29	2.29	2.29	2.29	2.29	2.29	2.29	2.29	2.29	na
TRANSMISSION											
Energy(MWh)	299816	92700	49509	17300	99957	52300	124011	1421460	130108	25792	2297773
Load Factor	na	na	na	na	na	0.627	na	0.542	na	na	na
Coincident Peak(kW)	70662	10086	8404	2404	14652	8122	20539	285618	26872	7075	455214
Peak Contrib. Factor	na	na	na	na	na	0.053	na	0.954	na	na	na
Non-coinc. Peak(kW)	80664	17253	8532	3974	17569	9522	24423	299390	26953	7111	495391
Energy Losses(%)	4.93	4.93	4.93	4.93	4.93	na	3.39	na	3.45	4.93	na
Power Losses(%)	7.15	7.15	7.15	7.15	7.15	na	7.15	na	7.15	7.15	na
PRIMARY DISTRIBUTION											
Energy(MWh)	279931	88130	37561	16447	95030	na	120580	na	125520	24521	707220
Load Factor	na	0.628	na	na	0.605	na	0.607	na	na	na	na
Coincident Peak(kW)	65609	10108	7003	2214	13604	na	19071	na	24951	6569	149929
Peak Contrib. Factor	na	0.631	na	na	0.034	na	0.041	na	0.997	na	na
Non-coinc. Peak(kW)	74897	16019	7922	3690	16312	na	22676	na	24926	6602	495391
Energy Losses(%)	10.2	na	10.2	10.2	na	na	na	na	na	10.2	na
Power Losses(%)	19	na	19	19	na	na	na	na	na	19	na
SECONDARY DISTRIBUTION											
Energy(MWh)	250840	na	33730	14770	na	na	na	na	na	22020	321360
Load Factor	0.472	na	0.6	0.564	na	na	na	na	na	0.47	na
Coincident Peak(kW)	63144	na	6321	1793	na	na	na	na	na	5321	66579
Peak Contrib. Factor	0.876	na	0.985	0.6	na	na	na	na	na	0.995	na
Non-coinc. Peak(kW)	80666	na	6317	2909	na	na	na	na	na	5340	75420

TABLE 9

Summary of Marginal Costs of Energy by Season Peak/Non-Peak Period

Generation Costs

(¢/KWH)

	Rainy Season		Dry Season	
	Peak	Non-Peak	Peak	Non-Peak
1. Energy Component	0.9658		0.9658	
2. Storage Costs *			0.3723	0.3723
3. Operation and Maintenance related to Energy	0.0740	0.0740	0.0740	0.0740
4. Cash Flow (+)	0.0093	0.0093	0.0093	0.0093
5. Materials and Supplies(++)	0.0033	0.0033	0.0033	0.0033
6. Total : 4 + 5	0.0126	0.0126	0.0126	0.0126
7. Revenue Requirement for 6.(+++)	0.0015	0.0015	0.0015	0.0015
8. General, Administrative and Institutional Expenses	0.0095	0.0095	0.0095	0.0095
9. Total Marginal Cost of Energy at Generation Level: 1+2+3+7+8	1.0508	0.085	1.4231	0.4573

(+) 1/8 of operation and maintenance expenses; (++) 1.406% of the incremental for the 1983-86 period and assigning 60% of it to the energy component; (+++) 12% of line 6.

Source: ICE, 1984

* storage costs are the same for peak and non-peak since both are under shortage conditions during the dry season.

TABLE 10

MARGINAL COSTS OF TRANSMISSION

1. Aditional Investments for Transmission	(¢x10^6)	1 089.8
2. Incremental Peak Demand for 1982-85	(KW)	118 685.0
3. Annualized Cost	(¢/KW-año)	1 253.9120
4. Increments in operation and maintenance, 1982-85	(¢x10^6)	7.80
5. Increments in administrative, general and institutional expenses 1982-85	(¢x10^6)	5.25
6. Cash Flow (+)	(¢x10^6)	0.98
7. Materials and Supplies(++)	(¢x10^6)	15.32
8. Total: 6+7 (+++)	(¢x10^6)	16.30
9. Revenue Requirement for 8	(¢x10^6)	1,96
10. Total expenses increment: 4+5+9	(¢x10^6)	15.01
11. Annual Incremental Cost: 10/2	(¢/KW-año)	126.47
12. Total Marginal Cost: 3 + 11	(¢/KW-año)	1 380.3820
	(¢/KW-mes)	115.0320

(+) 1/8 of operation and maintenance expenses; (++) 1.406% of the incremental investment for 1982-85 period; (+++) 12% of line 8

Source: ICE, 1984

TABLE 11

Demand Related Marginal Costs for Primary Distribution

			Adjustment Factor (+++++)	Peak Demand Cost per KW (++++++)
1. Additional Investment in Primary Distr. for the 1982-86 period	(¢x10^6)	723.10		
2. Incremental Peak Demand 1982-86	(KW)	34 462.00		
3. Annualized Cost (+)	(¢/KW-año)	2 604.85		
4. Incremental expenses in Op.& M.	(¢x10^6)	18.64		
5. Incremental expenses in administrative, general and institutional	(¢x10^6)	14.44		
6. Cash Flow (++)	(¢x10^6)	7.33		
7. Materials and supplies (+++)	(¢x10^6)	10.17		
8. Total: 6+7	(¢x10^6)	12.50		
9. Revenue Requirement(++++)	(¢x10^6)	1.50		
10. Total Increase in Expenses: 4+5+9	(¢x10^6)	34.58		
11. Annual Incremental Cost: 10/2	(¢/KW-año)	1 003.42		
12. Annual Marginal Cost: 3 + 11	(¢/KW-año)	3 608.27		
13. Monthly Marginal Cost	(¢/KW-mes)	300.69		
14. Residential			.987	296.78
15. General Primary			1.371	412.25
16. General Secundary			0.878	264.01
17. Industrial Secundary			1.442	433.59
18. Industrial Primary			1.037	311.82
19. Large Industrial Distributors			1.028	309.11
20. OED: Distribution			0.868	261.00
21. Public Lighting			0.869	261.30

(+) annuity of 12.41437 corresponding to 12% for 30 years; (++) 1/8 of operation and maintenance expenses; (+++) 1.406% of incremental investment for 1982-86 period; (++++) 12% of line 8; (+++++) Relation between coincident and non-coincident demand; (++++++) Adjustment factors based on line 13.

Source: ICE, 1984

TABLE 12

Demand Related Marginal Costs for Secondary Distribution

			Adjustment Factor (+++++)	Peak Demand Cost per KW (++++++)
1. Aditional Investment in Secund. Distribution (1982-86)	(¢x10^6)	510.75		
2. Incremental Peak Demand 1982-86	(KW)	18 813.00		
3. Annualized Cost (+)	(¢/KW-año)	3 370.35		
4. Increment in operation and maintenance	(¢x10^6)	11.47		
5. Incerement in administrative, general and institutional expenses 1982-86	(¢x10^6)	9.01		
6. Cash Flow (++)	(¢x10^6)	1.43		
7. Materials and Supplies(+++)	(¢x10^6)	7.18		
8. Total:6 + 7	(¢x10^6)	8.61		
9. Revenue Requirement (++++)	(¢x10^6)	1.03		
0. Total Increase in Expenses:4+5+9	(¢x10^6)	21.51		
1. Annual Incremental Cost: 10/2	(¢/KW-año)	1 143.36		
2. Annual Marginal Cost: 3 + 11	(¢/KW-año)	4 513.71		
3. Monthly Marginal Cost	(¢/KW-mes)	376.14		
4. Residential			1.008	379.15
15. General Secundary			0.896	337.02
16. Industrial Secundary			1.471	553.31
17. Public Lighting			0.887	333.64

(+) Annuity of 12.41437 corresponding to 12% for 30 years; (++) 1/8 of oper. and maintenance expenses; (+++) 1.406% of incremental investment for the 1982-86 period; (++++) 12% of line 8; (+++++)Relation between coincident and non-coincident demand; (++++++) Adjustment factors based on line 13.

Source: ICE, 1984

TABLE 13

MARGINAL COSTS CONSUMER RELATED

		1	2	3	4	5	6	7
1. Additional Investment in primary distr. 1982-86 period.	(£x10^6)							233.3
		18 630	22	5 847	213	8	2 924	274.59
2. New consumers, 1982-86	(£/cons.)	8 073.91	8 073.91	8 073.91	8 073.91	8 073.91	8 073.91	
3. Unified costs of primary distr., 1982-86	(£x10^6)							240.66
4. Additional Investment in secondary distr.		106.30		5 847	213		2 924	27 614
5. New consumers, secundary, 1982-86	(£/cons)	8 715.14		8 715.14	8 715.14		8 715.14	
6. Unified cost of secundary distr.: 4/5	(£x10^6)	39.12	0.71	12.28	6.86	2.19		
7. Total additions in services and meters	(£/cons)	2 100	32 200	2 100	32 200	136 800		
8. Unitary costs of 7: 7/2	(£/cons)	18 889.06	40 273.91	18 889.05	48 989.05	144 873.93	16 789.05	
9. Total Unitary Costs: 3 + 6 + 8	(£/cons)	2 344.96	4 999.75	2 344.96	6 081.68	17 985.18	2 084.25	
10. Annualized Cost (+)	(£x10^6)							5.76
11. Increment in expenses in O & M, primary	(£/cons)	208.27	208.27	208.27	208.27	208.27	208.27	
12. Cost. in expenses in O & M, secundary	(£x10^6)							5.33
13. Increase in O & M expenses, secundary	(£/cons)	193.02		193.02	193.02		193.02	
14. O & M costs, secondary consumer, 1982-86	(£x10^6)							4.46
15. Increase in administrative, general and institutional expenses, 1982-86, primary	(£/cons)	161.26	161.25	161.26	161.26	161.26	161.26	
16. Cost of line 15, by consumer: 15/2	(£x10^6)							4.19
17. Increase in adm., general, and inst. expenses, 1982-86, secundary.	(£/cons)	151.73		151.73	151.73		151.73	
18. Cost of line 16, by consumer: 17/2	(£/cons)	50.16	26.03	50.16	50.16	26.03	50.16	
19. Cash Flow (++)	(£/cons)	265.58	566.25	265.58	688.79	2 036.93	236.05	
20. Materials and Supplies (+++)	(£/cons)	315.74	592.28	315.74	738.95	2 062.96	286.21	
21. Total: 19 + 20	(£/cons)	37.88	71.07	37.88	88.67	247.56	34.35	
22. Revenue Requirement (++++)	(£/cons)	3 097.12	5 440.35	3 097.12	6 884.63	18 602.27	2 832.88	
23. Marginal Cost by Consumer: 9 + 12 + 14 + 16 + + 17 + 22								

Note: 1=Residential; 2=General Primary; 3=General Secundary; 4=Industrial Secundary; 5=Industrial Primary; 6=Public Lighting; 7=TOTAL

Note: (+)Annuity of 12.41437 corresponding to 12% for 30 years; (++) 1/8 of O & M expenses; (+++) 9.95 of line 9 (++++) 12% of line 21.

Source: ICE, 1984

TABLE 14

POWER AND ENERGY LOSSES (%)

	POWER (KW)			ENERGY (KWH)		
		Primary	Secondary		Primary	Secondary
	Transmission	Distribution	Distribution	Transmission	Distribution	Distribution
Residential	2.29	7.15	19.0	1.52	4.93	10.20
General Primary	2.29	7.15	-	1.52	4.93	-
General Secundary	2.29	7.15	19.0	1.52	4.93	10.20
Industrial Secundary	2.29	7.15	19.0	1.52	4.93	10.20
Industrial Primary	2.29	7.15	-	1.52	4.93	-
Industrial Transmission	2.29	-	-	1.52	-	-
Large Ind. Distrib.	2.29	7.15	-	1.52	3.39	-
OED:Transmission	2.29	-	-	1.52	-	-
OED:Distribution	2.29	7.15	-	1.52	3.45	-
	2.29	7.15	19.0	1.52	4.93	10.20

TABLE 15

SUMMARY OF MARGINAL COSTS BY SEASON AND TYPE OF CONSUMER

	Rainy Season		Dry Season		Annual Cost to Consumer
	Peak	Off-Peak	Peak	Off-Peak	(¢/Consumer
Residential					
Demand Cost(¢/Kw-month)	1141.7614		1141.7614		3097.12
Energy Cost(¢/KWh)	1.2498	0.1011	1.6927	0.5439	
General Primary					
Demand Cost(¢/Kw-month)	753.0909		753.0909		5440.35
Energy Cost(¢/KWh)	1.1224	0.0908	1.5200	0.4884	
General Secundary					
Demand Cost(¢/KW-month)	1048.3103		1048.3103		3097.12
Energy Cost(¢/KWh)	1.2498	0.1011	1.6927	0.5439	
Industrial Secundary					
Demand Cost(¢/KW-month)	1529.5567		1529.5567		6884.63
Energy Cost(¢/KWh)	1.2498	0.1011	1.6927	0.5439	
Industrial Primary					
Demand Cost(¢/KW-month)	642.3922		642.3922		18602.27
Energy Cost(¢/KWh)	1.1224	0.0908	1.5200	0.4884	
Industrial Transmission					(1)
Demand Cost(¢/KW-month)	298.6894		298.6894		
Energy Cost(¢/KWh)	1.0670	0.0863	1.4451	0.4744	
Large Indust. Distrib.					18602.27
Demand Cost(¢/KW-month)	340.7157		340.7157		
Energy Cost(¢/KWh)	1.1046	0.0893	1.4958	0.4807	
OED:Transmission					(1)
Demand Cost(¢/KW-month)	298.6894		298.6894		
Energy Cost(¢/KWh)	1.0670	0.0863	1.4451	0.4644	
OED:Distribution					(1)
Demand Cost(¢/KW-month)	340.7157		340.7157		
Energy Cost(¢/KWh)	1.1051	0.0894	1.4967	0.4810	
Public Lighting					3112.86
Demand Cost(¢/KW-month)	1070.7237		1070.7237		
Energy Cost(¢/KWh)	1.2498	0.1011	1.6927	0.5439	

Source: ICE, 1984

TABLE 16

AVERAGE MARGINAL COST OF THE ENERGY COMPONENT

	RAINY SEASON (+)					DRY SEASON (++)					(+++)
	MC Peak Energy (¢/KWh)	Peak Hours (%)	MC Off-Peak (¢/KWh)	Off-Peak Hours (%)	Average MC (¢/KWh)	MC Off-Peak Energy	Peak Hours (%)	MC Off-Peak (¢/KWh)	Off-Peak Hours (%)	Average MC (¢/KWh)	Average Annual MC
Residential	1.2498	82.46	0.1011	17.54	1.0483	1.6927	82.46	0.5439	17.54	1.4912	1.2329
General Primary	1.1224	75.14	0.908	24.86	0.8659	1.5200	75.14	0.4884	24.86	1.2035	1.0315
Gnl. Secondary	1.2498	78.00	0.1011	22.00	0.9971	1.6927	78.00	0.5439	22.00	1.4400	1.1915
Ind. Secondary	1.2498	74.77	0.1011	25.23	0.9600	1.6927	74.77	0.5439	25.23	1.4029	1.1445
Ind. Primary	1.7224	73.10	0.908	26.90	0.8449	1.5200	73.10	0.4884	26.90	1.2425	1.0105
Ind. Transmiss	1.0670	68.10	0.0863	31.90	0.7541	1.4451	68.10	0.4644	31.90	1.1323	0.9117
Large Ind.Dist.	1.1046	67.33	0.0893	32.67	0.7729	1.4958	67.33	0.4807	32.67	1.1642	0.9359
OED:Transm.	1.0670	80.69	0.0863	19.31	0.8776	1.4451	80.69	0.4644	19.31	1.2557	1.0332
OED:Distr.	1.1051	80.53	0.0894	19.47	0.9073	1.4967	80.53	0.4810	19.47	1.2989	1.0705
Public Light.	1.2498	28.13	0.1011	71.87	0.4242	1.6927	28.13	0.5439	71.87	0.8671	0.6087

(+)Rainy Season:7 months,June to December
(++) Dry Season:5 months,January to May
(+++) Obtained by weighting the seasonal cost by the lenght of each season

Source: ICE,1984

TABLE 17

SUMMARY OF AVERAGE MARGINAL COSTS

	Energy Average MC (¢/KWh) (+)	Demand MC (¢/KW-month)	Hours of Use (Hr.)	Demand Average MC (¢/KWh)	Consumer MC (¢/Consumer)	Average Consumpt. by Consumer (KWh/year)	Consumer Average MC (¢/KWh)	TOTAL Average MC (¢/KWh) (++)
Residential	1.2329	1141.76	344.6	3.3133	3097.12	1901	1.6292	6.1754
General Primary	1.0316	753.09	458.4	1.6429	5440.35	1016770	0.0054	2.6799
General Secund.	1.1816	1048.31	438.0	2.3934	3097.12	2001	1.5478	5.1228
Ind. Secundary	1.1445	1529.56	411.7	3.7152	6884.63	15727	0.4378	5.2975
Ind. Primary	1.0106	647.39	485.5	1.3232	18602.27	714777	0.0260	2.3598
Ind. Transmission	0.9117	298.69	457.7	0.6526	-	-	-	1.5643
Large Ind. Distr.	0.9359	340.72	443.1	0.7689	18602.27	17551666	0.0011	1.7058
OED:Transmission	1.0362	298.70	395.7	0.7549	-	-	-	1.7901
OED:Distribution	1.0705	340.72	418.3	0.8145	-	-	-	1.8850
Public Lighting	0.6987	1070.72	343.1	3.1207	3112.86	720	4.3234	8.0528

(+) Obtained from Table 16
(++) Obtained from the addition of the average marginal costs of the energy, demand and consumer components.

