Report No. 517

Issues in Rural Electrification

July 24, 1974

Public Utilities Department

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Document of the International Bank for Reconstruction and Development
International Development Association

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SUMMARY AND CONCLUSIONS

The following summary and conclusions provide a self-contained outline of the report.

I. Introduction

i. After an introductory review of rural electrification in developing countries, the report discusses three main topics:

(1) The prospects for successful investment in rural electrification;

(2) Approaches towards investment, as regards:

- economic justification;
- identification and preparation;
- finance;
- technical problems; and
- institutional problems.

(3) Implications for Bank policy and procedures.

The report indicates that there is plenty of scope for successful investments in rural electrification, provided they are properly selected and prepared; and it outlines an approach for undertaking them. Future Bank initiatives for providing funds and technical assistance in this field would require no serious revisions of policy and procedures. The report is an outcome of a research study in El Salvador, field trips to four countries, and correspondence with over twenty countries in Africa, Asia, EMENA and Latin America.

II. Rural Electrification in Developing Countries

ii. Levels of investment (paragraphs 2.2 to 2.5). Developing countries are putting increasing resources into rural electrification, and the resources countries allocate to it increase with their per capita incomes. Cumulative investment by countries within the Bank's area of operations was about $10 billion by 1971, or 10% of total investment in electric power. In the next ten years over $10 to $15 billion will probably be invested, and about one quarter of the village-rural population, or 300 million people, will then be receiving service (as compared to about three quarters in urban areas at the present time).

iii. Aims (paragraphs 2.20 to 2.23). The aims of the investments are both social and economic. On the economic side, most countries state that the results are disappointing unless the programs have a productive context; for social reasons, however, countries often extend service to areas of low income and productivity even if the service is not financially self-sufficient for several years.

iv. Response (paragraphs 2.15 to 2.19). There are many rural areas which have very little use for electricity; the level and growth of consumption is low and there are few productive uses. However, some areas show a surprisingly good and all-round response to rural electrification projects, reflected in high, sustained growth rates of demand from households, rural commerce, farms and agro-industries (though initial demands are often low). Typically, the annual rate of growth of demand in rural areas is 10 to 20% (c.f. 10% per year in urban areas); over 50% of consumption may be for productive uses (as in urban areas); and average levels of consumption per consumer 1,000 kWh per year (5,000 kWh/year in urban areas). The main productive uses of electricity in rural areas are for motive power and refrigeration on farms, agro-industries and village commerce. Over 20 kinds of non-domestic consumers may sometimes be found in villages, in addition to the farm and agro-industrial consumers outside them.

v. The phases of rural electrification (paragraphs 2.11 to 2.14). Most countries have some degree of rural electrification, but are in different phases of developing it, depending on the level of demand for electricity. Before public electricity supplies from the main grid are introduced into an area it is very common to find businesses and communities, in all countries, supplying their own electricity from small diesel or hydro-powered generators (autogenerators). The costs of such sources of electricity are high (typically 9 to 21 cents per kWh as compared with 3 cents in urban areas); nevertheless, such enterprises are often profitable. As the demand develops, and as load factors improve, public supplies from the grid (which are more capital, but less fuel intensive, and are very expensive for small demands) become cheaper. It is then economical to replace autogeneration in the main demand centers by extending public networks to them. Once the main demand centers are connected, the final phase of electrification can begin; many of the smaller demand centers - which may be the smaller villages or the farm and agro-industrial consumers outside them - are now close to the networks and can be connected at low marginal cost. Broadly speaking, African countries are in the early phases using autogeneration and bringing some public supplies to the larger demand centers; Asian and EMENA countries are in the midst of bringing public supplies to the main demand centers; while Latin American countries are concluding this phase and beginning the final one of marginal extensions to the smaller centers.

vi. Overall costs of public supplies (paragraphs 2.8 to 2.10; 2.22). As compared to urban areas, the costs of serving rural areas are quite high. Typically, on a good project:

	Urban	Rural
Average costs, cents/kWh	3	6 to 8 initially; 4 after 10 years
Load factors (% utilization)	50%	20% initially; 40% in later years
Average price, cents/kWh	3	4

Costs are very sensitive to the level and growth of demand, the level of utilization, the distances between demand centers, and the difficulty of terrain. Subtransmission line costs work out at $3,000 to $5,000 per km, depending on the terrain; over a wide range they do not vary with demand, so that average capital costs decline as the level of demand increases. Load factor improvements also mean that increases in kWh demand can be met with proportionately less investment in capacity; this too reduces average costs. The initial investments in public supplies may cost about $50,000 per demand center, rising to $200,000 or more for larger demands in remote areas; but marginal extensions to neighboring demand centers may cost as little as only one-tenth of such levels (again reflecting the very large economies of scale in the early phases of electrification). For villages, initial capital costs work out at about $800 per consumer, but drop to about half of this as the number of consumers and demand levels rise; this works out at $40 to $80 per inhabitant initially, dropping to $20 to $40 or less as demand rises. On an annual basis, capital costs amount to roughly two-thirds of all costs, the other third being fuel, billing, maintenance and administration.

vii. Financial returns (paragraphs 2.20 to 2.27). Experience indicates that revenues are low in the early years, even when response is good. There are high, initial fixed costs in constructing the networks and setting up a billing and administration system; and the demand and load factors have to develop from low levels. Prices are kept lower than average costs in the early years in the interests of (a) promoting efficient use of electricity and (b) social aims. Although prices are normally sufficient both to cover the costs of operation and maintenance, and to contribute usefully to investment costs, it takes several years for average costs to decline to the level of average prices charged, unless the rate of growth of demand is very high. (It should be added that the majority of the projects in most countries are less than 10 years old, and have not yet reached this stage.)

viii. The outlook (paragraphs 2.24 to 2.27). Where there is a good response to the investment, reflected in an all-round and quick growth of demand, the indication is that the investment is generating a number of useful social and economic benefits, even if financial performance is poor in the early years. One of the first problems of investment analysis in rural electrification is to investigate the nature of these benefits to determine if the investment is justified (see Part III).

ix. Oil prices and rural electrification (paragraph 2.28). The rise in oil prices has had particularly large effects on the costs of:-

- electricity from diesel powered autogenerators (increases of roughly 50 to 100% depending on use);

- kerosene for lighting;

- motive power from diesel engines used in irrigation and agro-industries (increases of 30 to 60%, depending on use).

Areas already electrified are largely insulated from these increases, as will be areas to be electrified, depending on the mix of hydro, coal and oil plant in the system. Generally the effects should be to increase the number of households and businesses using electricity (though, of course, the costs of energy will have risen for those who would otherwise have preferred substitutes). The consumer-response data provided in this report relate to periods before the oil price increases; 1972 cost and price data are also used.

III. Project Justification

x. Least-cost investments (paragraphs 3.37 to 3.41 and Part VI). As with other projects, the search for a least-cost solution is an important aspect of appraisal. Public supplies from the grid should be shown to cost less than (a) autogeneration and (b) alternative network layouts and expansion plans.

xi. Economic benefits (paragraph 3.3 to 3.13). These are all related to the uses to which electricity is put, and increase commensurately with the level and growth of use (or demand). Broadly speaking:

- for productive uses, electricity is often a cheaper or superior form of energy for motive power, refrigeration and, for some purposes, heat; this enables the producer to increase profits by cutting costs and expanding output;

- for domestic uses the economic benefits are the households' valuations of a superior quality of lighting and ironing, or of new products like fans, refrigeration and television.

The importance of village electrification as a means of encouraging people to live in villages rather than cities is also often cited as an economic benefit. Although there is evidence that village populations increase, and that people often migrate out of rural areas to villages, there is no evidence to show that electrification plays an important role in this. For example, countries with the largest rural electrification programs generally are the most urbanized. Nevertheless, the growth of village and rural economies continues to provide increasing uses of electricity in these areas.

xii. Revenues and benefit measurement (paragraphs 2.14 to 3.16). In many areas of investment the revenues, which are a minimum measure of people's monetary valuation of economic benefits, are sufficient to justify projects. This is not often true of rural electrification, though good pricing policies may raise revenues significantly. In economic justification, it is necessary to look beyond the revenues to determine what additional or "surplus" benefits consumers obtain. This can be done straightforwardly for productive uses by costing out the alternative sources of energy and power available. But for domestic uses, estimation of surplus benefits is too difficult on account of large random differences between consumers and the more complicated nature of household decision making. In practice, therefore, cost-benefit analysis of rural electrification projects has to concentrate on the monetary benefits revealed in the revenues plus the surplus benefits in productive uses. If necessary, some consideration can be given to other benefits when discussing unquantifiables during project justification.

xiii. Economic rate-of-return (IER) (paragraphs 3.17 to 3.46). The economic rate of return calculation can begin with a forecast of demand and revenues, an estimate of costs, and then make adjustments for shadow prices and surplus benefits in productive uses.

xiv. Criterion for accepting projects (paragraphs 3.47 to 3.59). Calculations of the IER concentrate only on economic factors and only on what can be quantified. The resulting estimate of the IER may be sufficient to justify the project. This is particularly true if a strong demand develops from:

- a number of villages, not too widely scattered;

- farms, agro-industries and rural commerce;

and if attention is paid to keeping costs down and to pricing policy. This occurs if projects are properly identified and prepared, and relate to the development priorities of the areas they are to serve (as discussed in IV). Also, a rural development program may stimulate the demand and thus raise the IER by providing, for example, additional uses of electricity on farms and agro-industries. Often, however, the IER may not be sufficient to justify the project, and it is then necessary to examine social aims and unquantifiables: this may or may not lead to a recommendation of accepting a project with an IER lower than the opportunity cost of capital. If the IER is somewhat lower than but close to the cost of capital, the following factors might argue for justification: economic benefits that could not be quantified; special concessions for low-income households and small businesses; and an allowance for the social consequences of urban-rural imbalance. But a low IER may also signal that demand is still insufficient for the project, poor pricing policies, wrong priorities or simply that the least-cost project has not been chosen. A judgement will thus be required in such cases on what is an acceptable IER; it will depend *inter alia* on the strength of the social arguments and the importance of the unquantified economic benefits.

In general, however, it can be said that the allowances for social arguments and unquantifiables are likely to be smaller than for alternative investments: (a) electricity is not a basic necessity, and water and health projects, for example, deserve a greater social weight; (b) alternative sources of light and energy, though generally inferior, are available even in the poorest regions; and (c) water, education, health and transport projects, for example, arguably have larger unquantifiable benefits.

xv. Pricing policy (paragraphs 3.60 to 3.68; 4.23). This requires compromises between economic, social and financial aims. Economic aims require a forward-looking view with prices related to the marginal costs of expanding investment and output, ignoring the large initial sunk costs; the need to encourage people to use electricity also requires a forward-looking view, with a promotional element in tariffs in the early years; and social aims require provisions for small consumers. On the other hand, to provide the resources for an expanding program, and to limit pressures on the public revenue, financial analysis may suggest higher prices for the larger and better off consumers, and above the prices suggested by economic analysis of marginal costs. In practical terms, these various considerations should result in:

- prices that are higher in rural than in urban areas;
- prices below average costs in the early years on account of the high initial fixed costs, and also of the need to encourage people to use the service;
- low prices only for small consumers;
- generally, prices which substantially exceed operation and maintenance costs; and
- recovery of investment costs in later years, to an extent depending on the financial goals (see paragraph xx).

In practice many of these requirements are not being met. Low prices, for example, are often charged for large consumers who are able to pay more; while cost recovery is often undermined by prices which decline unduly with the volume of consumption. Hence thorough attention to pricing policy is an essential part of project preparation and justification.

IV. Project Identification and Preparation

xvi. Project definition (paragraphs 4.3 to 4.8). The size of the project needs to be defined in terms of electrifying the main demand nodes of a region as a whole. This is because (a) administration, billing and maintenance responsibilities need to be planned on a regional basis; (b) many network components serve not one, but several demand nodes; (c) the region, rather than, say, the village, is a more appropriate unit for economic analysis and (d) there are too many villages and other demand nodes to be analyzed comprehensively on an individual basis.

xvii. Identification (paragraphs 4.9 to 4.12). Projects selected need to yield satisfactory economic returns according to the criteria discussed above. This occurs where the level and expected growth of the uses to which electricity is put are reasonably high. This depends in turn on the quality of complementary infrastructure; growing productive uses on farms, agro-industries and village commerce; the presence of some large villages or of several villages not too widely scattered; and on the level and growth of wages and living standards.

xviii. Electrification plan (paragraphs 4.9 to 4.12). This begins with a strategy of electrifying the larger demand centers, followed by marginal extensions to smaller centers or consumers close to the networks. Several plans need to be considered which examine various rates of network expansion, alternative policies regarding which demand centers to connect, and alternative network designs (so as to determine a least-cost policy). In new areas, the plan needs to begin with a pilot project.

xix. Rural development and rural electrification plans (paragraphs 4.18 and 4.19). The effect of rural development plans, insofar as they succeed in raising productivity and incomes in a region and improving rural infrastructure, generally increase the expected economic returns to rural electrification because they increase the uses to which electricity is put. A high IER to the rural electrification element also signals that it forms a very useful and productive part of the rural development plan.

V. Means of Finance

xx. Financial goals (paragraphs 5.1 and 5.2). The financial characteristics of new or expanding programs are such that the initial investment should be financed by some combination of debt, grants, equity or internal funds of the utility which results in a relatively "soft" blend for the capital structure of the program. The reasons for this are: (a) the long gestation period before demand and revenues build up to reasonable levels, and (b) the various economic, promotional and social constraints acting on pricing policy. Often, these factors are made more difficult, and the financial returns worse than they need to be, by ill-structured prices. But even with suitable reforms to pricing policy, funding on soft terms, and especially with long grace periods, is necessary. In practice, the kind of financial goals that might be achieved would evolve with the level and growth of demand:

- initially (say, during the first 3 or 4 years) revenues could generally be expected to cover operating and maintenance costs quite comfortably;

- in the next phase (say, up to 10 years) revenues could additionally be expected to service debt (assuming the soft blend as suggested above);

- in subsequent years, revenues may generally be sufficient to make an increasing contribution towards the costs of expansion (sufficient in magnitude, on some projects, to meet a good proportion of the capital required, and to give a good internal financial rate of return to the project).

But such achievements, as noted earlier, would depend on the level and growth of demand; reforms to pricing policy; well-prepared and well-run projects; and also on a systematic follow-up on projects to insure that financial targets are raised as soon as circumstances warrant. As a matter of principle, then, it should not be assumed that costs cannot be recovered over the life of the investment; but whether or not they are will be determined by the pricing policies of the agencies involved. The appropriate targets need to be reviewed in each case, bearing in mind: (a) the financial needs of the program (b) the effect of the program on the utility's overall financial performance, (c) the fiscal strength of the country, and (d) the economic and social objectives of the program.

xxi. Sources of finance (paragraphs 5.3 to 5.16). In most cases, a portion of the capital requirements will have to be provided by the government or the central electricity utility. The profits of the utility can be a substantial source, and using them has the added advantages of giving the utility some autonomy in expanding and running the program, and reducing the strain on the public revenue - which might be better used on projects such as water, education and health where funding problems are more severe. Also, there may be some scope for using general price increases on electricity to raise the funds for rural electrification, while tax increases may be unacceptable. On the other hand, government funding can be used to help the more backward regions, as a lever on the less innovative utilities (if there are several in the country), and to promote standardization and regional cooperation. The choice between using government funds or a public utility's profits (which are equivalent from an economic viewpoint) will depend on these institutional factors, the fiscal strength of the country and on the political acceptability of one arrangement or the other.

VI. Technical Problems

xxii. Public supplies from the grid consist of high voltage substations with transformers and medium voltage outlets; medium voltage subtransmission to the main demand centers in the rural areas; transformation to low voltages in the main demand centers; and local distribution at low voltages for service. Although this technology is standard, there is plenty of scope for cutting costs through examination of various design alternatives and expansion plans. The reasons are that, as noted in paragraphs (v) and (vi), costs vary enormously with the density and location of demand, economies of scale are strong and there is a wide range of technical options. Among the most important options to examine are:

(a) Autogeneration and public supplies. Relative costs, and thus the choice, are very sensitive to demand, location, terrain and utilization, as remarked in (v) and (vi). Autogeneration costs may range from 9 to 20 cents per kWh or more (1972 oil prices, depending on load factor. The costs of public supplies for the same load are lower at 4 to 18 cents for villages close together, but may be two or three times these levels for widely scattered villages. (See Table 2.5, for example.)

(b) Standardization of equipment, construction and contract procedures;

(c) Lowered design standards; lowered quality of supply;

(d) Alternative network layouts, expansion plans and equipment designs.

Some countries have reported substantial cost reductions by thorough attention to these options.

VII. Institutional Problems

xxiii. The establishment of good institutions is of course central to the success of the program. Experience in many countries underlines both the importance and difficulties of training personnel, of promoting the service, and of building up administrative units capable of taking on many of the responsibilities of running the program in rural areas. Failures in local administration in particular - for example in billing or in reporting on and dealing with breakdowns in service - may discredit programs in rural areas, and is a problem experienced by many countries. Local administrative units generally need strong support and assistance from the main electric utilities, particularly for training and for financial and technical assistance. But the extent of the support is partly a matter of policy. Countries have adopted (or are experimenting with) differing levels of delegated responsibility, with local administration placing:

- heavy reliance on the utility, and being responsible only for local billing and reporting on consumer complaints or requests for service: or

- medium reliance on the utility, and taking on additional responsibilities such as promoting service, identifying new areas to be served, and working out schemes with local people to extend service to them; or

- low reliance on the utility (as with the cooperative arrangement), and taking on many more of the financial, technical and administrative responsibilities.

Which of these arrangements is appropriate depends on the country, the available skills, the size and population of its rural areas, and the local culture. While, for example, cooperatives are reported to be working well in some countries, they are not suited to others. Also, different types of organization may work equally well; so in practice it is necessary to be flexible about their form.

VIII. Implications for the Bank

xxiv. The case for Bank assistance (paragraphs 8.1 to 8.10). This rests on three points: (1) The need expressed by developing countries for financial and technical assistance in this field. (2) The Bank's long experience with institution building and operations in the electric power sector. The programs to electrify rural areas are, in an important number of countries, being undertaken by institutions with which the Bank has had highly successful associations for many years. Rural electrification, which has so far formed a small but increasing fraction of their past investments, is a new dimension with new challenges and is likely to form an increasing portion of future programs. In many countries, there is a strong commitment to rural electrification and a desire to make it successful. (3) The good prospects for projects which are related to rural development priorities and can be justified. This last point rests, to repeat, on proper care and attention in project selection and preparation, and matching the project design to local needs.

xxv. The pattern of lending operations (paragraphs 8.9 and 8.10). Projects can be part of (a) rural development projects, or (b) projects for the electric power sector. Both have advantages and are worth pursuing:

(a) Rural development projects appeal because they promote coordination between sectors and generate large external economies. On the cost side, for example, improved roads reduce the costs of construction, maintenance and administration of the electrification program. On the benefit side, there are several inter-relationships: Rural development programs raise the level of output in agriculture and agro-industries, and through this the level of rural incomes. On account of increased incomes and improved infrastructure, commercial activity increases. Together, the growth of incomes and the growth of agriculture, agro-industries and commerce, create increasing demands for power and energy. These demands can be met by public supplies from the grid, local autogeneration or substitute sources of power and energy; which of these alternatives is best will be revealed by cost-benefit calculations.

(b) Electric power sector operations appeal because of the many financial, technical and administrative responsibilities delegated to the electric power sector, as is apparent from Section VII. Also, the sector still needs loans to finance its investments in generation and transmission capacity and in urban distribution networks.

In some countries, as in India and Iran, for example, rural electrification projects may be large enough to justify an operation specifically for this purpose. But in most countries this would not be the case. (See also the discussion on the lending program in (xxviii) below.)

xxvi. <u>Lending conditions</u> (paragraphs 8.11 to 8.15). Most loans would have to be made through the government (if it is a rural development loan) or the utility (if it is a power loan). The reasons for this are that local rural electrification agencies generally require a lot of financial support from the government or the utility so as to establish, expand and run the electrification programs. Even when local agencies are financially and technically strong, there is still a case for channelling aid through the government or the utility in order to promote regional and sectoral balance in the programs and cooperation between regions. Bank or IDA terms would of course apply according to the country; Bank terms might have to be passed on in part as equity, or blended with cheaper money, since the rural project could probably not generate funds to service a conventional Bank loan (though the utility often can). Local cost financing would be required since much of the materials and equipment would be provided domestically. Most loans would also have to make provisions for technical assistance.

xxvii. <u>Which countries?</u> (paragraphs 8.17 to 8.21; also see 2.11 to 2.14). There is scope for some degree of rural electrification in most countries though of course the type and extent of electrification depends on the level of development. As explained in paragraph (v), countries are in varying phases of the rural electrification process. Also, even when areas are already electrified, there is always a continual need for further investment to extend and reinforce networks within these areas (as in cities) to meet growing demands. Our estimates are that the following proportions of the village/rural populations may be served in 10 years time:

Africa and some Arab countries	-	less than one tenth
Asia and some EMENA countries	-	about one quarter
Latin American countries	-	about one third

Which countries would receive assistance would depend on the country's overall rural development effort, the claims for Bank help, and willingness to accept Bank conditions and procedures.

xxviii. <u>The revised lending program FY74-78</u> (paragraphs 8.22 and 8.23). (a) Power loans. Roughly $250 million of the revised lending program for electric power ($3,100 million, in 1974 prices, for 90 loans) is allocated to rural electrification. Nearly half of this, however, is absorbed by three projects, two in India ($40 million each in FY75 and 76) and one in Iran (about $20 million in FY75, but tentative). These are specifically for rural electrification. The remaining proposals, which are relatively small, are components of larger loans to the power sector in 10 other countries (Thailand, Nepal and Pakistan, Panama, Honduras, Mexico, Bolivia and Brazil; Liberia, Tunisia). These lending programs were drawn up without any particular focus on rural electrification needs in the member countries, nor did the Bank have suitably developed operational procedures and guidelines for lending for rural electrification. Following the approach outlined in this paper, identification and preparation might be expanded upon during FYs 75 and 76, leading to an increased rural electrification element in the second half of the program.

(b) Rural development loans. Roughly 50% of the loans for Agriculture in FYs 74 and 75 might be classified as rural development loans. The rural electrification element in the projects financed by these loans varies considerably between countries. Rough indications are that rural electrification may average about 10% of the project costs in Latin American countries, about 5 to 10% in Asia and EMENA and very little in Africa. In all, between $150 and $300 million of the projected $6,500 million for Agriculture and Rural Development loans might be associated with rural electrification, under present projections. Again, however, with intensification of initiatives to identify and prepare projects for rural development and rural electrification, these figures might be revised upwards during the second half of the revised lending program.

xxix. Operational procedures (paragraphs 8.24 to 8.31). Most of these would be unchanged, except in degree, in that more work would be required in identification, preparation and appraisal, and uncertainties would be greater. Apart from this, sector survey work (of the electric power or the rural sectors), identification, preparation and appraisal would require only a widening of scope. The proposal is to begin work in rural electrification with thorough surveys, identification and preparation - the ultimate success of operations rests on this.

xxx. Monitoring, evaluation, research (paragraphs 8.32 to 8.34). Because of the uncertainties and the widespread lack of information about rural electrification (and, indeed, about rural development) it would be desirable (a) to begin with pilot projects in areas without service, but where there are good grounds for introducing it, and (b) to incorporate monitoring and evaluation techniques into both regular and pilot projects. This should provide information for planning further expansion and also a basis for improvements in subsequent operations. Problems requiring separate research include: (i) the scope for cutting costs; (ii) the factors affecting consumer response; and (iii) the linkages between economic growth in rural areas and the demands stemming from farms, agro-industries and rural commerce.

xxxi. Requirements of Bank staff (paragraphs 8.35 to 8.37). The new institutional and technological dimensions of the work would of course impose further demands on staff. While many of the new skills can be acquired with experience, consideration should be given to recruitment of people with experience in the field, short training courses, and further cooperation (perhaps sharing resources) between Regional Projects Departments.

I. INTRODUCTION

1.1 The possibilities for Bank financing of village electrification projects were first outlined in the Sector Working Paper on Electric Power. Since then, a number of initiatives have been taken to improve our knowledge in this field. Inquiries were made to over 20 countries regarding the extent of their programs and future plans; a major research study has been undertaken in El Salvador, and is nearing completion; there have been brief field trips by staff members to three other Central American countries, and also to India, specifically to look at village electrification programs; pilot village electrification projects were financed in Ecuador on the condition that the socio-economic impact of these projects was monitored over time, and finally, connections have been established between the Bank and other institutions undertaking research in Turkey, Tunisia, Costa Rica, Colombia and the Philippines.

1.2 A number of countries have also formally approached the Bank for development assistance in this field, including Iran, Oman, India and Thailand.

1.3 The time now seems appropriate to report on our findings to date on rural electrification. A number of diverse questions have been raised since previous reports (listed in Annex 1) were issued. For example: What is the extent of rural electrification in developing countries? and what are the prospects for successful investment? Is the economic-rate-of-return calculation a suitable basis for project appraisal in low income areas? and if so, how do we estimate economic costs and benefits? How do we identify good projects? Which institutional and financial arrangements work best? What are the technical problems? Finally, what should the Bank do?

1.4 This report is written in response to such questions. It begins with an introductory discussion on:-

II. Rural electrification in developing countries
- the extent, costs and uses of rural electrification, the aims, and the outlook for investment,

then presents our current thinking on approaches towards investment, as regards:-

III. Economic justification procedures;

IV. Project identification;

V. Means of finance

VI. Technical problems;

VII. Institutional problems;

and concludes with a discussion of:-

VIII. Implications for Bank Policy and Procedures.

1.5 We now stand at the end of elementary inquiries to various countries and institutions, and at the end of limited field experience in India, Ecuador and Central America (including the research study in El Salvador, which is now being written up). Our evaluation of this material, which forms the basis of the present report, shows good grounds for the belief that useful and productive investments can be made; and we have proposed methods of undertaking them. So we also stand, if these proposals are accepted, at the beginning of project identification and appraisal work backed up by further research and evaluation.

II. RURAL ELECTRIFICATION IN DEVELOPING COUNTRIES

2.1 Rural electrification in developing countries is intended to serve both economic and social aims. To understand these aims and how they might best be achieved, it is first useful to know something about the extent and growth of village electrification in developing countries, the costs and the uses to which electricity is put; these matters are first discussed below.

Extent and Growth of Rural Electrification

2.2 Countries are putting increasing resources into rural electrification. As one might expect, the resources countries allocate to it increase with their per capita incomes, with the result that rural electrification is more extensive in Latin America than in Asia, and more extensive in Asia than in Africa:-

Table 2.1

	Population in 1971 /1 millions			Village/Rural Population /2 /3 Served 1971	
Region	Total	Village/2	Rural /2	Millions	%
Latin America	282	140	(50%)	32	23%
Selected EMENA Countries /4	143	87	(61%)	45	15%
Asia	934	700	(75%)	105	15%
Africa	182	165	(90%)	7	4%
	1789	1300	73%	187	14%

Source: Electrification data are compiled from miscellaneous documents and correspondence with the countries and are not official statistics. Population data are from UN documents.

/1 Population figures refer to the whole region, except EMENA (see 4).
/2 The definitions of "village" and "rural" vary between countries. Generally, villages are conglomerations of 5,000 to 10,000 people or less; rural refers to low density populations outside the villages, often living in clusters close to large farms.
/3 Electrification data not available for each country and the percentages should be taken as typical levels for countries in the region, about which there may be considerable variance.
/4 Cyprus, Egypt, Iran, Saudi Arabia, Tunisia, Algeria, Morocco, Turkey.

2.3 Total cumulative investment in rural electrification by developing countries within the Bank's area of operations was about $10 billion by 1971, or about 10% of total investment in the electric power sector. This figure includes generation, transmission and distribution which in the early stages of a project breakdown roughly as follows:

Investment in Generation and Transmission Capacity	30%
Investment in Sub-Transmission and Distribution Networks	70%

(Costs are discussed in more detail in paragraphs 2.6 et. seq.).

2.4 Future investment is likely to be much larger than in the past. We have formally questioned over 20 countries about their planned programs and have received information on several others. According to this information the rate of investment is generally likely to be higher than in the past and to form an increasing proportion of total investment. Some countries, including Iran, Egypt, Turkey and Thailand have announced major new initiatives, while others, in particular India and most of Latin America, are to continue and often expand on theirs.

2.5 The information is not good enough for a precise forecast of the level of investment, nor of the population likely to be affected. But it does seem that total new investment is likely to exceed $10-$15 billion in the next ten years (which is over 10% of total new investment), bringing supplies within the reach of 300 million more people; up to about half of these people, comprising 15% of the village/rural population, may be able to afford service. Thus a total of, say, one quarter of the village/rural population would be served in ten years time (as compared to about three quarters at the present time in urban areas).

Technology and Costs

2.6 Electricity is introduced into rural areas in three ways, through:

(1) Autogenerators serving single consumers;
(2) Autogenerators serving several consumers on a local network;
(3) Public supplies from the main grid system.

The term autogeneration refers to isolated generators powered by diesel engines, small steam turbines, or micro-hydro turbines. They range in size from about 5 kW, sufficient to meet minor needs of, for example, refrigeration and lighting on a farm, to over 1500 kW, sufficient to meet the motive power needs of a large sugar processing plant. Public supplies from the main grid consist of medium voltage (about 40 KV) subtransmission links to transmit electricity from the grid to the larger demand centers of an area, plus low voltage distribution within the demand centers.

2.7 Investment in rural electrification is mostly in public supplies from the main grid; at a guess, over 80% of rural electrification is supplied in this way. For small loads in remote localities, however, utilities often find that it is cheaper to meet electricity needs by installing small autogenerators. In the absence of public supplies, shops, farms and agro-industries will often install their own autogenerators to meet their own particular needs in lighting, refrigeration, heating and motive power; often, they also supply a few local consumers and provide public lighting if such demands occur when their equipment would otherwise be unused. Autogeneration, serving single or several consumers, is very common in rural areas.

2.8 Evidently, the utility must often make a decision whether to provide electricity from the grid or from local autogenerators. This decision depends on a number of factors, including the expected level and growth of demand, the expected utilization of the investment, the distance from the main network and the difficulty of terrain (which can affect costs enormously). The following table displays some typical cost data at two levels of demand:

Table 2.2

Typical Costs of Public Supplies and Autogeneration (1972 data)

		Autogeneration		Supply from Grid /1	
Capacity of Project	kW	50	25	50	25
Consumers Served		140	70	140	70
Capital Costs	$	34,000	25,000	56,000	38,000
Fuel, Operation and Maintenance	¢/kWh	6	6	0.5	0.5
Billing, Admin. etc.	$/year	2,000	1,000	2,000	1,000

Source: See Annex 2.

/1 Average length of subtransmission line per village = 4 km in this case. Note the economies of scale in capital costs. The 50 kW and 25 kW projects could serve fully developed loads in villages of about 2,000 and 1,000 people respectively. Demands from farms and agro-industries outside the village may add anything from 20 kW to 1000 kW or more to total capacity demands. Capital costs, it can be seen, range from $400 to $550 per consumer in the above case of supplies from the grid (or $40 to $55 per capita in the village served). However, for large villages of five to ten thousand people, these costs may drop to $200 per consumer ($20 per capita) or less.

2.9 The capital costs of supplies from the grid are much higher than those of autogeneration, but the fuel, operation and maintenance costs are much less. When the utilization of the project is high, this strongly favors the more-capital, less-fuel intensive investment in supplies from the grid. Taking the 50 kW projects, the relative annual costs of the two projects at various levels of utilization are:

Table 2.3 /1

	Autogeneration			Supplies from Grid		
Load Factor	10%	25%	50%	10%	25%	50%
Annual Capital Costs	$4,500	4,500	4,500	5,600	5,600	5,000
Fuel, O & M.	$2,600	6,600	13,200	200	500	1,000
Billing & Admin.	$2,000	2,000	2,000	2,000	2,000	2,000
Total	$9,100	13,100	19,700	7,800	8,100	8,600
Average, ¢/KWh	21	12	9	18	7	4

/1 See Annex 2 for calculations.