Source: ICE, 1984

TABLE 18

COMPARISON BETWEEN AVERAGE MARGINAL COSTS, AVERAGE COSTS AND TARIFFS

	Type of Tariff	Average Marginal Cost(¢/KWh)	Average Cost (¢/KWh)	Average Price of Tariff(¢/KWh)	Difference in Relation to Marginal Cost (%) (+)
Residential	T-1	6.13	3.35	1.61	-74
General Primary	T-2	2.68	2.43	2.46	- 8
General Secondary	T-2	5.12	2.43	3.63	-29
Industrial Primary	T-3	2.36	2.19	2.77	+17
Industrial Secondary	T-3	5.30	2.19	3.56	-33
Industrial Transmission	T-3	1.56	1.90	2.20	+41
Large Ind. Distrib.	T-3	1.71	1.90	2.20	+29
OED: Transmission	T-4	1.79	2.00	2.23	+25
OED: Distribution	T-5	1.89	1.95	1.25	-34
	T-6	8.05	2.85	.76	-91

(+) The difference is: $\frac{\text{Average Price of Tariffs} - \text{Average Marginal Cost}}{\text{Average Marginal Cost}}$

Source: ICE, 1984

TABLE 19

URBAN AVERAGE MARGINAL COSTS AND

AVERAGE TARIFFS

	Type of Tariff	Average Marg Costs(¢/KWh)	Average Tariff (¢/KWh)	Percentage of Modification (+)
Residential	T-1	3.65	1.55	+135
General Primary	T-3 or T-4	2.68	2.60	+ 3
General Secondary	T-2	2.62	2.77	- 5
Industr.Primary	T-3 or T-4	2.99	2.35	+ 27
Industr.Secondary	T-2	2.77	2.65	+ 5
Public Lighting	T-5	5.15	2.88	+ 79

(+) The percentage of modification is equal to:

$$\frac{\text{Average marginal Cost} - \text{Average Tariff}}{\text{Average Tariff}}$$

Source: ICE, 1984

Chapter VII

SURVEY ON BENEFITS OF RURAL ELECTRIFICATION

1. Introduction

Methodologies for evaluation of benefits of rural electrification have typically been divided into ex-ante and ex-post approaches. Utilities normally utilize an ex-ante, engineering-oriented approach that sometimes includes economic appraisals. The ex-post approach, in turn, covers a wider range of studies that include estimation of direct and indirect socio-economic benefits as well as a variety of other impacts during a significant time after the project was implemented.

Ex-ante analysis, as mentioned earlier, is usually carried out by engineers, utility related economists or international development banks and related agencies. The ex-post approach, including estimation of social and economic benefits as well as impacts, has been the usual concern of social scientists and economists not necessarily related to the utilities. While ex-ante analysis is more pragmatic and investment oriented, the ex-post approach tends to place more emphasis on the connection with the development process as a whole.

The fact that there has been little interaction between the two approaches may reflect more a gap between the "two cultures" of the analysts, rather than conflicting or contradictory views or methodological approaches. To this end we carried out a survey in three rural townships in Costa Rica during August 1985. The purpose of the survey was to enable us to estimate the economic benefits of rural electrification and assess its other impacts in an area where active promotion of rural electrifica-

tion is still going on. As controls we used two nearby towns--one electrified for some time and one only recently electrified.

There is a need to bridge the gap between these two types of approaches as well as to delineate the extensive and positive feedbacks between the ex-ante and ex-post studies.

2. Sample Design

The objective of the study made by us during 1985 was to measure the benefits which electrification brings to the residential sector and to the productive commercial sector in rural townships. To reach this objective, two surveys were made simultaneously. A residential survey was carried out by means of a stratified sample, and a complete census of the commercial population was made.

We decided to take the following towns of the province of Limon as the target population:

-Puerto Viejo, which is not electrified;

-Cahuita, which has been electrified for 3 years;

-Penhurst-Valle de Estrella, which has been semi-electrified for 9 years.

According to the General Directory of Statistics and Census (1980), 354 households existed in the 3 towns. Fixing the confidence level at 95% and a deviation of 5% with respect to the average in the variable categories, the size of the residential sample was chosen to be 186 households for a simple random design without replacement. In order to assure an

evenly weighted sample the sample was split proportionally among the towns. Because all places within the towns were represented in the sample a systematic mixed sample (with a space of two between those chosen) was used. The manner in which this sampling method treats a geographic distribution can be compared with an unrestricted mixed sample.

When the fieldwork was done, it was found that the population of households had fallen to approximately 314, for various reasons such as abandonment, destruction, etc. It was therefore necessary to substitute about 20 households for others whose central characteristics were similar and which formed part of the population. A copy of the original survey questionnaire is given in Appendix A.

The results of the fieldwork were as follows:

Results

	Households		Commercial	
Town	Pop.	Sample	Pop.	Sample
Cahuita	108	55	16	15
Puerto Viejo	102	57	10	10
Penshurt	104	55	6	5
Total	314	167	32	30

3. Socio-Economic Background of the Population

The main economic activities in the areas surveyed are agricultural poduction (46%), small business (8%), fishing (8%), and construction (6%). The majority are self-employed (38%), 12% employ at least one other person, 31% are employed in the private sector, and 11% work in the public sector.

The principal occupations are farmers (24%) and farm workers (17%).

Next are fishermen (7%) and businessmen (5%).

The vast majority of households do not engage in any productive or commercial activity from the home (92%). The remaining 3% are involved in activities such as making pastries, ironing or making clothes, selling meals, or repair. If other necessary supporting conditions/investments are in place--such as markets, credit, roads, etc.--then electrification may generate more activities in this area. As will be discussed later, the households generally believe this to be the case; that is, that electrification will bring about new businesses and jobs, and greater economic development in general.

49% of the households own their own homes, while the other 51% either rent or borrow. the average number of people permanently living in a house is 5.4. The average rent per month is 1450 colones, or about $28 (this is excluding the top 3% rent-payers, who pay up to 22,000 colones per month). 69% pay nothing at all.

The mean income of those surveyed is 7727 colones per month (approximately $150 per month). Figure 1 shows the income distribution.

The level of education of the principal wage earner is generally low: 40% never finished primary school, 28% completed this level but did not go any further. 8% had some secondary school education, while 4% went on to graduate. 5% attended a university.

4. Switchover to Electricity and Benefit Estimation

The most common uses of energy in those households surveyed are for lighting and cooking purposes. Appliance use is not a major factor, due to

the rural and lower income levels that prevail in the area under question.

When electricity is available, the majority of households opt for this energy source in order to meet their lighting needs. The most popular source following electricity is candle power, and then canfin (kerosine).

For those households which began to use electricity for cooking, prior energy sources were rather evenly split among gas, canfin, and firewood, with charcoal lagging behind. However, a fair percentage--26%--did not change over to electricity after it was made available to them. (See Table 1.)

The major cited reason which lies behind households' changes to electricity utilization is this energy source's convenience, cleanliness, practicality, and higher quality. Of those that actually made the change to electricity use, 93% listed at least one on the above characteristics as their reason. Significantly, only 5% stated that they changed because electricity was more economical and 2% gave other responses. (See Table 2.)

This seems to indicate, then, that the more qualitative benefits of electricity--the "inherent" qualities of electricity as an energy source--are indeed justifiable as economic benefits to the households, although they are difficult to quantify. It is this type of benefit which the consumer willingness-to-pay method hopes to capture.

Following up on this point, households were asked to rate various energy sources as cheap, normal, or expensive. For all energy sources, including electricity, the majority of responses fell into the "expensive" category, firewood being the exception.

And when asked what they would do if their electricity bill doubled, only 28% stated that they would keep consuming the same amount of electricity, while the remaining 70% would take some kind of action such as cutting-off service or decreasing consumption. (See Table 3.) In the same vein, only 25% stated that they would consume more electricity if their income doubled. The main reason stated for this was that they already used the necessary level--that there was no necessity to spend more. For those who would spend more, their chief explanation was that they would buy more electrical appliances.

The above responses give greater justification to the consumer willingness-to-pay method than normally seems to be the case. Using this method, consumers are asked how much they value given levels of electricity consumption. Generally, this would lead to fairly arbitrary responses. Yet the low income levels and the above responses indicate that these households are more knowledgeable than the general public about how much money they have available to spend on electricity. With low and relatively stable incomes, they have a good idea as to their monthly expenses. Thus when asked what they would do when faced with a doubled electricity bill, most would not continue the same level of consumption.

The other benefit estimation method used was based on investment in electrical appliances. That is, the economic benefits of electrification are judged to be equal to the amount which consumers spend on new electrical appliances purchased. The justification for this is that their use was made possible by electrification. The surveys questioned both those already electrified and those without electricity about how may appliances they had (or would buy, in the case of non-electrified households).

The willingness-to-pay method estimated the economic benefits of electrification at 133% more than the financial benefits of the project, while the appliance investment method estimated them at 84% more than the financial benefits.

A more conventional method of benefit estimation--that of valuing electrification at the cost of those energy sources for which it has been substituted--was not used. There were several problems with doing so, the combination of which made it unlikely that good results could be generated. The major problems were that (1) the degree of substitution which had taken place could not be determined with sufficient accuracy, (2) energy use was not clearly divided into end-use categories, and (3) household responses about prices and quantities of energy other than electricity.

5. Quality of Service

A majority (78%) of households stated that electricity outages were not frequent. The other 20% gave varying frequencies: 40% experienced outages at least once a week; and 45% experienced them at least once every 2 to 4 weeks. The duration of the outages was as follows: 40% find power restored within 0.5 hours, 51% within 1.5 hours, and almost 100% within 4 hours. However, virtually no one was willing to pay more for the purpose of correcting this situation. This suggests that the level of service reliability is sufficiently high.

The times most commonly stated as inconvenient for power outages were midday--due to lunch preparation--and evening (6 to 12 p.m.)--due to the problems of darkness ("insecurity", "can't read or watch television", "time when family is together").

6. Benefits of Electrification (For Households)

For those who would increase their electricity consumption if their income doubled, the vast majority would do so because they would buy more electrical appliances. The most frequent appliance named as the first to be bought was a refrigerator (28%), followed by a television (17%). The next most popular were stoves (13%) and stereos (9%), (see Table 4).

97% of non-electrified households stated that they would buy electrical appliances if electricity was made available to them. The most popular appliance was again the refrigerator (32%), followed by the television (17%), stove (14%) and washing machine (8%), (see Table 5). Current electrical appliance ownership in those towns already electrified is shown in Table 6.

Households named, or agreed to, quite a few qualitative benefits of electricity (giving further support to the consumer willingness-to-pay methodology). Overwhelming majorities felt that: electricity improved convenience/comfort, encouraged study and education, promoted family togetherness, and reduced robberies and assaults.

In addition, almost all stated that electrification facilitates work, especially for women. Only 1% said that electricity would make more work.

Finally, opinion was pretty much divided over whether electrification would favor the rich or the poor in particular: about 26% chose the rich, 23% the poor, and 45% said both.

The above responses closely follow the high expectations which generally develop regarding electrification.

The principal perceived advantages seen of electrification were that it brought greater convenience and greater security at night; plus there could be public lighting. Closely following this type of category (security) were hopes of greater benefit to the economy: greater tourism, generation of more businesses, more employment, and greater progress. (See Table 7.) In general, there was then this combined expectation of a higher standard of living and a spur to the area's economic development and growth.

Households thought that economic activity would be encouraged and generated by electrification. About 35% said that they would engage in some commercial activity if their town was electrified (such as restaurants, pulperias, and other small businesses). And almost 70% stated that electrification results in a great increase in income and 13% felt that it produced a moderate income increase, but only 14% felt that it brought about no change in incomes. Furthermore, almost 80% felt that electrification would generate a great deal of new employement, and 7% that it would produce a moderate number of new jobs. Only 10% said that no new jobs would result. However, when households which already had electricity were questioned about whether electrification had resulted in increased incomes, only 3% gave a positive response.

7. Benefits of Electrification (for Businesses)

43% of the businesses interviewed were bars or pulperias (general stores), 20% were restaurants, soda or refreshment establishments, 20% were cabins or hotels, and the others were varied activities such as stores or cabinet repair shops. All of these businesses work year-round, without any suspension in their activity. For most, (83%), there are variations in

production or services throughout the year.

Most employees are family members (in 67% of the businesses). 10% employ 1 outside person, 13% employ 2, and the remaining 10% employ between 3 and 6.

The average sales were in the order of 8700 colones per month. When asked if they thought it possible to sell more than they were selling at the time, 73% said yes. Of these, 57% said the deficiency was due to a lack of tourists/visitors, 20% listed money problems, 14% listed a need for electricity, and 9% a lack of equipment. (See Table 8.)

Businesses gave less enthusiastic responses about the monetary benefits of electricity than did households. Of those that had been electrified, 94% stated that it did not bring about an increase in the business' earnings. And only one business changed its principal activity after electrification (and this was not a major change).

Also, no business found that they worked a greater number of hours after electrification. And none found any other benefit that came from electrification.

FIGURE 1

HOUSEHOLD INCOME PER MONTH
(in 1000 colones)

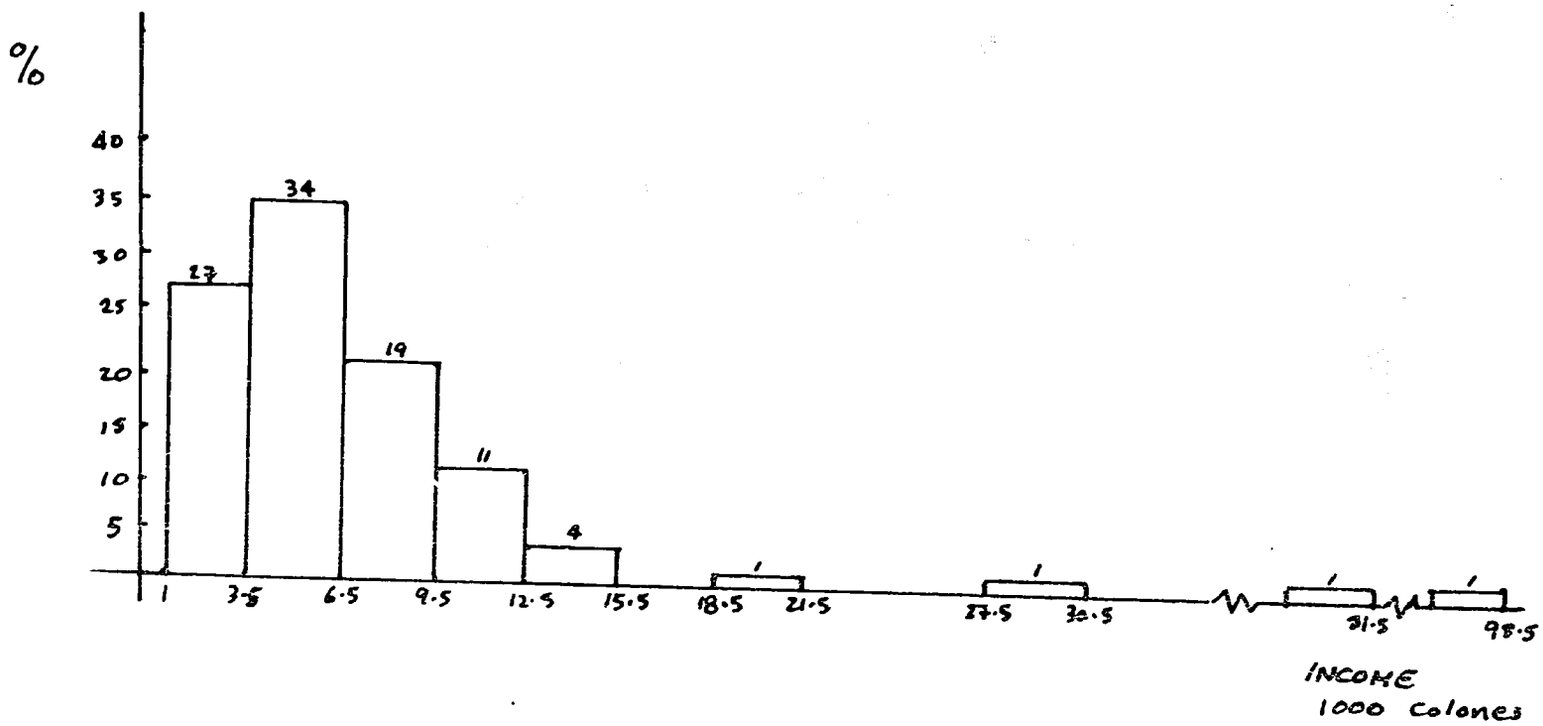


TABLE 1

ENERGY USED PRIOR TO ELECTRIFICATION

RESPONSE	PERCENTAGE
Gas	18
Canfin	16
Firewood	13
Carbon	6
Didn't change to electricity	26
Didn't live there before elec.	20
Didn't know	1

::

TABLE 2

REASONS FOR HOUSEHOLDS' CHANGEOVER TO ELECTRICITY USE

RESPONSE	PERCENTAGE
Electricity was cheaper	5
Electricity is of better quality, more convenient, cleaner, and makes things "easier"	63
Electricity is very useful; it was lacking in the past	21
Electricity is more convenient; don't have to mess with gas, candles, etc.	3
Other responses	2
Didn't know	6

::

REACTION TOWARDS A DOUBLED ELECTRICITY BILL

RESPONSE	PERCENTAGE
Would cut off service	17
Would not pay it	12
Would use another fuel	14
Would decrease elec. consumption	12
Would protest the increase	4
Would pay it	28
Other responses	5
Didn't know	6

::

TABLE 4

FIRST APPLIANCE TO BE BOUGHT (FOR THOSE WHOSE ELECTRICITY CONSUMPTION WOULD RISE IF HOUSEHOLD INCOME DOUBLED)

APPLIANCE	PERCENTAGE
Refrigerator	28
Television	17
Stove/Oven	13
Sound Equipment	9
Radio	4
Washing Machine	2
Other	15
Didn't know	11

::

TABLE 5

FIRST APPLIANCE TO BE BOUGHT (FOR THOSE WHO WOULD BUY ONE IF ELECTRIFIED)

APPLIANCE	PERCENTAGE
Refrigerator	32
Television	17
Stove/Oven	14
Washing Machine	8
Radio	4
Sound Equipment	3
Blender	1
Other	17
Didn't know	4

::

TABLE 6

ELECTRICAL APPLIANCE OWNERSHIP (IN ALREADY ELECTRIFIED TOWNS)

APPLIANCE	PERCENTAGE WHO OWN ONE OR MORE
Television	72
Iron	72
Refrigerator	45
Fan	17
Radio/Cassette	15
Sound Equipment	13
Radio	12
Brush	9
Console or Recordplayer	6

::

TABLE 7

PRINCIPLE ADVANTAGES OF ELECTRIFICATION (HOUSEHOLDS)

RESPONSE	PERCENTAGE
Results in a lesser degree of danger	11
Reduces delinquency	1
Makes public lighting available	10
Brings greater convenience/comfort	13
Makes things prettier, nicer	3
Greater food preservation	4
Less contamination	2
Produces more business(es)	8
Produces more jobs	7
Produces greater tourism	10
Brings about greater progress	6
Results in a higher living standard	2
No advantage	1
Other responses	3
Didn't know	19

TABLE 8

REASONS GIVEN FOR DEFICIENCY IN SALES

RESPONSE	PERCENTAGE
Lack of tourists/visitors	57
Lack of money	20
Lack of equipment	9
Lack of electricity	14

Chapter VIII

PUERTO VIEJO CASE

1. Project Description

The Puerto Viejo project is part of the national rural electrification plan and is of high priority as evidenced by the government's recent Emergency Decree on Rural Electrification. (1985) The towns to be electrified are located on the Atlantic Coast and the population is largely rural (68% rural in 1973). Complementary social infrastructure has been developing over the years. There is a major highway linking Puerto Viejo with San Jose . Secondary roads and feeder roads have been, and are being, constructed. Surveys conducted by ICE (Instituto Costarricense de Electricidad) inquiring about the residents' needs indicate that the existing road network and/or quality is insufficient.