2.10 The fuel bill heavily penalizes autogeneration. In general, it compares well with public supplies from the grid only at low levels of utilization - except when the demands are remote. This last point is important, since to extend a subtransmission link by 25 km to an isolated demand may cost around $100,000 ($10,000 per year at 10% annuity), with the following kinds of effect on the capital costs of public supplies:

Table 2.4

Capacity of Scheme	50 kW	50 kW
Distance from Grid,	4 km*	29 km
Generation and Transmission Costs, $	24,000	24,000
Subtransmission Costs, $	18,000	118,000
Local Distribution, $	14,000	14,000
Total, $	56,000	156,000
Annual Capital Costs, $	5,600	15,600

Source: See Annex 2. *The 4 km case corresponds to the data in Tables 2.2 and 2.3.

Such cost increases are sufficient to make autogeneration the better alternative for all but high load factor demands. To see this it is useful to consider the effect of distance on the cost comparisons previously presented in Table 2.3.

Table 2.5

Average Costs of Different Schemes (cents/KWh)

	Supplies From Grid		
Load Factor	4 km	29 km	Autogeneration
10%	18	40	21
25%	7	17	12
50%	4	8	9

(Note that average costs in urban areas are about 3 cents per KWh). Obviously, 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, so that if a good demand develops from farms, agro-industries and several villages, average costs decline very quickly to about 4 to 8 cents per kWh.

2.11 It is now possible to explain how electrification schemes evolve in rural areas. It is a fascinating process which has three or four phases. In the initial phase, only a few scattered, isolated businesses may need and can afford electricity. They obtain it by installing their own generators and it is common to find them used for such purposes as refrigerating milk on farms, providing light and heat to egg and chicken farms, for refrigeration and light in shops, for refrigeration on a large scale in slaughter-houses, or for the motive power needs of large agro-industries such as sugar processing. During this phase, the motive power needs of small farms and businesses are generally met directly by animals or by small diesel engines. In the second phase, a small collective demand for electricity may develop from several households and businesses to meet needs like public lighting, private lighting, and further demands from large and small businesses and farms. During this phase, small local networks ("micro-grids") are often extended from local autogenerators installed through public or private initiative. If the collective demand becomes large enough, and offers good utilization of equipment, the second phase may be by-passed or lead to the third phase - fully-fledged electrification from the grid system. The "micro-grids" are taken over and extended; subtransmission links replace the old auto-generators, which are scrapped or used elsewhere; and small and large businesses begin to turn to electricity as a source of motive power in preference to animals or diesel engines (often creating a useful second-hand market in the latter), and may even introduce some new processes as a result.

2.12 During this third phase, a number of major demand centers can be identified in a region, stemming from the larger villages and the farms and agro-industries which lie outside them. A network design plan has to be worked out, to route the network so as to economize on the heavy costs of subtransmission and distribution lines. Once the networks have been established, a fourth and final phase follows quite obviously. Centers of low demand are now close to the networks and can be connected up at very low marginal cost. Whereas the initial thrust into a region may cost $50,000 to $200,000 per demand center, secondary thrusts into areas of low demand may now cost only $5,000 to $20,000. (Many areas of low demand remain remote from the main networks, and for this reason it is never worth electrifying them from the main grid; even in N. America and Europe, where rural electrification programs were substantially completed 20 years ago, many areas continue to be served by local autogenerators.)

2.13 Practically every country has some degree of rural electrification, but different countries are in different phases. Broadly speaking, African countries are largely in the first phase of private generation, but are gradually beginning the second and third phases of meeting the larger collective demands from the grid or local autogenerators. Asian and EMENA countries are mostly in the midst of the third phase, of connecting the main demand centers to the grid. Most Latin American countries are in the fourth and final phase, of connecting low demand centers to networks already established in rural areas.

2.14 As remarked earlier, the term rural electrification is normally associated with electrification from the grid system, that is, with the third and fourth phases of electrification. The relative magnitudes of these phases may be gauged from Table 2.1 and also from the following statistics for Mexico, which show that over 50% of the rural population live in areas of low demand:

Table 2.6

Population Distribution of Villages in Mexico

Population of Village	No. of Villages	Population No.	Population %	Remarks
Less than 100	55,376	1,823,900	7%)	Low Demand Areas, 25% Electrified
100 - 499	28,494	6,944,500	26%)	
500 - 999	7,346	5,091,900	19%)	
1000 - 4999	5,207	9,681,800	37%)	Medium-to-High Demand Areas, 80% Electrified
5000 - 9999	416	2,894,300	11%)	
	96,839	26,436,400	100%	

Source: Supplied by Comision Federal de Electricidad.

Similar distributions in the size of village, and in the areas of high and low demand, can be observed in most countries. (In the Cameroons, much emphasis is placed on forming larger-sized villages before providing electricity and other infrastructure.)

Uses of Electricity

2.15 There is a surprisingly wide range of uses of electricity in rural areas, for both household and productive needs. Generally speaking, the total demand stemming from productive needs is higher than that stemming from households, as can be seen from the following table:

Table 2.7

Percentage Distribution of Electricity Demand in Urban and Rural Areas for Various Countries (1971 data)

	Rural Areas					Urban	
	Productive Demands				Domestic	Productive	Domestic
	Farms	Agro-Industry	Commercial-Community	Total	Total	Total	Total
Ethiopia	-	-	-	55%	45%	44%	56%
Tanzania	-	-	-	75%	25%	80%	20%
Chile	9	26	32	67%	33%	n.a.	n.a.
Costa Rica	-	-	-	70%	30%	43%	57%
Nicaragua	15	.....45.......		60%	40%	30%	70%
El Salvador	-	-	-	45%	55%	60%	40%
India	59	.....21.......		80%	20%	89%	11%
Pakistan	23	.....17.......		40%	60%	90%	10%
Taiwan	10	.....16.......		26%	74%	80%	20%

Sources: Rural data: Correspondence and miscellaneous documents provided by the countries.
Urban data: From similar sources and Bank Appraisal Reports.

These data, which refer to typical situations, understate the productive uses since many small business demands creep in under domestic and general tariffs.

2.16 The relative demands from households and producers change markedly from one area to another. Often, the demand in an area may be dominated by one large consumer, as with irrigation or cotton processing; and though some areas may use electricity for a wide range of productive purposes, others may use it for little more than domestic and public lighting.

2.17 In addition to the various agro-industrial demands which develop from the local agriculture, it is not uncommon to find demands developing from 20 or more commercial activities in a single village, such as for light and refrigeration in shops and services, and for light, heat and motive power in workshops (carpentry, welding and repairshops, for example). Community demands may include public lighting and demands from the local church, a water pump, a police station, school and health centers. Growth in local agriculture and wages, and improvements in complementary infrastructure, can thus generate all kinds of uses for electricity.

2.18 Consumption levels in rural areas are of course much less than in urban areas. But again it is surprising that there is often a strong response to rural electrification from consumers, reflected in high, sustained rates of growth of demand once an area is electrified:

Table 2.8

Level and Growth of Consumer Demand
in Urban and Rural Areas. Estimates for Various Countries (1971) /1

	Demand per Consumer, kWh/year /2		Yearly Rate of Growth of Demand	
	Rural	Urban	Rural	Urban
India	1000	n.a.	15%	10%
Thailand	200	4000	12 - 20%	22%
Ethiopia	800	2000	40%	15%
Costa Rica	1900	6000	20%	10%
El Salvador	1000	4000	20%	10%

Sources: Rural data are estimates based on various documents and project reports provided by the countries. Urban data inferred from Sector Working Paper on Electric Power and Bank Appraisal Reports.

/1 Data purely illustrative, not average, for the country.
/2 Rural data for selected areas; Urban data for capital cities, except for Thailand, which is an average.

Demand per consumer varies between areas largely on account of variations in the type of productive uses, and also with the age of the project on account of the growth of demand per consumer. Irrigation pumpsets, for example, consume about 3000 kWh per year in India, while a large agro-industry may consume 100,000 kWh per year or more.

2.19 To sum up, there is often a surprisingly strong response to rural electrification projects. This is reflected in high rates of growth of demand, though they start from very low initial levels. This response stems from a wide range of uses of electricity.

The Aims of Rural Electrification, and the Conflicts Presented by Low Financial Returns

2.20 Having discussed the demand side and the supply side, it is now useful to put the two together and discuss the net returns - social, economic and financial - that are expected from the investments.

2.21 Most countries stress the social importance of their rural electrification programs, in particular the need to raise the standard of living in rural areas and to provide a counterweight to excessive urbanization. But many of the returns, as illustrated above, are of economic importance since they stem from the voluntary demands of communities, houses and businesses for a cheaper or superior form of energy. Indeed, many countries state that unless the programs are set in an economic context, the results are disappointing. For this reason, they stress the importance of both economic and social aims.

2.22 Where the economic content of rural electrification programs is large, it may seem reasonable to expect satisfactory financial returns - electricity increases energy use in the area, often reduces energy costs, and is far superior in quality to the alternatives. But there are three reasons why this is not the case, at least for a period of years:

a) the high initial investment costs associated with low density populations, often remote from the main networks;

b) low initial demand levels in relation to the capacity of the networks (which have large indivisibilities); it may take over 10 years for demand to develop fully in relation to capacity;

c) the arguments for keeping tariffs low in relation to costs to meet the social aims of cheap energy to low income households and small businesses.

The following figures illustrate these points:

Table 2.9

Comparative Data for Urban and Rural Areas

	Urban	Rural
Consumption: kWh/consumer/year	4,000	600*
Load Factor	50%	20%*
Investment in subtransmission and distribution per consumer (approx.)	$100	$300
Average costs, cents/kWh (approx.)	2.5	6 to 8*
Average price, cents/kWh (approx.)	2.8	4
Mean per capita incomes	$800	$125

Source: El Salvador Study.

* Figures refer to typical initial conditions.

The initial average costs are over two or three times those of urban areas, and though average prices are nearly 50% higher, this is not of course sufficient to make up the deficit. As both load factors and the level of demand rise, average costs decline very quickly; but the possible financial gains from this are often undermined by the system of declining block tariffs widely adopted in many countries throughout the world.

2.23 Financial assistance is generally considered to be necessary, therefore, at least in the early years. The assistance takes several forms, including low interest capital from internal or international sources, special depreciation provisions, preferential tariffs and contributions in kind from the rural areas, such as unpaid labor. (It is also interesting to note that when it was desired to promote rural electrification in the USA in the 1930's, it was considered necessary to finance it on concessionary terms in accordance with the Rural Electrification Act of 1936.)

The Outlook

2.24 So long as the investment programs are expanding, the fact is that continued financial assistance is required. Accepting this, however, three other facts are becoming clear:

a) In many electrified areas in all parts of the world the financial returns are improving markedly over time, though from very low initial levels. One reason is that there are substantial economies of scale as demand and consumer density increase.

b) Although existing projects are in the 'best' areas, extensions to 'worse' areas in the same region need not undermine overall financial or economic performance; the 'best' areas have absorbed the brunt of the high initial costs and, as explained earlier, subsequent extensions cost much less.

c) Financial performance can often be improved significantly by appropriate attention to pricing policy. Low prices often exist in places where they are unnecessary on account of ill-structured tariffs - the consumption of large farms and agro-industries is often subsidized, for example, even though they are able and willing to pay more for the service.

2.25 Taking a long perspective, therefore, and a constructive attitude towards tariff policy, it seems there are prospects both for continued expansion and improved financial performance.

2.26 Nevertheless, the prospects of low financial returns in the initial years, and the arguments for subsidizing small businesses and low income households, remove a simple criterion for project selection based on financial profitability. A broader basis for project selection is called for and is being sought by many countries and institutions.

2.27 Hence there are serious difficulties with project justification and identification, as there are, of course, serious difficulties with finance, institutional development and technical choice. None of these seem insurmountable however, as will be apparent from the following analysis of them.

Supplementary Note on the Effects of Oil Price Increases

2.28 The recent rise in oil prices has had particularly large effects on the costs of:-

- electricity from diesel powered autogenerators (increases of roughly 50 to 100% depending on use);

- kerosene lighting;

- motive power from diesel engines used in irrigation and agro-industries (increases of 30 to 60%, depending on use).

Areas already electrified are largely insulated from these increases, as will be areas to be electrified, depending on the mix of hydro, coal and oil plant in the system. Generally the effects should be to increase the number of households and businesses using electricity (though, of course, the costs of energy will have risen for those who would otherwise have preferred substitutes). The consumer-response data provided in this report relate to periods before the oil price increases; 1972 cost and price data are also used.

III. PROJECT JUSTIFICATION PROCEDURES

3.1 In the social and economic justification of rural electrification projects, it is useful to begin with a study of economic returns and then work social factors into the analysis. Confusion between social and economic aims is then avoided and trade-offs (to the extent that they occur) can be examined. This approach is followed below. The starting point is a discussion to clarify:

a) The nature of the (economic) benefits.

This is followed by a discussion of:

b) Practical aspects of benefit measurement;

c) forecasting demand and benefits;

d) cost analysis; and

e) cost-benefit (economic rate-of-return) calculations.

This covers the economic side. It will be seen that it is a traditional analysis of forecasting benefits and comparing them with the costs of the (least-cost) project in an economic rate-of-return calculation. The social side is then brought into the picture in the discussion of:

f) Criteria for project acceptability.

Finally, if the social and economic aims are to be met in practice, it is necessary to attend to the following, which are also discussed:

g) Pricing policy;

h) provisions for low income families and small businesses.

3.2 There are two main purposes, it should be noted, of the economic analysis of costs and benefits. One is the usual one of providing a consistent guideline for an efficient allocation of investments between the various sectors in urban and rural areas, and some indication, therefore, of economic priorities. The other is to provide some measure of the economic costs of investments when social aims are strong, economic returns low and conflicts arise. (Conflicts do not always arise, however, and some investments are socially <u>and</u> economically desirable.) Economic rate-of-return calculations can be very helpful for these purposes, and are adopted here. They only break down when social arguments are overwhelmingly strong -- as with water supply projects in drought areas. But this, in our experience, is <u>not</u> the case for rural electrification.

(a) The Nature of the Economic Benefits

3.3 There is a very close relationship between the level of use of electricity and the level of benefits derived from it, in the sense that when use is low, only a few people may be benefiting marginally from the service, and conversely when use is high. The benefits most frequently quoted, and which are all related to use, are that electricity:

(i) increases productivity and output in rural areas through reducing the costs of energy and thus increasing the profitability and output of farms, agro-industries and commerce;

(ii) adds to the standard of living in village homes and communities;

and, on account of (i) and (ii):

(iii) helps stem migration from rural areas to cities -- the problem of urban-rural balance.

(The third is related to use because to the extent that people and businesses are attracted to rural areas by electricity, they will use it.)

3.4 There is, in fact, little hard evidence as to the effect of electricity on migration. Our investigations have revealed, as one might expect, that older people migrate mainly in search of jobs, while the younger ones migrate in search of jobs and education or to begin families. Also, the countries with the largest rural electrification programs generally are the most urbanized (see Table 2.1 for example).

3.5 Nevertheless, despite migration to cities, and whatever its causes, the economic output of farms, agro-industries and rural commerce is increasing, large numbers of villages are increasing in population and are in a process of modernization. The result is that the demands for electricity, and the range of uses to which it is put, are also increasing. Hence there are positive benefits to look for, even if electricity by itself has little or no effect on stemming migration to cities.

3.6 In monetary terms, and ignoring complications about shadow prices and income distribution for the moment, the benefits of electricity to families and businesses are to be measured by the amount of the family or business income they are prepared to allocate to it. This is the monetary value placed by individuals on the service. Small businesses and low income families, in particular, make this allocation decision very carefully. The decision is made in the light of the many complex and varied circumstances of the family or business and of the alternative uses of this portion of family or business income.

3.7 The estimation of benefits, in monetary terms, can begin by adding up these monetary valuations over all family and business consumers. For practical purposes it is useful to divide the monetary benefits into two parts:

- actual revenues (the "direct consumer benefits")

- the surplus monetary benefits ("consumers' surplus benefits")

where the latter simply reflect the point that people generally do value service by more than the amount they may be asked to pay for it.

3.8 Revenue estimation presents no new problems apart from the difficulties of forecasting; but what is the nature of the surplus benefits? and how can they be estimated?

3.9 For farms, agro-industries and commerce, there is normally a substitute for publicly supplied electricity in the form of:

- Autogenerators for large agro-industries;

- diesel engines for many purposes, including irrigation, corn grinding, and motive power in small agro-industries;
- often, animal power;

- small autogenerators for refrigeration on farms;

- kerosene refrigerators, etc.

The surplus benefits are the net advantages of electricity over these alternatives. In many activities the same output can be produced by the substitute, so the net advantages are cost-savings. This is commonly the case, for example, with uses of electricity for motive power, as in irrigation pumping and corn grinding, where diesel engines can do the same job, though often at a higher cost. It is also the case for many large farms and agro-industries which can also produce the same output using diesel powered autogenerators, though again, often at a higher cost.

3.10 In other activities, however, electricity is far cheaper or of higher quality, and extra output also results; the net increase in the profits of the activity are the benefits. This is often the case, for example, for small businesses using electricity for motive power or refrigeration. The alternatives (including the associated capital and maintenance costs) are often too expensive or unreliable, and the business cannot make a profit with them. So new 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.

3.11 By taking a representative sample of such activities, covering different types and sizes, 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 consumer, it is then possible to calculate total surplus benefits directly. 1/ Clearly the level of these benefits rises commensurately with the number and total demand of these consumers.

3.12 On the household side, the surplus benefits of some uses, such as for lighting and ironing, are also the net advantages over substitutes; while the benefits of others, such as refrigeration and television, are generally the household's valuation of a new product, practical substitutes not being readily available. As remarked earlier, the total monetary benefits would be the amount of income the households are prepared to allocate to such goods.

3.13 It is, however, exceptionally difficult to estimate the monetary value of surplus benefits to households, even with well-conceived sample surveys and elaborate econometric analysis. The problems of randomness, of specifying a correct algebraic model of household behavior, and of identifying the separate influences on household behavior, have so far precluded reliable estimation. What we do know, however, is that when service is benefiting many households, there will be a strong demand for it, reflected in quite good revenues (the direct benefits). So it is still revealing to look at the direct benefits even if the surplus benefits cannot be estimated -- though the point that such monetary benefits are omitted from the economic rate of return calculations means that tolerance is needed for projects with returns somewhat below the opportunity cost of capital (see paragraphs 3.47 et.seq.).

(b) Practical Aspects of Benefit Measurement

3.14 In practice, therefore, it will be necessary to confine cost-benefit analysis to what can be measured, and to supplement this as necessary by descriptive analysis. The benefits which can be measured will generally be:

- the direct benefits to households, reflected in the revenues;

- the direct benefits to farms, agro-industries and commerce, again reflected in the revenues;

1/ The forthcoming research study in El Salvador will provide illustrations of such calculations.

- the surplus benefits to farms, agro-industries, and commerce, reflected in the net effects on profits and output of electricity to these activities.

Descriptive analysis of households, and of household demand, can be couched in terms of indications of living standards, the number and percentage of the people demanding service and what they are likely to use it for. Analysis of the growth of the area, its history, whether people are likely to move into it and/or remain there are also important.

3.15 Where there is a strong demand for "productive uses" the above basis of benefit estimation will be more than sufficient to justify a good project. The revenues from farms and agro-industries should boost the project, unless tariffs are low. Counting in the surplus benefits to productive uses will boost justification further. If, for example, 80% of demand is from productive uses, and surplus benefits are (typically) 50%, then benefits are 120% of revenues not counting household demand, and 140% in total. This can make a large difference in rate-of-return calculations.

3.16 Where, on the other hand, there is a small demand for productive uses, coupled with low tariffs and a low level of demand from households, justification will be difficult -- as perhaps it should be in these situations.

(c) Forecasting Demand and Benefits

3.17 Demand forecasting in areas hitherto without service involves more uncertainty than in areas with service, on account of information shortages; it requires, therefore, a good deal of judgment and guesswork. This points to the importance of flexibility in project design and investment planning, as discussed in VI; and to the need to collate information from several sources and to experiment, as discussed below.

(i) Evidence from Other Projects

3.18 The most concrete basis for a forecast is provided by projects already functioning in other areas of the country. Most countries in Latin America, EMENA, and Asia, and several in Africa have had pilot projects and sometimes extensive programs for several years. The obvious thing to do is to examine how both domestic and non-domestic consumers have responded to these projects; things to look at are:

- The growth in the number consumers;
- the growth in consumption per consumer;
- the types of consumer, including a breakdown by large and small, irrigation, various agro-industries, various levels of household consumption, etc.;
- the changes in load factor, and, if possible,

- the kinds of uses to which electricity is put.

This information should not be difficult to obtain in a well-run program; if it is, serious questions should be raised about whether projects are being monitored properly and about the systematic keeping of records.

3.19 An elementary understanding of the areas in which these projects are located is also necessary in order to understand the factors which affect the projects' returns. Often, a look at the living conditions in an area, its infrastructure and the growth of local agriculture, agro-industries, commerce and wages may be sufficient for this purpose.

3.20 In building up forecasts from experience with other projects, it is of course desirable to take areas that are comparable with the area under consideration -- comparable population and income levels, and comparable with respect to local infrastructure, housing quality, and levels of activity in agriculture, agro-industries and commerce; or more generally, areas which are comparable in levels of development and size.

3.21 Such coincidences in levels of development and size do not always occur even within broad limits. However, to obtain an impression of how levels of development and size interact with the project, it is a good idea to look at how projects have functioned in larger and smaller areas, and in both more and less developed areas. This will provide a range to the forecasts.

(ii) Evidence from Neighboring Countries

3.22 If such evidence is scarce or is not available within the country, either because there are no pilot projects or because they are new and it is too early to form a judgment, the experience of neighboring countries is often highly relevant (indeed one can often go further afield than this). Again, the aim is to see how people and businesses have responded to projects in different situations.

(iii) The Use of Pilot Projects

3.23 Where there is absolutely no local precedent for the forecast, it is of course difficult to justify a full scale program. The case for pilot projects and the use of these as a base for forecasting, as well as experience in project design and management, is a strong one. It should be noted, too, that pilot projects can often be provided out of a very small fraction of a utility's budget. Typically about 5 villages can be electrified for $250,000 depending on their size and location.

(iv) Evidence from Low-Income Areas of Cities

3.24 As regards household demand, it is often the case that many households in villages are no poorer than many electrified households in low income areas of cities. Analysis of the latter may give some indication of likely response from households in villages (even though the costs of serving villages are higher).

(v) Economic and Social Analysis of the Area

3.25 Any evidence carried over from the experience in other localities and countries must, of course, be supplemented by local inquiries. On the non-domestic side, items to look at are:

- the type and growth of local agriculture;
- the development of local agro-industries;
- the extent of local commerce (strong correlations here with population of area);
- quality of local infrastructure such as roads, schools, water and health centers;
- any government plans on projects for the area.

Apart from its importance for forecasting, this information is important for determining priorities. For this reason, it is perhaps best provided by regional surveys of the rural sector.

3.26 On the domestic side, items to look at are:

- family income data (if available or ascertainable);
- quality of housing;
- history of the area;
- migration in the area.

There are some empirical points to be made about each of these items.

3.27 The main factor which determines household demand is household income. Electrical appliances and the costs of running them can be expensive for a low income family, even if large subsidies are offered on electricity costs. The following table illustrates these points.

Table 3.1

Relation Between Household Income and Expenditure on Electricity /1

Appliance	COSTS: US$ Connection /2	Appliances	Electricity	Annual Total /3	Family Income /4	Per Capita Family Income /4	Annual Cost ÷ Family Income
Lights (L)	13	2	6	9	430	72/6	2%
L+Iron (I)	18	15	8	15	550	90	3%
L+I+Refrig. (R)	18	270	22	81	850	140	10% /5
L+I+TV	18	240	10	62	1,000	170	6%
L+I+R+TV	18	600	40	160	2,300	380	7% /5

/1 Source: El Salvador Study.
/2 Includes housewiring.
/3 Using 20% annuity on connections and appliances.
/4 Group means. Family size of 6 taken in computing per capita family incomes.
/5 Refrigerator sales often used to augment family income by unascertainable amounts; family income is probably underestimated.
/6 The actual threshold income, at which families began to consume, was about $50 per capita.

3.28 Family income and costs are not the sole determinants of course. A large proportion of families in rural areas often can afford electricity but nevertheless do not request it. One reason for this is that there is a high propensity for families to move between regions in search of jobs, the opportunities for which may vary seasonally in the case of agriculture and agro-industries. Illiteracy, fragmentation of the family unit, a lack of incentive to develop the home, are also important. Generally, though there are exceptions, it is those families which seek better housing who are also likely to seek electricity; some kind of solidity or permanence in house structure is an important indicator of the likelihood of demand.

3.29 Turning to the history of the area, this too can provide indications of the likelihood of demand. Many villages, for example, have long (if scantily recorded) histories, with long traditions in commerce and socialization; for this reason they can and do form points for growth.

3.30 Related to this is the possibility of people migrating into an area. Even in the presence of migration from rural areas to cities, rural populations often do not decline. Furthermore, there is evidence from several countries to show that villages are often able to attract people out of rural areas on a par with cities. (Nearly all the villages we have studied in El Salvador also showed a general increase in the number of homes.) Evidence of this kind is exceptionally important in indicating people's regard for the future of the village; and it also indicates whether demand can be expected to grow.

3.31 This list of items for economic analysis is not, of course, exhaustive. Nor is such information often available. But analysis of what is known about the development of the area will add substance to the forecasts decided upon.

(vi) Evidence on Energy Use

3.32 Further evidence on the potential demand for electricity can be obtained by a sample study of energy use by households and businesses in the area. Items to concentrate on are:

- types, costs, and extent of motive power (generally animal and diesel) for various purposes;
- sources and costs of refrigeration;
- sources and costs of light in businesses and homes;
- sources and costs of heating for various purposes.

This information is not only useful for forecasting, but also for benefit calculations. Although it is not often available, it is not too difficult or costly for the utility to obtain, and it is all part of good record-keeping and an institutional interest in the prorgram. When it is not available, no harm is done by suggesting that someone should look into it, even if it is on a sample basis.

(vii) Building up a Forecast

3.33 Attempts are being made to interpret such data econometrically or through other statistical models. This is of course to be encouraged.

3.34 But generally, forecasts have to be made in a rough and ready way. In practice, the most straightforward thing to do is to begin with concrete evidence from other electrified areas within the country and, if possible, from other countries. Next, an economic analysis of the area should indicate whether the demand data obtained from these areas should be revised up or down: such revisions will be further strengthened by the studies of energy use. If there are concrete plans for the area's development, the revisions can be made fairly precisely, otherwise they can only be based on judment, the bounds of which can be determined by studying areas of higher and lower levels of development from the one considered.

(viii) Demand for Community Purposes

3.35 These include street lighting and service to schools and health centers. They can be estimated directly from technical coefficients.

(ix) Forecasting Benefits

3.36 From the demand forecasts, the forecasts of revenues follow rather obviously to give the direct benefits. To get the consumers' surplus benefits it is first necessary to distinguish between the various types of consumer:

- various sizes and types of farms, agro-industries and commerce;
- demand for community purposes;
- various levels of household demand.

An idea of what they use electricity for and of the costs of the substitutes will then give a basis for estimating surplus benefits per unit of demand. As remarked earlier, it will only be practicable, in general, to estimate surplus benefits for consumption for "productive uses". But information about what households are expected to use electricity for will give some qualitative idea of the benefits; also, as will be apparent later, this information is particularly important (i) for shadow price adjustments and (ii) for analyzing income distribution issues in pricing policy.

(d) Cost-Analysis

3.37 Once the forecasts of demand and benefits have been obtained, the next steps are to determine:

- the least-cost means of meeting demand, and
- if costs can be further reduced by lowering design standards and accepting an increase of supply interruptions.

The second problem is discussed later (Part VI), except to note here that some countries report large economies by careful attention to design and by keeping standards to a bare minimum.

3.38 The main alternatives to be considered in the least-cost exercises are:

(i) public supplies from the main grid;

(ii) the same, but with different network layouts, equipment capacities and expansion plans; and

(iii) local autogenerators serving local micro-grids.

The third needs to be considered before the initial decisions are taken to bring electricity into an area; and also, of course, for obviously small demands in remote areas. In areas close to the grid, or close to existing subtransmission networks, the main alternatives to be considered are (i) and (ii), that is, alternative plans for public supply.

3.39 Both the least-cost studies and the comparisons of costs (of the least-cost proposal) with benefits require a dynamic analysis over a long time horizon. As illustrated in Section II, costs change enormously over time with the growth of demand and utilization of equipment (load factors); and since the electrical equipment in the networks lasts about 30 years, this is the sort of time horizon needed for the study of costs and benefits.

3.40 Although there are periodic needs to reinforce and extend networks as demand increases, the costs of service per consumer and per unit of power and energy demand decline (in real terms). This is the case for both autogeneration and public supplies, for the following reasons:

(1) There is a large initial fixed cost in setting up the local networks and installing local-autogeneration or, in the case of public supplies, of setting up the subtransmission links to the main grid. Also, equipment costs per unit capacity decline very quickly with size. The following data taken from a project in Ethiopia illustrate these points:

Table 3.2 /1

		1st Year	7th Year	14th Year
Peak Demand	kW	100	425	1,120
Capacity /2	kW	150	1,150	1,500
Total Investment	$	104,000	254,000	288,000
Investment per kW Demand	$/kW	1,040	598	257
Investment per kW Capacity	$/kW	690	220	192
Average Costs per Consumer	$	870	320	72

/1 Source: Supplied by Ethiopian Electric Power and Light Company (1971 data). Data relates to Ghimbi district, 450 km from Addis Ababa. Population about 10,000 but apparently increasing rapidly. Forecasts were based on experience with similar project in Shashemene district which was of "similar economic status".

/2 Local autogeneration of following capacities 1 x 150 kW in 1st year; 1 x 150 kW + 2 x 500 kW by 7th year; 3 x 500 kW by 14th year.

(2) Related to (1) is that costs decline as consumer density increases. For a rural center with 500 persons per square mile, the Kenya Light and Power Company reports initial investment costs of $1,700 per kW, as compared with $250 per kW for a center of three times this population density (1971 prices).

(3) There are also fixed costs of administration, billing and maintenance which also decline in relation to demand. Again, this is illustrated by data supplied by the Ethiopian Electric Power Company.

Table 3.3 /1

	1st Year	7th Year	14th Year
Peak Demand, kW	100	425	1,120
Energy Demand, kWh per year	120,000	629,000	3,307,000
Capacity Costs, $ per year /2	15,600	38,000	43,200
Fuel Costs, $ per year	5,400	28,200	148,400
Admin. Costs - Fixed, $ year /3	13,600	13,600	15,100
- Variable, $ year /4	5,000	11,000	28,000
Total Costs per year, $	39,600	90,800	234,700
Average costs, cents per kWh	33.0	14.4	7.1
Admin. Costs, cents per kWh	15.6	3.9	1.3

/1 Same project as for Table 3.2; all cost data refers to 1971 (including fuel) and are presented here for purposes of comparison.
/2 15% annuity applied to capital costs of Table 3.2.
/3 Mainly comprise the salaries of the branch manager, clerk, cashier, production foreman and 4 mechanics, 1 distribution foreman and 4 electricians, plus guards.
/4 Meter readers and miscellaneous.

The costs, it can be seen, are dominated in the initial stages by the fixed costs of capital and administration. Later it is the fuel costs which predominate. The factors underlying costs structure thus shift markedly over time.

(4) As the demand per consumer increases, load factors improve. This means that peak demands and thus the investments in

more capacity do not rise as quickly as energy demand. Typically, load factors may rise from 10-20% initially to 30-40% after 10 years, thus doubling the returns only at the cost of extra fuel.

3.41 The changes in demand, load factor and cost structure over time clearly have an important bearing on both the least-cost and the cost-benefit analysis. In most cases it will be necessary to estimate a time-stream of costs for the following items:

- Running costs, related to kWh sales. Fuel and variable costs of maintenance and administration, mainly.