In 1979, ICE judged that the electricity service and the water service for the Atlantic Coast zone were both inadequate and therefore included a group of towns along the Coast as part of the Second Stage of Rural Electrification.

2. Design

In this project, the network stretches from Cahuita to Puerto Viejo; 30.5 km of lines are projected. This consists of the distribution system only: 8.2 km of 3 primary lines alone; 3.6 km of 3 phase primary with secondary lines; 6.2 km of 1 phase primary lines alone; 9.8 km of 1 phase primary with secondary lines; and 2.7 km of secondary lines alone (see Figs. 1 and 2).

The maximum voltage fluctuation for the primary lines is set at 10%; this same figure is specified for the secondary circuits. Studies done by the Asian Development Bank (ADI), (Smith,1983) have shown that specifications of a fluctuation less than 10% could have a major impact upon costs. Further specifications included protection against lightning damage. Concrete posts are used. The transformers used are self-protected for residential and commercial service and conventional for industrial service.

For the distribution system, considering the number of consumers per kilometer of distribution line and the large distance over which the lines are spread, a voltage level of 34.5 kw was deemed the most adequate (also considered were norms established by ICE for similar projects).

The project considered here (financed by a loan from the IDB) is part of an Atlantic Coast distribution system: 387 kilometers of distribution lines and 161 kilometers of distribution networks in the process of construction. This large work is divided into several components. The Puerto Viejo project is part of the L.D. La Bomba - Sixaola extension of 100 km which brings the population of the affected area onto the National Interconnected System.

Project design is a key element in the determination of costs--attention to necessary adaptations in materials and standards and to possible cost reductions can contribute to financial viability along with other potential benefits such as backward linkages. In rural areas, consumer expectations regarding both service <u>quality</u> (as measured by the magnitude of voltage fluctuations) and service <u>reliability</u> (as measured by the frequency and duration of power outages and the number of affected consumers) are fairly modest (ADB study). This factor should be taken into account

when the project design is being made and an exercise in this direction is presented later in this monograph.

3. Characteristics of the Population

The project beneficiaries may be classified as rural inhabitants with very low incomes. ICE states that the principal socio-economic justifications of an RE (Rural Electrification) project is related to income distribution goals and to the creation of conditions in rural areas which decrease rural-to-urban migration, the enhancement of living conditions and an increase in employment opportunities. These goals and the accompanying political will behind it (as evidenced by the Emergency Decree) will serve to justify the project and to ensure its implementation, regardless of the project's financial qualifications. And indeed, as the RE plan intends to reach out to the very poor and to accomplish the above goals, the chances for financial viability are doubtless fairly small. This is because financially viable projects generally have a number of characteristics in common (ADB study), most of which are not found in the Puerto Viejo area: an already present and growing demand for electricity, a growing economic base of small- to medium-sized industries and commerical businesses, a high population density, and above-average incomes. Such factors, combined with tariffs set near to the long run marginal cost of supply, tend to produce financially self-sufficient projects.

ICE estimates that more than 90% of the families to be served by this current RE plan can be classified as poverty-stricken. What is more, about 83% can be fit into the category of extreme poverty.

While some infrastructure is in place (e.g., some roads, education

investments), one problem cited with relation to well-being is the areas' inadequate supply of uncontaminated water.

The above considerations are important in evaluating the probable "success" of an RE project. The project appears unlikely to be financially viable given its characteristics. In addition, even RE's socio-economic impact may be hindered or lessened due to an insufficient level of infrastructure (i.e., uncontaminated water, better roads). Or it may be that other socially-oriented development investments would produce a greater return. If the government's goal is related to income distribution and the improvement of living standards in the designated areas, then other social infrastructure investments should be analyzed along with the RE plan in order to determine which one indeed generates the greater benefits given a certain investment amount. Perhaps RE combined with, or as part of, a more generalized rural development scheme may be the most appropriate choice. While it appears that indeed other such investments are planned and in execution, a closer and more explicit link between them and RE could produce a greater return from the project, along with a fuller achievement of RE's potential benefits.

4. Methodology

The project analysis for Puerto Viejo was carried out using the UNIDO methodology, which evaluates and separates project impacts along various lines (financial, economic, political goals). The difference between the financial and the economic analyses is especially important in this case--these are made in detail and the differential between the two rates of return is quite substantial. The estimation of the economic benefits is derived from recent survey results of both electrified and non-electrified

households and businesses in the area.

5. Tariff Structure

Tariffs for the residential sector are lower than those for the commercial sector. Both have a structure where tariffs increase with kwh consumption. The setting of tariff structure may be done with varying purposes in mind, some of them conflicting, such as the achievement of financial self-sufficiency versus the goal of income redistribution. These equity goals, along with a lack of appropriate data and price distortions of other fuels, impede the implementation of an efficiency-oriented long-run marginal cost tariff structure.

Generally (as ADB found), the monthly tariff charges do not make electricity unaffordable to households; it is more often the initial cost of service provision and, for farmers and businesses, inadequate credit availability. The survey results for the Puerto Viejo project, show that this does not appear to be a problem there.

6. Financial Analysis

Tables 1-3 show the financial analysis: investment costs, operating and maintenance costs, projected revenue generation, and the net present value of the project. The financial internal rate of return (IRR) is only about 4%.

The cost figures were provided directly by ICE. The revenue projection was calculated from estimations of the numbers and growth rates of consumers and demand, and using a weighted tariff. The weighted tariff was in turn estimated with the help of the survey data which supplied data on

what percentage of consumers were within various categories of consumption.

7. Economic Analysis

The estimated shadow price for unskilled labor supplied by ICE is about .70. While this figure may have changed somewhat since the time of its first calculation, it is not something to be overly concerned with since unskilled labor makes up only 10% of the labor employed, and that only during the first year of the project. The shadow price weight for foreign exchange (i.e., imported goods) is about 1.08. This adjustment factor is equal to the black market price for colones (as of October 1985).

While the above two adjustment factors were fairly straightforward in their estimation, the determination of the economic benefits of electrification did not prove to be so easy, nor the results so reliable. Two different methods (and thus analyses) were carried out, and the end results, while different, are fairly similar--indicating that both approaches may be reasonable.

i. Analysis I: The Product Value Method

One way of estimating the economic benefits of electrification is to value this as the amount which the customer values new electric products purchased. This is justifiable as electrification made possible their use. The amount which households and businesses are willing to pay for such products is the total benefit (World Bank, 1975).

In the case of Puerto Viejo, the benefits were calculated in the folg manner: First the average annual amount spent on products, per consumer, in a nearby electrified town, was calculated. This amount was then

applied to the number of consumers to be electrified in the Puerto Viejo project's first year. (This assumes that all products are purchased in the first year of electrification. While a more rigorous estimation may be made, spreading the benefits over time as products are purchased, this requires knowledge of that time frame, and the simplification made here should still be a fairly good approximation.) This final amount represents total economic benefits (revenues plus consumer surplus).

This methodology was used to calculate the benefits for both the commercial and the residential sectors (Analysis I), giving a benefit adjustment factor (AF) of 2.26 for the commercial sector and an AF of 1.84 for the residential sector. The internal rate of return is 19.5%.

ii. Analysis II: The Willingness-to-Pay Methodology

This method makes use of the economic concept of willingness to pay. The idea is to estimate what exactly the consumer is willing to pay for the provision of electricity.

This amount was estimated for the residential sector (the required data was unavailable for the commercial sector) from survey data. Both electrified and non-electrified households were questioned as to how much they would pay for electric service. For the electrified households, the AF was estimated as 2.39 and as 2.32 for the non-electrified households (surprisingly close, lending some more validity to this method). While the willingness-to-pay (WTP) method is generally of questionable reliability due to a lack of reliability of the survey method, things may be different in this case. Because this is a rural area where almost all of the households have very low and stable incomes, consumers there are much more

knowledgeable than would be the average consumer about their budgets and about how much they have available to spend on electricity.

Further support of the WTP method comes from the survey results in the area. Households were asked what they felt were the various benefits of electrification. For example did they feel that increased security resulted? (yes or no). The majority of responses were positive for the following potential benefits: increased security; lessening or easing of the work which women did (e.g., cooking, ironing); enhancement of education (able to read, go to classes at night); and enhancement of community and family life; increase in comfort; and increases in income and employment levels. In addition, electricity was generally seen as less expensive than other forms of energy (gas, diesel, etc.). What may occur, however, is that these benefits go unrealized due to insufficient supporting infrastructure and/or complementary investments, or because these types of benefits simply are not generated by electricity. There is indeed considerable debate as to whether this is so. RE projects usually produce high expectations such as the above--expectations which often go unfulfilled. If this is the case, then economic benefits have been overestimated. However, the overall and intangible psychological benefit of electricity may produce such benefits--the above queries may serve as a proxy for this unmeasurable aspect.

Analysis II used the willingness to pay (wtp) method for the residential sector and the product value method for the commercial sector. The method of estimating the benefits gave an internal rate of retunr of 25%.

Notice that for both cases (Analyses I and II), the difference between the results of the financial and the economic analyses is very great--the

financial analysis gives an internal rate of return of 4% while economic Analysis I gives an IRR of 19%. This effect is due to the high economic benefits of electricity to consumers, both residential and commercial. Aside from rendering the project much more worthwhile, this also indicates that tariffs can be higher--with the end result being that electricity would be priced at something closer to its true cost, and thus at least this RE project need not be subsidized to such a large extent. This is significant in that RE generally receives huge subsidies--huge in the amount of money spent and large relative to other public investments in rural infrastructure development. However, the overall goals involved in RE and equity consideration must also play an important role.

8. Savings and Income Distribution Impact Analyses

The analysis of the project's impact on savings is presented in Table 4 (and 6), whose calculation depends on the income flow analysis in Table 5 (and 7). The savings impact depends on each group's MPS (marginal propensity to save). Again due to data limitations, the MPS for each group is a fairly arbitrary estimate, although at least the relative MPS factors amount the sectors have some validity. If this aspect of the project is seen as important, then the analyst should perform a sensitivity analysis for this stage, using various combinations of MPS factors.

The savings analysis here shows a negative impact on the project's overall net present value (NPV). This results because the sector that (given the numbers here) saves the most--the project--happens to lose the most throughout the course of the project. The internal rates of return drop 16% and 22% for Analysis I and II respectively.

The income distribution analysis (Table 7 (and 12)), is similar to the savings analysis in that the estimation of the weights used was again fairly arbitrary. Given the government's wish for income redistribution, the consumers' and workers' benefits received greater weight. This part of the analysis contributed positively to the project's NPV giving an IRR of 23% for Analysis I and 38% for Analysis II.

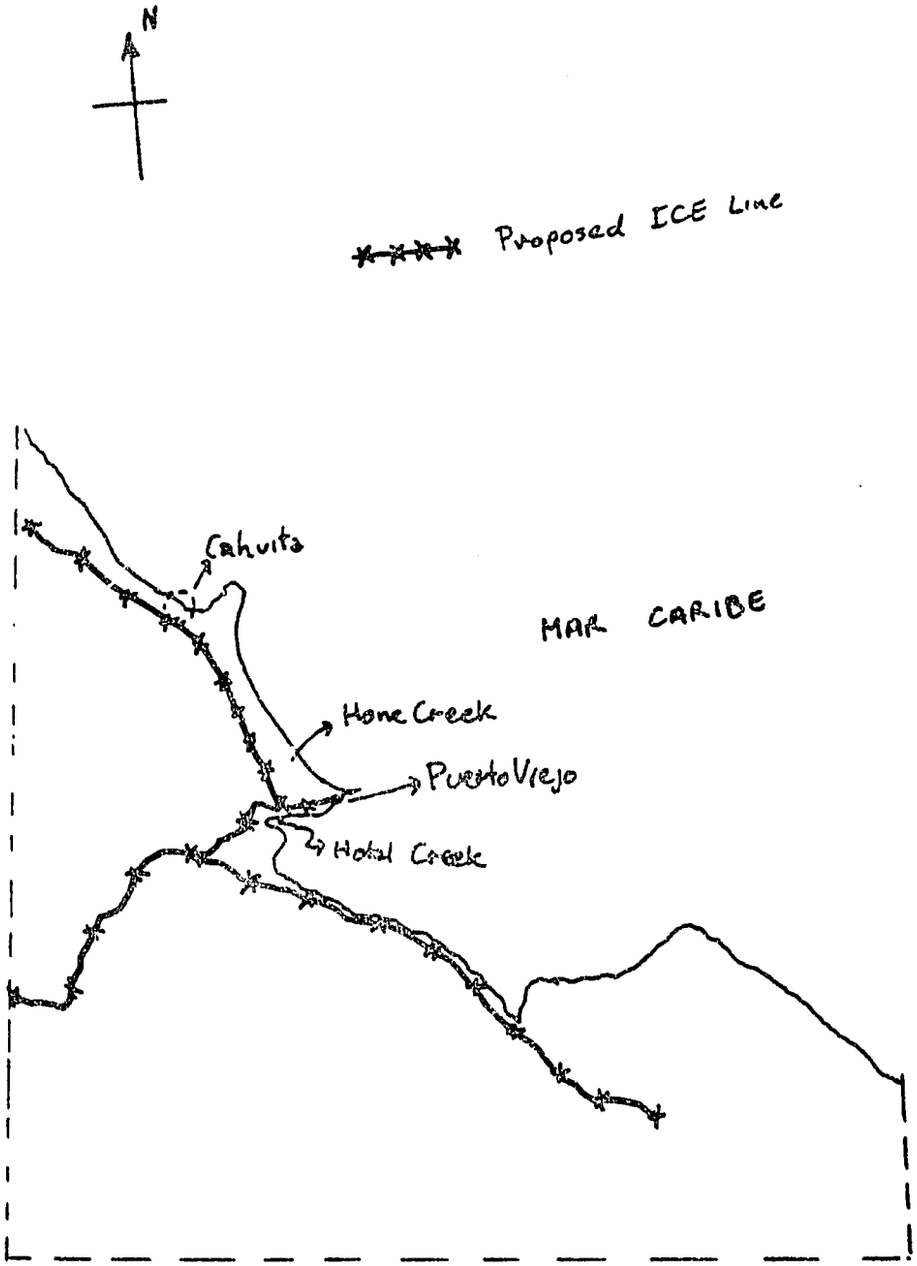
9. Project Merits and Demerits

Here the factor with the greatest weight is the government's Emergency Decree on Rural Electrification, which gives a highest priority to RE. This decree encompasses the goals of reduced rural-to-urban migration, increased employment, increased production, rural industrialization and the improvement of living conditions in the rural areas--all aspects typically named and collected into this stage of the UNIDO methodology. While it has not been determined to a satisfactory extent whether these goals have been or will be reached, the Emergency Decree in effect assumes that an attempt to reach them will be made. As far as any decision about whether or not to go ahead with the project, the prior financial and even the economic analysis is unnecessary. The political will exists and the project will be implemented. Thus one determination of a quantitative measure for the factors of this stage, the amount will simply be that which is needed to give the project a sufficient return. Using Analysis I yields an IRR of 20% and Analysis II yields 27%.

The above is not to say that all of this analysis is suspect. On the contrary, the analysis may be used for the current project in order to discover any cost-saving measures (for example, in the project design) and in the future for better evaluation and choice between rural development

projects. Knowledge of the results of such analyses can increase the chances for rural electrification to reach its greatest potential.

For the Puerto Viejo case, Castagnola (1986) estimated the marginal cost of rural electricity supply to be much closer to the proposed tariff than was the case for the second stage project as a whole (Chap. VI). He esitmated an average marginal cost of 2.60 colones per kwh. In this case the deadweight losses shrink to an insignificant proportion of the benefits (less than 5%) and can be ignored in the analysis.