- Capacity costs, related to kW peak demand. Generators, local distribution networks and, in the case of public supplies from the grid, transmission and subtransmission capacity.

- Fixed overheads. Administration, mainly.

(e) Cost-Benefit (IER) Calculations

3.42 As in other projects, the time-streams of costs and benefits need to be calculated on a present worth basis. Calculations of internal economic rates of return (IER) and cost-benefit ratios also follow customary practices.

3.43 Shadow price adjustments are, as usual, required to allow for distortions in the pricing system. We have found that the most important adjustments to make are for:

(i) Net tax revenues: - These are part of the Government's profit stemming from sales of electrical appliances and equipment, and also of electrical energy if the utility pays taxes on inputs or sales. These should be counted in on the benefit side (or deducted from the cost side); often they can be quite large if appliances are heavily taxed.

These revenues are offset to some extent by reduced tax revenues due to a reduced use of substitutes. Mainly, this is only significant for farms and agro-industrial demands which would otherwise use autogenerators, diesel engines and alternative sources of refrigeration.

(ii) Foreign exchange: - The usual shadow price adjustments need calculating when the balance of payments is in disequilibrium and/or if there is heavy protection. The penalty applies to electrical appliances and equipment as well as to the production of electricity.

The penalty is partly offset because substitute sources of energy and equipment are often imported. Again, the most significant cases are generally to be found in the demands of farms and agro-industries -- autogeneration, diesel engines, substitute sources of refrigeration.

(iii) Capital: - A specific adjustment may often be needed to allow for scarcity of credit. This affects, mainly, the sales of appliances and equipment and the costs of connection. Local inquiries may sometimes show effective rates of interest above the opportunity cost of capital. The profits made out of this do not, of course, accrue to the consumers but to the sellers; nevertheless, they are part of the monetary benefits.

(iv) Labor: - The main element here is to be found in construction of the networks, where unskilled labor costs may form about 25% of initial investment costs, depending on the difficulty of terrain. The excess of wages over the shadow wage of labor can be deducted from cost-streams. Since it is linked to investment rather than operations, the adjustment will be lumpy.

3.44 Evidently the calculation of shadow price adjustments requires good records and data about consumers. Items (i) and (ii), for example, require some knowledge of what consumers use electricity for, and item (iv) a study of credit. It is desirable to encourage utilities to record and take an interest in such data. It is useful not only for cost-benefit calculations and investment decisions, but also for efficiently running and promoting electrification programs.

3.45 The assumption of the analysis becomes clearer if each of the time-streams of benefits, costs and shadow price adjustments are listed separately, so that the cost-benefit tableau contains, for example:

Benefit Streams: -

- direct benefits to households (revenues);
- direct benefits to agro-industries, farms and commerce (revenues);
- surplus benefits to agro-industries, farms and commerce.

Cost Streams: -

- generation, capital costs;
- transmission and subtransmission, capital costs;

- local distribution networks, capital costs;

- generation, energy costs;

- administration and maintenance costs.

Shadow Price Adjustment Streams: -

- net tax revenues (deducted from costs, or added to benefits);

- net foreign exchange penalties;

- profits from credit rationing;

- shadow wage adjustments to labor costs.

The cost streams, of course, refer to the least-cost project.

3.46 Some demand statistics, on total demand, its division between productive and domestic uses, load factors and numbers of consumers might also be added to the tableau for explantory purposes.

(f) The Criteria for Project Acceptability

3.47 Most of the economic factors so far discussed act to increase the calculated returns to electrification. The economic picture is thus somewhat more optimistic than the financial one. Taking a long run view, for example, shows benefits rising faster than costs (this is not so apparent in the financial analysis which is heavily preoccupied with financing the initial investments, low short-run returns and high risks). Counting in the surplus benefits to farms, agro-industries and commerce will, if the demands for these "productive uses" are high, add quite significantly to the calculated returns. The shadow price adjustments will generally be favorable towards the project because tax revenues, and the shadow price adjustments for capital and labor are likely to be greater than the penalties on foreign exchange costs. (In the El Salvador study we have found that the net adjustment for shadow prices works out at about +30% of sales; the mark-up for surplus benefits to agro-industries, farms and commerce varies, but may average around 50% or more of sales to these consumers.)

3.48 After all such adjustments have been made, what should be the criterion for project acceptability?

3.49 Strictly speaking, it should be somewhat lower than the opportunity cost of capital because some social and economic benefits generally cannot be quantified but are nevertheless considered to be important. Among these are:

- The surplus benefits to households;
- the value judgment that rural poverty is unacceptable and some degree of subsidy is desirable;
- institutional benefits in that it is a stimulus to public and private institutions, as well as to the area itself, to take a stronger interest in the area's development; this should feed back positively on the returns to the project but to an immeasurable extent (an example of Professor Hirschman's dictum that the benefits of unintended side effects on institutions are often more far-reaching than those of the intended effects of policy); 1/
- the expected returns may be lower than the optimistic returns; but an optimistic view of the project should be taken: the social consequences of neglect in rural areas far outweigh the risks of limited success.

(Related to the last point is the observation by many countries that demand is often higher than expected; and as regards institutional benefits, it is commonly reported that the initiative of one institution leads to initiatives by others.) Such matters are clearly of sufficient importance for tolerance to be exercised when the quantified economic returns are somewhat lower than the opportunity cost of capital. The degree of tolerance will depend on the country and in particular on its fiscal strength.

3.50 How much lower than the opportunity cost of capital the IER can be permitted to go is a matter of judgment; only experience and discussion can decide. But there are several related arguments for not permitting it to go too low.

3.51 Firstly, if rural electrification is to contribute towards the economic output and wages in rural areas, it must be couched in a productive context. Where it is, the demands from agriculture, agro-industries and commerce will be large, and the revenues and surplus benefits from these should provide a good economic return to the investment. In this respect, electricity is simply a factor input to agriculture and rural commerce, so the economic returns should be comparable to other investments in these sectors. Indeed, on a good project with strong demands from these consumers, the IER may often exceed the opportunity cost of capital and there will be no need to invoke the above arguments.

1/ "A Bias for Hope" - A. O. Hirschman, 1970.

3.52 On the other hand, where the IER is low it is a sign that demands for productive uses may be low and that its contribution towards raising productivity and incomes in the areas is limited.

3.53 Secondly, and closely related to this, is that it may signal that there is insufficient attention to the development of local infrastructure and agriculture: poor or no credit for example, or bad roads. 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.

3.54 Thirdly, low economic returns can also lead to disillusionment among both investors and, perhaps more important, consumers. One reason for this is that even subsidized electricity and the appliances to use it often cost far more than consumers anticipate; this can be an exceptionally unwelcome setback for low income households and a high rate of disconnection results. Another reason is that where development is expected but not realized there is cynicism (our study in El Salvador and an AID sponsored study in Costa Rica and Colombia have found solid evidence of this).

3.55 Fourthly, where there is a strong demand from households and businesses, a low IER probably indicates that tariffs are too low and wrongly structured. Many of the larger household consumers in villages are often above average per capita incomes, while many of the larger farm and business consumers make quite good profits. It is invariably the case, however, that subsidies continue, even though such consumers are able and willing to pay more. Tariffs can be restructured so as to help the lower income groups more while enabling the utility to earn a better financial return and extend service more widely.

3.56 Fifthly, the basic reason for a low IER is low levels of use on a high-cost project. It is possible in such cases that a least-cost solution has not been found. Low demand stemming from simple uses like lighting, ironing and one or two refrigerators in village shops, can be met by small diesel or micro-hydro powered autogenerators at relatively low costs. When such alternatives are adopted, the economic rate of return is not only good but the schemes are often financially profitable.

3.57 Finally, there is the obvious point that a low IER signifies an inefficient investment and, perhaps, wrong priorities. For the $250,000 or more which it may cost to electrify about five villages, good water supplies may be provided; alternatively, respectable improvements to the access roads can be contemplated (this has the added advantage of cutting the costs of electrification significantly); or schools and health centers can be built -- villagers generally list these to be higher in their preferences.

3.58 In sum, the economic return calculation provides some useful messages. A high IER signifies a good investment. An IER somewhat below but approaching the opportunity cost of capital deserves tolerance since there are several benefits of importance which cannot be quantified. Low and very low IERs on the other hand may signal an ineffective project, wrong priorities and the possibility of disillusionment.

3.59 It should be added that postponement or rejection of electrification projects until priorities are sorted out need not lead to disaster -- as with rural water projects in drought areas for example. Farms, agro-industries and commerce can and do turn to useful substitutes in the form of diesel motors and autogenerators, and households are well adapted to using substitutes and doing without electricity.

(g) Pricing Policy

3.60 Pricing policy, like investment policy, has to take into account the social and economic aims of the program. In addition, financial obligations have to be designed and met for various reasons -- fairness to investors and other (non-rural) consumers; to reduce the burden, such as it exists, on the public revenue; and to enable the utility finance, and perhaps widen the scope of its investments. To reconcile these various requirements of pricing policy, the most appropriate approach is to proceed in four steps (as outlined in the references in Annex 1):

(i) Estimate the structure of marginal costs;

(ii) decide on the form of a metering and tariff policy which may practically reflect this structure in one or two respects; this will meet efficiency aims;

(iii) incorporate any fairness aims into the pricing structure; and finally;

(iv) place any further financial burden on those elements of tariff structure so as to minimize any adverse impact on fairness and efficiency.

A few remarks can be made on each of these steps.

3.61 The marginal costs of reinforcements and extensions to capacity, in order to meet increased demand, are well below (less than 50% of) average costs for the first 10-20 years of a project on account of the high initial fixed costs. Economies of scale and increasing consumer density also act to reduce the long-run marginal costs once an area is electrified (note again the cost estimates provided earlier in 3.37 et. seq.). For many years there is also excess capacity in the sub-transmission and distribution networks. In principle, efficient use of the services should not be held back by high sunk costs. Hence, there is an economic rationale for not demanding too high a financial return on assets, at least in the early years. (This is also desirable in the interests of promoting the project.)

3.62 As far as possible, there should be some steadiness in pricing policy. For this reason, it is best to take estimates of the long-run marginal costs (or average incremental costs) of future reinforcements and extensions and expansion -- of generation, transmission, sub-transmission and distribution -- as an initial basis for pricing policy calculations.

3.63 Metering and tariff policies have to be simple for most consumers. Complicated tariffs bewilder most people, and advanced metering is often too expensive. For most domestic consumers in rural areas, and for a good number of small business consumers, a flat rate tariff, accompanied as necessary by a fixed charge (which could serve revenue raising purposes or as an incentive to economize at times of peak demand) will do. Where metering and billing costs are very high, a device to reduce them is to eliminate meters and introduce a fixed charge, related to the setting on a simple load limiter, for very small consumers; however, this arrangement is only suitable if fuel costs are not high, for it encourages wasteage of energy. Seasonal variations in tariffs -- "wet" and "dry" seasons -- may be contemplated if there tends to be energy shortages in the dry season. For the larger farms and agro-industrial consumers more complicated metering (such as time-of-day for irrigation and other uses) may be considered.

3.64 The widely adopted system of declining-block tariffs to all consumers has several defects, and its application in rural areas should be questioned. Small household consumers don't understand it, it doesn't exploit willingness or ability to pay and so keeps financial returns down, and it has no obvious economic merit.

3.65 Fairness aims can be incorporated by providing concessions on one or more of the elements of the tariffs at low levels of consumption. Devices which can be used are a low first block followed by a higher flat rate in excess, say, of 50 kWh/month, a low connection cost to small consumers, and concessions on fixed charges.

3.66 If it is desired to raise financial returns further, while minimizing the impact of tariff increases on efficiency and fairness, increasing the fixed charges to large consumers and/or raising the flat rate at high levels of consumption are obvious devices.

3.67 Pricing policy clearly has an important bearing on the social and economic aims of the investments. It is nevertheless true that most pricing policies are a direct contradiction of these aims. Generally, the larger consumers get subsidized the most in tariff systems unrelated to economic aims and which also undermine financial performance. Pricing policy will, therefore, require thorough attention during appraisal, not only from the viewpoint of finance, but also from the viewpoints of fairness and efficiency.

(h) Provisions for Low Income and Small Business Consumers

3.68 Concessions to these consumers are of course helpful but the income distribution impact is small in relation to household or business income. The cost of electricity rarely exceeds 2 to 5% of the household or the business budget, even in rural areas (see Table 3.1 for example). There are two further points to bear in mind: (i) the larger businesses are often making good profits and there is no need for concessions; they are often willing and able to pay more and by being expected to do so will help financial performance; (ii) similarly, as remarked earlier, many household consumers in rural areas are also able and willing to pay more.

IV. PROJECT IDENTIFICATION AND PREPARATION

4.1 Perhaps the single most important factor which determines a program's success is care and thoroughness in identifying and preparing projects -- identifying the areas to be served, working out the investment plan, choosing equipment and designing networks so as to keep costs down and the continuity of service to satisfactory level, and attending to all the financial and institutional matters which will enable the program to be expanded and run efficiently. Project appraisal and justification, in a broad sense, is nothing more than establishing if the groundwork on these matters has been properly done.

4.2 This section discusses the economic side of identification and preparation, while later sections deal with finance, technology and institutions. The discussion begins with the problem of:

a. Defining Project Areas;

and then turns to:

b. Identifying Areas for Investment;

c. Working Out an Investment Plan;

d. The Relation Between Rural Electrification and Rural Development Plans;

e. Uncertainty and the Need for Experimentation and Evaluation; and

f. Pricing Policy.

(a) Defining Project Areas

4.3 One particular problem of identifying and appraising projects is posed by the very large number and interconnectedness of projects to be considered. It is particularly troublesome if the village is defined to be the unit for project evaluation. Even small countries have several thousand villages. Roughly speaking there are two to four thousand villages for each million of rural population, so that a country with a rural population of 30 million may have about 100,000 villages (as in Mexico for example). It is too much to expect (or to ask) that appraisal can be rigorous and comprehensive in each of these cases: it is also unnecessary.

4.4 Generally it is better to think in terms of the best way of introducing electricity into a region or zone, and then to calculate the overall costs and benefits of electrifying the region. One reason is that most of the non-domestic consumption stems from outside the villages--irrigation is an obvious example, but it is also widely the case, for example, for the processing of rice, sugar, coffee and cotton. Villages are major demand nodes, of course, but so are demands outside the villages. Another reason is that the appropriate unit for economic analysis is the region rather than the village. It is an analysis of a region - of its demography, agriculture, wage levels, agro-industries, commerce and general infrastructure - which will give the main indications of the desirability of introducing rural electrification.

4.5 There are also technical and administrative reasons for thinking in terms of a region. Plans have to be made regarding the locations and capacity of substations and transformation points, the various voltage levels of subtransmission and distribution, the type of automatic protection equipment, and the routing and interconnection of the circuits between the various demand nodes. (Most lines and substations in any case serve not one, but several demand nodes.) Administration, maintenance and billing procedures also need to be worked out on a regional basis. Costs can be reduced considerably by coordinated planning rather than ad hoc piecemeal extensions in a region.

4.6 So generally it makes sense to enlarge the definition of the project and to relate it to the problem of electrifying a region or zone. In doing so, there are two sources of error to guard against. The first is that this procedure does not of course imply electrifying the whole region. There will be many demands not worth bothering with because they are to small and remote from the main demand nodes. Other demands can wait until the networks have been constructed to meet the more important demands; after this, extensions to neighboring demand nodes can be accomplished at low marginal cost.

4.7 The second source of error to guard against is that the sizes of the regions chosen for analysis should not be too large, otherwise control can be lost. The aggregate return can be held down heavily by a number of, for example, ill-chosen extension projects. One thing that is apparent is that some places are emphatically worth electrifying and others are emphatically not; but the latter are often electrified and this detracts not only from the merits of the former, but often from the whole program.

4.8 As in many other aspects of this work, the actual size of the region defined for study, and thus the 'size' of the project, is a matter of judgement. It is influenced by the availability of data, by the structure of economic and political institutions for regional administration as well as by project technicalities. Each of the following has to be considered:

- A similar problem occurs in arranging for local administration of the project. Within the region, local administration may be responsible for promoting the project and making arrangements to bring new consumers into the system, for billing, reporting faults, keeping records and perhaps undertaking some local engineering and maintenance work. They will, therefore, provide the information base for future extensions and supervision.