PROJECT FROM:

CAHUITA, THROUGH
HONE CREEK, TO
PUERTO VIEJO

FIGURE 1

TRAMO Nº 2. PUERTO VARGAS A PUNTA DE RIEL

TRAMO Nº 3. PUNTA DE RIEL A HONE CREEK

Ancla

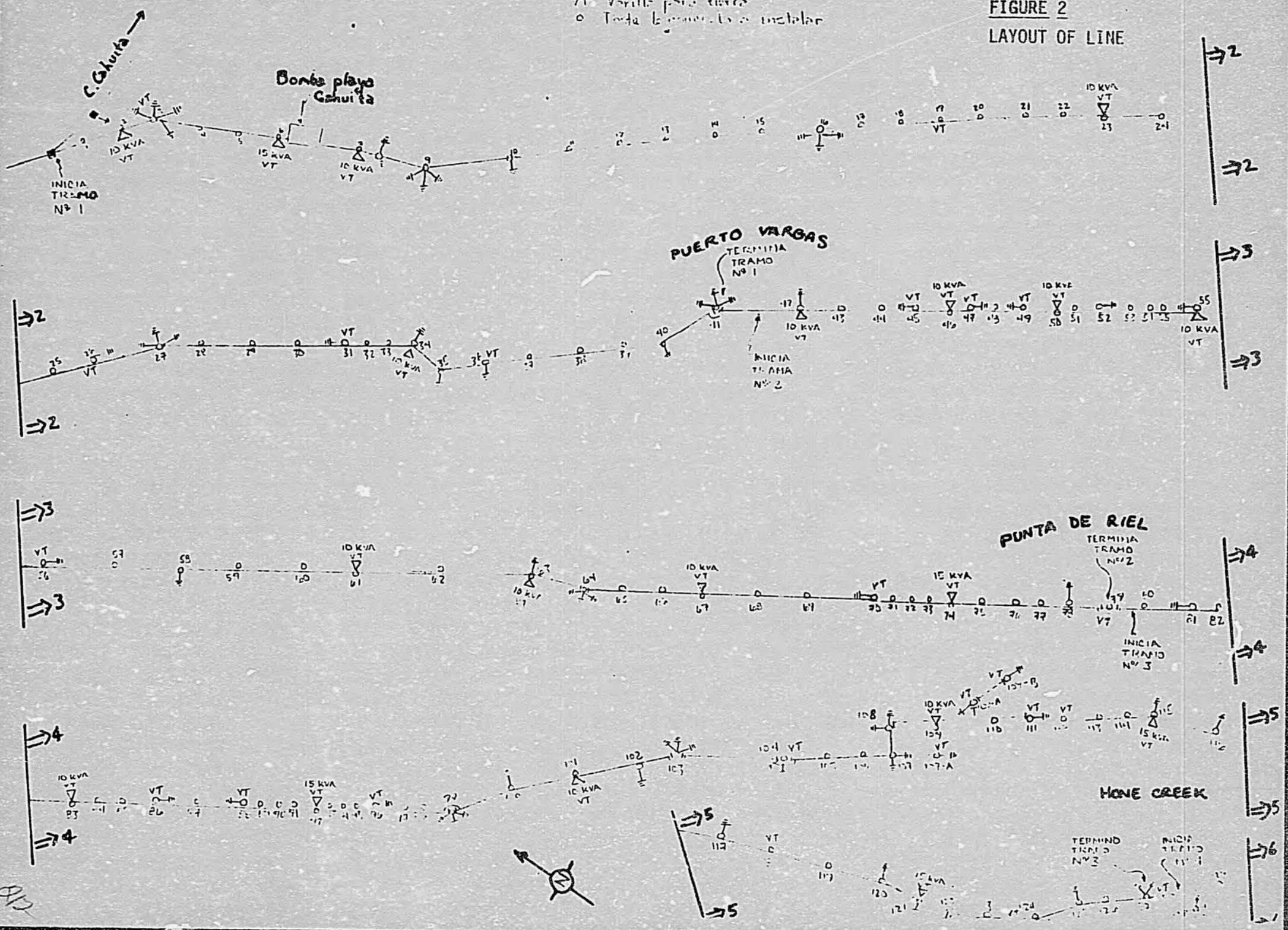
Δ Tranca encaden capacit. indicado a instalar

VT Varilla para tierra

o Tarta la conexión a instalar

FIGURE 2

LAYOUT OF LINE



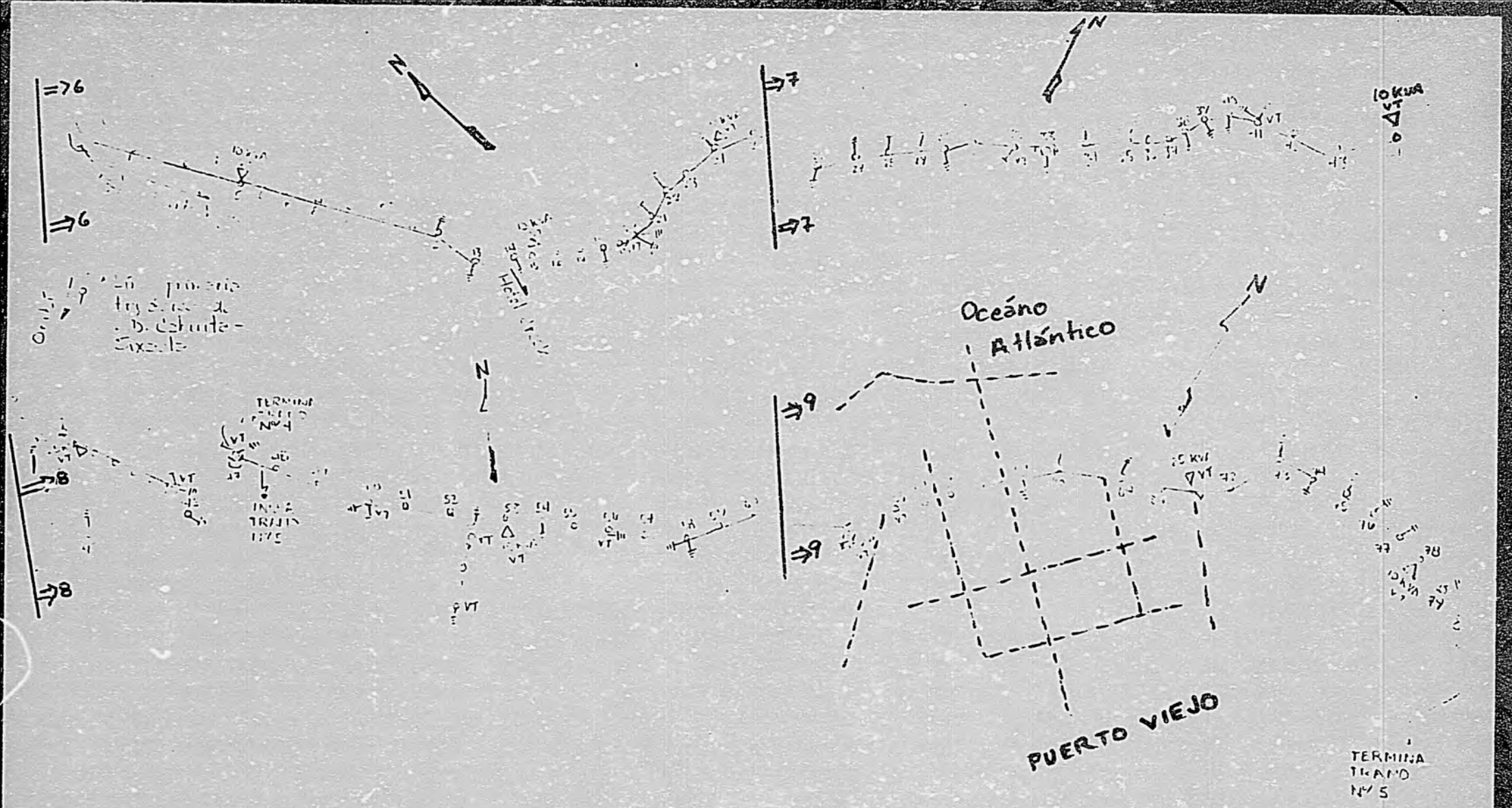


FIGURE 2

LAYOUT OF LINE (CONT.)

STAGE ONE: FINANCIAL ANALYSIS
BASED ON UNIDO GUIDELINES

TABLE I
BASIC DATA FOR INVESTMENT COSTS
(All costs in 1000 colones at market prices)

ITEM	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
1. Engineering and Management	2839	0	0	0	0	0	0	0	0	0	0
Foreign(labor)	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	0	0	0	0	0	0	0	0	0	0
Local(labor)	0	0	0	0	0	0	0	0	0	0	0
(materials)	2839	0	0	0	0	0	0	0	0	0	0
Direct Costs of Construction	10585	0	0	0	0	0	0	0	0	0	0
a)Generation	0	0	0	0	0	0	0	0	0	0	0
Import(labor)	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	0	0	0	0	0	0	0	0	0	0
Local(labor)	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	0	0	0	0	0	0	0	0	0	0
b)Transmission	0	0	0	0	0	0	0	0	0	0	0
Import(labor)	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	0	0	0	0	0	0	0	0	0	0
Local(labor)	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	0	0	0	0	0	0	0	0	0	0
c)Distribution	10585	0	0	0	0	0	0	0	0	0	0
Import(labor)	0	0	0	0	0	0	0	0	0	0	0
(materials)	2501	0	0	0	0	0	0	0	0	0	0
Local(labor)	2666	0	0	0	0	0	0	0	0	0	0
(materials)	5417	0	0	0	0	0	0	0	0	0	0
d)General Facilities	0	0	0	0	0	0	0	0	0	0	0
Import(labor)	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	0	0	0	0	0	0	0	0	0	0
Local(labor)	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	0	0	0	0	0	0	0	0	0	0
Costs without Specific Assignment	1145	0	0	0	0	0	0	0	0	0	0
Import(labor)	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	0	0	0	0	0	0	0	0	0	0
Local(labor)	0	0	0	0	0	0	0	0	0	0	0
(materials)	1145.01	0	0	0	0	0	0	0	0	0	0
TOTAL INVESTMENT	14568	0	0	0	0	0	0	0	0	0	0
Import(labor)	0	0	0	0	0	0	0	0	0	0	0
(materials)	2801	0	0	0	0	0	0	0	0	0	0
Local(labor)	2666	0	0	0	0	0	0	0	0	0	0
(materials)	9401	0	0	0	0	0	0	0	0	0	0

TABLE II
BASIC DATA FOR OPERATION AND MAINTENANCE EXPENDITURES
(all costs in 1000 colones at market prices)

ITEM	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
1. Operation	0	204	204	204	204	204	204	204	204	204	204
a) Generation	0	0	0	0	0	0	0	0	0	0	0
Foreign (labor)	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	0	0	0	0	0	0	0	0	0	0
Local (labor)	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	0	0	0	0	0	0	0	0	0	0
b) Transmission	0	0	0	0	0	0	0	0	0	0	0
Foreign (labor)	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	0	0	0	0	0	0	0	0	0	0
Local (labor)	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	0	0	0	0	0	0	0	0	0	0
c) Distribution	0	204	204	204	204	204	204	204	204	204	204
Foreign (labor)	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	33	33	33	33	33	33	33	33	33	33
Local (labor)	0	101	101	101	101	101	101	101	101	101	101
(materials)	0	69	69	69	69	69	69	69	69	69	69
2. Maintenance	0	72	72	72	72	72	72	72	72	72	72
a) Generation	0	0	0	0	0	0	0	0	0	0	0
Foreign (labor)	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	0	0	0	0	0	0	0	0	0	0
Local (labor)	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	0	0	0	0	0	0	0	0	0	0
b) Transmission	0	0	0	0	0	0	0	0	0	0	0
Foreign (labor)	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	0	0	0	0	0	0	0	0	0	0
Local (labor)	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	0	0	0	0	0	0	0	0	0	0
c) Distribution	0	72	72	72	72	72	72	72	72	72	72
Foreign (labor)	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	16	16	16	16	16	16	16	16	16	16
Local (labor)	0	50	50	50	50	50	50	50	50	50	50
(materials)	0	6	6	6	6	6	6	6	6	6	6
3. Insurance	0	0	0	0	0	0	0	0	0	0	0
Foreign	0	0	0	0	0	0	0	0	0	0	0
Local	0	0	0	0	0	0	0	0	0	0	0
3. Fuel	0	3	3	3	3	3	3	3	3	3	3
Foreign	0	3	3	3	3	3	3	3	3	3	3
Local	0	0	0	0	0	0	0	0	0	0	0
TOTAL	0	279	279	279	279	279	279	279	279	279	279
Foreign (labor)	0	0	0	0	0	0	0	0	0	0	0
(materials)	0	52	52	52	52	52	52	52	52	52	52
Local (labor)	0	151	151	151	151	151	151	151	151	151	151
(materials)	0	75	75	75	75	75	75	75	75	75	75

TABLE III
REVENUE DATA
FINANCIAL ANALYSIS

ITEM	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Revenues											
-residential	520.59	633.04	776.39	941.91	1125.92	1343.53	1515.50	1704.70	1911.94	2142.29	2404.33
-commercial	305.22	345.15	392.70	443.25	507.29	553.24	599.43	658.46	731.09	806.39	895.28
-pub.lighting	3.92	3.92	3.92	3.92	3.92	3.92	3.92	3.92	3.92	3.92	3.92
Total Revenue(1000 Colones)	829.74	982.11	1173.01	1389.09	1637.14	1900.69	2118.85	2367.09	2646.96	2952.31	3295.23

NET PRESENT VALUE AT DIFFERENT DISCOUNT RATES (1000Colones)

	0%	5%	10%	15%	20%	25%	30%	IRR
Present Value	3946.765	-826.861	-3704.48	-5456.14	-6520.84	-7156.47	-7518.78	0.039299

TABLE 4
ECONOMIC VALUE OF SAVINGS I

	Income Impact	MPS	Impact	Net Impact	Adj. Factor	Impact Value
At r=0%						
Project	(20,797,105.61)	0.50	(10,398,553.30)	(4,223,348.70)	1.05	(4,434,516.14)
Government	239,642.21	0.10	23,964.22			
Workers	79,994.70	0.10	7,999.47			
Consumers	20,477,469.70	0.30	6,143,240.91			
At r=15%						
Project	(8,402,569.08)	0.50	(4,201,284.54)	(1,732,676.37)	1.05	(1,819,310.71)
Government	191,254.64	0.10	19,125.46			
Workers	69,560.61	0.10	6,956.06			
Consumers	8,141,753.83	0.30	2,442,526.15			
At r=25%						
Project	(5,366,345.93)	0.50	(2,683,172.96)	(1,120,342.79)	1.05	(1,176,359.93)
Government	171,372.28	0.10	17,137.23			
Workers	63,995.76	0.10	6,399.58			
Consumers	5,130,977.89	0.30	1,539,293.37			

I + NCF(ec)	
at r=0%	19,830,067.39
at r=15%	744,598.88
at r=25%	(3,309,239.65)

****

TABLE 5
INCOME FLOW ANALYSIS I

Project	(550,982.09)	(485,295.52)	(575,450.26)	(676,850.50)	(794,459.32)	(914,798.79)	(1,016,126.45)	(1,132,782.10)	(1,265,581.60)	(1,409,576.64)	(1,576,663.02)
imports	(100,047.50)	(1,977.36)	(1,977.36)	(1,977.36)	(1,977.36)	(1,977.36)	(1,977.36)	(1,977.36)	(1,977.36)	(1,977.36)	(1,977.36)
unsk.labor	(39,937.35)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
benefits	(410,937.24)	(483,318.16)	(573,480.92)	(674,853.14)	(792,481.96)	(912,821.43)	(1,014,149.09)	(1,130,804.74)	(1,263,604.24)	(1,407,598.28)	(1,574,685.66)
Government											
imports	20,009.50	395.47	395.47	395.47	395.47	395.47	395.47	395.47	395.47	395.47	395.47
unsk.labor											
benefits											
Workers											
imports											
unsk.labor	7,999.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
benefits											
Consumers											
imports											
unsk.labor											
benefits	246,562.34	289,920.90	344,088.55	404,911.89	475,489.17	547,692.86	608,409.45	678,482.84	758,162.54	844,558.97	944,811.39
Total	(276,410.78)	(194,909.15)	(230,974.26)	(271,523.15)	(318,574.67)	(366,710.46)	(407,241.52)	(453,903.78)	(507,029.58)	(564,621.20)	(631,416.15)
Total Q1 (51)	(290,231.92)	(204,654.61)	(242,522.97)	(285,099.30)	(334,503.40)	(385,045.98)	(427,603.60)	(476,598.97)	(532,374.76)	(592,852.26)	(663,038.96)
Net Benefit(Cost)	(13,327,090.45)	1,461,448.15	1,794,803.07	2,171,055.75	2,604,956.00	3,080,643.84	3,446,903.57	3,869,454.03	4,359,151.11	4,898,007.26	5,508,734.21
Internal Rate of Return	0.16										

at r=10%: 4,901,959.73
at r=15%: 744,596.08
at r=20%: (1,648,732.60)

TABLE 6

ECONOMIC VALUE OF SAVINGS II

	Income Impact	MPS	Impact	Net Impact	Adj. Factor	Impact Value
At r=0%						
Project	(27,443,129.46)	0.50	(13,721,564.73)	(5,439,775.83)	1.05	(5,711,754.53)
Government	(324,244.99)	0.10	(32,424.50)			
Workers	79,994.70	0.10	7,999.47			
Consumers	27,687,379.75	0.30	8,306,213.93			
At r=15%						
Project	(10,958,697.28)	0.50	(5,479,348.64)	(2,194,684.78)	1.05	(2,304,419.02)
Government	(54,834.01)	0.10	(5,483.40)			
Workers	69,560.61	0.10	6,956.06			
Consumers	10,943,970.68	0.30	3,283,191.20			
At r=25%						
Project	(6,944,373.52)	0.50	(3,472,186.76)	(1,403,734.53)	1.05	(1,473,921.26)
Government	10,303.39	0.10	1,030.34			
Workers	63,995.76	0.10	6,399.58			
Consumers	6,870,074.37	0.30	2,061,022.31			

SI + NCF(ec)	
at r=0%	28,589,156.16
at r=15%	4,295,201.69
at r=25%	(1,060,363.10)

TABLE 7
INCOME FLOW ANALYSIS II

1.Project	(675,924.35)	(609,030.52)	(733,595.51)	(874,695.65)	(1,036,485.78)	(1,209,050.80)	(1,351,652.17)	(1,613,715.93)	(1,696,253.77)	(1,895,532.00)	(2,126,627.18)
inputs	(100,047.50)	26,217.00	26,217.00	26,217.00	26,217.00	26,217.00	26,217.00	26,217.00	26,217.00	26,217.00	26,217.00
unsk.labor	(39,997.35)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
benefits	(535,879.49)	(635,247.52)	(759,813.51)	(900,912.65)	(1,062,702.78)	(1,235,267.80)	(1,377,869.17)	(1,539,932.93)	(1,722,470.77)	(1,921,749.00)	(2,151,844.18)
2.Government											
inputs	20,009.50	(5,243.40)	(5,243.40)	(5,243.40)	(5,243.40)	(5,243.40)	(5,243.40)	(5,243.40)	(5,243.40)	(5,243.40)	(5,243.40)
unsk.labor											
benefits											
3.Workers											
inputs											
unsk.labor	7,999.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
benefits											
4.Consumers											
inputs											
unsk.labor											
benefits	321,527.70	381,148.51	455,888.11	540,547.59	637,621.67	741,160.73	826,721.50	923,959.76	1,033,482.46	1,153,049.40	1,291,106.51
Total	(326,387.60)	(233,125.41)	(283,951.80)	(339,391.46)	(404,107.51)	(473,133.55)	(530,174.07)	(594,959.57)	(660,014.71)	(747,726.00)	(839,764.07)
Total	(342,707.06)	(244,781.68)	(297,099.39)	(356,361.03)	(424,312.69)	(496,790.23)	(556,602.77)	(624,749.55)	(701,415.44)	(785,112.30)	(881,752.27)
FLI SUMMAT(sc)	(13,129,681.67)	2,007,022.52	2,395,534.55	2,834,555.74	3,330,231.70	3,874,435.21	4,317,907.29	4,807,202.65	5,390,486.22	6,010,691.37	6,726,970.66

Int.Rate of Return 0.22

NPV:
at r=5% 16,695,231.01
at r=10% 9,149,518.93
at r=15% 4,295,201.69
at r=20% 1,092,679.60

TABLE 8

INCOME DISTRIBUTION ANALYSIS I

	Income Impact	Adj. Factor	Adjusted Value	Net Adj. Value
t r=0%				
-project	(20,797,106.61)	1.00	(20,797,106.61)	5,139,366.10
-government	239,642.21	1.00	239,642.21	
-workers	79,994.70	1.25	99,993.38	
-consumers	20,477,469.70	1.25	25,596,837.13	
r=15%				
-project	(8,402,569.08)	1.00	(8,402,569.08)	2,052,828.61
-government	191,254.64	1.00	191,254.64	
-workers	69,560.61	1.25	86,950.76	
-consumers	8,141,753.83	1.25	10,177,192.29	
r=25%				
-project	(5,366,345.93)	1.00	(5,366,345.93)	1,298,743.41
-government	171,372.28	1.00	171,372.28	
-workers	63,995.76	1.25	79,994.70	
-consumers	5,130,977.89	1.25	6,413,722.36	
+ NCF(ec)				
at r=0%	29,403,949.63			
at r=15%	4,616,738.20			
at r=25%	(834,136.31)			

TABLE 9

INCOME DISTRIBUTION ANALYSIS II

	Income Impact	Adj. Factor	Adjusted Value	Net Adj. Value
r=0%				
-project	(27,443,129.46)	1.00	(27,443,129.46)	6,941,843.61
-government	(324,244.99)	1.00	(324,244.99)	
-workers	79,994.70	1.25	99,993.38	
-consumers	27,687,379.75	1.25	34,609,224.69	
r=15%				
-project	(10,958,697.28)	1.00	(10,958,697.28)	2,753,382.82
-government	(54,834.01)	1.00	(54,834.01)	
-workers	69,560.61	1.25	86,950.76	
-consumers	10,943,970.68	1.25	13,679,963.34	
r=25%				
-project	(6,944,373.52)	1.00	(6,944,373.52)	1,733,517.53
-government	10,303.39	1.00	10,303.39	
-workers	63,995.76	1.25	79,994.70	
-consumers	6,870,074.37	1.25	8,587,592.96	

DI + NCF(ec)	
at r=0%	41,242,764.40
at r=15%	9,353,003.53
at r=25%	2,147,075.70

Chapter IX

OPTIMIZATION OF RELIABILITY AND COSTS IN A RURAL ELECTRIFICATION LINE

1. Introduction

There have been two trends in the pursuit of economically efficient designs of electricial grids: marginal cost analyses on the demand side, and cost minimization techniques on the supply side. the work of Gellerson and Munasinghe (1979) and Munasinghe (1979) has pointed to the possibilities of realizing cost savings by varying power supply reliability standards. This means that reliability can be treated as a variable thus incorporating a new source of eventual cost reduction that can play a positive role under the usually constrained fiscal realities of most LDCs.

The preferences of the consumers by categories (residential, industrial and so on) can be made to reveal a preference for a certain level of reliability. Thus there is a tradeoff, at the margin, between higher reliability, lower outage costs with consequent higher supply costs and the losses incurred by consumers due to power failures. As Munasinghe points out

> '...at a given electricity price the optimum reliability level, which maximizes the benefits that consumers receive by using electricity after subtracting the supply costs, should be established at the point at which the marginal increase in the supply costs is exactly offset by the marginal decrease in outage costs.' (Munasinghe, 1979, p. 5)

As depicted in Figure 1, the objective is to find an equilibrium between the Marginal Supply Costs (MSC) of energy (a supply curve) and the Marginal Outage Costs (MOC), based on how the consumers value, at the margin, the costs of interruption of supply (a demand curve of the quantity of

reliability). In other words, the system planner should increase the reliability level up to the point at which MSC are equal to the expected benefits from the MOC avoided because of that improved reliability.

This approach has the following features:

1) In the traditional approach the system is planned to meet a forecasted load demand at some predetermined, desired level of reliability. In the approach commented upon, the system planner must design a number of alternative systems to meet the future demand, at each of several targeted reliability levels. The different alternatives are compared, and that which minimize the total costs (sum of outage costs and system costs), is chosen.

2) The approach stresses the role of the consumer preferences and the importance of the measuring of outage costs based on the economic activity performed by different kinds of electricity consumers.

3) The approach is versatile enough to apply it to the optimization of power systems at various levels of aggregation.

The approach can be summarized in the following methodological steps:

a) Determination of the costs incurred by different categories of consumers--residential, industrial, commercial and so on--as a consequence of electric power failure.

b) Forecasting of load-demand and prices within the area to be served by the electricity utility.

c) Design of different technical schemes to supply the forecasted load at different levels of reliability. A more detailed analysis shuld show expected annual frequency and the duration of power failures for each reliability level.

d) Estimation of investment and operation costs for each alternative design.

e) Calculation of both the marginal supply costs and the marginal outage costs for each level of reliability.

The present chapter applies the general methodology suggested by Munasinghe to the specific case of a rural electrification project: the electrification of a town. This is the first application of the cost-reliability approach to a rural setting and shows the step-by-step pro-

cedure to address the issue and the type of simplifications that are needed to make this approach a useful, inexpensive and practical technique for rural electrification projects. The empirical work is based on the field-work done by Gray (1985) under the supervision by the authors of this paper.

The study was done for the Cahuita-Puerto Viejo line as an extension to the benefit-cost analysis and the marginal cost analysis discussed in Chapter VI. For this line three different technical designs were made, each with different technical designs and, each with different construction costs and reliability. Based on the records of a line already in operation in a nearby county, the statistical history of the hours of interruption of service and the valuation by the consumers of the outage costs, were applied to the Cahuita-Puerto Viejo line.

In the case of commercial and industrial consumers a questionaire asked about the losses that occur due to the interruption of electricity supply, what are the materials and goods that get spoiled and the cost of that spoilage, the costs incurred for not producing a certain amount of products due to the outage and so on. Also, given the present level of reliability if they had invested in alternative power supply. The fact that none had invested in alternative supply supports the conclusions of this chapter that the optimum level of reliability is very close to the present level used by ICE. (Appendix B shows these two questionnaires.)

In the case of domestic consumers, the questionnaire tried to establish the amount in excess of the present amount that the consumers were willing to pay to prevent an hour of outage at different times of the day. The consumers seem to be rather satisfied with the present level of

reliability given the small amount of excess that they are willing to pay to improve the system's reliability. Nonetheless an amount of 5 colones per hour outage was estimated for residential consumers.

2. The Reliability-Costs Optimum

The two basic curves needed to find the optimum are the Marginal Supply Costs and the Marginal Outage Costs. The former is the relation that exists between the initial investment costs and maintainance and operation costs related to the incremental change in energy consumption during a determined period of time (10 years in this case). The latter is the relation between the costs incurred by the consumers (or the benefits lost) due to power failure weighted by type of consumer, related to the incremental change in energy that was not consumed due to the outages.

3. Outage Costs

Electricity is used by consumers in different productive, recreational, and educational activities, and so on. In order for this wide range of activities to be efficient the system must have an adequate level of reliability. The outage costs, when they occur, can be direct or indirect. The direct costs are those that occur during an outage; the indirect are those accrued when a certain level of outages are expected.

During an outage the consumer will experience direct costs due to the interruption of productive or recreational activities. The indirect costs are those related to the installation of alternative electric power plants or other back-up systems.

For the determination of the direct costs it is important to have a

sense of the duration of the outage, the frequencey, the hours of the day that they occur and the technology used by the consumer.

There are two ways to measure outage costs. One is related to the price that consumers are willing to pay for a determined level of system reliability. The other is related to the estimation of the costs that an interruption of service has on the productive, recreational or other activities carried out by the consumers. The latter is the method used in the estimation of the MOC for industrial consumers and the former for residential consumers.

The marginal supply costs can be computed as follows:

$$MSC = \frac{P.V.C._t}{P.V.E}.$$

where

$P.V.C_t$ = present value of the investment and O and M costs

$P.V.E$ = present value of the annual incremental energy consumption.

The marginal outage cost is the relation between the total costs of interruption as it is valued by the consumers in relation to the amount of energy that is not consumed due to the interruption of service:

$$MOC = \frac{P.V.C_I}{P.V.E_I}$$

where

$P.V.C_I$ = present value of the costs of interruption as valued by the consumers

$P.V.E_I$ = present value of the energy that was not consumed due to the outage.

Both the MSC and the MOC vary with different levels of reliability. For each level of reliability a MSC and a MOC can be obtained. When plotted on a graph of marginal costs versus reliability level as the one shown in Figure 1, the optimum is found were both lines intersect.

For the empirical work, three designs were made for the Cahuita-Puerto Viejo line. The first one is the standard design of the Costa Rican Institute of Electricity (ICE) and two alternative ones with lower costs and also lower reliability. For alternative Design A, the usual concrete poles used by the public utility were replaced by wood poles. The opinion of the maintenance engineers of the region is that this would imply a small reduction in reliability because of the propensity of different types of local birds to make holes in the poles and to roost in the metal structure that supports the wires.

Alternative Design B included the wood poles and also the substitution of the traditional wire designed against corrosion and other problems related to the effect of the proximity of the ocean, with a type of wire less resistant to the effect of the sea winds. (The AAAC N.4/0 type by the AAAC N.1/0 type.) This design has also lower costs but higher probability of outages due to both the problems of corrosion and also the lower mechanical resistance of the conductors.

Based on the records of a survey carried out by the maintainance engineer in a county located nearby in the Province of Limon in the Atlan-

tic Region of Costa Rica, the valuation by residential and commercial (or industrial) consumers of the outage costs was obtained. These results where then applied to the Cahuita-Puerto Viejo line.

4. Calculation of Marginal Supply Costs (MSC) and Marginal Outage Costs (MOC)

Based on the statistical records of the Freehold-Siquirre line that was taken as the base case the number of hours per year of interruption was of 437. This is based on the Standard Design. Given that the characteristics of the line the expected number of interruptions in hours per year for Alternative Design A is 525 hours/year and for Alternative Design B is 650 hours/year. The reliability index was computed as 0.95 for the Standard Design and as 0.94 for Alternative Desgn A and 0.93 for Alternative Design B.*

To calculate the marginal supply costs (MSC) two streams of data are needed: the investment and O and M costs and the change in energy demand during the first ten years of the project. In Table 1 the increases in demand from 1985 to 1995 are shown. Demand, based on historical data, is assumed to increase at around 7% per annum and the regional load factor is 0.67.

Tables 2, 3 and 4 show the stream of costs for th strict Standard Design usually used by ICE, and the Alternative Designs A and B. The present value of the costs are 12.157 million colones for the Standard Desgin; 11.695 million for Design A and 11.525 million for Desgin B. The

*Reliability being defined as:

$$\left(1.0 - \frac{\text{number of hours of interruption per year}}{\text{number of hours per year}}\right)$$

discount rate is taken to be 15%. Table 5 shows the stream of energy increments and the present value of that stream calculated at a discount rate of 15% is 329.57 Mwh/year.

Using the results obtained in Tables 2, 3, 4, and 5, the marginal supply costs (MSC) for each of the three levels of reliability are calculated by means of the definition of MSC given above. The results are summarized in Table 6. To calculate the marginal outage costs (MOC), the basic information was obtained from the records of the survey carried out by Gray (1985) in the Freehold-Siquirres region that gvies the evaluation by the consumers of the monetary costs of service interruption. The results are a valuation of service interruption of 68 colones per hour for the commercial-industrial consumer and of 5 colones per hour for the residential consumer.

The calculation of the marginal outage costs has two streams of values that need to be estimated: the cost of interruption as valued by the different consumers (residential and commercial-industrial), and the energy not consumed per annum due to the outages.

The first stream is determined based, for each year, on the following formula:

C_I = interruption costs
= (Number of hours of interruption/year) x (Number of Residential Consumers) x (Cost/hour of interruption as valued by residential consumer) + (Number of hours of interruption /year) x (Number of commercial and industrial consumers) x (Cost/hour of interruption as valued by commercial industrial consumers)

This first stream is summarized in Table 7 giving a present value for

the Standard Design of 8.817 million colones; 10.602 million colones for the Alternative Design A and, 20.197 million colones for Alternative Design B.

The second stream of data is related to the amount of energy that is not consumed due to the interruptions, i.e.:

$$E_I = \text{(Number of hours of interruption /year)} \times \text{(KW installed)} \times \text{(Load Factor)}.$$

Table 8 summarizes the changes in energy consumption due to the interruption of service. The present values for that stream of energy changes is 248.47 Mwh for the Standard Design; 298.00 Mwh for the Alternative Design A and, 547.81 Mwh for Alternative Design B. Based on the results of Tables 7 and 8 it is possible to calculate the marginal outage costs (MOC). A summary of the basic results is presented in Table 9. Based upon the MSC and the MOC values for the three levels of reliability Figure 2 can be drawn. The optimum is located rather close to the standard design used by ICE in its present technical designs of rural electrification lines. In a more strict sense the intersection of the MSC and the MOC is located between the Standard design and the Alternative Design A. This would suggest that the present design could be relaxed, but just by a small amount.

There are, nonetheless, some caveats that must be explicitly stated. Sensitivity analysis shows that the results are very sensitive to the evaluation that the consumers give to the cost of interruption. In this case, if commercial consumers value the cost of interruption, by more than 70 colones per hour, the standard design is indeed the optimum. If however, commercial consumers value the hourly cost of interruption as 50 colones per hour or less, Alternative Designs A and B are closer to the

optimum. This points out the need to enhance the survey techniques in order to obtain a more accurate valuation of the consumer preferences for a certain level of reliability as shown in their valuation of the outage costs.

The present analysis has made some simplificaitons for the sake of clarity in the presentation of the method. For example, the time of interruption has been averaged and all calculatons are done on an hourly basis, the time of the day that interruptions take place was not taken fully into account; consumers were divided just in two categories (residential and commercial-industrial) thus various aggregations were performed, and so on.

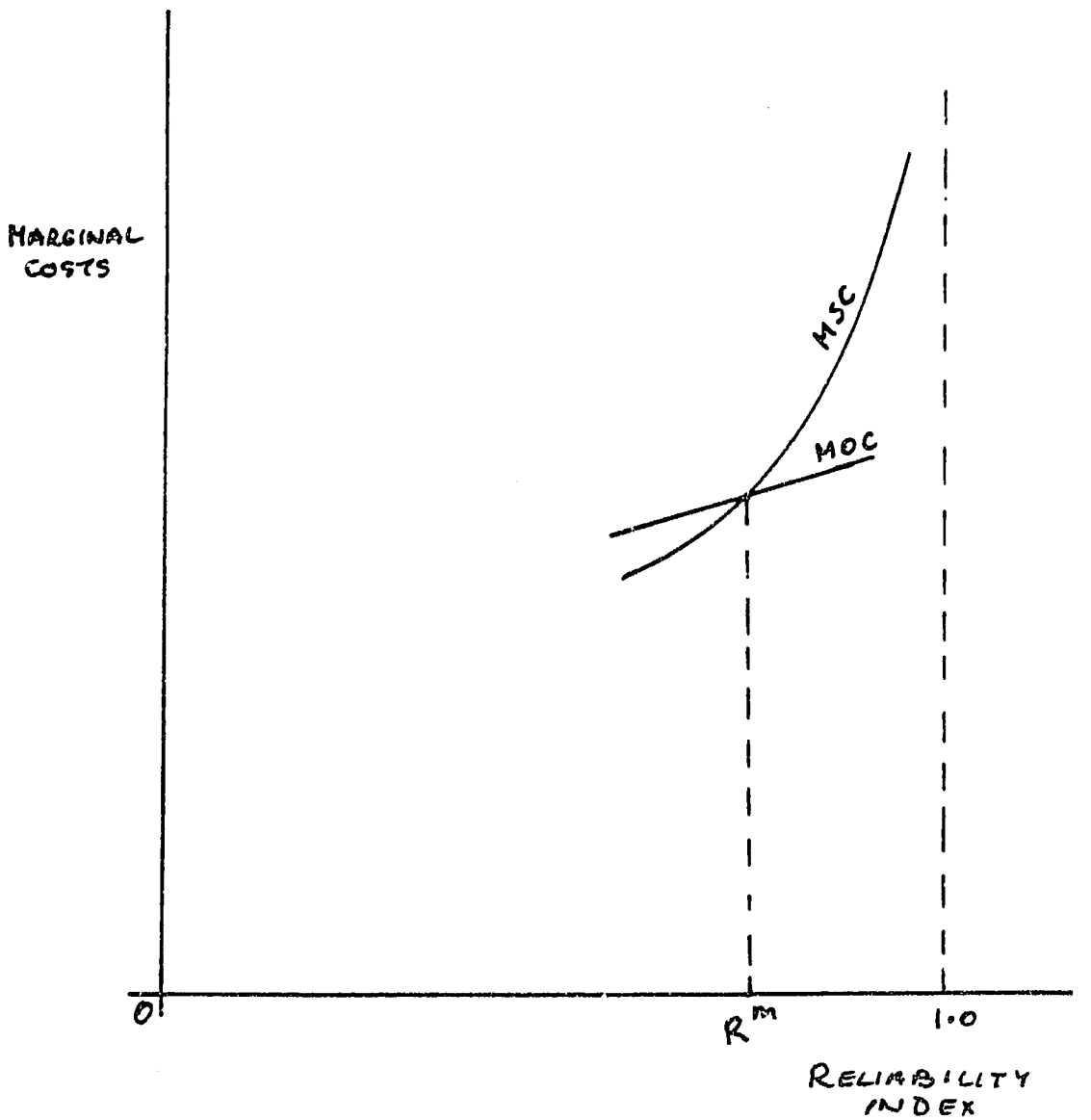
For a more comprehensive study see Gellerson (1982). The Gellerson study was done for a whole country, Panama, and it had the purpose of analysing the economic costs which result from unplanned interruptions in the supply of electricity within the national electricity grid of that country south of Costa Rica. Given that the study had a national coverage it included urban consumers and the outage costs were found to be much more significant than in the only-rural case presented in this chapter. These costs average about $0.93 per KWH not supplied for an outage of approximately one-half hour duration. One of his major findings was that outages impose relatively large economic costs when they affect industrial consumers and thus it would be more cost effective to improve the reliability of supply to industrial consumers than to other types of consumers. Given its scope, the Gellerson study did not present results for alternative designs with various reliability levels, but estimated the total economic costs of outages which occur in the national electricity grid at the existing level

of reliability and by extension the economic benefits resulting from any increase in this level of reliability.