- Many countries are divided into a number of economic and political administrative districts, and it will often be useful to follow this division. Indeed the institutional framework (for local administration) is often best designed round such districts because it gives the districts a more direct involvement with the project and its success. Finally, the census and economic data are often classified according to such districts.

- Once the major demand centers have been identified, the network design will follow and it is often quite obvious on site how large the region should be from the viewpoints of expansion planning, administration, and thus of project identification and evaluation. Very often, these considerations may lead the utility to group several districts together.

(b) Identifying Areas for Investment

4.9 Having decided that it is best to evaluate projects on a regional or zonal basis, how is it decided which regions or zones to electrify and at what rate?

4.10 In answering this question, the obvious point to keep in mind is that the projects identified must eventually pass the appraisal test. From an economic viewpoint, then, the short answer is to choose regions which are likely to offer satisfactory economic rates of return to the investment, where the calculation and criteria are as discussed in Section III.

4.11 From this it follows that the projects should be in regions where reasonably strong and growing demands might be expected for the service, and where the resulting benefits can justify the costs. In general this will be the case for regions where:-

- the quality of infrastructure, particularly of roads, is reasonably good;

- there is evidence of growth of output from agriculture, and where, therefore:

- there is evidence of a growing number of productive uses in farms and agro-industries;

- there are a number of large villages, not too widely scattered;

- wages and living standards are improving,

- there are plans for developing the region;

- the region is reasonably close to the main grid (though if demand is particularly strong, remote regions may be considered too).

4.12 Such information about the region merely indicates the likelihood of useful investment. The first test will come where some rough estimates of demand and costs are made. From the demand estimates, the revenues and the consumers surplus benefits to non-domestic consumers can be estimated -- again, rather approximately. If the economic returns look reasonable, subject to all the allowances discussed earlier (in III) for social aims and for the economic benefits which cannot be quantified, a more thorough plan can be worked out and appraised rigorously.

(c) Working Out an Investment Plan

4.13 Generally, several alternative plans have to be considered in the interests of ensuring that (i) reasonable demands have not been excluded from the plan; (ii) unreasonably low demands have not been included when the costs of inclusion are high; (iii) the proposed expansion plan is not too fast or too slow; and (iv) that a least-cost plan has been determined.

4.14 In the case of regions which are to receive electricity from the grid for the first time, the first phase of an electrification plan consists of pilot projects -- unless there is good information about the use of auto-generators in the area indicating that demand is likely to be strong. This provides the necessary information and experience for future expansion, and for flexibility in decision making.

4.15 Both the pilot projects and the early phases of electrification concentrate on the main demand centers; subsequent phases extend the network to the smaller villages, and to new farm and agro-industrial consumers. Evidently, the early appraisals for electrifying the region need to make some allowance for the net benefits of subsequent extensions.

4.16 Following the pilot projects and the decisions to construct the main networks, decisions about subsequent reinforcements and extensions can be made on an incremental basis, as the demand develops, through a comparison of incremental returns with incremental costs (an exercise which can be left in the responsibility of the distribution engineers, say, rather than central management). This permits flexibility in decision making and enables the engineers to match investments and capacity more closely to the demand. The ground rules for decisions to extend the networks can often be stated quite simply: for example "the expected revenues, once the demand has developed, should be greater than (a) the annuitised capital costs of extension, plus (b) local running costs, plus (c) costs of bulk supply." Cost-coefficients for (b) and (c), per kWh of demand, and the appropriate annuity rate need to be specified.

4.17 Summing up, the investment plan generally begins with a pilot project followed by a more comprehensive network plan which is:

- the best of alternative proposals regarding which demand centers to connect up (in the early phase); and

- the least costly of alternative layouts and designs to connect up these centers.

Subsequent reinforcements and extensions can be decided on an incremental basis.

(d) Rural Electrification and Rural Development Plans

4.18 The returns to rural electrification increase with the level of development in rural areas. On the cost side, improved roads reduce the costs of construction, maintenance and administration of the electrification programs. On the benefit side, there are several inter-relationships, as follows. Rural development programs raise the level of output in agriculture and agro-industries, and through this the level of rural incomes. On account of increased incomes and improved infrastructure, commercial activity increases. Together, the growth of incomes and the growth of agriculture, agro-industries and commerce create increasing demands for power and energy. These demands can be met by public supplies from the grid, local autogeneration or substitute sources of power and energy. Which of these alternatives is best will be revealed directly by the calculations of the costs and benefits of public supply; the reason is that these calculations involve a comparison of public supplies with the alternatives.

4.19 Hence the economic rate-of-return calculation also provides a measure of the need for the project when there are plans for developing the area at public, private or local initiative; that is, it indicates if the electrification project fits into the rural development plans for the area. The main effects of such plans are, as just indicated, to raise the expected economic returns.

(e) Uncertainty and the Need for Experimentation and Evaluation

4.20 Uncertainty, and the related problems of information shortage and inexperience, can only be reduced through concrete experience and evaluation. This rather obvious point is the main reason for beginning with pilot projects. As a general rule:

- in countries without a rural electrification program, and where there are good grounds for embarking on one, experimentation is a necessary first step; this will generate information and experience for the subsequent program;

- in countries with programs, evaluation may be encouraged as a basis for improvements.

4.21 Part of the task of project preparation is to identify the need for and define the scope of such experiments and studies. One particular requirement is to keep their size within reasonable bounds and concentrate on what is relevant. A common occurrence, for example, is for the studies to become very large, costly and time consuming; often much can be accomplished by elementary investigations which concentrate on a few items such as:

- demand analysis;
- cost analysis;
- effectiveness of various management and promotional procedures;
- descriptive studies, for projects in selected areas, of the development of local agriculture, agro-industries and commerce; of the living standards of households and the community; and of how these relate to project performance.

If the utilities keep good records, all the project-related information should be available. If it is not, a start should be made to keep good records. (In many countries with rural electrification programs, records are not good, even on obvious things like demand and costs.)

(f) Pricing Policy

4.23 During project justification, it is necessary to show that pricing policy is satisfactory, as discussed earlier. During the preparatory stages, the main work will be in estimating the long-run marginal costs, selecting a simplified metering and tariff system, and then working promotional, social, and financial aims into the cost structure. In practical terms this results in:

- prices that are higher in rural than in urban areas;
- prices well below average costs in the early years, on account of the high initial fixed costs (and also to help promote the project);
- some degree of cost recovery in later years; and
- low tariffs only at low levels of consumption.

Decisions on the price levels and structure are generally less flexible than investment decisions, on account of the exceptional unpopularity and difficulty of effecting price changes. For this reason it is necessary to get the pricing policy into a satisfactory shape during the early stages of the program.

V. MEANS OF FINANCE

Financial Goals

5.1 The financial characteristics of new or expanding programs are such that the initial investment should be financed by some combination of debt, grants, equity or internal funds of the utility which results in a relatively "soft" blend for the capital structure of the program; long grace periods are also required. The reasons for this are: (a) the long gestation period before demand and revenues build up to reasonable levels, and (b) the various economic, promotional and social constraints also acting on pricing policy. Often, these factors are made more difficult, and the financial returns worse than they need to be, by ill-structured prices. But even with suitable reforms to pricing policy, funding on soft terms is necessary. In practice, the kind of financial goals that might be achieved would evolve with the level and growth of demand:

- initially (say, during the first 3 or 4 years) revenues could generally be expected to service debt (assuming the soft blend as suggested above);

- in subsequent years, revenues may generally be sufficient to make an increasing contribution towards the costs of expansion (sufficient in magnitude perhaps, on some projects, to meet a good proportion of the capital required, and to give a good internal financial rate of return to the project).

But such achievements would depend on the level and growth of demand; reforms to pricing policy; well-prepared and well-run projects; and also a systematic follow-up on projects to insure that financial targets are raised as soon as circumstances warrant.

5.2 As a matter of principle, then, it should not be assumed that costs cannot be recovered over the life of the investment; but whether or not they are will be determined by the pricing policies of the agencies involved. During project preparation and appraisal it is thus necessary to review the financial targets bearing in mind:

- the financial needs of the program;

- the effect of the program on the utility's overall financial performance,

- the fiscal strength of the country; and

- the economic and social objectives of the program.

Domestic Finance

5.3 In the early years of rural electrification projects, average costs are exceptionally high -- perhaps three or more times the average costs of urban electrification projects. Though average prices are generally higher than in urban areas, they have to be kept down as far as possible in the early years in the dual interests of promoting efficient use of the project and meeting social aims. The transition to the point where average costs fall below prices, and for cost-recovery to begin, may take 5 to 15 years on quite good projects -- larger, of course, if the social aims are strong or prices are poorly structured. Furthermore, as the programs expand, the low financial returns on assets of new projects offset financial gains which may be appearing from the older projects.

5.4 The result is that continual financial assistance is required on new or expanding programs. On the domestic side, the main sources of financial assistance are:

(i) Funds from the government, either as cash grants or as loans at low interest rates;

(ii) Funds generated internally in the utility through general tariff increases to urban areas or to the country at large; or through cost reductions as the utility expands;

(iii) Raising and restructuring tariffs in rural areas;

(iv) Offering bulk supplies to the distributors at lowered prices;

(v) Local contributions in kind (e.g. "self-help" in the form of unpaid local labor).

Private sector finance is of course ruled out for some time on account of high risks. The last two items are only of indirect help, and mainly on expanding programs, since they reduce the financial burden rather than raise funds. Combinations of (i) to (v) are often used. What are their merits?

(i) Government Funding

5.5 Grants and low interest loans from the government have particular advantages in large countries where the supply and distribution of electricity may be undertaken by several independent regional utilities. It can be used to help the more backward regions, as a lever on the less innovative utilities, and to promote cooperation between regions. This system is used in India, under the administration of the Rural Electrification Corporation (REC). Apart from its success in deflecting capital to the more backward regions, it has also promoted some degree of coordination in policy, including equipment standardization, and a considerable interchange of ideas and experience.

5.6 The case for this source of financing is stronger the greater the fiscal strength of the country. When the public revenue is heavily burdened, however, it is practically necessary to turn to other sources. One of the more copious of these is internal cash generation.

(ii) Internal Cash Generation

5.7 Tariff increases to urban consumers, or to the country at large, can raise funds on an enormous scale. In many countries, tariff increases have been highly successful in providing capital to finance the very large investment programs of electric utilities; for many years the encouragement of this has been a cornerstone of Bank policy. There is no reason why a similar policy cannot successfully serve a similar purpose in financing rural electrification. Only a small increase in the average level of urban tariffs can provide funds for quite ambitious programs of rural electrification. Roughly speaking, when rural electrification takes 10% of total investment, a 5% increase in general tariffs will meet 50% of annuitised investment costs.

5.8 The same effect can be obtained as the system expands by keeping prices constant, apart from adjustments for inflation. The reason is that average costs in utilities generally decline (in real terms) with system expansion. The extra profits this leads to can be used to finance rural electrification.

5.9 The device of using internal cash generation is evidently worth pursuing if other sources are difficult to tap. An economic argument can be advanced in its favor in that it is consistent with the general aims of promoting urban-rural balance. Also, it can be adapted to a variety of institutional arrangements. Where electricity distribution is administered through several independent utilities, it can take the form of a trust fund to be redistributed through some central agency. Where electricity supply is the responsibility of one national organization, the transfer is internal. And where, for example, distribution is through cooperatives, soft loans or straight cash grants can be offered to them.

(iii) Increased and Restructured Rural Tariffs

5.10 Generating funds, or reducing the need for them, by increasing or restructuring tariffs may seem a contradiction - if this can be done, why the problem of finance in the first place? Mainly it is a question of degree: while the problem of finance is genuine, it appears that it is made far more difficult than it should be by badly structured tariffs that even conflict with the social aims of the programs. This is so even though tariffs in rural areas generally are higher than those of urban areas. The two most common defects of tariffs are:

- excessive use of declining block tariffs (which do not correspond to marginal cost structure);

- low tariffs are often offered to large consumers who are able and willing to pay more.

Flat rate or two-part tariffs, redesigned to pass on more of the financial burden to larger customers, can result in very useful improvements in financial returns. (It is necessary not to go too far in this regard, of course, since large consumers can and sometimes do opt for the alternative energy sources if the flat rates are set too high above the costs of supply.)

(iv) Low-Priced Bulk Supplies to Rural Areas

5.11 The device of selling electricity at low prices to the electricity distribution agencies in rural areas is also useful, and it can help them function on a normal profit and loss basis. (It is pointless to apply it, of course, if generation and distribution is undertaken by the same entity.) But the device has its limitations. The capital and running costs of generating and transmitting electricity - that is of providing supplies to distributors - are less than 40% of the total cost of providing supplies to rural areas. So if electrical energy were sold in bulk at half price to the distribution agencies, it would only cut their costs by 20%. This is helpful, but generally it is not sufficient.

5.12 One other limitation of this device is that it is not very helpful in raising the capital initially required for electrification: its effectiveness is after the investment, not before, so that its resource mobilization function is weak. Nevertheless it can help financial viability and reduces the funding requirements for the expansion programs of distributors.

(v) Local Contributions

5.13 Local contribution in the form of unpaid labor, materials and capital are also helpful, if limited in scope; they also engender more local interest in and appreciation for the area's development. As regards unpaid labor, however, the question should be raised if, through sensible financial policies, there is the means to pay for it; it is provided by the lowest income groups and the idea of not paying them should not be accepted lightly.

A Comparison of Domestic Sources of Finance

5.14 The main sources to consider will be the public revenue, general tariff increases and raising or restructuring tariffs in rural areas. The latter is worth considering in its own right if only to reconcile the three viewpoints of efficiency, fairness and finance, as discussed in Part III (paragraphs 3.60 et. seq.). But there is a distinct limit to this device, which in any case cannot be expected to raise funds in the early phases of the program.

5.15 Hence the public revenue or internal cash generation must be invoked. Internal cash generation has the advantage of giving the utility added autonomy in expanding and running the program. Apart from this, the choice is one of acceptability rather than economics, since the public sector could obtain its funds from a tax on electricity, and might even be doing so. Taxes may be unpopular, however, while price increases can be sneaked in during inflationary adjustments, or may even be acceptable if the intent of the increase is announced; internal cash generation through the occurrence of cost reductions as the system expands may, on the other hand, pass unnoticed. So the choice is a matter of politics, and will depend on the country's fiscal strength and the acceptability of one device or the other.

International Finance

5.16 Several countries have approached the Bank for finance of rural electrification. Also, on account of the low financial returns, and of the difficulty of raising funds, the suggestion has been made, sometimes explicitly, that the loans should be on soft terms as are AID and IDB loans. However, the justification of IDA credits reflects international inequalities in incomes, whereas the justification of soft loans for rural electrification reflects national inequalities. It has been shown that the latter problem can be met by appropriate tariff and financial policies within the country. Hence there seems to be no grounds for altering IDA policy except to note that when a country qualifies for IDA credits, well-conceived rural electrification projects would sometimes provide a good and productive use of them.

VI. TECHNICAL PROBLEMS

6.1 The distribution networks for rural electrification normally have five basic elements:

(1) High Voltage/Medium Voltage Substations (Typically 150/44 KV) comprising: high voltage connections to the main grid; transformation to intermediate voltage levels for medium voltage distribution over a wide area; switchgear and automatic protection devices to isolate the network or parts of it in case of faults or of maintenance needs; medium voltage outlets.

(2) Medium Voltage Sub-Transmission Networks.

(3) Medium Voltage/Low Voltage Substations (Typically 44/13 KV) comprising: transformation to low voltage levels for distribution over small areas; switchgear and automatic protection devices to isolate the network or parts of it in case of faults or of maintenance needs; low-voltage outlets.

(4) Low Voltage Distribution.

(5) Transformation to service voltage levels appropriate for use by households, commerce, agro-industries and farms at points close to these loads. The larger consumers may require their own transformers, but for households one transformer may serve e.g. one or more streets.

Occasionally, one of the transformation stages may be left out, depending on the area covered, the load density and the proximity of the main grid.