For our study, even given its adaptation to reducing costs of information gathering and the necessary simplifications needed to address the rather local character of the scheme--the general results found point to the fact that the consumers define the optimum level of reliability through their assessment of the outage costs. Also that this valuation is strongly linked to the overall benefits that the consumer perceives getting from rural electrification. The methodology should therefore be carefully tailored to take into account the differences in social, economic, productive, recreational, etc. activities that take place in each region. Properly used this method can provide a rigorous methodology to determine the design criteria of rural electrification systems. Their combined use with benefit-cost analysis and marginal costs analysis constitute an integrated, rigorous and systematic way of assessing rural electrification projects.

FIGURE 1

MARGINAL SUPPLY COSTS VS. MARGINAL OUTAGE COSTS



MOC= Marginal Outage Costs
MSC= Marginal Supply Costs
R^m= Optimum Reliability Index

FIGURE 2

MARGINAL SUPPLY COSTS (MSC) AND MARGINAL OUTAGE COSTS (MOC)

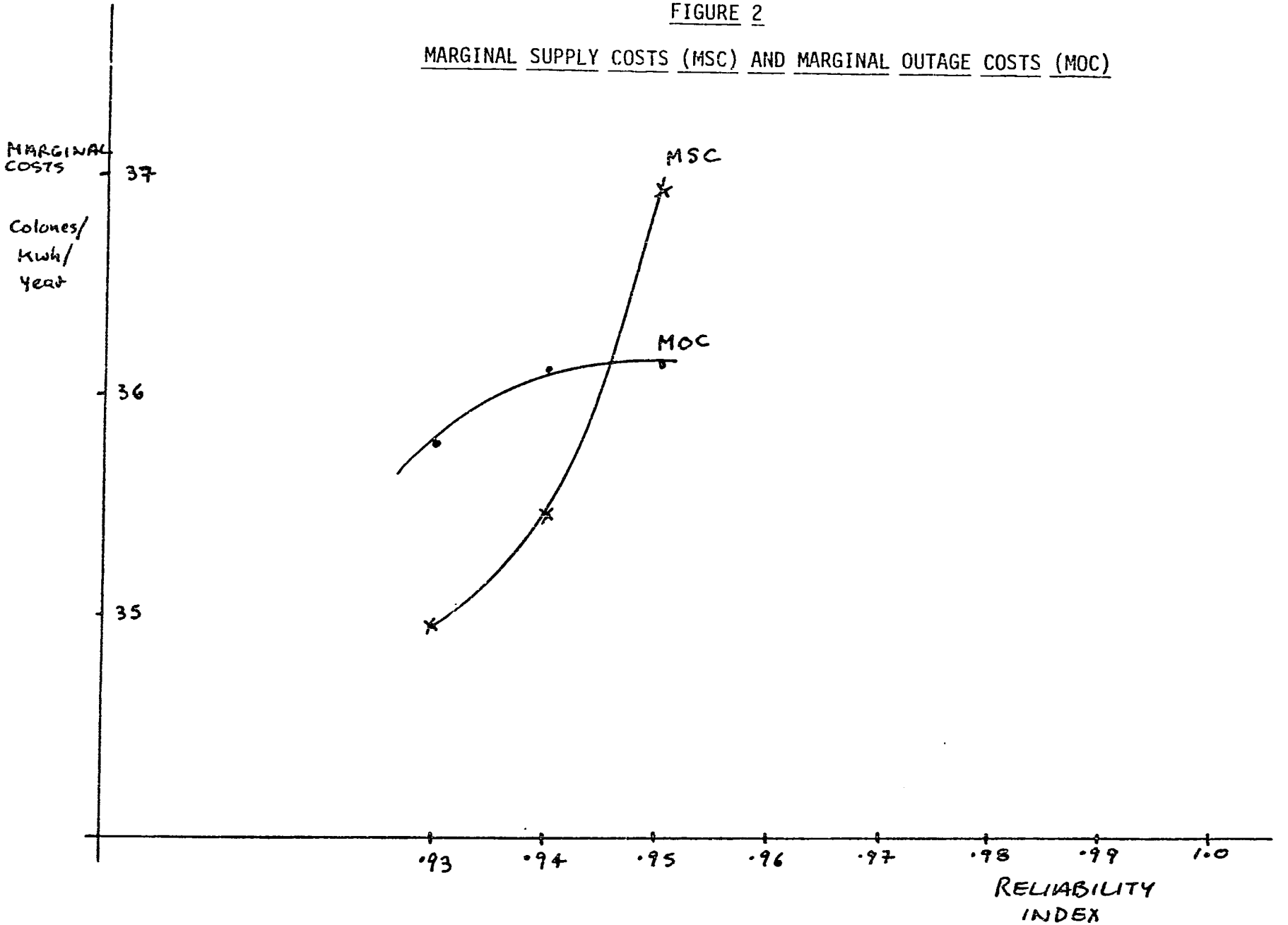


TABLE 1

Power and Energy Demand Increments for the Cahuita-Puerto Viejo Line: 1985-1995

Year	Power in KW	Change in Kw	Energy in MWH/year	Change Energy
1985	109	-	639	-
1986	117	8	686	47
1987	126	9	739	53
1988	136	10	798	59
1989	147	11	863	65
1990	158	11	927	64
1991	170	12	997	70
1992	184	14	1079	82
1993	199	15	1167	88
1994	215	16	1262	95
1995	232	17	1361	99

Note: Load Factor to o 0.67

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TABLE 2

CAHUITA - PUERTO VIEJO

SUPPLY COSTS (10^3 Colones)

Standard Design @ 15% Discount Rate

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995				
Investment Materials	6,636														
Labor	1,848														
Per Diem	61														
Fringe Benefits	83														
Transportation	46														
Distribution Expenses	2,098														
SUB TOTAL	10,772														
O & M															
Materials		66	66	66	66	66	66	66	66	66	66				
Labor		151	151	151	151	151	151	151	151	151	151				
Fuel		3	3	3	3	3	3	3	3	3	3				
Per Diem		57	57	57	57	57	57	57	57	57	57				
SUB TOTAL		277	277	277	277	277	277	277	277	277	277				
Present Value P.V.= 12,157	10,772	240	209	182	158	137	119	104	90	78	68				

TABLE 3

CAHUITA - PUERTO VIEJO

ALTERNATIVE DESIGN A

SUPPLY COSTS (10^3 Colones)

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995				
Investment Materials	6,302														
Labor	1,848														
Per Diem	61														
Fringe Benefits															
Transportation															
Distribution Expenses	2,016														
SUB TOTAL	10,310														
O & M															
Materials		66	66	66	66	66	66	66	66	66	66				
Labor		151	151	151	151	151	151	151	151	151	151				
Fuel		3	3	3	3	3	3	3	3	3	3				
Per Diem		57	57	57	57	57	57	57	57	57	57				
SUB TOTAL		277	277	277	277	277	277	277	277	277	277				
Present Value P.V.= 11,310	10,310	240	209	182	158	137	119	104	90	78	68				

TABLE 4

CAHUITA - PUERTO VIEJO
ALTERNATIVE DESIGN B
SUPPLY COSTS (10^3 Colones)

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995				
Investment Materials	6,127														
Labor	1,848														
Per Diem	61														
Fringe Benefits	83														
Transportation	46														
Distribution Expenses	1,975														
SUB TOTAL	10,140														
O & M															
Materials		66	66	66	66	66	66	66	66	66	66				
Labor		151	151	151	151	151	151	151	151	151	151				
Fuel		3	3	3	3	3	3	3	3	3	3				
Per Diem		57	57	57	57	57	57	57	57	57	57				
SUB TOTAL		277	277	277	277	277	277	277	277	277	277				
Present Value P.V.=11,525	10,140	240	209	182	158	137	119	104	90	78	68				

TABLE 5

CAHUITA - PUERTO VIEJO

ANNUAL INCREMENTS IN ENERGY DEMAND (MWh/year)

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995				
Energy Increments	0	47	53	59	65	64	70	82	88	95	99				
Present Value P.V.= 329.57		40.87	40.0	38.7	37.1	31.8	30.2	30.8	28.7	27.0	24.4				

TABLE 6

MARGINAL SUPPLY COSTS

Design	Reliability Index	Present Value Supply Costs (Million ¢)	Present Value Energy Increments (MWh./year)	MSC (¢/MWh/yr.
Standard	0.95	12.157	329.57	36,880
A	0.94	11.695	329.57	35,480
B	0.93	11.525	329.57	34,960

TABLE 7

CAHUITA - PUERTO VIEJO

TOTAL COSTS DUE TO INTERRUPTIONS (10^3 Colones)

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Standard	1,121	1,199	1,283	1,373	1,469	1,572	1,682	1,800	1,926	2,060	2,205
P. V. =8,817	1,121	1,042	970	902	839	781	727	676	629	585	545
Design "A"	1,347	1,441	1,542	1,650	1,766	1,889	2,021	2,163	2,314	2,476	2,650
P. V.= 10,602	1,347	1,253	1,165	1,084	1,009	939	874	813	756	704	655
Design "B"	2,566	2,746	2,938	3,143	3,364	3,599	3,851	4,120	4,408	4,717	5,047
P. V.= 20,197	2,566	2,388	2,221	2,066	1,923	1,789	1,665	1,549	1,441	1,341	1,248

TABLE 8

CAHUITA - PUERTO VIEJO

PRESENT VALUE OF ENERGY INCREMENTS

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995				
Design Standard	31,914	34,147	36,538	39,096	41,832	44,761	47,894	51,246	54,834	58,672	62,779				
P.V.= 248,470	31,914	29,366	27,403	25,412	23,844	21,932	20,594	18,961	17,546	16,428	15,066				
Design "A"	38,340	41,023	43,895	46,968	50,253	53,773	57,538	61,565	65,875	70,486	75,420				
P.V.= 298,000	38,340	35,260	32,840	30,480	28,000	26,300	24,700	22,700	21,050	19,700	18,090				
Design "B"	73,030	78,142	83,612	89,464	95,727	102,428	109,598	117270	125475	134262	143667				
P.V.= 574,817	73,030	67,950	63,219	58,819	54,732	50,913	47,375	44,081	41,016	38,170	35,512				

TABLE 9

MARGINAL OUTAGE COSTS

Design	Reliability Index	Present Value Outage Costs (Million ¢)	Present Value Energy Changes (MWh./year)	MOC (¢/MWh per year)
Standard	0.95	8.817	248.47	36,172
A	0.94	10.602	298.00	36,165
B	0.93	20.197	547.81	35,763

Chapter X

SUMMARY AND CONCLUSIONS

1. Introduction

The purpose of this monograph was the systematization of a framework for the analysis of rural electrification projects, which was capable of overcoming the apparently contradictory approaches currently in use. The review of the literature on RE in general, and for Costa Rica particularly, served as a spring-board for assessing the contributions as well as the limitations of previous works in the field.

In determining the viability of a RE project a careful cost-benefit analysis is necessary. A procedure to perform this sort of analysis has been suggested based on the general UNIDO methodology for project appraisal. This has the advantage of approaching the project by stages that can provide an economic analysis from the country's perspective, and inter- and intra-temporal analyses based upon the social and political interests of the decision makers. The approach suggested permits the government clearly to assess the cost to the economy of any decision based on non-efficiency considerations. It is also fairly easy to alter the appraisal to take into account changing priorities and the concerns of the decisionmakers. In this respect the apparent contradiction between social benefit analysis and economic benefit analysis can be elucidated by increasing levels of social adjustments to the pure economic approach.

This monograph has also stressed the need to establish a consistent and comprehensive assessment of the benefits and costs of the RE project. This has been complemented by a marginal cost approach to RE project

pricing.

2. Summary

Chapter I looked at the overall "development policy" setting of rural electrification and indicated the major policy choices being; (i) between rural electrification and rural development with rural electrification as merely one facet, and (ii) between rural electrification and other decentralized energy options. The choices of these policy directions depend to large extent on what we expect the actual economic and social outcomes of a rural electrification project to be, and to a lesser extent upon an *a priori* view of how development could, or should occur.

Chapter II describes the historical development of electrification in Costa Rica and summarizes all of the existing literature. This chapter documents the rapid progress so far made with over 70% of the rural households now being electrified. It also demonstrates the value placed upon central grid electrification by both the government and the rural population.

Chapter III focusses on the comparative international literature on rural electrification. It also reports an analysis of the choice of grid electrification or a decentralized diesel-powered local grid in the town of Boca del Parismina. Interestingly, the costs of supplying the 115 households by either of the options differs byonly 0.08% with the decentralized option being only 20,000 colones cheaper in present value terms. This would seem to indicate that for systems with large amounts of hydrocapacity it may be initially economical to move directly to central grid systems.

The lack of adequate benefit measurement techniques often leads to an

underestimate of the benefits of rural electrification. Chapter IV reviews the literature on benefit measurement and introduces the notion of benefit-cost analysis. Chapter V follows with a discussion of the UNIDO method for social benefit-cost evaluation and detailed application to the Second Stage of Rural Electrification in Costa Rica. To our knowledge this is the first time an application has been made of this methodology to the evaluation of investments in rural electrification. The results obtained are of significance for policy decision about extending rural electrification in Costa Rica - and we believe the results are also generally applicable to RE projects in many other countries. The results show that RE investments are quite poor from the financial point of view, poor to marginally acceptabl from an economic point of view, and reasonably attractive when the distribution of the benefits to poorer sections of the population receive political weighting in the analysis. These results may not be, in themselves, surprising but the advantage of the UNIDO methodology is that the weighting of benefits can be made very clear to all concerned - if no less arbitrary. Our argument for the use of this method is that many different competing RE projects are available and this method will help rank the choice between them. Similarly, there are many competing investments in other sectors such as transport, argiculture, etc., and if we apply the same methodology and the same political weights to distributional impacts and to merit goods, then the methodology will help rank projects between sectors.

The bulk of the literature on marginal cost pricing in public utilities deals with the question of setting tariffs. Our Chapter VI was carried out with this in mind. The chapter discusses the problem of defining what is meant by marginal costs and how to evaluate them. We have chosen

the Average Incremental Cost (AIC) method on the assumption that it more realistically smoothed the impact of future investments to meet incremental demand. We also believed that the difference between the AIC and the one next preferred by us - the Long-Run Incremental Cost (LRIC) - would be small. Castagnola (1986) carried out a comparison of the two methods applied to the Second Stage of Rural Electrification in Costa Rica and found the range of differences between AIC and LRIC was from - 2% to + 3%. In Costa Rica we see that there is a large difference between the average marginal cost of energy, 6.2 colones per kwh, compared to a tariff averaging out at 1.6 colones per kwh. Chapter VI points out one of the major methodological flaws with the use of the UNIDO method of benefit-cost analysis. This is the fact that the benefit-cost analysis is carried out based upon the total project costs and project benefits. If the benefits, however, are functions of the prices charged (i.e. tariffs) then some allowance needs to be taken for the deadweight losses incurred by this "below marginal cost" pricing scheme.

In the chapters discussed so far we were relying upon some small scattered surveys carried out by ICE to estimate the willingness to pay benefits of rural electrification. We carried out our own survey of energy use in three rural areas in the east coastal region of Costa Rica. Chapter VII reports on the results of these surveys. In general the surveys show that electricity is highly valued by the population. To our surprise - using willingness to pay and the cost of appliances as two independent measures of benefits we found great similarities between the two approaches. We were also surprised to find that, based upon the value of appliances purchased, business had a much lower expectation of benefits (by 25%) than households. This appears to contradict most of the literature on the

benefits of rural electrification. Maybe it is an indication that in middle-income couintries, such as Costa Rica, electrification will have higher values to residences than to business users. On reflection this makes sense since exact substitutes are more readily available (both type and scale of demand) to businesses than to private households.

Chapter VIII applies the benefit-cost methodology to a small RE project in Puerto Viejo in the province of Limon. The results indicate that the project is not attractive from the financial point of view but very attractive from the economic point of view. (19% IRR opposed to 3.9%). For this project there is no need to appeal to "social weights" for project justification. For this case, as might be expected, the average marginal cost of energy is considerably lower (2.2 colones/kwh) than the average marginal cost for the Second Stage Project as a whole. Hence, the deadweight losses are very small (less than 5% of total benefits).