6.2 This technology is standard, though the design and layout of the networks and the choice of voltage levels, equipment capacities, protection devices, etc. require engineers of considerable experience and skill. (Most of the engineers within the Bank are versed more in generation and transmission planning, so that it would be desirable to increase staff experience in distribution network planning if the intention is to invest in this area, as discussed in VIII.)

6.3 Costs can be cut substantially by careful attention to design and standards of supply. When deciding if a particular arrangement is appropriate, it is useful to raise a number of questions of the following type:

a. Are small local auto generators cheaper than connection to the main grid? For small and/or remote demands, diesel powered generators or, if water is available, micro hydro units, are often better. (One particular problem to take into account with regard to diesels is the problem of maintenance: most countries report unfavorably on this problem which stems from the shortage of skilled operators.)

b. Are equipment and procedures sufficiently standardized? Many countries report substantial cost savings by standardizing on voltages, on equipment and on construction and contract procedures.

c. Are equipment standards too high? Lower design standards with regard to the construction of overhead lines and equipment are things to look for.

d. Closely related to (c), can more interruptions to supply be permitted? If so, design standards and the extent of standby capacity (in circuits and equipment) can be reduced. The reliability of very basic networks may often be quite high. Added protection and standby capacity might be justified for the larger loads, when the costs of interruptions are high (as in urban areas, but to a much lesser extent in rural areas).

e. Can the capacity of the networks and their equipment be matched more closely to the demand? Extending and reinforcing the networks and changing equipment as the demand develops, are obvious procedures. Though they are commonly practiced, it is not uncommon to find considerable excess capacity in the networks -- sometimes enough to meet 20 years growth in demand, for example.

f. Can costs be reduced by further attention to network layout? Often, careful routing in relation to the demand nodes, difficulty of terrain, quality of roads and other factors can further reduce costs. A further possibility is to increase substation sizes and reduce the number of substations or vice versa.

g. Is the strategy of network extensions sensible? In many instances costs are too high because the initial networks cover too wide an area; many of the fringe areas (including fringe areas of villages) would best be electrified later, once the demand has developed.

h. Can demand be met through one or two phases for a time, intead of three phases? This, too, cuts costs.

i. Is the choice of voltages and numbers of transformation stages correct?

j. Can mobile generators be used, at low demand levels, until demand levels justify permanent service? (these are then transferred to other areas).

Large cost reductions have been reported by thorough attention to these matters.

VII. INSTITUTIONAL PROBLEMS

7.1 The interdependence of the many elements of an investment program is such that the program's success can be undermined by a failure in any one of them. This is also the case for the institutional arrangements to run the program. At the local level of responsibility, for example, negligence in billing or a lack of trained personnel to repair faults, can discredit the program within the locality. At a more central level of responsibility, inappropriate directives as to which areas to electrify, for example, or bad pricing policies, may eventually discredit the program nationally, however well attended to the other aspects of the program may be.

7.2 Analysis of institutions therefore requires a careful look at each of their elements. In discussing this problem, it is convenient to classify the elements in terms of who is responsible for them -- that is, in terms of organization.

Tasks and Responsibilities of the Institutions

7.3 The diversity of tasks connected with rural electrification programs is such as to require special institutional arrangements at all levels of economic administration: namely, at the levels of:

(i) The Government;

(ii) The Electric Utility; and

(iii) Local Administration in the Rural Areas.

The division of responsibilities between these three levels depends partly on the situation and partly on the nature of the tasks. Table 7.1 lists the more important tasks and how they are sometimes allocated, though the allocation obviously changes from case to case.

Table 7.1

Typical Tasks and Division of Responsibilities in Rural Electrification Programs

TASK	MAIN RESPONSIBILITY OF: 1/ Public Sector	Electric Utility	Local Administration
1. Tariffs	*	*	
2. Finance	*	*	
3. Economic Analysis and Linkage with Development Aims	*	*	
4. Program Directives and Ground Rules	*	*	
5. Forecasting		*	
6. Identifying Markets		*	*
7. Engineering Planning		*	*
8. Equipment Procurement		*	*
9. Construction		*	*
10. Maintenance - identification			*
- repairs		*	
11. Standardization		*	
12. Promoting Regional Cooperation	*	*	
13. Training		*	
14. Supervision		*	*
15. Accounting		*	*
16. Record Keeping		*	*
17. Billing			*
18. Consumer Relations			*
19. Promotion		*	*
20. Provision of Credit (to consumers)		*	*

1/ An asterisk in two columns indicates that the task may be performed jointly, or by one of the two.

(i) The Government

7.4 Where the country has a singificant rural development program, there is clearly a need for the public sector to take an active interest in order to promote coordination between investment in related sectors, particularly in agriculture, agro-industries and other rural infrastructure projects such as roads, schools, water and health. In addition, where the country is large and electricity is generated and distributed by independent regional utilities, a central government agency (such as the REC in India) may be needed to promote standardization, cooperation between regions and a regional balance in the rural electrification program.

7.5 A further function for the public sector is to provide general directives and ground rules for tariff and financial policies, the allocation of funds, and the criteria to be used for project appraisal and selection. This is traditional, of course, except that the scope of the directives and ground rules needs widening to cover the special problems of rural electrification.

7.6 Much of the public sector's involvement need only be indirect if the ground rules and directives are well laid, and also if there is more reliance on pricing policy and less reliance on the public revenue as a means of finance.

(ii) The Electric Utility

7.7 Much of the public sector's policy of course needs to be worked out jointly with the utility, as is customary, particularly as regards tariffs, finance, the levels of investment and which programs are practicable.

7.8 Many other tasks can only be the exclusive responsibility of the utility (though some are occasionally delegated to local administration). These include forecasting, engineering design and construction, deciding on what quality of service is appropriate, maintenance, accounting, procurement and contracting, centralization of records, standardization, promoting interchanges of ideas and experience between areas, providing advice and supervision, and providing facilities for training the personnel of the local administrative units. In addition, the utility may assume the responsibility for promoting the service, provide credit, and undertake the job of connecting consumers to the networks.

(iii) Local Administration in the Rural Areas

7.9 In some countries the extent of local administration is minimal, its function being to look after billing, record consumer requests for connection and report on local problems such as electrical faults, maintenance needs and consumer complaints.

7.10 Other countries place far more emphasis on local administration. This is the case where co-operatives are established, as in Costa Rica, Colombia, Nicaragua and about ten other countries. It is also the case in Mexico, for example, where the Co-op system is not used, but large regional offices are established (one in each state) under the joint leadership of technically qualified personnel and local officials. The primary purpose of such arrangements is to enable a close contact between consumers and the supplier to be attained. The local administrations identify new areas to be served and work out an electrification plan with representatives of the villagers and businesses. They have the responsibility of promoting and extending service, and perhaps of supplying credit. In addition to this and to the routine work of billing, keeping records and looking after consumer complaints, they may also take on a good deal of the engineering construction and maintenance work, and look after accounts.

Which Institutional Arrangement is Best?

7.11 At the moment, there is no clear answer to this question. The main debate is about the extent to which the responsibilities just outlined should be delegated to local administration. It is sometimes said that the utility can provide this quite well with the added advantage that the more talented and motivated people can, in working at the center, spread their efforts more widely. On the other hand, close contact with consumers and care in identifying the needs of the area are clearly important, and local administration is in principle best suited for this. Also, delegated responsibility is reported to have provided a spur both to efficiency and to an interest in the project's success, in some of the countries visited by staff members. It is probable that a greater responsibility should be placed on local administration the larger and more populous the rural areas, even if it is only because central administration by the utility is too costly and difficult in these circumstances.

7.12 But there is in fact little evidence to show that one approach works better than another. A recent AID sponsored study in Costa Rica and Colombia found that consumers were indifferent between the co-ops and the utility serving them; all that mattered was good service. 1/ In this sense the merits of Co-ops and other forms of local administration, as compared to the merits of supply from the utility, rest on the incentives to good management rather than on the incentives to consumers (which is one of the benefits which Co-ops are thought to have).

7.13 In practice it is necessary to be flexible in deciding on the form of organization. On the one hand, several arrangements may work well; on the other, different arrangements suit different countries and cultures.

1/ It was found, however, that theft of electricity was lower in a Co-op arrangement because it was resented by consumers (who were of course members of the Co-op).

Analysis of Institutional Problems

7.14 To identify institutional problems it is probably a good idea to make a checklist of the kinds of tasks listed above in Table 7.1. The questions can then be asked: how well is each task being performed? and what steps can be taken to improve those that need improving? The answers to these questions may sometimes point to specific actions, such as "more funds should be provided for training personnel" (often cited as a bottleneck) or "records should be better kept on project performance" (another commonly neglected matter). Alternatively, the answers may point to the need for major organizational changes.

VIII. IMPLICATIONS FOR BANK POLICY AND PROCEDURES

The Need for Development Assistance from the Bank

8.1 The possibilities for development assistance from the Bank in rural electrification were first enunciated in the Sector Working Paper on electric power. Subsequent studies undertaken by the Bank in this and related fields have also pointed to a need for a widening of the Bank's aims in its investments in the electric power sector and to relate them to rural development policy. Finally, over 25 countries have formally or informally urged the Bank to provide assistance, both technical and financial.

8.2 Although development assistance is being provided in this field by AID and IDB, it is generally accepted that assistance needs expanding upon. By 1973, the financial aid provided by AID and IDB, who began efforts in 1964, amounted to $230 million in 14 countries. In contrast, countries in the Bank's sphere of operations are to invest perhaps over $10 billion in the next ten years, that is, about 10% of total investment in electric power.

8.3 It is also a field in which the Bank has a comparative advantage for development assistance. The programs to electrify rural areas (and also low income areas of cities) are for the most part being undertaken by institutions with which the Bank has had highly successful associations for many years. Rural electrification, which has so far formed a small but increasing fraction of their past investments, is a new dimension with new challenges and likely to form a larger and significant portion of future programs. Generally speaking there is a strong commitment to rural electrification and a desire to make it successful.

Prospects for Successful Projects

8.4 The main case for development assistance, however, must rest on the desirability of rural electrification. In this regard, it is apparent that in many rural areas, there are only a few elementary needs for electricity and the high costs of public supply from the grid cannot be justified; in such areas, these needs are best served by local auto generators or by substitute energy forms.

8.5 However, there are also areas where there is scope for successful investment. In areas where there are clear signs of rural development taking place, as a result of public and private investments in agriculture and agro-industries, and public investments in local infrastructure, electrification can often augment development. It can usefully add to the profitability and output of farms, agro-industries and commerce through providing a superior and cheaper means of motive power, lighting, refrigeration and, for some purposes, heating; and it can serve a number of uses in households, even at quite low levels of household income. The evidence for this is the often strong response of rural households and businesses to electrification projects, reflected in sustained high rates of growth of demand from all categories of consumers, though from low initial levels.

8.6 Furthermore, the growing emphasis on rural development in many countries will, as shown earlier, react positively on rural electrification projects. Finally, it is also probable that, as per capita incomes increase in developing countries, some of this increase will filter through to rural areas, partly due to increased urban and international demands for rural products and partly due to improved economic linkages between urban and rural areas; this process will also generate increasing rural demands for energy and thus for electricity.

8.7 Nevertheless, there are the familiar difficulties of investment in rural areas. Response, though often much better than expected, is very uncertain. Project justification and identification requires information from the utilities and about rural areas that is often hard to find. Costs are high, and a lot of care and ingenuity is needed to keep them down. Finance, as usual, is difficult to find, and requires, on the domestic side, hard compromises between pricing for efficiency, social and financial needs in rural areas, and at the national level, between utility pricing policies and the public revenue. Finally, institutional failures may discredit the programs in the rural areas and nationally. On the other hand, these kinds of difficulties are one reason for aid; the other reason, of course, is that if the difficulties are resolved, the investments can do some good.

8.8 To move from these conclusions to formulating a policy of Bank assistance, it is necessary to consider:

- The pattern of Lending Operations;
- Lending Conditions;
- Which Countries?
- The Lending Program;
- Operational Procedures;
- What is Required of Bank Staff; .

These matters are now discussed in turn.

The Pattern of Lending Operations

8.9 Loans for rural electrification will generally have to be elements of loans to:

(a) packages of rural development projects; and/or

(b) the electric power utilities.

The former appeals because it promotes coordination between sectors, sorts out priorities and generates very large external economies -- that is, the economic gains from different investments augmenting each other. The latter appeals, if some degree of coordination already exists in the country, because of the many institutional, financial and technical responsibilities delegated to the utilities. But whichever approach is taken, the criteria for accepting the rural electrification component of rural development is the same: some coordination between sectors will be necessary and should have the effect of raising the expected economic returns to the investment; the projects must be well chosen in terms of meeting the social and economic aims of the program; and the projects will have to be carefully and thoroughly prepared institutionally, technically and financially. Provided these criteria are met, the approach to lending can be through (a) or (b).

8.10 Rural electrification loans specifically to the utilities will generally have to be elements of larger loans to them. There are three reasons for this. One is that, with the exception of large countries, rural electrification is not a suitable vehicle for lending on a large scale since it typically absorbs no more than 5 to 10% of total investment in electric power. Second, rural electrification is only an added dimension to the work of the electric power sector, and there is still the need to continue with the expansion of generation and transmission capacity (doubling every 5 to 7 years in most countries) and of service to urban areas. Third, many issues connected with rural electrification relate to the sector as a whole - tariffs and finance, for example, the promotion of regional balance and regional cooperation, and the provision of technical assistance, training and supervision.

The Content of Lending Operations

(a) The Borrowers

8.11 Lending for rural electrification would generally require involvement with institutions at all levels:

(i) The Government -- either rural development or rural electrification agencies, if such agencies are established;

(ii) The Central Electricity Utility;

(iii) Local Electricity Distribution Agencies (e.g. co-ops or State electricity boards).

In most cases, funds and other assistance would best be channelled through (i) or (ii), because local agencies generally require a lot of financial support and assistance from the government or the utility so as to establish, expand and run their rural electrification programs. Even when the local agencies are financially and technically strong (because, say, they may also be serving cities in the region) there is still a good case for channelling aid through (i) or (ii), as in India, in order to promote regional and sectoral balance in the programs, and cooperation between regions. Finally, funds and assistance would also be needed for the country's overall electrification program (if it is a power loan) or for the country's rural development program (if it is a rural development loan).

(b) Bank and IDA Conditions

8.12 Whether Bank or IDA conditions should apply to the loan depends, as discussed earlier (5.14), on the country. If Bank conditions apply, this inevitably means that lending must not only be through the government or the utility, but also that the funds would be channelled to the rural areas at concessionary rates. This is unavoidable unless tariffs are set undesirably high in the early years of rural electrification programs -- a decision which would act against promoting efficient use of the investments.

(c) Finance of Materials and Equipment

8.13 The kinds of materials and equipment involved in rural electrification, and their share in total costs when the projects are intitally constructed, are illustrated in Table 8.1.

Table 8.1

Cost Breakdown of a Rural Electrification Project /1

Item	Cost, $	%	Remarks
Substation	86,000	10	
Poles and Fixtures	280,000	33	) 162 miles
Conductors and Protection	178,000	21	)
Line Transformers	61,000	7	
House Connection	19,000	2.5	) 1,100 houses,
Meters	12,000	1.5	) initially /2
Street Lights	5,000	0.5	
Administration, Engineering	180,000	21.5	
Interest During Construction	11,000	1.5	
Other	10,000	1.5	
	842,000	100	

/1 San Carlos Co-operative, Costa Rica (1969 data). Project serves about fifteen villages. Data exclude a provision for the co-op's working capital.

/2 Capacity of scheme sufficient to serve over 5,000 consumers.

8.14 Much of the equipment, in particular poles, lines, small transformers, switchgear and substations, can often be manufactured in the country on very competitive terms with international suppliers. In general, therefore, support for rural electrification would involve support for local manufacturing and local cost financing, though the extent of this obviously depends on the country.

(d) Technical Assistance and Program Development

8.15 The shortage of skilled and trained workers to develop, maintain and run rural electrification programs is commonly cited. Most loans would thus have to make a provision for technical assistance.

8.16 A further area where technical assistance can be provided is in (a) establishing and monitoring pilot projects or (b) evaluation of existing projects. As discussed in previous sections (3.18, 3.23 and 4.20 et. seq.) this provides the information base and the experience for program development.