Chapter IX attempts to carry out an economic analysis of the choice of the system reliability applied to the Puerto Viejo case. Such studies have been suggested in the past but our study is the only one we could find that had actually applied the methodology to the case of rural electrification. We found that the intersection of the marginal supply cost curve and the marginal outage cost curve was fairly close to the presently supplied level of reliability. In other words, the consumers value the level of reliability at the margin at close to what it costs to supply. This fact was picked up in our survey work (reported in Chapter VII) where no one was willing to pay more for improvement of the quality of service. It is widely assumed in the literature that for rural electrification projects quite low levels of reliability are what the consumers are willing to pay

for. In Puerto Viejo this is certainly not the case.

All of our work has focussed on a variety of ex-ante methods for evaluating projects - as this indeed should be the case of professionals interested in the future planning of electric power systems. Future planners, however, should adjust their forecasts based upon what the relevant experiences in the country have been. This implies the need for carrying out post-mortems on previous projects - a form of ex-post analysis.

3. Ex-Post Analysis

The main purpose of ex-post analysis is targeted toward the information that is relevant for new RE projects. Following Cecelski's framework for analysis (Cecelski, 1979), there are four aspects of ex-post methods:

i). Meeting Targets. This includes two trends. One is to assess whether the project was completed under the pre-established time schedule or, in general, whether it was even finished. The second one is to determine whether the targets proposed in the RE project have been met, such as the number of villages electrified and kilowatt-hours sold. The 'meeting target' method is a good measure of success in construction, in forecasting, and materialization of demand.

For example, for the second stage of Rural Electrification in Costa Rica, that was planned to start in 1980 and end in 1983, by early 1985 there was a three year delay in its construction. This would indicate a series of problems that a rigorous analysis of this first ex-post method would clearly show up. Nonetheless, as was stated elsewhere in this paper, an ex-post analysis must be put into the framework of macroeconomic and

crisis in the last five decades, GDP decreased by 20%, unemployment doubled and political circumstances influenced the accomplishment of many public projects. The project was later on pushed forward in early 1985 with an Emergency Decree that re-established the original targets and by early 1986 the project is already 80% accomplished. Thus, correctly framed the Second Stage of Rural Electrification has met its construction targets when "normal" circumstances were in play. For the towns electrified in early 1980 the demand increased at the expected growth rate of 7 percent thus indicating that the demand was being materialized as expected.

ii). Financial Viabiltiy. In a limited way, this method measures whether the financial benefits and costs effectively matched the assumptions established in the final viability study. It tests the present financial strength of the RE project after some time of operation. Indeed, this approach is highly appealing to the funding agencies or banks insofar as it shows the return of the project from a private point of view. Cecelski summarizes this in the following way:

> The use of financial viability or completion of agreed construction as a criterion for success is an understandable approach on the part of lenders, particularly commerical banks, who will be concerned that they be repaid in a timely fashion, and that the power sector be insulated from political pressures in other parts of the government and be able to make decisions about grid expansion or investment in capacity on a financial basis. (Cecelski, 1979; pp. 8.)

In this respect, it is also important to address the ex-post analysis of this aspect in a wider context. As our study had shown, the

Government subsidized the rural consumer. the cost of providing an extra KWh, at the margin, is four times higher than the tariffs actually paid by the consumer. The benefit-cost analysis showed that the internal rate of return for the first stage of the UNIDO methodology (Financial Analysis) is very low and that would make the project not feasible from a strict financial perspective. Furthermore, the case of Costa Rica indicates that the pricing of electricity has to be addressed from a national perspective, that is, what the public utility targets is to decrease nationwide the deficit that arises from the subsidies given to various residential consumers. It is not aimed to make each project such as rural electrification, financially viable for itself. However, what the ex-post financial viability assessment shows is that the consumers are on average increasing their demand for electricity, they are willing to pay for the service and have not decreased their consumption with rate increases that have occurred during the last years.

iii). Impact on Users. The precise question that this approach must answer is: What changed after electrification? The objective is to determine the benefits attributable to RE.

The two studies analyzed in Chapter II of this monograph are a good sample of the sort of points addressed by this type of method.

For example, for Puerto Viejo compared with the newly electrified towns, the increase in applicance ownership indicates a major impact of electrification. The percentage of people who own radios more than doubled between the two types of towns (47% owned a radio in the electrified towns and only 19% in the non-electrified town); the percentage of refrigerator

ownership more than quadrupled (37% in relation to 8%); the percentage of electric irons almost doubled (65% in relation to 34 %). In the analysis of the survey in Chapter VI another set of aspects of the impact on users were stated such as the perception that the consumers have on their personal security, in achieving greater comfort, producing more tourism, greater food preservation and so on.

iv). Cost-Benefit Assessment. The purpose is to evaluate the costs and benefits of the RE scheme, i.e., confront the assumed values of the ex-ante analysis with the actual outcomes of the project already implemented. This will provide information to assess the correctness of the viability study and to provide substantial elements for feedback to other RE projects in nearby regions.

Actually the outline of this last aspect follows the structure developed in Chapter V of this paper, i.e., it must try to assess the benefits and costs of RE. These costs and benefits are the ones that were originally used to appraise the project or new evidence that arose once the project was implemented.

The benefit-cost analysis that was done in Chapter VIII on the Puerto Viejo case pointed to the use of ex-post results from two electrified towns to assess the feasibility of a rural electrification scheme in a nearby non-electrified town.

4. Future Research

Based upon this study of rural electrification we believe that further work is needed in the following four areas:

i). Benefit Estimation. More case studies need to be carried out to improve the basis for estimating benefits. The crude methods outlined in this monograph could be greatly improved.

ii). Marginal Cost Estimation. More theoretical and practical work is needed to put these concepts on a firmer footing. Several case studies would establish some guidelines for which method is preferable under which conditions. This work would be extremely helpful to the agencies involved in setting tariffs.

iii). Optimum Levels of Reliability. Much more analysis of the technical options need to be explored in order to give a wider selection of cost and performance for electric power systems in developing countries. In addition similar studies should be done for decentralized and autogeneration systems.

iv). Rural Electrificatin and Rural Development. Research needs to be carried out to develop a methodology that will show the benefits of rural electrification as an integral part of rural development. The methodology used in this monograph is not adequate to do this.

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APPENDIX A - SURVEY QUESTIONNAIRE

ENCUESTA SOBRE BENEFICIOS DE LA ELECTRIFICACION (AID)

HORA I: _____

HORA T: _____

DIRECCION: _____

_____ BARRIO: _____ NºCuestionario / / / /

CANTON: _____ DISTRITO: _____ NºTarjeta .... /1/

SELECCION PRIMARIA: _____ VIVIENDA Nº _____ Sel. Primaria / / / /

ENTREVISTADO: _____ TELEFONO: _____ UBICACION .... / / / / /

RELACION CON EL JEFE: _____ PUEBLO ELECTRIFICADO / / /

Sí ☐ No ☐ 13

INTRODUCCION: Sr., Sra., Srta.: Nosotros andamos haciendo un estudio para la AID, sobre el consumo de energía con el propósito de que no falte la electricidad, el canfín, etc. Le agradeceríamos mucho si fuera tan amable de contestarnos unas cuantas preguntas. No le voy a quitar más de unos pocos minutos. Lo que usted diga es ESTRICTAMENTE CONFIDENCIAL y de gran ayuda para el país.

B. CARACTERISTICAS DE LA VIVIENDA

B1. Para empezar sería usted tan amable de decirme, esta vivienda en que Uds. viven es propia, alquilada, prestada o cedida?

1 ☐ Propia Pagada (PASE A B3)
2 ☐ Propia Pagándola
3 ☐ Cedida o Prestada
4 ☐ Alquilada
OTRA _____ (ESPECIFIQUE)

/ /

B2. Cuánto pagan por mes? ₡ _____ ☐ No hace ningún pago

/ / /

B3. Y para alumbrar su casa ustedes utilizan electricidad o alguna otra cosa?

1 ☐ Electricidad (PASE A B5) 2 ☐ Otra cosa

/ /

B4. Qué otra cosa utilizan?

1 ☐ Candela
2 ☐ Focos
3 ☐ Canfinera
4 ☐ Carbura
5 ☐ Otro _____ (ESPECIFIQUE)

A. Cuántas candelas usan por noche? _____
B. Entonces cómo cuántas candelas gastan por semana? _____ (PASE A C1)

/ /
/ /
/ / /
/ /
/ / /

Cuántas usan por noche? _____

Cuánto gasta por mes? Cantidad: _____ ₡ _____

(INDICAR EL NUMERO DE BATERIAS, CANTIDAD DE CANFIN, ALCOHOL O DEL COMBUSTIBLE QUE UTILIZAN) (PASE A C1)

B5. Sería tan amable de decirme cuántos KWh gastan por mes de luz? (SUGIERA QUE LE ENSEÑEN EL RECIBO)

(SI LE MUESTRAN EL RECIBO ANOTE: Nº de Medidor: _____ KWh: _____

/ / /

(SI NO LE MUESTRAN EL RECIBO PREGUNTE: Cuánto pagaron por el último recibo de luz? ₡ _____

/ / / / /

9 ☐ Tienen planta propia ¿Hace cuánto la compró? HACE: _____ ¿Cuánto les costó? ₡ _____

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C. OTRAS FUENTES DE ENERGIA

C1. Y ahora cuáles de los combustibles que le voy a mencionar utilizan ustedes aquí en la vivienda? Por ejemplo para limpiar pisos, blanquear ropa, encender el fuego u otra actividad similar. (SI TIENE PLANTA ELECTRICA PROPIA ANOTE SUS GASTOS)

COMBUSTIBLE	NO	SI	GASTO POR MES ¢	CANTIDAD POR MES (LITROS)
Gasolina	0 /_/	1 /_/		
Diesel	0 /_/	1 /_/		
Canfín (para cocinar)	0 /_/	1 /_/		
Canfín (para otros usos)	0 /_/	1 /_/		
OTRO: _____ (ESPECIFIQUE)	0 /_/	1 /_/		

C2. Utilizan ustedes gas? 1 /_/ Sí 2 /_/ No (PASE A C5) /_/

C3. Qué tipo de cilindro utilizan (compran)?
1 /_/ Pequeño (12 libras) 2 /_/ Mediano (25 libras) 3 /_/ Grande (100 libras) /_/

C4. Cuánto tiempo les dura el cilindro? (DIAS): _____ /_/_/

C5. Y ustedes con qué cocinan los alimentos?
1 /_/ Cocina eléctrica
2 /_/ Cocina de gas
3 /_/ Cocina de canfín
4 /_/ Cocina de leña
5 /_/ Plantilla eléctrica
6 /_/ Plantilla de gas
7 /_/ Plantilla de canfín
8 /_/ Anafre de _____
9 /_/ Fogón de _____
0 /_/ Otro _____ (ESPECIFIQUE) /_/_/

(ENTREVISTADOR: SI EL PUEBLO NO ESTA ELECTRIFICADO PASE A F1)

C6. Y antes de que electrificaran (pusieran la luz) el pueblo, ustedes cocinaban con lo mismo de ahora o cambiaron? /_/
1 /_/ Cocinaban con lo mismo (PASE A F1) 2 /_/ Cambiaron

C7. Con qué cocinaban antes de que se electrificara el pueblo? /_/
_____

C8. Y por qué motivo dejaron de usarlo? _____ /_/_/
_____

F. CARACTERISTICAS FAMILIARES

F1. Sería usted tan amable de decirme:

Cuántas personas viven permanentemente en esta vivienda? (INCLUYA TANTO A LOS DE LA FAMILIA COMO A HUESPEDES Y NO PARIENTES)

Nº Personas: _____ /_/_/

A. Cuántos niños (menos de 10 años) _____

B. Cuántos son jóvenes (10 a 17 años) ____ /_/

C. Adultos (18 y más) ____ /_/

(ENTREVISTADOR: VERIFIQUE QUE LA SUMA DE A, B y C COINCIDA CON EL TOTAL DADO AL PRINCIPIO EN F1) /_/ 71

F2. Aparte de las personas que viven en la casa tienen ustedes otros comensales? /_/_/_/2/

1 ☐ Sí 2 ☐ No (PASE A T1) /_/

F3. Cuántos comensales tienen?

_____ comensales /_/

F4. Cuántos de ellos le pagan? Nº _____

Y cuánto dinero le pagan? ₡ _____ por _____ /_/_/_/

HAGA F5 SOLO SI EL PUEBLO ESTA ELECTRIFICADO, SINO PASE A T1

F5. Tenía comensales antes de que se electrificara el pueblo? /_/

0 ☐ No 1 ☐ Sí ¿Cuántos? _____

T. TENENCIAS DE LA FAMILIA

T1. De los siguientes artefactos me gustaría que me dijera cuáles posee y hace cuánto los compró?

ARTEFACTO	NO	SI	¿Cuántos?	Elect.	Bater.	Ambos	Hace cuánto lo compró? (el último)	
1.Radiograbadora	0 ☐	1 ☐	_____	1 ☐	2 ☐	3 ☐	_____	/_/_/_/_/
2.Radio	0 ☐	1 ☐	_____	1 ☐	2 ☐	3 ☐	_____	/_/_/_/_/
3.Televisor	0 ☐	1 ☐	_____	1 ☐	2 ☐	3 ☐	_____	/_/_/_/_/_/

¿BLANCO Y NEGRO?

☐ Sí ☐ No

(SI NO TIENE ELECTRICIDAD PASE A T2)

	NO	SI	Hace cuánto lo compró?	
4. Ventilador	0 ☐	1 ☐	_____	/_/_/
5. Equipo de sonido	0 ☐	1 ☐	_____	/_/_/
6. Consola o Tocadiscos	0 ☐	1 ☐	_____	/_/_/
7. Cepillo Eléctrico	0 ☐	1 ☐	_____	/_/_/
8. Algún Otro? _____ (ESPECIFIQUE)			_____	/_/_/ 33

T2. Tienen ustedes refrigeradora? Con qué funciona?

1 /_/ No (PASE A T6) 2 /_/ Sí ¿Con qué funciona?

1 /_/ Electricidad (PASE A T6)
2 /_/ Canfín
3 /_/ Gas
4 /_/ Otro _____

/_/

T3. Y cuánto gasta su refrigeradora?

1.Canfín _____ Gal/Lits/Bot. _____ mes/sem/día /_/_/

2.Gas _____ Cilindros peq. _____ mes/sem/día /_/_/

_____ Cilindros med. _____ mes/sem/día /_/

_____ Cilindros grand. _____ mes/sem/día

T4. Y qué marca es su refrigeradora? Y de qué tamaño?

MARCA: _____ TAMAÑO: _____ PIES CUBICOS /_/_/

ENTREVISTADOR: (SI NO CONTESTA NUMERO DE PIES, SONDEAR TAMAÑO)

1 /_/ Pequeño 2 /_/ Mediano 3 /_/ Grande /_/_/

T5. Y la Refrigeradora hace cuánto la compraron?

Hace: _____ /_/ Años /_/ Meses /_/ Días /_/

T6. Podría usted decirme si tienen en su hogar plancha? /_/

Tiene plancha? Con qué funciona?

0 /_/ No 1 /_/ Sí

1 /_/ Electricidad /_/_/
2 /_/ Carbón
3 /_/ Otro _____ (ESPECIFIQUE)

T7. Y hace como cuánto la compraron?

Hace: _____ /_/ Años /_/ Meses /_/ Días /_/_/

A. USO DE LA ELECTRICIDAD

(SI NO TIENE ELECTRICIDAD PASE A A12)

A1. Cuando se electrificó el pueblo, por qué decidieron ustedes utilizar la electricidad?

_____ /_/_/

_____

_____

A2. Aquí se va la luz frecuentemente?

1 /_/ Sí 2 /_/ No (PASE A A5) /_/

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A3. Como cada cuánto se va y cuánto tiempo dura en volver?

Se va cada: _____ /_/_/

Dura en volver: _____ /_/_/

A4. "Usted estaría dispuesto a pagar más de lo que paga porque eso no sucediera"

0 /_/ No 1 /_/ Sí ¿Cuánto? _____ /_/

A5. Para usted de qué hora a qué hora es peor que se vaya la luz?

De las : _____ a las _____ /_/_/_/_/_/

Por qué? _____

_____ /_/_/

_____

A6. Tomando en cuenta lo que ustedes ganan, cree usted que en esta zona los combustibles que le voy a mencionar son caros, tienen un precio normal o son baratos?

	3. CARO	2. NORMAL	1. BARATO	9. NS/NR	
1. Electricidad	/_/	/_/	/_/	/_/	/_/
2. Gasolina	/_/	/_/	/_/	/_/	/_/
3. Diesel	/_/	/_/	/_/	/_/	/_/
4. Canfín	/_/	/_/	/_/	/_/	/_/
5. Gas	/_/	/_/	/_/	/_/	/_/
6. Leña	/_/	/_/	/_/	/_/	/_/
7. Carbón	/_/	/_/	/_/	/_/	/_/

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A7. Qué haría usted si mañana aumentarán la electricidad al doble? /_/NS/NR /_/_/_/3/

_____ /_/_/

_____

_____

A8. Gastaría usted más electricidad si sus ingresos aumentaran al doble?

0 /_/ NO 1 /_/ Sí /_/ NS/NR (PASE A A9) /_/

Por qué? _____ /_/_/

_____

A9. Si ustedes a partir de mañana ganaran el doble, comprarían algunos artefactos eléctricos?

1 /_/ Sí 0 /_/ No (PASE A A11) /_/

A10. Cuáles artefactos eléctricos compraría? /_/ NS/NR

1. _____ 3. _____ /_/_/

2. _____ 4. _____ /_/_/

A11. Con la electrificación los ingresos de la familia aumentaron?

0 /_/ No 1 /_/ Sí ¿En cuánto aproximadamente? _____ /_/_/

(ENTREVISTADOR PASE A A16) 10

A12. Cuando electrifiquen el pueblo piensa comprar algunos artefactos eléctricos?

1 ☐ Sí 0 ☐ No (PASE A A14) /_/

A13. Cuáles artefactos eléctricos comprarían? ☐ NS/NR

1. _____ 3. _____

2. _____ 4. _____ /_/ /_/ /_/

A14. Y pondrían ustedes alguna actividad comercial, como venta de comida, queques, pulpería, taller, etc., si se electrifica el pueblo?

0 ☐ No 1 ☐ Sí ¿cuál actividad? _____ /_/ /_/

A15. Ahora me gustaría que me dijera, tomando en cuenta su ingreso, ¿cuánto podrían ustedes pagar para que les colocaran la luz?

_____ /_/ /_/

A16. Tomando en cuenta el ingreso de ustedes cuánto sería lo más que podrían pagar mensualmente por la luz?

₡ _____ por mes /_/ /_/

A17. En su opinión la electrificación (LEER ALTERNATIVAS)

	MUCHO	REGULAR	NADA	NS/NR	
1. Mejora la comodidad	3 ☐	2 ☐	1 ☐	9 ☐	/_/
2. Aumenta los ingresos	3 ☐	2 ☐	1 ☐	9 ☐	/_/
3. Favorece el estudio	3 ☐	2 ☐	1 ☐	9 ☐	/_/
4. Promueve la unión familiar	3 ☐	2 ☐	1 ☐	9 ☐	/_/
5. Reduce los robos y asaltos	3 ☐	2 ☐	1 ☐	9 ☐	/_/
6. Produce nuevos empleos	3 ☐	2 ☐	1 ☐	9 ☐	/_/
7. Otra: _____ (ESPECIFIQUE)	3 ☐	2 ☐	1 ☐	9 ☐	/_/

A18. En su opinión con la electrificación cuáles se benefician más ¿los hombres o las mujeres?

1 ☐ Los hombres 2 ☐ Las mujeres 3 ☐ Igual (Ambos) /_/

A18A. ¿Por qué opina así? _____

_____ /_/ /_/

_____

A19. En su opinión con la electrificación cuáles se benefician más los ricos o los pobres?

1 ☐ Los ricos 2 ☐ Los pobres 3 ☐ Igual (Ambos) /_/

A19A. ¿Por qué? _____

_____ /_/ /_/

_____

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A20. En su opinión cuáles son las dos principales ventajas que ha traído o podría traer la electrificación para este pueblo?

1. _____ / / /

2. _____ / / /

/ / NS/NR

A21. Y las dos principales desventajas que ha traído o que podría traer la electrificación a este pueblo cuáles son, en su opinión?

1. _____ / / /

2. _____ / / NS/NR / / /

J. CARACTERISTICAS DE LA FAMILIA

Ahora le agradecería que me diera algunos datos adicionales:

J1. Quién es el principal sostén económico de la familia? (EL PRINCIPAL SOSTEN ES EL QUE APORTA LA MAYOR ENTRADA ECONOMICA A LA FAMILIA)

1 / / Entrevistado 2 / / Otro ¿Quién es? _____ / /

J2. Y cuál es la ocupación o actividad principal que _____ (PRINCIPAL SOSTEN) desempeñó la semana pasada?

(O LA ULTIMA VEZ QUE TRABAJO)
CON DETALLE:

_____ / / /

/ / Pensionado (PASE A J5)

J3. Y a qué se dedica la empresa, compañía, finca o establecimiento en la que _____ (PRINCIPAL SOSTEN) trabajó?

CON DETALLE:

_____ / / /

J4. Y en ese trabajo que es _____ (PRINCIPAL SOSTEN): empleado, trabaja por cuenta propia, patrono o trabajador familiar?

1 / / Empleado público

2 / / Empleado privado / /

3 / / Cuenta propia (sin emplear a ninguna persona)

4 / / Patrono (empleando a una o más personas por sueldo o salario)

J5. Y cuál es el salario (ingreso ganancia) mensual que _____ (PRINCIPAL SOSTEN) recibe de ese trabajo?

₡ _____ POR MES / / /

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J6. Además de (PRINCIPAL SOSTEN), usted podría decirme cuántas personas de las que viven en la vivienda trabajan?

RELACION CON EL JEFE DE FAMILIA	OCUPACION	CATEGORIA OCUPACIONAL	INGRESO O SUELDO MENSUAL	
				/ / /
				/ / /
				/ / /
				/ / /

J7. Reciben ustedes otros ingresos como alquileres, rentas, intereses, etc.?

1 /_/ Sí 0 /_/ No (PASE A J9)

J8. Como cuánto reciben por mes? ¢ _____ POR MES / / /

J9. Cuál es el último grado o año de enseñanza que aprobó _____ ?
(PRINCIPAL SOSTEN)

0 /_/ Sin estudios
1 /_/ Primaria incompleta
2 /_/ Primaria completa
3 /_/ Secundaria incompleta
4 /_/ Secundaria completa
5 /_/ Superior incompleta
6 /_/ Superior completa

/ /

E. ACTIVIDADES ECONOMICAS DE LA FAMILIA

E1. Podría decirme si en esta casa se realiza alguna actividad comercial como (LEER ALTERNATIVAS)

/ / /
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	NO	SI
1. Pastelería o hace queques	0 /_/	1 /_/
2. Bar, Pulpería	0 /_/	1 /_/
3. Planchado de ropa	0 /_/	1 /_/
4. Venta de Comida	0 /_/	1 /_/
5. Hace o vende cerámica ...	0 /_/	1 /_/
6. Hace ropa	0 /_/	1 /_/
7. Salón de Belleza	0 /_/	1 /_/
8. Taller de Soldadura	0 /_/	1 /_/
9. Taller de Ebanistería ...	0 /_/	1 /_/
10. Taller de Artesanía	0 /_/	1 /_/
11. Taller de Radio y T.V. ..	0 /_/	1 /_/

12. OTRA ACTIVIDAD: _____
(ESPECIFIQUE DETALLADAMENTE)

/_/ NO REALIZA NINGUNA ACTIVIDAD

ENTREVISTADOR: SI REALIZA ALGUNA ACTIVIDAD COMERCIAL RECUERDE QUE DEBE HACER EL CUESTIONARIO ADICIONAL PARA ACTIVIDADES COMERCIALES.

VISITAS	HORA	FECHA	RESULTADO	COMENTARIOS
1º	_____	_____	_____	_____
2º	_____	_____	_____	_____
3º	_____	_____	_____	_____

FECHA _____ HORA _____ ENTREVISTADOR _____

GRADO DE COOPERACION

1 /_/ Bueno
2 /_/ Regular
3 /_/ Malo

VALIDEZ DE LAS RESPUESTAS

1 /_/ Verdaderas
2 /_/ Dudosas
3 /_/ Muy dudosas

SUPERVISOR: _____ REVISADA: 1 /_/ Sí 2 /_/ No

OBSERVACIONES: _____

_____

_____

_____

ENTREVISTADOR: SI LA FAMILIA POSEE ALGUNA ACTIVIDAD COMERCIAL NO OLVIDE LLENAR LA BOLETA RESPECTIVA.

HORA I: _____

HORA T: _____

SOLO PARA ACTIVIDAD COMERCIAL

ENCUESTA SOBRE BENEFICIOS DE LA ELECTRIFICACION (AID)

DIRECCION: _____

_____ BARRIO: _____

CANTON: _____ DISTRITO: _____

SELECCION PRIMARIA: _____ VIVIENDA Nº _____

ENTREVISTADO: _____ TELEFONO: _____

RELACION CON EL JEFE: _____

PUEBLO ELECTRIFICADO

Sí ☐ No ☐

Nº Cuestionario / / /

Nº Tarjeta .... /

Sel. Primaria / / /

UBICACION .. / / / /

/ / / 13

ENTREVISTADOR: SI LA ACTIVIDAD ES DE UNA ENTREVISTA EN LA VIVIENDA NO LEA LA INTRODUCCION Y PASE A E1

INTRODUCCION: Sr., Sra., Srta.: Nosotros andamos haciendo un estudio para la AID, sobre el consumo de energía con el propósito de que no falte la electricidad, el canfín, etc. Le agradeceríamos mucho si fuera tan amable de contestarnos unas cuantas preguntas. No le voy a quitar más de unos pocos minutos. Lo que usted diga es ESTRICTAMENTE CONFIDENCIAL y de gran ayuda para el país.

E. ACTIVIDAD COMERCIAL

E1. ENTREVISTADOR: (ANOTE LA(S) ACTIVIDAD(ES) COMERCIAL(ES) A QUE SE DEDICA LA PERSONA O EL ESTABLECIMIENTO SEGUN SEA EL CASO)

ACTIVIDADES

1. _____ / /
2. _____ / /
3. _____ / /
4. _____ / /

E2. Y en esta(s) actividad(es) comercial(es) quién es el dueño: un hombre o una mujer?

1 ☐ Hombre 2 ☐ Mujer / /
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E3. Para cada uno de los siguientes combustibles me gustaría que me dijera si usa y como cuánto gasta de cada uno de ellos (aproximadamente) en esas actividades comerciales que poseen? (NO OLVIDE ANOTAR LA UNIDAD EN QUE LE DAN EL GASTO)

COMBUSTIBLE	No	Sí	Como cuánto gasta por mes: Gasto	Unidad	
1. Electricidad	0 ☐	1 ☐	_____	_____	/ / /
2. Gasolina	0 ☐	1 ☐	_____	_____	/ / /
3. Diesel	0 ☐	1 ☐	_____	_____	/ / /
4. Kerosene	0 ☐	1 ☐	_____	_____	/ / /
5. Leña	0 ☐	1 ☐	_____	_____	/ / /
6. OTRO _____ (ESPECIFIQUE)	0 ☐	1 ☐	_____	_____	/ / /

E4. Sería tan amable de decirme qué artefactos o equipo utilizan en esa(s) actividad(es) y si son de gasolina, electricidad, de baterías, etc.?

ARTEFACTOS USADOS	De qué es?	Hace cuánto lo compró	Como cuánto le costó?	
1. _____	_____	_____	_____	/ / / / / / / /
2. _____	_____	_____	_____	/ / / / / / / /
3. _____	_____	_____	_____	/ / / / / / / /
4. _____	_____	_____	_____	/ / / / / / / /

E5. Para cada uno de esos artefactos o herramientas usted me podría decir si lo compró con ahorros suyos, con plata que le prestó un banco o un conocido o como se financió la compra (PREGUNTE EN EL MISMO ORDEN QUE QUE ANOTO)

ARTEFACTO	Lo compró con: Plata Propia	Plata del Banco	Plata de un amigo	OTRO (ESPECIFIQUE)	
1. _____	1 ☐	2 ☐	4 ☐	_____	/ /
2. _____	1 ☐	2 ☐	4 ☐	_____	/ /
3. _____	1 ☐	2 ☐	4 ☐	_____	/ /
4. _____	1 ☐	2 ☐	4 ☐	_____	/ /

E6. Y usted esa(s) actividad(es) la(s) realiza durante todo el año o hay meses que las suspende?

1 ☐ Todo el año (PASE E8)

2 ☐ Hay meses que suspende las actividades / / 67

E7: Cuál(es) actividad(es) suspende y en qué mes?

ACTIVIDAD QUE SUSPENDE	MESES EN QUE SUSPENDE ACTIVIDAD	
		/ / /
1. _____	E F M A M J J A S O N D	/ / /
2. _____	E F M A M J J A S O N D	/ / / /
3. _____	E F M A M J J A S O N D	/ / /
4. _____	E F M A M J J A S O N D	/ / /

E8. De la(s) actividad(es) comercial(es) que realiza usted todo el año hay meses en que produce o vende más y en otros menos?

1 /_/ Sí 0 /_/ No (PASE A E10) / /

E9. En cuáles meses vende más?

E F M A M J J A S O N D / / /

E10. En esas actividades comerciales que ustedes realizan, trabajan personas particulares (que no son familia de ustedes)?

0 /_/ No (PASE A E12) 1 /_/ Sí ¿Cuántos? _____ / /

E11. Sería tan amable de decirme de esos particulares, cuál es el trabajo que hace cada uno y como cuánto se gana por mes?

	OFICIO	SALARIO	MES	SEM.	DIA	
1.	_____	_____	/_/	/_/	/_/	/ / / / /
2.	_____	_____	/_/	/_/	/_/	/ / / / /
3.	_____	_____	/_/	/_/	/_/	/ / / / /
4.	_____	_____	/_/	/_/	/_/	/ / / / /

E12. En la actualidad como cuánto vende usted en esas actividades?

VENDE: ₡ _____ / / /

E13. Tomando en cuenta la gente del pueblo y de otros que le podrían comprar, usted cree que podría vender más de lo que vende actualmente?

1 /_/ Sí 0 /_/ No (PASE A E16) / /

E14. Como cuánto más cree usted que podría vender?

PODRIA VENDER: ₡ _____ / / /

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E15. Y usted no produce más para la venta por falta de dinero, de equipo, de tiempo o de qué?

1 /_/ Dinero 4 /_/ Tiempo

2 /_/ Equipo 8 /_/ OTRO: _____ (ESPECIFIQUE)

/ / /

E16. Podría usted decirme hace cuánto tiene estas actividades comerciales?

	ACTIVIDAD	¿Hace cuánto la tiene?	¿Y como cuánto le deja por semana?	
1.				/ / / / / / /
2.				/ / / / / / /
3.				/ / / / / / /
4.				/ / / / / / /

(ENTREVISTADOR: SI NO TIENE ELECTRICIDAD TERMINE LA ENTREVISTA)

E17. Con respecto a la(s) actividad(es) comercial(es) que ustedes realizan, la electrificación hizo que:

1/_/ Aumentaran las ganancias ¿En cuánto? _____ / / /

2/_/ Cambiaron de actividad productiva ¿De cuál a cuál?

De _____ a _____ / / / / /

3/_/ Aumentaron las horas de trabajo ¿Cuántas horas? _____ / /

4/_/ OTRO: _____ (ESPECIFIQUE) / /

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VISITAS	HORA	FECHA	RESULTADO	COMENTARIO
1º				
2º				
3º				

FECHA: _____ HORA: _____ ENTREVISTADOR: _____

GRADO DE COOPERACION

1 /_/ Bueno

2 /_/ Regular

3 /_/ Malo

VALIDEZ DE LAS RESPUESTAS

1 /_/ Verdaderas

2 /_/ Dudosas

3 /_/ Muy dudosas

SUPERVISOR: _____ REVISADA: 1 /_/ Sí 2 /_/ No

OBSERVACIONES: _____

Apéndice B.1

APPENDIX B

SURVEY OF COSTS OF OUTAGE

CUESTIONARIO SECTOR INDUSTRIAL

Nombre de la firma o Compañía.

Si usted experimenta una interrupción no programada de electricidad, cual es el valor de materiales y productos que se dañan o deterioran? Varía este valor con la duración de la interrupción?

Mientras dura la interrupción, que porcentaje de producción normal no se produce?

Una vez restablecida la energía, cuanto tiempo debe transcurrir antes de reanudar la producción? Varía el tiempo de reinicio con la duración de la interrupción?

b) Que porcentaje de la producción normal no se produce durante el período de reinicio.

Existe alguna producción en retardo? Si es así, cuánto más se podra producir por hora de trabajo?

a) Cuáles son sus horas normales de trabajo?

b) Es dueño usted, de sus propias fuentes alternativas de energía? Si es así Cuánto costaron y por cuánto tiempo han sido usadas?

Si su producción total se reduce por una interrupción, la cubriría usted trabajando en horas extras?

Cuántas interrupciones experimenta usted cada mes, en promedio, y cuándo ocurren?

Son un problema las numerosas fluctuaciones de voltaje? Causan daños en el equipo

Cuál fue el valor total de su producción el año pasado?

Apéndice B.2

CUESTIONARIO SECTOR RESIDENCIAL

1. Consumo promedio de electricidad últimos 3 meses _____ KWh/mes _____ ¢/mes

2. a. Piensa que el suministro de electricidad es: Bueno _____ Regular _____ Malo _____

   b) Hay muchas fallas en el suministro de electricidad Sí ____ No ____

3. a) Durante últimos 3 meses, cuánto tiempo ha pasado sin electricidad sin haber sido anunciado _____ minutos por mes. b) Durante que horas la electricidad es esencial en sus ratos de esparcimiento _____ c) aproximadamente que fracción de las fallas eléctricas han ocurrido en esas horas _____%

4. Si ocurre una falla en estas horas de diversión (Por ejemplo viendo TV, leyendo, escuchando música, cenando, etc). Cuánto estaría dispuesto a pagar adicionalmente para evitar la interrupción durante a) un minuto _____¢, b) cinco minutos _____ ¢, c) treinta minutos _____¢, d) una hora _____¢, e) hora y media _____ ¢, f) dos horas _____¢

5. Si una falla inesperada ocurre en otra hora, por ejemplo cuando se están haciendo los trabajos domésticos cuánto estaría dispuesta a pagar adicionalmente para evitar la interrupción durante a) un minuto ____¢, b) cinco minutos _____¢, c) treinta minutos _____¢, c) una hora _____¢, d) hora y media _____¢, e) dos horas _____¢

6. a) Siente Ud. que la electricidad es un servicio importante Sí _____ ____
   b) Le parece que la electricidad es un servicio muy caro Sí _____ No _____

7. En promedio, cómo distribuye sus ratos de descanso y diversión en las tardes y noches a) Ver T.V. _____ horas, b) escuchar radio _____ horas, c) leer ____ horas, d) cenar _____hrs e) conversar _____ horas, f) salir _____ horas, g) otros _____ horas

8. Normalmente a que horas se acuesta _____

9. Si se le reduce el número de fallas en el servicio eléctrico a la mitad, cuánto estaría dispuesto a pagar adicionalmente en su tarifa de electricidad _____¢

10. Cuántas personas viven en su casa _____

11. Aproximadamente cuánto fue el ingreso familiar en los últimos 3 meses _____¢

12. Si el número de fallas mensuales en el servicio eléctrico se duplican, cuánto cree que sería justo se le descontara de su tarifa _____¢