Which Countries?

8.17 In most countries, it seems, there is scope for some degree of rural electrification, involving the electrification of selected:

- villages (and, in Africa and the Arab countries, small towns);
- surrounding farms and agro-industries.

But the extent of the possibilities and the type of electrification varies with the country, as discussed in Part II. The situation is roughly as follows, though records are not good enough for a detailed account.

8.18 In Africa and some Arab countries the main programs are concerned with electrification of small towns, the larger villages and the larger businesses located in or near to them. Auto-generation is the main option, though public supplies can be contemplated in areas close to the main networks. However, in ten years time, these programs are unlikely to have extended service to more than one tenth of the village/rural population.

8.19 Several countries in Asia and EMENA are in the midst of a strong push towards electrifying the large and medium sized villages and the surrounding farms and agro-industries. In some cases, as in parts of India and Taiwan, the programs are also extended towards the smaller villages. Public supplies from the grid are the main option, auto-generation being an alternative for small or remote demands. About one quarter of the village/rural population might be receiving service in ten years time.

8.20 In Latin America, several countries are also in the midst of programs to electrify the larger villages and surrounding farms and agro-industries; other countries have completed this phase, and are moving out to the smaller villages and new farm and agro-industrial consumers. Again, the main option is public supplies to replace local auto-generation, which, apart from remote or low demand areas, is becoming extinct. About one third or more of the village/rural population might be receiving service in ten years time.

8.21 The main question about these programs is, of course, which programs in which countries are socially and economically desirable and require support? As in all aspects of Bank operations, the answer to this should evolve in the course of sector, pre-investment, project and other studies. At the present time it can be said that there are no grounds for dismissing the idea of some degree of rural electrification in any country. While it is possible to find, in any country, that some of the investments are of very little use, it is equally true that others are very useful and the high costs can be justified. Indeed, the first phases of rural electrification -- of private auto generators serving one consumer or several connected to micro-grids -- were historically carried out by private enterprise and were profitable. Growth of output in agriculture and agro-industries, improvements in rural infrastructure, migration to villages, and increases in rural wages, eventually act to increase the demand for electricity and the case for replacing auto generation by public supplies from the grid. The question is therefore reduced to one of timing: has the demand developed sufficiently to justify the investment? The answer to this, in any particular country, can be provided by survey, identification and appraisal work in the course of operations.

The Revised Lending Program FY 74-78

(a) Electric Power Loans

8.22 Roughly $250 million of the revised lending program for electric power ($3,100 million, in 1974 prices, for 90 loans) is allocated to rural electrification. However, $100 million of this is absorbed by three projects, two in India ($40 million each in FY75 and FY76) and one in Iran (about $20 million in FY75, but tentative. These are specifically for rural electrification. The remaining proposals, which are relatively small, are components of larger loans to the power sector in ten other countries (Thailand, Nepal, and Pakistan; Panama, Honduras, Mexico, Bolivia and Brazil; Liberia; Tunisia). However, initiatives to identify and prepare projects with significant rural electrification components might be expanded upon during FYs 75 and 76, leading to an increased rural electrification content in the second half of the program.

(b) Rural Development Loans

8.23 Roughly 50% of the loans for Agriculture in FYs 74 and 75 might be classified as rural development loans. The rural electrification element in projects financed by such loans varies considerably between projects and countries. Rough indications are that rural electrification may average about 10% of project costs in Latin America, may be 5 to 10% in Asia and EMENA, and very little for Africa. In all, about $150 to $300 million of the projected $6,500 million for Agriculture and Rural Development loans might be associated with rural electrification, under present projections. Again, however, intensification of initiatives to identify and prepare projects with rural electrification components might increase the rural electrification content of the second half of the program.

Operational Procedures

8.24 The kind of work to be done -- economic, institutional, financial and technical -- was outlined in Sections III to VII. The following discussion is about the implications of this work as regards:

(a) Sector Surveys -- of The Energy or Electricity Sector;

(b) Sector Surveys -- of The Rural Sector;

(c) Project Identification, Preparation and Appraisal;

(d) Supervision;

(e) Research.

The following discussion of these topics follows a very obvious and well-known pattern. The reason is that no serious revision of operational procedures is needed for dealing with rural electrification projects. The differences are mainly in degree, in that the uncertainties are larger than usual, problems can be tougher, and extra tolerance may be needed (as discussed in III) on projects with quantified economic returns which are lower than, but approaching, the cost of capital.

(a) Surveys of the Electricity (or Energy) Sector

8.25 Since rural electrification is only one aspect of the sector's investment program, it will probably be necessary to report on it separately but in parallel with the other aspects. As regards the rural electrification aspect, surveys need to discuss the origins of the program, the aims, and past and future developments; analysis is required, as is customary, of the institutions, finance, technology and economics of the program.

8.26 To proceed from this to the identification work of a sector survey, would, in many instances, be impractical. Problems, not projects, will often be identified. Records are often exceedingly poor and totally insufficient for investment analysis; institutional problems may be severe and may require a variety of reforms, technical assistance programs and other measures before successful investment can begin; while financial difficulties may arise from poor pricing policies, over-expansion or a technology that is too costly. Sector surveys may often have to concentrate on these problems for a time and to point to the types of studies or programs that might be commissioned to resolve them. The basic work of project identification can then begin.

8.27 When, on the other hand, the programs are well organized and planned, and records are properly kept, the basic work of project identification can probably be accomplished quite efficiently in the course of the sector survey.

(b) Surveys of the Rural Sector

8.28 As far as rural electrification is concerned, the important points about these surveys, which complement surveys of the electricity sector, are that:

- They may often lead to the identification of a rural electrification component as part of the rural development package;

- they should also identify the extent of and the need for coordination between investments in various sectors.

(Identifying useful and workable projects during the course of these surveys may present difficulties far greater than those discussed above for electric sector surveys. Important as these difficulties are, however, they are not an issue for this paper.)

(c) Project Identification, Preparation and Appraisal

8.29 The work of project identification, which may be done during or as a result of sector surveys (or specially commissioned studies), may generally be confined to a rough assessment of (i) the institutional, technical and financial capacities of the borrowers and (ii) regional analysis of the expected economic returns and the factors which bear on them. If the prospects for successful investments look reasonable, according to the criteria discussed in Part III, feasibility and preparatory studies can be initiated or commissioned, as is customary.

8.30 The terms of reference for project feasibility and preparation studies need to request:

- estimates of the expected economic returns;

- an investment plan which is:

    (a) the best of several alternatives as regards the rate of expansion and which demand centers are connected; and

    (b) the least-cost method of following this expansion path;

- technical design;

- an evaluation of sources of equipment;

- institutional plans;

- the financial plan, and tariff studies;

- provisions for monitoring the project and record keeping.

This provides the material for appraisal. On some occasions, the terms of reference may need to request the preparation of pilot projects as a first conditional step in the investment program, or the evaluation of existing projects as an information base for the proposed plan.

(d) Supervision

8.31 The main problem with supervision is likely to be poor records. The only way round this is to set up a good monitoring and record keeping system during the preparatory stages of the project. Items which need to be recorded include, for example, demand statistics, revenues, costs, faults and maintenance problems.

(e) Research

8.32 The work of supervision might be expanded occasionally to examine more widely the project's impact on the area's development. In addition to project related data, the following kind of information can also be recorded and backed up by small scale survey work:

- developments in local agriculture and agro-industries;

- socio-economic developments in the village communities;

- demographic changes;

- changes in household incomes;

- changes in local infrastructure.

This information can often be obtained and analyzed by local consultants.

8.33 Similar kinds of supporting research can be very useful in the preparatory stages of the program, either: (a) to monitor pilot projects, as with the Bank financed project in Ecuador, or (b) to evaluate ex post the impact of specific programs, as with the research project in El Salvador. The research need not, of course, be confined to sociology and economics, but might also usefully look at institutional problems, for example.

8.34 Apart from research into overall project performance as part of project preparation, evaluation and supervision in particular countries, there are a number of specific problems to research into, such as:

(a) Consumer response. How does this differ between countries? and what factors affect response? We are particularly short of insights into this in African and Asian conditions.

(b) Costs. What is the precise scope for cost reductions? Can costs really be cut substantially by standardization and by keeping design standards to a bare minimum, as is often suggested? The indications are that this is possible and has been done, but engineering design studies are needed to investigate this matter.

(c) Forecasting, in particular, the movements of the exogenous variables which explain the strong growth of demand often observed from farms, agro-industries and village commerce.

Items (a) and (c) are often best carried out by local researchers.

Requirements of Bank Staff

8.35 Where there are good institutions to work with, identification, preparation and appraisal might proceed in the usual way, but as a component of a power or a rural development loan. The main work would be in preparation: in setting up the terms of reference and providing supervision and assistance regarding:

- economic and social analysis of alternative plans;
- engineering standards and design;
- financial arrangements;
- institutional arrangements;
- tariffs.

8.36 Where the institutional difficulties and the problem of information shortages are more serious, it would of course take longer to build up successful operations. This is, of course, a familiar problem with new operations. The main work consists of seeing that the various difficulties are attended to in order that identification, preparation and appraisal can begin.

8.37 While the problems and the procedures for attacking them are familiar (and there is no reason to suppose, as remarked above, that present operational procedures need revision before dealing with rural electrification), some new skills and experience will probably be needed in the Bank. Much of these might best be acquired in the course of actual operations. But consideration should also be given to (a) sending staff on short training courses, e.g. in distribution network planning and running distribution systems; (b) recruitment of some people with experience in the field, particularly distribution engineers; (c) cooperation between the Regional Departments. As regards (a) and (b) it might be noted that investments in urban and rural distribution networks take over 50% of total investment in electric power.

ANNEX 1

REFERENCES

Previous material written in or prepared for the Bank on this subject are:

(1) "The Appraisal of Village Electrification Projects," Public Utilities Department, Note No. 6, August 1, 1973.

(2) "Back to Office and Full Report on the El Salvador Village Electrification Study," D. Anderson, May 1973.

(3) Various documents cited in (1) and (2).

(4) "UN Inter-Regional Seminar on Rural Electrification," New Delhi, December 1971. Full Report by T.B. Russell, February 1972.

(5) "Electrificacion Rural," February 1974. Report prepared by Universidad Centroamericana Jose Simeon Canas, San Salvador, El Salvador.

(6) On Pricing Policy:

Public Utility Reports Nos. RES 1 and RES 3, on "Economic Analysis of Electricity Pricing Policies: An Introduction" (Jan. 9, 1974) and "Framework for Electricity Tariff Studies" (March 18, 1974) by Messrs. Anderson and Turvey.

(7) World Bank Sector Working Paper or Electric Power, 1972.

COSTS COMPARISONS OF AUTOGENERATION AND PUBLIC SUPPLIES FROM THE GRID

A2.1 The costs of supplies through electrical networks connected to the main grid system vary with load density and the terrain. The following are typical data for villages in El Salvador, in a region where the average length of subtransmission lines is 4 km per village:

Annex Table 2.1 - Public Supply Costs

		Network Capacity	
		50 kW	25 kW
Consumers Served		140	70
Village Size		2,000	1,000
Capital Costs:			
Generation and Transmission		$24,000	$12,000
Subtransmission		$18,000	$18,000
Local Distribution		$14,000	$ 8,000
Total		$56,000	$38,000
Running Costs:			
Generation	cents/kWh	0.5	0.5
Operating and Maintenance	$/year	2,000	1,000

Source: El Salvador Study (1972 price data).

A2.2 This data does not include the demand and costs of serving local agro-industries, which may add anything from 10 kW to over 1000 kW to local demand.

A2.3 Subtransmission costs change with load density since the average length of line per load center changes. The above figures are based on a subtransmission cost of $4,500 per km (which is higher than many countries report). If, then, the average length of line per village rises by, say 25 km, in a sparsely populated, or remote area, the subtransmission costs rise by $112,500.

A2.4 For diesel, most of the above costs change, except those for local distribution. Typical data for motor-generator sets are as follows:

Annex Table 2.2

kW Capacity	Price (f.o.b.)
30 - 35	$ 6,500
50 - 60	$ 8,000
80 - 90	$ 9,500
90 - 110	$11,000
115 - 140	$12,500

Source: "Detroit Diesel" motor-generator sets (1974 data).
1972 data are about 30% lower, at a guess.

To add to these costs, are the costs of transport, installation and accessories which together amount to about 50% of capital costs. Also, it is fairly common practice to have one spare motor-generator unit on account of the problems of breakdown and maintenance. So the above prices should be multiplied by 1.5 x 2.0 = 3.0 in order to make comparisons with public supplies from the grid (or a factor of 2 to convert to 1972 prices).

A2.5 Other cost items are:

Control Board and Substation (50 kVA)	$5,000
Fuel	6 cents/kWh

These data are based on observation of various projects. The fuel costs would be about 5 cents per kWh in 1972 prices, depending on the efficiency of the motor, to which a nominal amount of 1 cent per kWh has been added for generator maintenance (which is expensive).

A2.6 In sum, the cost data for providing electricity from auto-generation on the same scale as in Annex Table 2.1 would be roughly as follows:

Annex Table 2.3 - Autogeneration Costs

		Network Capacity 50 kW	25 kW
Consumers Served		140	70
Village Size		2,000	1,000
Capital Costs:			
Generators /1		$15,000	$12,000
Substation		$ 5,000	$ 5,000
Local Distribution		$14,000	$ 8,000
Total		$34,000	$25,000
Running Costs:			
Fuel	cents/kWh	6	6
Operating and Maintenance	$/year	2,000	1,000

/1 Taking a unit price of $7,500 for the 50 kW set and $6,000 for the 25 kW set, by interpolating the data in Table A2.2.

These figures are only rough, and may change enormously according to the country and the date. Inflation and changes in oil prices in particular, make precise estimates very difficult.

A2.7 In view of the different levels of capital and running costs, the total costs of the schemes vary according to how much they are used. Also, while the capital costs of autogeneration appear to be much cheaper, this equipment only lasts for about 10 years, as compared with about 25 - 30 years for the electrical equipment.

A2.8 To allow for these points, the following table compares the cost of the alternatives for three levels of utilization (load factors of 10%, 25% and 50% respectively) and puts all costs on an annual basis taking a 17% annuity for the motor-generators and a 10% annuity for the remaining electrical equipment (corresponding to 10 and 30 years respectively at 10% interest).

Annex Table 2.4 - Annual Cost Comparisons

Network Capacity	25 kW			50 kW		
Load Factor	10%	25%	50%	10%	25%	50%
Autogeneration Costs - $						
Capital	3,300	3,300	3,300	4,500	4,500	4,500
Running*	2,300	4,300	7,600	4,600	8,600	15,200
Total	5,600	7,600	10,900	9,100	13,100	19,700
Total/kWh (cents)	25	14	10	21	12	9
Public Supply Costs - $						
Capital	3,800	3,800	3,800	5,600	5,600	5,600
Running*	1,100	1,250	1,500	2,200	2,500	3,000
Total	4,900	5,050	5,300	7,800	8,100	8,600
Total/kWh (cents)	22	9	5	18	7	4

* kWh of output per kW capacity = 876 kWh at 10% load factor
= 2,190 kWh at 25% load factor
= 4,380 kWh at 50% load factor

A2.9 In this case public supplies are cheaper for all loads except those of very low load factors of about 10%. On the other hand, if the average length of subtransmission line per village were 25 km, instead of 4 km assumed above, annual capital costs would rise by over $10,000, with the following effects on the average costs of public supplies.

Annex Table 2.5 - Annual Costs of Public Supplies (25 km)

Network Capacity		25 kW			50 kW		
Load Factor		10%	25%	50%	10%	25%	50%
Annual Costs	$	14,900	15,000	15,300	17,800	18,100	18,600
Annual Costs/kWh	(cents)	70	27	14	40	17	8

A2.10 From this data it is apparent that (a) load density is enormously important in reducing average costs, and (b) so are the size of load and load factor.

A2.11 One major element in reducing average costs is the presence of agro-industrial demand, which may improve load factors and also increase the level of consumption by factors of two to ten or more -- though extra sub-transmission networks are generally needed to reach them.

A2.12 The above analysis is also rather static. A full analysis of course requires a study of the growth of demand and of costs over time.